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LEME**NEWS**

MJL sweeping away quaternary sands

A LEMEr sweeping away Quaternary sands at the Windabout Cu-Co prospect, Mt Gunson area, South Australia. "Who is this outback sampling hygiene expert?" The answer is: "Melvyn Lintern (CSIRO Exploration and Mining, Perth) demonstrating sampling techniques to an Adelaide University Honours Student".

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CRCLEME

Cooperative Research Centre for Landscape Environments and Mineral Exploration

CRC LEME is an unincorporated joint venture between CSIRO, The Australian National University, Curtin University of Technology, University of Adelaide, Geoscience Australia, Primary Industries and Resources South Australia, NSW Dept. of Mineral Resources and the Minerals Council of Australia, established and supported under the Australian Government's Cooperative Research Centres Program.

CRC AUSTRALIA

From the Chief Executive Officer

Dennis Gee

Welcome back to LEME News! It has been an uncomfortably long period – in fact 18 months - since the last edition appeared, and it is gratifying to know that it has been missed by stakeholders and LEMErs. And what an eventful 18 months it has been! I can speak with some intimate knowledge on the latter seven months for that is the period of time I have been with LEME. To some extent it has been a baptism of fire, as we have grappled with the aftermath of the departure of BRS, the withdrawal of University of Canberra and take-up of their privileges by ANU, the project reviews, and now we are in the middle of drawing up the research programs and budget for next year. And all this is taking place in a period of dwindling external income from sponsoring agencies, and a sharpened focus by our core participants on the question of "equity".

And speaking of welcomes, I would like to say how pleased I am with the way in which I have been welcomed into LEME by everyone, by those both within and outside the CRC. It has made my new assignment actually enjoyable – despite its multitude of challenges. I especially want to pay tribute to my management team here in Perth head office - Paul Wilkes, Gary Kong, John Mills and Sue Game - who have given me enormous help and guidance, and played a daily role in my reorientation into this strange thing called a Cooperative Research Centre. I also know we have a fantastic Executive composed of Program Leaders and Regional Directors that keep me on my toes. But they also have a wonderful spirit of cooperation, with a desire to make LEME hum again.

Whilst on a thanksgiving note, I must give resounding acknowledgement to the scientific and executive leadership that my predecessor Dr Ray Smith has given to LEME over the last eight years. Ray decided to step aside as CEO and go back to his research interests within LEME. I am sure all his friends and colleagues in the exploration industry will continue to follow his work. It was under the stewardship of Ray that the new discipline of Regolith Science came to maturity.

LEME2 is not quite what it was in the halcyon days LEME1 which enjoyed benefits of a vigorous mineral exploration industry. History may well judge this as a seminal phase of Australia's history, never to be repeated. But we knew this was coming, and this was part of the reshaping of the new LEME machine to bring in the environmental aspect. We now have two quite different groups of stakeholders, with their own demands. The challenge for myself, the Executive and indeed the Board, will be to forge the right balance, so the great team of researchers do not bud into two separate groups. So let me restate the basic mission of LEME – it is to apply regolith science to the challenges that face Australia in the fields of mineral exploration and natural resource management. I am confident that the vibrancy and relevance of the new discipline of regolith science will binds us all together.

We now have a strategic plan which is a guiding document for all our planning. However it is still a living and evolving document. It sets out our research priorities and how the two main streams are to be coordinated and integrated. Our research work into the applications of regolith science in natural resource management, especially in land salination, will increase in importance, and this is reflected in some of the articles in this issue of LEME NEWS. Our salinity projects basically fall into two categories. Firstly there are specific site studies under contracts of work, funded by and reporting to, State and catchment agencies under the National Action Plan for Salinity and Water Quality (NAP), and strategic research into salinity-related processes in the regolith.

However there will remain a strong focus on mineral exploration in the firm belief that there are many more discoveries to be made beneath our extensive regions of transported regolith. We are now in the process of developing a new portfolio of projects in Program1 (Regolith processes) and Program2 (Exploration Under Cover). These will include generic process projects (mainly geochemical), regional focus projects (multidisciplinary studies in the Curnamona, central Gawler, Western Lachlan and Yilgarn geological regions), and technological development projects – mainly geophysical. All of these projects will have value to mineral explorers. We can kick many of these off on existing LEME operating funds, and carry-over external funding arrangements, but to make the breakthroughs in exploration technology, we will need more industry funds. That remains a major challenge for all in LEME.

Our scholarship program continues to be an outstanding success. This year we have 14 Honours scholars, and 24 PhD scholars distributed across our three core universities - Adelaide, Curtin and ANU. Their research projects are closely integrated with all the core research priorities, and our scholars are clearly making a major contribution to the objectives of LEME.

I urge all of our stakeholders to keep abreast of developments in LEME. This can be done by attending our conferences, seminars and workshops, reading our open-file releases, and above all – tuning in regularly to our webpage **www.crcleme.org.au**. Our site is being continually updated and enhanced by Jennie Campbell at the Perth Head Office.

EDITORIAL

This newsletter includes only some of the research activities that have been going on within LEME projects over the past year. It has been a busy time, it appears, with results just coming to the surface!

Salinity mapping and associated work focusing on natural resource management have been at full capacity only a few months - as reported by Program 4 Leader Ken Lawrie. In this area too, Rob Fitzpatrick's report on Acid Sulfate Soil Seepage is particularly relevant as the problem becomes more evident in Western Australia. Rob presented at a Dept of Environmental Protection workshop - Identifying, Managing and Assessing Acid Sulfate Soils - held at Curtin University 12-13 June.

On the minerals exploration side of things, we have a number of excellent research reports, and I draw your attention to the LEME-AMEC seminar being held Wed 18 June, at which some past and some very recent LEME work is being presented. An Abstract Volume will be available via our web site after the event and Presentation Material.

And talking of the web - LEME will be increasingly using its web site - http://crcleme.org.au - as the main medium for conveying its activities and research results to its clients and stakeholders. A number of the articles appearing in LEME NEWS will also be put on the web. I refer to - WHAT'S ON THE WEB?

Susan Game
Editor
susan.game@csiro.au

HYDROTHERMAL ZIRCON: A RESISTATE MINERAL AND PATHFINDER IN EXPLORATION

Ken Lawrie [1,2] & Terry Mernagh[1]

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[2] Cooperative Centre for Landscape Environments and Mineral Exploration – ken.lawrie@ga.gov.au

Several resistate minerals such as rutile, apatite and tourmaline have previously been suggested as suitable indicator minerals in exploration for porphyry Cu deposits. Joint research between Geoscience Australia and CRC LEME has found hydrothermal zircons (and rutile) are present (Figures 1, 2), in a wider range of deposit types than previously recognised. Zircon is a relatively stable 'resistate' mineral under most conditions of weathering, erosion and transport, and is often concentrated in heavy mineral fractions in sediments and regolith materials. These factors, and their distinctive chemistry, make them a useful indicator mineral in the exploration for a range of hydrothermal mineral deposit types.

Hydrothermal zircons have been identified and characterised by the following series of techniques: (1) their distinct morphology and paragenetic relationships to ore and mineral assemblages within the orebodies, (2) the higher concentration of zircon within the orebody relative to that of the host rocks, (3) the presence of ore and alteration minerals as solid mineral inclusions within zircons, (4) similar fluid inclusion compositions in zircons and associated ore and gangue minerals, and (5) their trace element composition and zonation as measured by the CSIRO-GEMOC nuclear microprobe and LA-ICPMS analysis.

Studies within a number of deposit types have demonstrated the distinctive chemical composition of 'hydrothermal' zircons when compared to temporally and spatially associated magmatic zircons. Trace element composition and zonation within hydrothermal and magmatic zircons was measured by the CSIRO-GEMOC nuclear microprobe and LA-ICPMS analysis. Zircons within high sulphidation epithermal Au deposits at Gidginbung (N.S.W., Australia) and Nena (Papua New Guinea) are characterised by enrichment and zonation in As, Sb, Cu, Th, Yb and Fe. The Dam porphyry-related, breccia-hosted Au-Cu oxide deposit (NSW, Australia) contains zircons that are characteristically enriched in Fe, Cu, Sn ,Sb, and Ba. Zircons within the Enterprise intrusive-related aureole-hosted vein Au deposit (N.T., Australia) are distinctively enriched in Cu, As, Ag, Yb and Th (Figure 3), as well as Sn, Sb and Ba. Zircons within the Bottle Creek orogenic vein Au deposit (Western Australia), are also distinctive in comparison with host rocks, and are enriched in Fe, As, Sr, Sn, Sb, Ba.

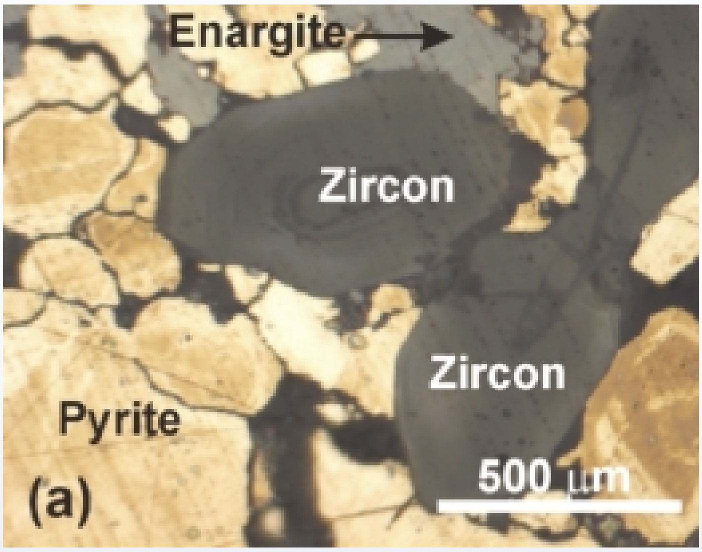


Figure 1 Hydrothermal zircons intergrown with suphides at the Gidginbung Au-Cu deposit, N.S.W.

Continued on Page 4

HYDROTHERMAL ZIRCON: A RESISTATE MINERAL AND PATHFINDER IN EXPLORATION

Continued from Page 3

LA-ICPMS analysis of hydrothermal zircons in intrusive-associated Au-Cu deposits hosted in the Gidginbung Volcanic Belt show that these have distinctive Ce and Hf compositions in comparison with magmatic zircons. The distinctive chemistry of hydrothermal zircons is thought to be indicative of the strong chemical disequilibrium represented by the ore-forming environments. This technique may lend itself to the precise dating of other ore deposits where hydrothermal zircons have previously gone unrecognised. Moreover, this technique may be of particular use in the isotopic dating of metallogenic events or individual ore deposits in a number of terranes where there is a lack of suitable minerals that can be dated precisely. Often, the effects of overprinting metamorphism, deformation, and magmatic or hydrothermal events may reset other isotopic systems. In these instances, U-Pb dating of hydrothermal zircons directly associated with mineralisation may have a particular advantage over other isotopic systems that rely on less stable minerals. Furthermore, zircons are more likely to survive weathering and abrasion during sedimentary transport.

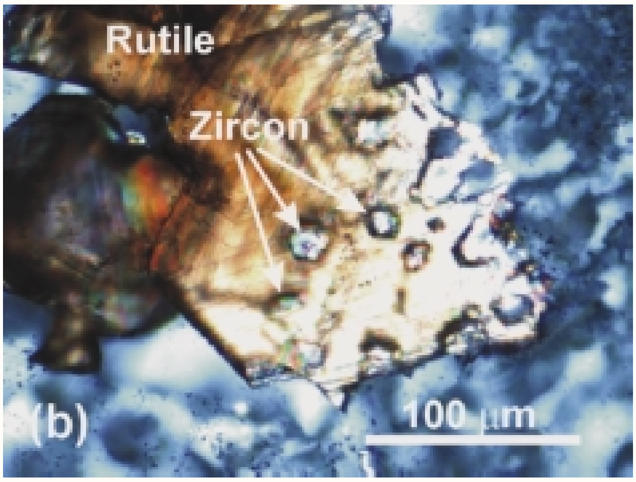


Figure 2 Hydrothermal zircons within hydrothermal rutile, Gidginbung, N.S.W.

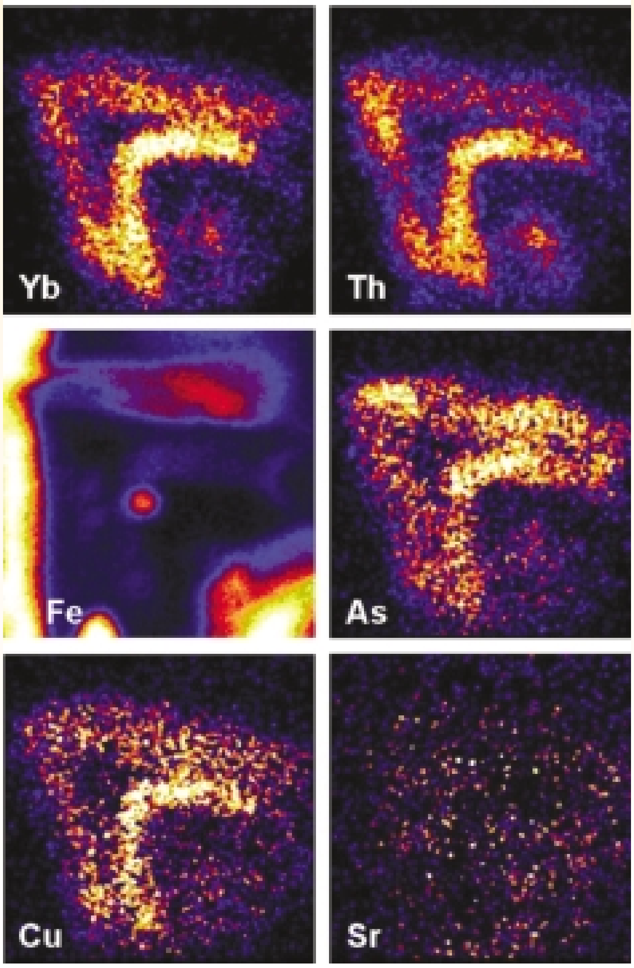


Figure 3. Chemical zonation in hydrothermal zircons from the Pine Creek (Enterprise) Au deposit in Northern Territory.

The oscillatory nature of the chemical zoning in many of the hydrothermal zircons studied in this project suggests that they have distinctive chemical fingerprints (Figure 3). Work is on-going to chemically characterise hydrothermal zircons in a range of bedrock terranes and regolith environments to determine their suitability as indicators to nearby mineral deposits.

BHEI 2003, 7-9 JULY

CURNAMONA PROVINCE - REALISING THE POTENTIAL

Featuring latest developments in the geology and mineralisation of the Broken Hill, Olary, Koonenberry and surrounding areas.

Full details on LEME web site http://crcleme.org.au/ under 'EVENTS', with link to the NSW Dept Mineral Resources site and registration.

Highlights of this years Broken Hill Exploration Initiative Conference will include the latest information on exploration and geological concepts across the province, geochronology, lead isotopes, first images from the Falcon airborne gravity survey, interpretation of hyperspectral data and an account of operations by Perilya and Consolidated Broken Hill since their takeover of the Broken Hill mining leases.

CRC LEME staff will present the following papers during Session 4:– "Regolith – Raising the Profile" on Tuesday 8 July

11:00-11:30 Steve Hill: Exploration without hitting "rock bottom".

11:30-11:50 Dirk Kirste: Regolith geochemical approaches in the Curnamona Province.

11:50-12:10 Ian Lau, Alan Mauger, Graham Heinson and Patrick James: Remote spectral mapping of regolith in the Olary Domain.

12:10-12:30 Kylie Foster: What do Cold Chisel and the Broken Hill 1:25,000 Regolith-Landform mapping program have in common?

REGOLITH EXPRESSION OF AUSTRALIAN ORE SYSTEMS

A compilation of geochemical case histories and conceptual models
Compilers and Editors: C.R.M. Butt, M. Cornelius, K.M. Scott and I.D.M. Robertson

The geochemical expression of bedrock mineralization in the regolith is affected by geological, geomorphological and environmental conditions that are unique for every location. However, many similarities in dispersion characteristics may be present over extensive regions and it is possible to summarize these characteristics as conceptual dispersion, process and exploration models, based on evidence from suitable case histories.These models can then be used to anticipate the surface expression of mineralization in a given area, to design an effective exploration program and to evaluate any anomalies.

Two model schemes of this type have been produced: -

- "Conceptual Models in Exploration Geochemistry, 4: Australia" by C R.M Butt and R E Smith, 1980, deals exclusively with Australian conditions and is supported by 52 case histories,
- "Regolith Exploration Geochemistry in Tropical and Subtropical Terrains" by C R M Butt and H Zeegers, 1992 extends beyond Australia and is again illustrated by relevant case histories.

This monograph expands and updates the earlier compilations and models for Australia by including the outcomes of the last two decades of intensive exploration activity and regolith research. It will be a reference to the geochemical expression of ore systems in the Australian regolith and it is intended to sell for less than $50.

Over 100 case histories will be included, from a wide range of published and unpublished sources, and include hitherto unreleased exploration data. They are being documented systematically, with authors from industry, universities, geological surveys and research organizations.

Pending publication, case histories are being progressively released as PDF files on the CRC LEME website (at http://crcleme.org.au). The status of the case histories is provisional and there will be some further minor editing and reformatting prior to release of the monograph as hard copy.

Case histories are still being sought and potential authors should contact the compilers (Ian.Robertson@csiro.au or Keith.Scott@csiro.au) if they wish to contribute. It is intended to continue to add to the compilation of case histories on the web site after hard copy publication as an ongoing resource for the exploration industry.

In addition to the basic data available in the case histories, the volume will include recommendations on exploration procedures, including terrain analysis, sample type, sampling interval, analytical procedure, element selection and data interpretation.. It is intended that it will provide a substantially improved understanding of the impact of weathering and regolith cover on exploration methods, leading to reduction in exploration costs for concealed base metal, polymetallic and gold deposits in areas of residual and transported regolith.

Those currently on the web are:

Beasley Creek Gold Deposit, Laverton District, Western Australia

Bottle Creek Gold Deposits, Menzies District, Western Australia

Chatterbox Shear Gold Deposits, Laverton District, Western Australia

Cornishman Gold Depost, Southern Cross Mining District, Western Australia

Cox-Crusader Gold Deposit, Lawler District, Western Australia

Devlin Creek Base Metal Deposits, Central Queensland

Eloise Cu-Au Deposit, Cloncurry District, Queensland

Fender Gold Deposit, Cue, Western Australia

Frogmore Copper Deposit, NSW

Harmony Gold Deposit, Baxter Mining District, Western Australia

Hera Au-Cu-Zn-Pb-Ag Prospect, Nymagee, New South Wales

Killara Copper Psuedogossan, Western Australia

Lefroy and Beaconsfield Gold Mines, Tamar Region, Tasmania

Little Eva Cu-Au Deposit, Quamby District, Queensland

Lights of Israel Gold Deposit, Dayhurst, Western Australia

Mount Torrens Lead Prospect, South Australia

Mulga Rock Uranium and Multielement Deposits, Officer Basin, Western Australia

Murrin Murrin Nickel Laterite Deposit, Western Australia

Pajingo Epithermal Gold Deposits, NE Queensland

Palaeochannel Gold Deposits, Mount Pleasant District, Western Australia

Panglo Gold Deposit, Eastern Goldfields, Western Australia

Parkinson Gold Deposit, Murchison Goldfields, Western Australia

Penny West Gold Deposit, Youanmi, Western Australia

Taurus South Gold Mineralization, Bulong District, Western Australia

Thursdays Gossan Porphyry Copper Prospect, Western Victoria

Ulysses Gold Deposit, Western Australia - Melita Project

Waterloo Base Metal Deposit, Mt Windsor Sub-Province NE Queensland

Wonawinta Zn-Pb-Ag Prospect, Cobar District, New South Wales

Wyoming Gold Deposit, Central Western NSW.

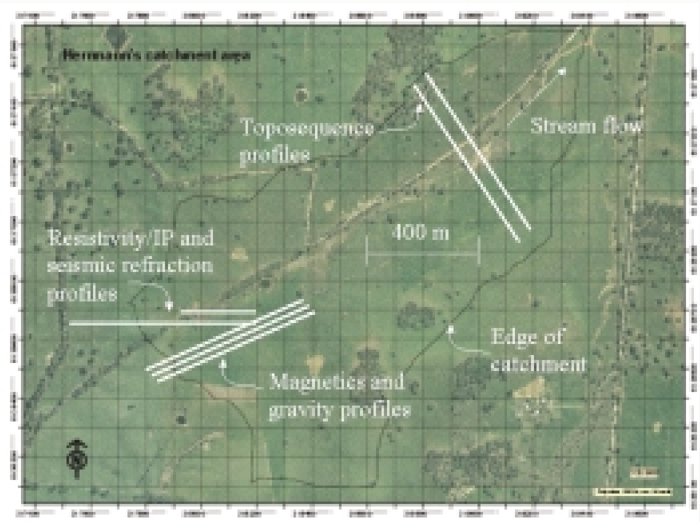
Pedo-Geophysics Teaching and Research in the Adelaide Hills

Graham Heinson, Nick Direen, Mark Thomas, Andrew Baker, Rob Fitzpatrick, Patrick James, Brendan Coleman, Matthew Hutchens, Hashim Carey and the 3rd year Mineral and Environmental Geophysics Class at the University of Adelaid. Contact Graham Heinson at: graham.heinson@adelaide.edu.au

INTRODUCTION

Herrmann catchment, shown in Figure 1, is in the Adelaide Hills, a few kilometres east of Mount Torrens and 40 km northeast of Adelaide. The field-site contains Cambrian massive sulphide mineralisation and a variety of environmental problems, principally salinity, acid drainage and acid sulphate soils. Two LEME PhD students are currently working in this area; ***Andrew Baker*** is an isotope geochemist mapping mineral pathways through cover sequences, and ***Mark Thomas*** is working on transient salinity effects using geophysics to map areas susceptible to salinity. The area is important as a natural laboratory for regolith landscape processes that has recently been covered by the National Action Plan (NAP) aerial mapping program.

FIGURE 1



Ortho-photograph of the Herrmann's catchment, with location of major geophysical transects.

Over two days in May, eighteen students from the third year Mineral and Environmental Geophysics class at University of Adelaide designed and carried out geophysical investigations to address fundamental regolith issues in Herrmann catchment. Mark and Andrew identified the aims for the geophysical surveys as:

- Define near-surface hydraulic structure
- Map clay concentrations
- Identify salinity pathways and areas of transient salinity
- Relate geophysical signatures to pedological information.
- Define depth to basement and location of sulphides
- Define fracture orientation as pathway for fluids (and fluid flow)
- Define aquifer structure to identify flow paths through weathered layer
- Map structure beneath cover

Figures 2, 3 and 4 show some of the students at work.

FIGURE 2

Gravity measurements by Susan Barnes and Edeltraud von Furt.

FIGURE 3

Seismic refraction experiment, hammer shot by Nathan Reid.

Nine different geophysical techniques were carried out along profiles shown in Figure 1. These included DC resistivity and induced polarisation (IP), seismic refraction, gravity, magnetics, magnetic susceptibility, electromagnetics (EM), self potential (SP) and elevation. East-west transects, 500-1000 m long, were conducted across known sulphidic mineralisation and a structurally-controlled magnetic anomaly identified from NAP aeromagnetic data. In the second week, a 500 m long transect across the main watercourse, from drainage divide to drainage divide, in a northwest-southeast orientation was mapped to define soil toposequence processes.

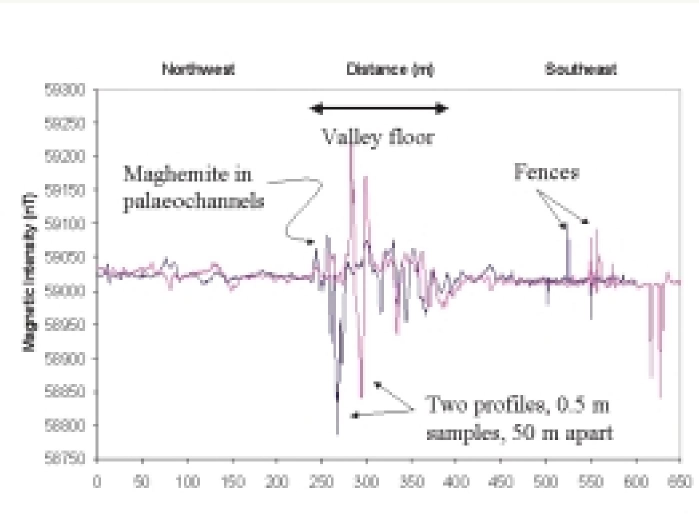
FIGURE 4

Dr Nick Direen explains the use of a magnetometer base station for the robing magnetometer surveys.

RESULTS

Data sets are being modelled and interpreted by the third year students as part of their reporting process, which will link back to the LEME postgraduates. Initial results are exciting. Figure 5 shows portable magnetic measurements across the toposequence transect in Figure 1. Two profiles were collected, approximately 500 m long and separated by 50 m, with a sample interval of 0.5 s and sample spacing of about 1 m. A base station magnetometer was used to log transient variations which were typically less than 5 nT. The interesting features in Figure 5 are short-wavelength (< 20 m), but high magnetic responses within the valley. Such signatures are due to maghemite concentrations, probably concentrated in palaeochannels within the valley. The source of maghemite is likely to be colluvial accumulations after bushfires on the slopes of the valley. Similar morphologies in the magnetic signatures may indicate meandering of the palaeochannels, which may be clarified by a denser grid survey.

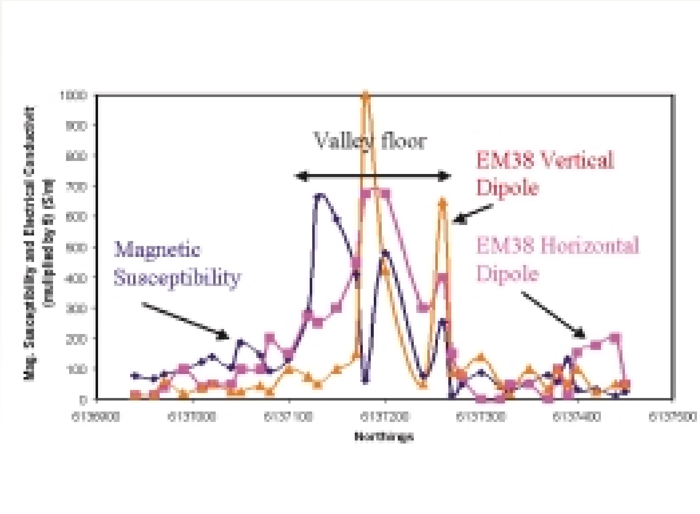
FIGURE 5



Two magnetic profiles across the northern soil toposequence profiles, showing presence of maghemite in palaeochannels.

Figure 6 shows a composite plot of electrical conductivity from an EM38 in two modes and soil volume magnetic susceptibility across the same transect, but this time with a sample spacing of 20 m. The EM38 vertical dipole mode is most sensitive to surface conductivity, while the EM38 horizontal dipole has highest sensitivity at about 50 cm depth. There is clear correlation between the magnetic susceptibility from maghemite and electrical conductivity from salts and/or clays in the valley palaeochannels. Results shown in Figures 5 and 6 indicate that high-resolution ground geophysical methods can be used to map regolith environmental systems and act as a proxy for soil toposequence processes. The question as to how well the airborne geophysical data can identify environmental processes is the core of Mark Thomas' PhD thesis.

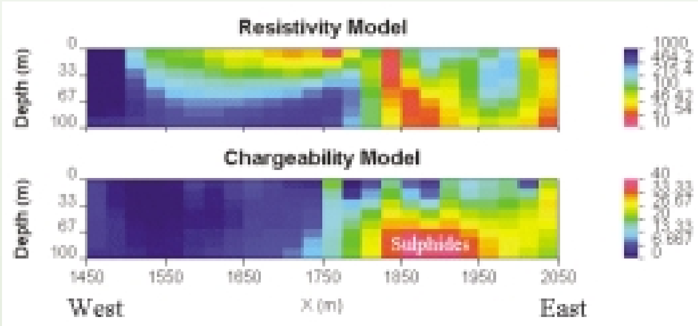
FIGURE 6



Composite plot of electrical conductivity from an EM38 in two modes (vertical mode – red triangles; horizontal mode – magenta squares) and soil volume magnetic susceptibility (blue diamonds).

Mapping mineralisation beneath cover was a second objective. Locating sulphide mineralisation at the head the catchment is important in determining controls on formation of acid sulphate soils, and sources of acid drainage. A 650 m long dipole-dipole resistivity and IP survey with 50 m sample intervals found clear evidence for sulphides in basement beneath cover, particularly in the IP data. Figure 7 shows resistivity and chargeability models along the profile. The resistivity model shows a break in the resistive structure (blue-region) at the location of the known pyrite

FIGURE 7



Electrical resistivity and IP chargeability models indicating location of sulphide mineralisation.

LEME PUBLICATIONS

LEME ensures its research developments and results are readily available to clients - the mineral exploration industry and natural resource managers - as well as the general public.

We are placing newly released Open File Reports on the CRC LEME web site (http://crcleme.org.au) for limited periods, with chapters downloadable in .pdf form. The reports can also be purchased conveniently in CD format, or hard copy produced to order. Abstracts from the whole range of Open File Reports can downloaded from the web, and the majority are available in hard copy for sale.

Those released this year are:

CRC LEME Open File Report 144

Geophysical and remote sensing methods for regolith exploration. E Papp, Editor

CRC LEME Open File Report 146

Resonance Acoustic Profiling Trials in Australia. M Cornelius, Editor**.**

CRC LEME Open File Report 147

Regolith landforms of the Gilmore project area. R Chan and D Gibson**.**

CRC LEME Open File Report 148

Regolith, geomorphology, geochemistry and mineralisation of the Sussex-Coolabah area in the Cobar-Girilambone region, North-western Lachlan Fold Belt, NSW. R Chan, R S B Greene, N de Souza Kovacs, B E R Maly, K G McQueen and K M Scott.

CRC LEME Open File Report 149

Regolith architecture and geochemistry of the Hermidale area of the Girilambone region, North-western Lachlan Fold Belt, NSW. R Chan, R S B Greene, M Hicks, B E R Maly, K G McQueen and K M Scott.

CRC LEME Open File Report 150

Regolith studies at Edoldeh Tank (ET) Gold Prospect, Gawler Craton, South Australia. (full details follow) and

Monograph

Regolith Expression of Australian Ore Systems. A compilation of geochemical case histories and conceptual models. These case histories are being systematically released as downloadable .pdf files on the CRC LEME web site, pending publication. There are some 30 case histories there now (see separate article)

Monograph

Regolith Landscape Evolution Across Australia. R R Anand, P de Broekert, Editors. A compilation of numerous regolith-landscape case studies and landscape evolution models. Generally, regions of outcropping bedrock and *in situ* regolith are well explored; the greatest potential lies beneath under-explored, substantial, largely transported cover. These areas are complex. The cost of future discoveries will be reduced by understanding the regolith and landscape evolution processes and improving interpretation of geochemical dispersion from ore deposits. This will also aid environmental research and management. These case histories are also being placed on the web, pending publication.

(Enquiries to LEME HEAD OFFICE: crcleme-hq@csiro.au. Tel: 08 6436 8695

Publications

Pedo-Geophysics Teaching and Research in the Adelaide Hills

mineralisation, however the chargeability model from the IP data more clearly defines the presence of sulphides (red-region). Although the formations have been drilled previously, profiles in Figure 7 were collected in an afternoon at very low cost, and provide considerable extra constraint on the depth and extent.

CONCLUSION

The Herrmann catchment field geophysics has been valuable as a combined teaching and research exercise. Students were presented with real LEME exploration and environmental problems, and collected field data to address issues. The students developed teamwork skills and gained a better understanding of the importance of integrating geophysics, geology and geochemistry. For LEME postgraduate researchers, teamwork has provided new models that would have been time consuming to achieve otherwise.

ACKNOWLEDGEMENTS

We would like to thank all of the farmers in the catchment for their generous co-operation with this project, and in particular Noel Herrmann and Trevor Neumann.

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Fritsch E. and R.W. Fitzpatrick (1994). Interpretation of soil features produced by ancient and modern processes in degraded landscapes: I A new method for constructing conceptual soil-water-landscape models. *Aust. J. Soil Res.* **32**, 889-907. (colour figs. 880 - 885).

Land management reference:

Fitzpatrick R.W., J.W Cox, B. Munday, and J. Bourne, (2003). Development of soil- landscape and vegetation indicators for managing waterlogged and saline catchments. *Australian Journal of Experimental Agriculture*: Special Issue featuring papers on "Application of Sustainability Indicators" **43** 245-252.

Spatial and remote sensing key reference:

Fitzpatrick R.W., D.A. Bruce, P.J. Davies, L.R. Spouncer, R.H. Merry, E. Fritsch and D. Maschmedt (1999). Soil Landscape Quality Assessment at Catchment and Regional Scale. Mount Lofty Ranges Pilot Project: National Land & Water Resources Audit. CSIRO Land & Water Technical Report. 28/99. 69pp. http://www.clw.csiro.au/publications/technical99/tr28-99.pdf

Mineral exploration key reference:

Skwarnecki, M., Fitzpatrick R.W., and Davies P.J. (2002). Geochemical dispersion at the Mount Torrens lead-zinc prospect, South Australia, with emphasis on acid sulfate soils. Cooperative Research Centre for Landscape Environments and Mineral Exploration. CRC LEME Restricted Report No 174. pp. 68 (volume 1) (plus 13 appendices: volumes 2 and 3).

Most recently released - available in DVD:

CRC LEME OPEN FILE REPORT 150

Regolith Studies at Edoldeh Tank (ET) Gold Prospect, Gawler Craton, South Australia

Volume 1 Text, Volume 2 Appendices

M J. Lintern, I.J. Tapley, M.J. Sheard, M.A. Craig, G. Gouthas and A J. Cornelius

Extract from: Preface and Executive Summary . . .

The Edoldeh Tank (ET) Regolith Project is part of the broader "South Australia Regolith Project" of CRC LEME, the principal aim of which is "to develop technically efficient procedures for mineral exploration in the major cratons of South Australia through a comprehensive understanding of the processes of regolith development and landscape evolution and their effects on the surface expression of concealed mineralisation".

This project is a follow-on to an initial study of regolith geology and geochemistry in the Gawler Craton, sponsored by CRC LEME, PIRSA and Gawler Joint Venture exploration tenement holders completed in 2002. It was developed after extensive consultation with industry geologists, and an excursion to various sites. The principal problems identified relate to verification of the thickness of transported overburden and to procedures for exploration in terrains where transported overburden is present.

The principal objective of the ET Regolith Project was to evaluate the use of components of transported overburden for detecting buried Au deposits in the western Gawler Craton. Five prospects (ET, Monsoon, South Hilga, Golf Bore and Jumbuck) were initially investigated. The objective was to determine the most suitable site for a detailed study. A single traverse, several hundred metres in length, was selected across each prospect that had mineralisation, transported overburden and adequate drill spoil. The regolith stratigraphy was described at each site and drill spoil collected for multi-element analysis. An existing company geochemical database for each prospect was also used. The results of the five prospect survey are reported in Lintern *et al*, 2002. The initial studies (Lintern *et al*, 2002) indicated that ET has the following properties:

1) two hundred drill holes spread over the prospect with cuttings in good condition;

2) a large Au in calcrete anomaly that had not been linked to a primary source, leaving potential for additional areas of investigation and possible drill targets;

3) indications that mineralisation might be expressed in the transported overburden;

4) a greater spread and thickness of transported overburden compared with other sites; and

5) sand dunes, typical of the western Gawler Craton, and a hindrance to exploration in this region so there are few, if any, previous studies in this type of terrain.

Regolith mapping at ET was based on the identification and detailed representation of the distribution of surficial material and the broader surface regolith units. The map was not only based on datasets commonly used in regolith map construction *e.g.*, Landsat TM, aerial photography and DEM, but also processed AIRSAR, and HyMapTM datasets played an important role in determining the final regolith-landform relationships. Regolith stratigraphy was determined using field observations, collection and analysis of drill cuttings from chip trays, and PIMA analysis. These data determined relationships between materials, weathering, landform history and the geochemical data. Drill cuttings, calcrete, soil and vegetation were collected to determine the distribution of Au and other elements, which was visualised in 3D and 2D.

The principal results indicate that:

1. In *in situ* regolith, Au was found to be concentrated in calcrete near the surface and above an interpreted leached zone of low Au concentration that can extend down several tens of metres into weathered regolith. The surficial Au anomaly extends from the ridge into transported regolith and, in places with thin (<5 m) sand cover, appears to be locally enhanced, possibly due to Au additions to the surface from underlying buried mineralisation in the transported overburden. Calcrete appears to be the best sample medium for Au exploration in preference to soil, vegetation and silcrete. Gold appears to be the best target element although As may also provide information on the location of mineralisation.

2. Datasets obtained by remote sensing were useful in discriminating regolith units and in determining surface mineralogies. They were important in the construction of the regolith-landform map.

3. Landsat TM was most useful in mapping at the 1:5000 scale required for this study. A DEM was generated from aerial photographs and was useful in distinguishing landforms. Ground-truthing was important in delineating features such as the extent and type of lag deposits, and in the final construction of the map.

4. The complimentary use of PIMA and visual logging of chip trays enabled determination of selected clay mineralogy, colour and lithology of the regolith including the boundary between transported and *in situ* regolith. 3D and 2D visualisations of the data assisted in determining the regolith stratigraphy and were able to integrate the information from PIMA, geochemistry and other data sets.

The study has led to a better understanding of Au dispersion in sand dunes, improved interpretation of calcrete-hosted Au anomalies, and indicated potential new drilling targets.

M. J. Lintern and I. J. Tapley
Project Leaders
April 2003
(mel.lintern@csiro.au.
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Dating ferruginous regolith

Dr Brad Pillans, Australian National University

brad.pillans@anu.edu.au

Australian regolith is typically strongly oxidised, and characterised by a variety of ferruginous segregations including nodules, concretions, cements and colour mottles. Such materials, when dominated by hematite, are suitable for paleomagnetic dating, as illustrated by Brad Pillans' role in dating regolith at Lucas Heights last year.

In late July 2002, Brad was asked to assist in geological assessment of the risk associated with faults that were discovered in the excavations for the replacement nuclear reactor at the ANSTO Lucas Heights facility in Sydney. Critical to the assessment was constraining the timing of last movement on the faults by paleomagnetic dating of an unfaulted iron oxide layer.

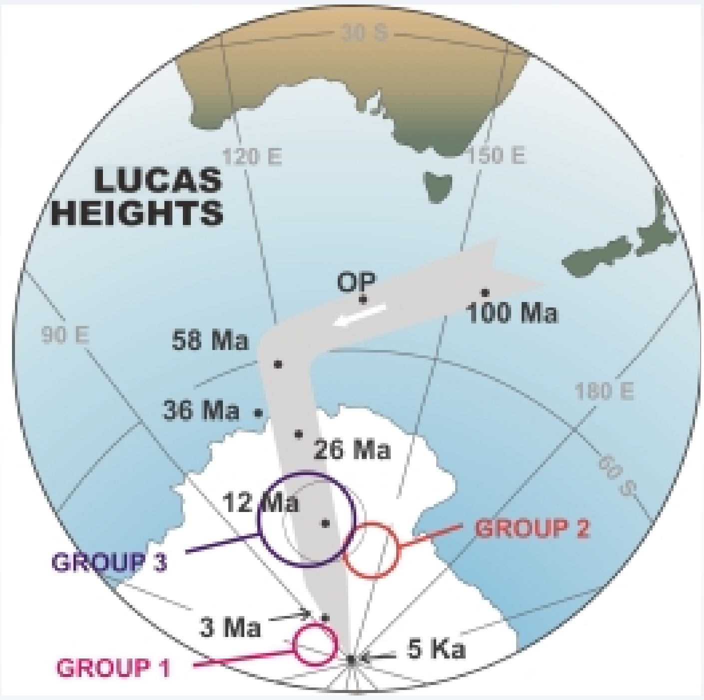
Brad's initial measurements had demonstrated that the layer had reversed magnetic polarity, and therefore older than the last major reversal of the Earth's magnetic field (the Matuyama-Brunhes reversal), dated at 780,000 years.

However, a review panel from the International Atomic Energy Agency (IAEA) concluded that such a minimum age was not "adequately conservative" because one fault strand had a reverse component of movement, consistent with the present regional stress field that has prevailed for the last 20 million years.

Brad then suggested that he might be able to establish an older minimum age by using the Cainozoic Australian apparent polar wander path. A month of intensive work followed, during which time Brad measured many more samples, sufficient to calculate a well-defined paleomagnetic pole. In the end, three groups of ages were determined (Figure 1), reflecting the long duration of weathering and iron-oxide formation at Lucas Heights. The critical group of specimens (Group 2) from the unfaulted iron oxide layer yielded an age estimate of 9±4 million years, which the review panel accepted as sufficiently long to establish the fault as "non-capable". In other words, the risk of future fault movement was negligible, and approval was given to proceed with construction at the reactor site.

The paleomagnetic methods used in the Lucas Heights study have been widely applied by Brad, and PhD student Martin Smith, and are beginning to provide a chronological framework for ferruginous regolith throughout Australia. Brad presented a summary of this work at the Australian Geological Congress in Adelaide last year, showing that deep oxidation of ferruginous saprolite has been markedly episodic over the past 200 Ma. Martin and Brad, in conjunction with Jim Dunlap, are also investigating the application of (U-Th)/He dating methods to dating iron oxides. It is interesting to note that Bob Pidgeon (Curtin University) has also been developing techniques to date lateritic duricrust using the same (U-Th)/He series.

The economic and social benefits that stem from CRC LEME's regolith dating project are not always obvious to the wider community. At a time when more and more government and industry funds are being directed to applied science, the Lucas Heights study is a timely reminder that there must also be continued funding for the kind of basic or pure science that underpins the applications. These techniques will be important in introducing the fourth dimension of time into understanding processes in the regolith.



Paleomagnetic poles, determined by Brad Pillans, for three groups of ferruginous regolith samples from Lucas Heights (circles are 95% confidence limits for each pole), compared with the Late Cretaceous-Cainozoic apparent polar wander path for Australia. Ages of reference poles are in millions of years (Ma). OP = late Cretaceous thermal overprint pole from Sydney Basin. Paleomagnetic ages are 2±1 Ma (Group 1), 9±4 Ma (Group 2 = unfaulted iron oxide layer) and 14±8 Ma (Group 3).

PROGRAM 4 SALINITY-RELATED PROJECTS

Ken Lawrie, Tim Munday, Paul Wilkes– ken.lawrie@ga.gov.au

CRC LEME staff in Program 4 are currently working on a number of projects in South Australia and Queensland that are funded under the National Action Plan for Salinity and Water Quality (NAPSWQ). The project areas in South Australia are in Riverland, Tintinara, Jamestown, Angas-Bremer Hills and Angas-Bremer Plains (Figure 1), and Lower Balonne catchment in southeast Queensland. Research in these areas is being conducted in collaboration with CSIRO Land and Water Division, PIRSA, Queensland Department of Natural Resources and Mines (QDNRM) and the Bureau of Rural Sciences (BRS). All projects involve close community consultation.

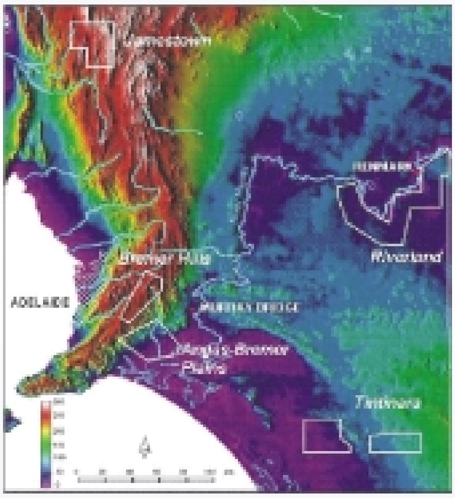


Figure 1: South Australian SMMSP catchment areas covered by airborne geophysical date (white polygons). Study areas are shown on a pseudocoloured DEM for the State.

SOUTH AUSTRALIAN PROJECTS

In the Mallee Highlands Zone (Riverland and Tintinara), there has been an increase in groundwater salinity as a consequence of dryland agriculture and higher rates of irrigation recharge. Near-surface clays reduce the effect of irrigation recharge and consequent leaching of salt accumulated in the soil zone. Irrigation schemes placed to coincide with the distribution of these clays, rather than more permeable sand units, has the affect of prolonging the life and quality of groundwater resource. Management of this issue therefore requires a better understanding of the distribution of the clays, which are relatively conductive and therefore can be mapped by airborne EM systems.

In the *Riverland Project*, LEME's role is to calibrate and invert Helicopter Frequency Domain Electromagnetic (HEM) data to deliver products which will help predict rates of groundwater recharge. Specifically, the intent is to map a near-surface clay, known locally as the "Blanchetown Clay", which acts as an aquitard and reduces recharge to the lower aquifer. The Blanchetown Clay is not everywhere present in the regolith, but its presence is characterised by elevated conductivities relative to other overlying and underlying regolith units. The project aims to better understand the causes of observed conductivity variations recorded in the HEM data, and to generate maps of the spatial distribution and thickness of this layer. The reliability of these maps is also determined by other factors that may influence conductivity in the near surface, such as artefacts caused by HEM inversion procedures. A secondary objective is to define the variability in the conductivity (that is the solute content) of the deeper aquifer to help constrain solute models for predicting water quality within the aquifer.

The *Tintinara Project* has similar objectives. The HEM data and derived products are being used to help determine rates of groundwater recharge (Mallee Highlands Zone) and variations in groundwater quality (Coastal Plain Zone). In the Coastal Plain Zone, where the water table is near the surface, the aim is to better understand the variability of groundwater conductivity in terms of salinity, variations in soil type and topography. These factors are important in developing plans for preserving biodiversity.

In the *Angas-Bremer Hills Project* scientists are using gamma-ray spectrometry (Figure 2) and digital elevation models (DEM) to delineate regolith materials and predict geomorphic and hydrologic processes in an upland landscape. A preliminary scoping study showed a correlation between electrical conductivity (ECs) in streams, and regolith materials identified from old, coarser resolution, gamma-ray datasets. Hence this project focuses on understanding the relationships between salt stores and regolith materials using higher resolution gamma-ray airborne datasets specifically acquired for the project.

Selected sub-catchments within Angas-Bremer Hills are being used to understand relationships between geology, slope processes, salt stores and regolith materials. Relationships between remotely sensed datasets and regolith types are being applied in a GIS environment to produce a series of maps, fully attributed in regolith and hydrological terms. Fieldwork allows descriptions of regolith and soils including their texture, mineralogy, and geochemistry. Mapping of soils and regolith involves interpretation and integration of gamma-ray imagery and terrain attributes. In selected catchments, ground EM data, when calibrated with drilling, helps to build 3-D regolith and salt store models. Radioelement measurements and geochemistry of soils and weathered bedrock are being used to validate airborne gamma-ray spectrometry. This project will input the regolith component into the overall hydrological model of the area that is the responsibility of CSIRO Land and Water based in Adelaide.

Figure 2: Bremer Hills - Ternery Image from the airborne radiometrics (red - Potassium, Green - Thorium, Blue - Uranium).

Continued on Page 12

PROGRAM 4 SALINITY-RELATED PROJECTS

Continued from Page 11

Angas-Bremer Plains project includes important irrigation areas and aquatic habitats that are at risk from rising groundwater and secondary salinity. Groundwater systems are complex, being influenced by varied regolith and sedimentary systems. Consequently, land management strategies need to be based on an understanding of origin, nature, character and distribution of regolith materials in three dimensions. Interpretation of aerial geophysics, particularly AEM, is contributing to this understanding. This provides a basis for more sophisticated management approaches, including improved irrigation scheduling, water re-allocation through local water trading, deep drainage and pumping.

An appreciation of sub-surface geology is also important in developing management approaches to the margins of Lake Alexandrina and associated wetlands. Rising saline watertables in the area presents a hazard to production and local ecosystems. Detailed ground studies allied to careful interpretation of the airborne geophysics are important in constraining hydrogeological models.

The main objective of the Angas-Bremer Plains project is to provide a regolith framework to better understand the hydrology of the area. A time-domain AEM dataset and new airborne magnetics and gamma radiometric datasets have been acquired and ground validation is proceeding.

QUEENSLAND PROJECT

LEME is working on another NAPSWQ-funded project in the Lower Balonne Catchment in southeast Queensland (Figure 3). This is in collaboration with QDNRM and BRS. The study evaluates the use of airborne geophysics, principally gamma radiometrics and time-domain airborne electromagnetics (AEM), for mapping surficial floodplain deposits and salinity in groundwater systems. The project is novel in its application of AEM technology to the study of large inland fluvial floodplains, in an area where little is known of the distribution of salts, and the hydrogeology is thought to be dominated by a regional groundwater flow systems.

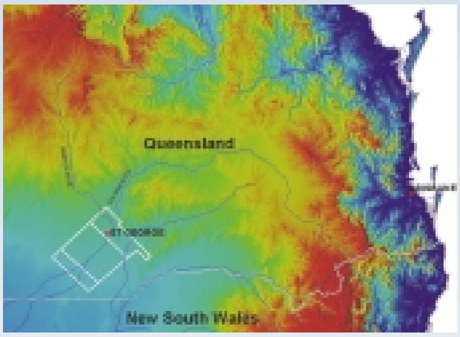


Figure 3. Location map showing Lower Balonne airborne geophysics survey area superimposed on DEM.

A regolith landform map has been produced from interpretation and ground validation of gamma radiometrics (Figure 4), aerial photos, Landsat TM and ASTER data. This map reveals a complex sequence of floodplain systems. The relative timing of deposition of these surficial deposits has been established, and processes of erosion and deposition are now understood (Figure 5). An understanding of the surface geomorphology has proven particularly useful in interpreting the distribution of sub-surface aquifers.

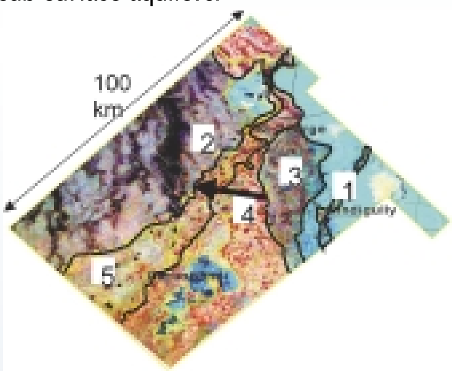


Figure 4. Lr Balonne Project area, SE Queensland. Ternary gamma radiometrics image (Red – potassium, Green- Thorium, blue, uranium); surface geomorphological units are mapped (polygons 1-5). Unit 1 is the weathered Cretaceous bedrock (Griman Creek Formation); 2 is the Moonie Fan complex; 3, 4 and 5 are progressively younger floodplain deposits of the Balone River.

The AEM survey is the largest flown in Australia specifically for salinity and natural resource management issues. Preliminary work on the electrical structure of this area shows that standard inversion modelling of AEM data (using EMflow software, or Layered Earth Inversions) is unsuitable because of increasing conductivities with depth. Standard modelling packages cannot handle these electrical profiles, and the conductivity values generated by standard software algorithms are likely to be misleading. Production of a robust AEM dataset in this area has required the trialling of new modelling approaches and software. The products generated to date have significantly improved the reliability of conductivity-depth maps.

The AEM data has been calibrated using both existing borehole information and new drilling. Correlations have been made between the surface distribution of regolith materials and the underlying depth-conductivity structure provided by AEM. Iinterpretation of AEM is being used to develop a hydrogeological model (by QDNRM and BRS) that will provide a basis for groundwater modelling and salt hazard assessment. The model uses sedimentological and regolith data to help constrain aquifer connectivity. A second phase of the project will examine salinity and groundwater dynamics in order to refine the groundwater model.

These techniques developed by LEME will lead to reliable conductivity-depth models for use in Australian landscapes. Regionally, the outcomes could influence the management of groundwater resources and land management practices in the Lower Balonne River catchment. Finally, our work will provide a basis for prioritising future investment.

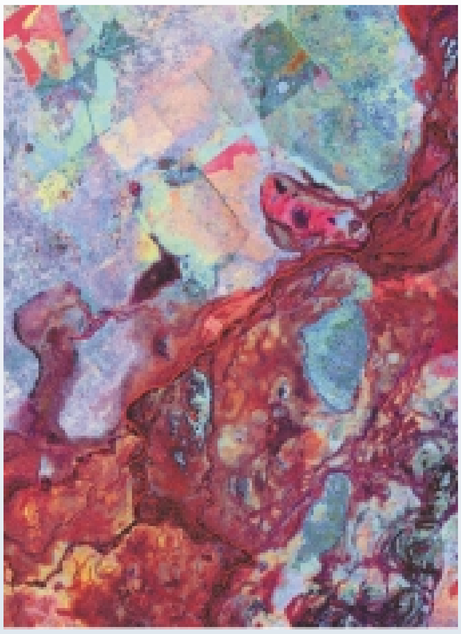


Figure 5. Landsat TM5 image over the boundary between the current Balonne floodplain deposits and the older Maranoa fan materials. The younger (darker red) floodplain materials are deposited in channel, overbank, crevasse splay and scour channels that incise the older alluvial fan deposits.

The Western New South Wales Regolith Project

INTRODUCTION

The Western New South Wales Regolith Project aims to assist mineral exploration in Western NSW through a greater understanding of the regolith. Specific objectives include the production of regolith-landform maps, development of geochemical exploration approaches to sediment-covered areas and development of regional regolith and landscape evolution models emphasising their importance to mineral exploration. The project is funded by the NSW Department of Mineral Resources (DMR).

The project started in July 2001 and has a lifetime of 3 years. Project staff are from Geoscience Australia (GA) (Patrice de Caritat, Dirk Kirste, Kylie Foster), Adelaide University (Steve Hill) and NSW DMR (Richard Barratt, Barney Stevens, Kingsley Mills and Tim Sharp). Two Honours theses have been completed as part of this project (Rod Dann, Tessa Chamberlain), and several PhD, MSc and Honours theses are in progress (Leanne Hill, Karen Hulme, Melissa Quigley, Robert Grzegorek and Robbie Morris). Several GA contractors (Simon Debenham, Jaclyn Brachmanis, Anthony Senior, Ben Mayo) and Graduate Recruits (Ancret Lewis, Karen Earl, Matilda Thomas, Jaclyn Brachmanis) have also made significant contributions.

This summary overviews progress as we enter the third year, and outlines future research directions.

REGOLITH-LANDFORM MAPS

One of the primary objectives of our Core Participant, NSW DMR is the production of regolith-landform maps, which started as part of the Basins Program of LEME-1. Figure 1 shows the status of map production around Broken Hill. Map sheets released to-date are:

- **Balaclava** 1:25 000 regolith-landform map
- **Redan** 1:25 000 regolith-landform map
- **Triple Chance** 1:25 000 regolith-landform map
- **Kinalung-Quondong West** 1:25 000 regolith-landform map
- **Mount Gipps** 1:25 000 regolith-landform map
- **Pinnacles** 1:25 000 regolith-landform map
- **Broken Hill Special** 1:100 000 regolith-landform map
- **Tibooburra Special** 1:25 000 regolith-landform map (~400 km to the north of Broken Hill)

All the above maps are available for purchase via CRC LEME Headquarters, and the Broken Hill Special map is also part of the latest NSW DMR Broken Hill GIS CD-ROM launched in late 2002. Work has started on other map sheets (Wahratta, Thackaringa, Rockwell, Balaclava 2nd edition and Teilta). These maps provide a context within which mineral exploration companies can design appropriate sampling strategies that take into account the regolith materials (distribution and origin), landforms and potential geochemical dispersion pathways.

GEOCHEMICAL SAMPLING MEDIA

A number of test areas have been investigated to identify best regolith sampling media for mineral exploration. Recent studies

Continued on Page 14

Stillwell Award 2002

Congratulations to *Ravi Anand* and *Mark Paine*, who have received the prestigious Stilwell Award from the Geological Society of Australia for the best paper in the Australian Journal of Earth Sciences in 2002. The award will be presented at the 17th AGC to be held in Hobart, February 2004

This was for their thematic issue

Regolith geology of the Yilgarn Craton, Western Australia: implications for exploration. (AJES volume 49, 3-172, 2002).

Comment from CEO CRC LEME, Dennis Gee:

The volume brings together the pioneering research of LEME 1 and the earlier work of the CSIRO Regolith Group. It will remain the authoritative reference for regolith studies and geochemical exploration in the etched lateritic landscapes of Western Australia.

Dr Ravi Anand (left) and Mr Mark Paine

Extract from the Volume 49 'Introduction' by AJES Editor in Chief, A E Cockbain.
"This thematic issue starts with an introduction that surveys the history and background of regolith studies, followed by a discussion of weathering and laterite profile terminology. The main section of the issue is devoted to regolith materials, which are dealt with under the headings: lag, soils, sediments, ferruginous materials, calcrete, silcrete and silicification and multiple duricrusts. The section on regolith distribution and patterns of regolith on the Yilgarn Craton looks at mapping of the regolith and discusses regolith-landform mapping units. A discussion on the geomorphic history of the Yilgarn Craton analyses various landscape evolution models and summarises what is known of the regolith-landform history of the craton. Finally, the authors discuss the implications of exploration in terms of the economic significance of the regolith and the choice of sampling media"

ACCOLADES TO LEME STAFF

CSIRO OH&S AWARDS

LEME researchers, *Ian Robertson* and *Mel Lintern*, from CSIRO Exploration and Mining in Perth along with Steve Fraser from Qld were the recipients of a CSIRO OH&S Achievement Award. They formed the "Field Safety Project Team" whose objective was to provide a translation of CSIRO OHS policies related to field work into simple and practical procedures designed to prevent injuries during field trips and aid prompt recovery should an incident occur. As a result of the Field Safety Project, standardised field safety authorisation, communication and emergency procedures have been implemented across all CSIRO Exploration and Mining sites and other Divisions are now using some of these procedures to improve their own.

Program 3 Leader, **DR COLIN PAIN**, based at Geoscience Australia, Canberra has received two marks of recognition recently.

- Honorary appointment as Adjunct Professional Associate - Regolith Science in the School of Resource, Environmental and Heritage Sciences, University of Canberra
- Annual Citation for Excellence in Reviewing 2002 - from the Australian Journal of Earth Sciences

Dr Colin Pain

Colin has over 30 years experience in geomorphology, regolith geosciences and landscape evolution as applied to mineral exploration and environmental issues and is a co-author of two books "Regolith, Soils and Landforms" and "The Origin of Mountains". He was instrumental in the bid process for both LEME 1 (Landscape Evolution and Mineral Exploration) and LEME 2 and has been a Program Leader and Executive Committee member for the Centre since 1995.

(Figure 1) build on previous case studies and include:

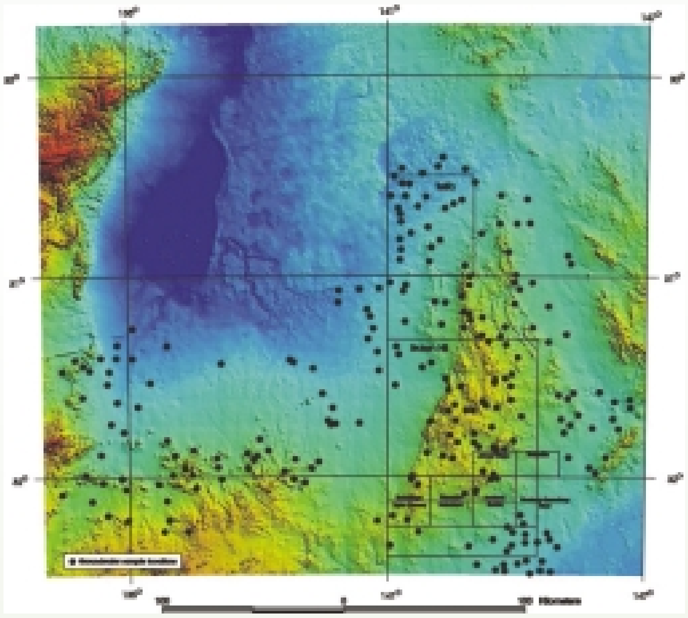
- **Stevens Creek** catchment (groundwater, stream sediments, vegetation)
- **Southern Curnamona Province**, including areas of outcrop in the Olary and Barrier Ranges and areas covered by the Callabonna Sub-basin (groundwater, surface regolith)
- **Northern Leases** area (surface regolith, saprolite, vegetation)
- **Teilta** 1:100 000 map sheet (groundwater, calcrete, silcrete, vegetation)

In the Stephens Creek catchment, groundwater and river red gum chemistry successfully outlined known mineralisation. A hydrological model of groundwater systems was established. Interpretation of sulfur and lead isotope data, in conjunction with trace element concentrations, identifies areas with likely Broken Hill type mineralisation, one of which is located well away from known mineralisation, below 80 m of sedimentary cover.

The regional groundwater investigation on the Barrier Ranges and adjacent margins of the Callabonna sub-basin (to the west), Murray basin (south) and Bancannia trough (east) is focussing on processes that affect the composition of groundwater. Evaporation, mixing, adsorption and mineral dissolution have been identified as important controls on groundwater composition. Emphasis is on quantifying effects of each major process in order to model geochemical evolution of groundwater composition. Here too, combining sulfur, lead, strontium, oxygen, hydrogen, carbon and chloride isotope data with major, minor and trace element concentrations is yielding interesting results. A methodology to use groundwater geochemistry as a vector to mineralisation will be developed.

FUTURE DIRECTIONS

Mapping of regolith-landforms at 1:25 000 scale of the Broken Hill region will continue over the next 12 months. We plan to



produce another 4 maps, mostly from the southern Broken Hill Domain. Mapping at 1:100 000 scale will continue, with priority being given to Teilta 1:100 000 map. Groundwater results will be compiled and published, and a methodology developed to use groundwater for mineral exploration under cover. GIS for all available geochemical data will be produced. Results of regolith sampling will be published in LEME volumes and elsewhere, and will be compiled with other data into 3D models of landscape evolution and geochemical dispersion. Staff will be actively involved in conferences and associated field trips (BHEI Conference in July 03, 17th AGC, Hobart in February 04), communication and reports via the LEME website, and short courses (Regolith Mapping, Hydrogeochemistry) that relate to this research.

Patrice de Caritat
Project Leader
May 2003 – Patrice.de.caritat@ga.gov.au

CRC LEME - AMEC MINERALS EXPLORATION SEMINAR

WEDNESDAY 18 JUNE 2003, Perth

This is the first CRC LEME technical presentation for 2003 and is supported by the Association of Mining and Exploration Companies (Inc). The objective is to convey to mineral explorers the results of recent LEME work, including work recently out of moratorium. We have put together a program which is both retrospective looking at some of our previously released material, as well as forward looking at some of the strategic research priorities LEME sees as important to the industry.

LEME is now in its second seven-year term. Its role is to apply regolith science to the problems facing Australia in the areas of mineral and natural resource management. It retains a strong commitment to addressing the challenges of mineral exploration in areas of transported regolith. In this regard it is undertaking and developing a wide range of integrated projects that use multi-disciplinary approaches to look at three-dimensional architecture of the regolith. The projects focus on the time-dependent physical, chemical, biological and hydrological processes that control geochemical dispersion of minerals in the regolith.

R Dennis Gee
Chief Executive Officer, CRC LEME

Peter Buck
Chairman, AMEC, Mineral Exploration & Technical Committee

PROGRAM OF TALKS

LEME research Priorities and directions - Dr Dennis Gee

Regolith geology, processes and logging - Dr Ravi Anand

Form to function: Giving meaning to observed airborne electromagnetic responses in regolith settings - Dr Tim Munday

Hydrogeochemistry and supergene gold - Dr David Gray

Platinum group elements in the regolith, Ora Banda Sill - Dr Charles Butt

3D regolith modelling as an aid to exploration of deeply weathered terrains -Yandal Belt - Dr Ravi Anand

Murrin Murrin regolith and geochemistry - Dr Martin Wells

Gold anomalies in transported regolith - Dr Charles Butt

Calcrete as a sampling medium - Gawler Craton - Mr Mel Lintern

Woodie Woodie unveiled - Assoc Prof Jayson Meyers

Weathering of base metal deposits, western Lachlan Fold Belt - Mr Keith Scott

Adelaide University geophysical development - Dr John Joseph

Atlases, Open File Reports and Thematic volumes - Dr Ian Robertson

AMEC-LEME Panel Discussion "Where is LEME going from here " - Chaired by Dr Peter Buck

Seminar Abstracts will be available to purchase on CD (Contact LEME Publications officer on crcleme-@csiro.au) and will be downloadable from the web (http://crcleme.org.au)

CRCLEME

Cooperative Research Centre for Landscape Environments and Mineral Exploration

ADVANCES IN REGOLITH 2003

The Cooperative Research Centre for Landscape Environments and Mineral Exploration is hosting three regional regolith symposia in late 2003:

Central Symposium-Adelaide University, 13-14 November 2003

Eastern Symposium-Australian National University, 19-21 November 2003

Western Symposium-Curtin University of Technology, 27-28 November 2003

Each symposium will address the strategic themes of CRC LEME, which include:

- Improving our understanding of regolith processes and landscape evolution:
- Making exploration geochemistry work through cover;
- Developing geophysical techniques to interpret regolith architecture;
- Using regolith knowledge to enhance prospectivity in geological regions;
- Developing methods to map and predict salinity with outcomes linked to mitigation and remediation.

Additional special themes will also be addressed at each different node including:

- Biological Factors in Regolith Formation (ANU)
- Acid Sulphate and Saline Regolith (Adelaide University)
- Geophysical Imaging and Dating of the Regolith (Curtin University of Technology).

This invitation extends to all regolith or regolith-related discipline researchers in Australasia. Invitees include Honours and postgraduate research students and also professionals working in regolith research within universities, state and federal research institutions, retirees and the general regolith geoscience community. Presenters do not necessarily have to be affiliates of CRC LEME.

Registrants are invited, in the first instance, to attend the closest symposium unless they wish to present in one of the special themes (above). Abstracts for all three symposia will be published as a single, fully refereed CRC LEME Report, "Advances in Regolith 2003". Abstract submissions close 31 August, registration closes 31 October.

Further information and registration forms are available in the First Circular on the CRC LEME WWW site at: http://crcleme.org.au/.

Contact the three regional regolith symposia conveners:

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NOTE: Proceedings from the first CRC LEME short regolith conference -

Regolith and Landscapes in Eastern Australia
are available from the CRC LEME Head Office.
Contact Publications Officer: crcleme-hq@csiro.au
136 pages + CD ROM, $44 (incl GST) + $7.70 postage
Look at the CRC LEME website: crcleme.org.au under Publications/Monographs for further details.

Discovering manganese ore under cover using 'Hoistem'

Associate Professor Jayson Meyers
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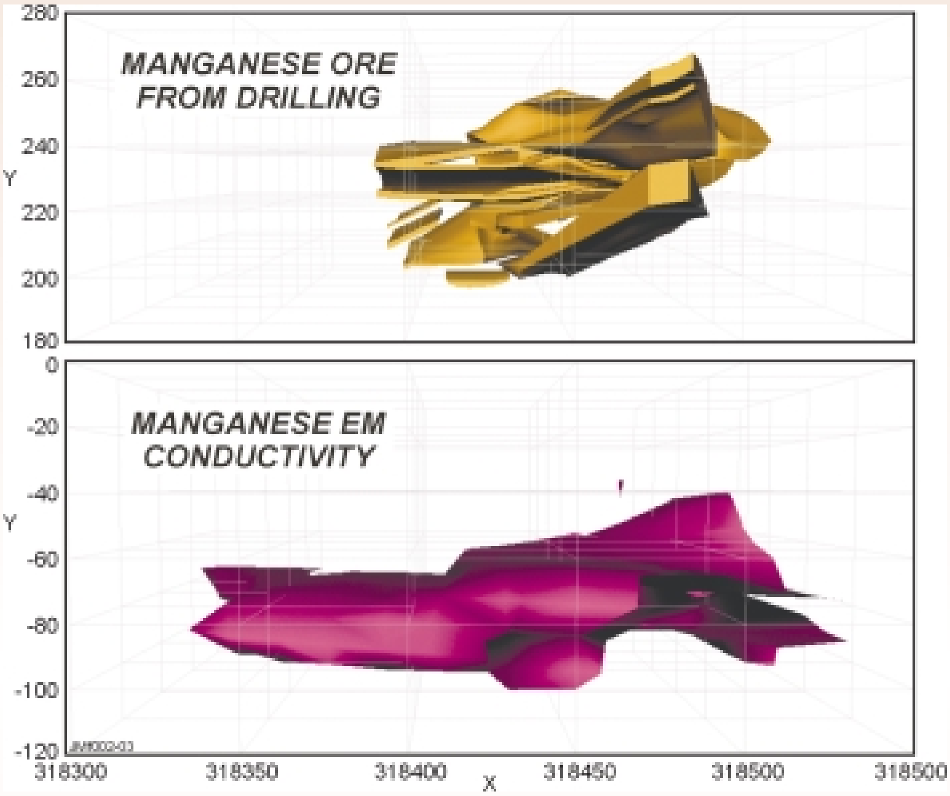
LEME research has contributed to the discovery of several new manganese ore bodies in the Woodie Woodie manganese mine corridor, located in the Pilbara region of Western Australia. The Woodie Woodie Mine is owned and operated by Pilbara Manganese Limited, a subsidiary of Consolidated Minerals Limited, who sponsored this project. High-grade manganese ore is mined by Pilbara Manganese using open cut methods, and the ore is shipped by truck to Port Hedland for export around the world where it is primarily used in steel making.

Manganese was discovered at Woodie Woodie over 50 years ago, and has only been mined on a large scale by Pilbara Manganese over the last five years. Geologists at Pilbara Manganese recently recognized that the manganese ore is deposited from hydrothermal solutions into ancient dolomite sedimentary layers that are 2.5 billion years old. The deposits sit in fault and pipe like structures within the dolomite, and they may not always come to the surface. Some ore bodies are also buried by glacial sediments from the Permian period, about 250 million years ago, and younger sedimentary deposits. For these reasons, this project sits under LEME Program 2, Exploration Under Cover.

At the recommendation of LEME researchers, an innovative time-domain helicopter electromagnetic system called Hoistem was employed to explore for buried manganese ore bodies previously missed by other geophysical prospecting methods. The Hoistem system is under development by Newmont Mining and GPX Airborne, and was used at Woodie Woodie as part of an ongoing R&D project run by Pilbara Manganese and Curtin University Exploration Geophysics Department in association with CRC-LEME. The Hoistem system works like a flying metal detector that looks for conductivity changes in the ground, such as conductive manganese ore in an electrically resistive dolomite.

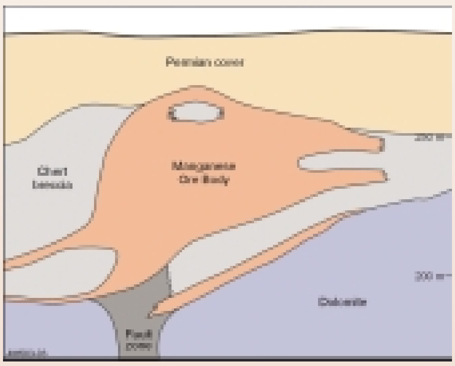
FIGURE 1



Following supervision of logistics and parameter testing at site, the data were processed by LEME researchers using innovative methods to enhance the response of conductive manganese targets and to separate this response from other conductive features, such as saline groundwater and clay filled drainage valleys. A number of targets were drilled and about five new manganese prospects were discovered within the northern part of the Hoistem survey, and more targets in the south are to be drilled this year. One of these 'blind discoveries' has turned out to be one of the largest single manganese ore bodies found to date in the Woodie Woodie corridor, having a resource of 1.2 million tonnes. It sits under 25 metres of Permian clay and was named 'Chris D' after a former company director. Chris D and other Hoistem discoveries have significantly increased Pilbara Manganese resource base and extended the mine life by several years.

Research is continuing on the geophysical nature of manganese mineralisation and ore forming processes, and the application of innovative geophysical methods for further exploration success. This project is supervised by LEME researcher Dr. Jayson Meyers and LEME PhD scholarship recipient Anousha Hashimi, both from Curtin University Exploration Geophysics.

FIGURE 2



Caption

The successes of MTEC

Continued from Back Page

- Regolith Geology and Mineral Exploration—11 days at Masters-level taught alternately between Broken Hill and Kalgoorlie. This course is aimed at professional Masters and postgraduate students as well as industry extension professionals with little or no experience in regolith-dominated terrains. The course is staffed by professionals from most of CRC LEME's core parties as well as industry.

To date, CRC LEME has brought together over **190** participants including Honours and postgraduate students from Australian National University, Curtin University of Technology, La Trobe University, Monash University, University of Canberra, University of Melbourne, University of New England, University of New South Wales, University of Tasmania, University of Western Australia and Wollongong University. Industry and research participants have come from Sons of Gwalia, Barrick Gold, Otter Gold, Western Mining Corporation, PIRSA, NSWDMR, Natural Resources and Environment Victoria, CSIRO, Geoscience Australia and the Council for Geoscience of South Africa.

Each of the courses offers an excellent opportunity to learn about the various aspects of regolith geoscience in a concentrated format, taught by interested people in interesting places. As well as being a wonderful learning opportunity for students and industry professionals alike, the initiative also highlights the successes of collaboration within CRC LEME, showing the research and teaching strengths that true cooperation can deliver.

Two more courses remain for 2003: Environmental Mineralogy (16-20 June, ANU); and Regolith Geology and Mineral Exploration (4-15 August, Broken Hill).

For more information about CRC LEME participation in the MTEC initiative and course information for the remainder of 2003 and 2004, please visit the CRC LEME WWW site **http://crcleme.org.au/** and look under "Education" or contact CRC LEME MTEC representative:

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Happy mappers from Melbourne and La Trobe universities on the plains at Cockburn, on the NSW-SA border, during the 2002 Regolith Mapping and Field Techniques course.

New LEM

Broken Hill "over there". Steve Hill (Adelaide University) lecturing, Junction Mine gossan, Broken Hill line of lode. The Students are participating in the recent Regolith Mapping and Field Techniques shortcourse - a week long Honours-level shortcourse delivered by CRC LEME for the National Geoscience Teaching Network, part of the Minerals Tertiary Education Council.

CRC LEME is committed to graduating at least 60 PhD students and an equivalent number of Honours students, during its lifetime. To this end LEME is currently guaranteeing more than $600K from its cash reserves each year to provide new scholarships for students to work on regolith-related research. In October 2002 LEME advertised nationally for 30 Geoscience scholarships and was greatly encouraged to receive more than 50 applications from suitably qualified students. A rigorous review and assessment process over the summer recess and a coincidental release of matching funds by one core party university led to the offering of a much larger than anticipated number of scholarships, with about 48 students overall receiving funding.

Seven Summer scholarships worth about $1000 each were offered with one student (Jennifer Leonard) at ANU studying chemical changes in regolith associated with Eucalypt types. Six Summer Scholars at Adelaide University including students from both second and third year, worked on projects ranging from rare earth element geochemistry of albitising brines associated with the Paratoo copper deposit (Jason Tilley) to an experimental geophysical study of groundwater flow using self-potential electrical methods (Emma Hissey). Emma also produced a poster of her research topic, which was displayed at the ASEG conference in Adelaide.

There were fewer incoming Honours students in LEME in 2003, reflecting smaller Honours classes due to lower third-year numbers in each core party university. Nevertheless, between 5-6 Honours students at each node have just begun preparation for Honours research projects. At ANU Bear McPhail is supervising one student working on geochemistry for mineral exploration (Edward Summerhayes) and another on break-of-slope salinity problems

E Scholars and Students in 2003

(Jodi Webb), whilst four other students are involved in regolith landscape evolution studies including mining (Kristy Bewert), palaeodrainage (Daniel Glanville) and soil management (Louisa Roberts and Susan Tate).

At Adelaide three LEME scholars are working on regolith geophysics (Alan Cadd), regolith geochemistry for diamond exploration (Amy Lockheed) and regolith landform evolution in an urban catchment (Sam McDermott). Each of these students is being supervised by one of the new LEME-related staff members at Adelaide. A further two students (Alex Pengelly and Rob Grezgorzek) will be funded from project funds to work, respectively on remote sensing and regolith mapping projects in the Curnamona area.

A further five Honours scholars are being funded through Curtin University, three in geophysical applications to regolith studies (Nigel Cantwell, Brendan Corscadden and Matthew Hope) and in geochemical expression of sulphide orebodies (Chris Buxton) and tree growth in salt affected landscapes (Claire Robertson).

In 2003 CRC LEME was spectacularly successful in attracting new postgraduate students into research programmes. In particular, students entering with external (APA and IPRS) scholarships allowed the release of further LEME funds and a large raft of Science Faculty half-scholarships at Adelaide University doubled the number of students there. Six new postgraduate (5 PhD and 1 M Phil.) scholars were accepted at ANU. Proposed projects range from environmental, including the role of regolith in agroforestry (Glenn Bann), hydraulic conductivity dynamics (Michael Turner) and environmental applications (Matthew Lenahan) to research concerned with regolith processes. Amongst these Katie Dowell will study the origin of opaline silica, while Kathryn Fitzsimmons will study regional landscape evolution and David Little intends to model biological factors in regolith formation. As ANU have now replaced UC as the sole Canberra university node, they are seeking further postgraduate applicants. *[contact Dr Bear McPhail, Geology Dept, ANU for further information bear.mcphail@anu.edu.au]*

At Adelaide University, the acquisition of both APA and IPRS award students and the offering of 50% matching Faculty scholarships for each LEME scholarship offer, together with the input of funds from both the SA DWLBC and CRC PBMDS allowed 12 students (11 PhD and 1 MSc) to take up scholarship offers, a significant boost to the overall AU and LEME postgraduate cohort. These students will be studying in six main areas of research. Two students (Tania Dhu – applications, and Phillip Heath – mathematical modelling) are undertaking geophysical projects whilst a further 3 will concentrate on geochemistry (Karin Hulme – biogeochemistry of Curnamona, Pierre Wulser – uranium exploration in the Callabona sub basin and Mark Fritz – baseline geochemistry of saline soils). Isotope geochemistry of calcretes and palaeoenvironmental studies will be undertaken by Aija Mee and Hazell Haywood, supervised by a new LEME staff member, Assoc Prof David McKirdy. A new link with the AU NCPGG through Assoc Prof Simon Lang will see Mark Riley (regolith mapping and delta formation) and Victor Waclawik (remote sensing of regolith) study the western shores of Lake Eyre. The final input of funds from DWLBC and PBMDS with Assoc Prof David Chittleborough will support a large collaborative project studying the influence of drainage in areas of salinity, principally in the southeast of SA. Michael Durkay (mobility of elements in drained saline soils), Sean Mahoney (Remote Sensing and GIS) and David Mitchell (Remote Sensing and spatial technologies) are the LEME participants in this study, which will also include two further, largely PBMDS-funded student projects.

A further five new LEME scholars were funded at Curtin University. The group of environmental geochemistry students supervised by Dr Ron Watkins received scholarship and operating funds to continue their studies, with Troy Cook (pollutant traps) and Bobak Willis-Jones (groundwater acidity) working towards MSc degrees and a new PhD scholar (Ryan Noble) on the distribution of arsenic near surface. Sam Lee is beginning a study on groundwater management at Cape Range Peninsula and finally Anousha Hashemi will join the Curtin Geophysics postgraduate group investigating exploration techniques for high grade manganese ore.

To conclude, this listing of 48 students newly entering LEME research projects adds to 25 Honours students who graduated from our core party Universities in 2002 and the ongoing 26 Postgraduates currently actively engaged in LEME research, to continue the strong educational focus to CRC LEME.

Pat James, CRC LEME Education and Training Program Leader, Adelaide University, 19 March 2003 – patrick.james@adl.edu.au

Foreground, Hazel Hayward (left, Adelaide University), Kylie Foster (Geoscience Australia), Kristy Bewert (ANU) and Bree Agar (University of Canberra), clambering over the silcrete looking south over the northern Barrier Ranges. Gorge Paddock, Fowlers Gap.

OBJECTIVE LOGGI

The Objective Logging Regolith Project is an initiative developed in 2002 to provide technologies to support the Australian mineral exploration industry in optimising the huge amount of information gained from exploration drilling. It aims to develop a practical automatic interpretation tool for quickly logging regolith materials available as core, drill chips, or pulps.

The main problems encountered by geologists working in intensely weathered terrain are:

- discriminating bedrock type from its weathered counterpart,
- distinguishing transported from *in situ* regolith, and
- identifying hydrothermal alteration from weathering mineralogy.

These tasks are particularly difficult for geologists of all levels of experience , who are assigned to prospect mapping and logging drill chips. Manual logging is slow, subjective, difficult to repeat and expensive. Important features may be overlooked. There is an urgent need to develop procedures to log regolith materials rapidly and accurately, using properties that may not be evident through simple inspection. The most effective route will be instrumental determination of mineralogy and petrophysical properties.

Thus, the intent is to provide the exploration geologist, mining engineer, geomorphologist or environmental scientist with a meaningful, objective analysis of regolith materials to aid geochemical, geological, geophysical and geotechnical interpretation. The goal is not to replace experience but to complement and refine this knowledge through the rapid analysis and presentation of mineralogical (spectral) and multi-parameter petrophysical (magnetic susceptibility, density) measurements of the regolith.

The project aims to develop automated procedures that permit the rapid differentiation of regolith materials by exploiting contrasts in their mineralogical and petrophysical characteristics. Speed, repeatability and objectivity are critical so as to present results that can be used by non-specialists.

Over the last five years, CSIRO Exploration and Mining, as well as several companies and consultants, have demonstrated that a significant amount of mineralogical information can be derived from spectral reflectance of rocks and regolith. The most frequently used instrument has been the PIMA-II field-portable spectrometer. PIMA-II has a limited spectral range (1300-2500 nm) and cannot always detect the most relevant minerals needed to identify regolith. However, ASD FieldSpec Pro Spectroradiometer (Figure 1) has a wider spectral range 350-2500 nm than PIMA and identifies a variety of minerals including clays and iron oxides, using cores, chips and pulps (Figures 2-5). The instrument is portable and suitable for laboratory and field use. It collects spectra and characterises materials in seconds. These large datasets will be supplemented by control datasets to provide constraints to interpretation.

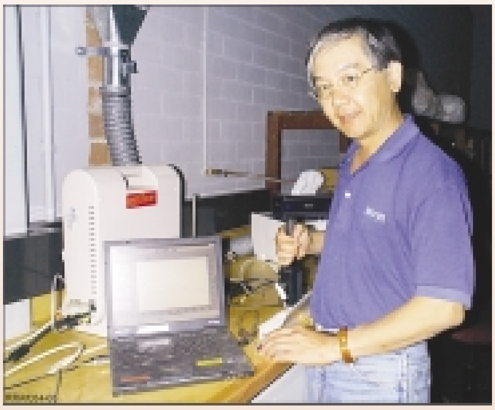

Figure 1:ASD FieldSpec Pro Spectroradiometer with a contact probe for collecting spectra of regolith materials, with Cajetan Phang.

The project is underway with industry collaboration in the first year and is working in a range of regolith environments in SA, NSW, and the Yilgarn Craton of WA. The project will draw on the skills and experience of the CSIRO Mineral Mapping Group to help develop appropriate processing and interpretation procedures for dealing with regolith materials and settings. If viable and practical technologies and procedures are identified, we will seek industry support in the second year for software engineering and development of an operational product. There will be a market assessment to determine options for commercialisation.

One of the main outcomes of this project should be 3-D mineral maps and discrimination of transported from *in situ* regolith. However, successful combination and interpretation of field, mineralogical and petrophysical data have the potential to determine:

- the bedrock type from its weathered counterpart,
- position of regolith material within an *in situ* weathered profile, and
- differentiation of alteration from weathering mineralogy.

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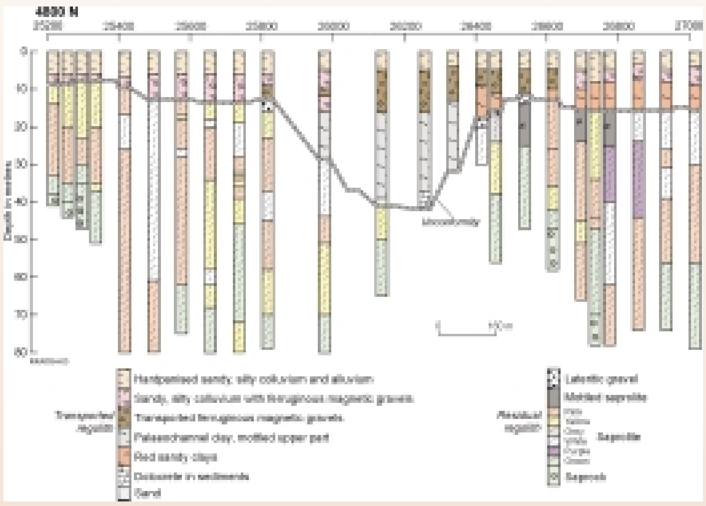
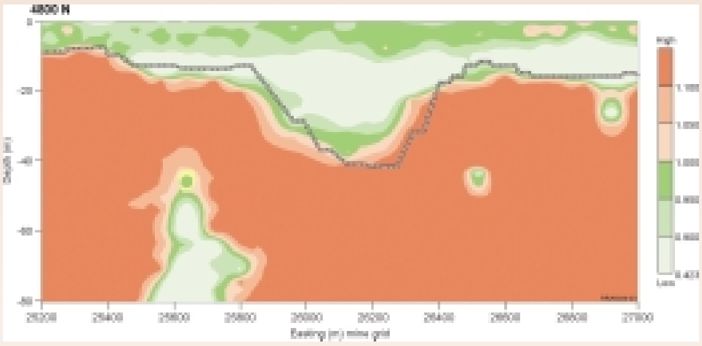


Figure 2 : Drill intersections logged by field observations of regolith materials in drill spoils. The unconformity between transported and residual regolith is interpreted from field observations.

NG OF REGOLITH

Figure 3 (Right): Interpretation of the unconformity between transported and residual regolith based on kaolinite crystallinity index derived from the ratio of relative absorption depth at 2160 nm and 2177 nm of reflectance spectra corrected for hull. A ratio =1 demarcates the transported –residual regolith boundary comfortably. Highly crystalline kaolinite is generally associated with saprolite though pockets of less crystalline kaolinite are envisaged.



Kaolinite crystallinity and unconformities in the Regolith

When using geochemical exploration techniques in areas of cover, it is important to be able to accurately define the unconformity in order to conduct interface sampling and be confident that residual saprolite has been encountered. This is difficult in areas with a variable thickness of transported cover, especially where palaeochannels occur.

In such areas, hyperspectral information (derived from PIMA or ASD spectrometer) can be used to identify changes in the regolith type. One useful parameter involves determining the kaolinite crystallinity index, using the depth of the “ordered kaolinite feature” at 2160 nm relative to the depth of the “disordered (or dickite domain) feature” at 2180 nm. Because kaolinite in the transported material is more disordered than that in residual saprolite, it is argued that transported kaolinite tends to be disordered (poorly crystalline) because of transportation, whereas residual kaolinite is more ordered (more highly crystalline).

However, situations where more ordered kaolinite occurs higher in regolith profiles or where there is no change in the kaolinite above and below an unconformity are observed in places within the Gawler and Yilgarn Cratons (Phang and Anand, 2000) and within the Lachlan Fold Belt. In the latter area, PIMA spectra indicate that the 1900 nm water absorption feature is better developed in transported sediments due to the greater presence of hydrated minerals than below the unconformity (Figure 1;Chan *et al* 2001, 2002).

An understanding of regolith processes also allows mineralogical changes, like the tendency for smectites to decrease as weathering proceeds, to be utilised in some areas. Thus it is important to use spectral information within a knowledge of regolith processes, and abrupt mineralogical changes should always be regarded as possible indicators of major changes in the regolith and detailed inspection of that change-over interval should be undertaken to determine why it occurs.

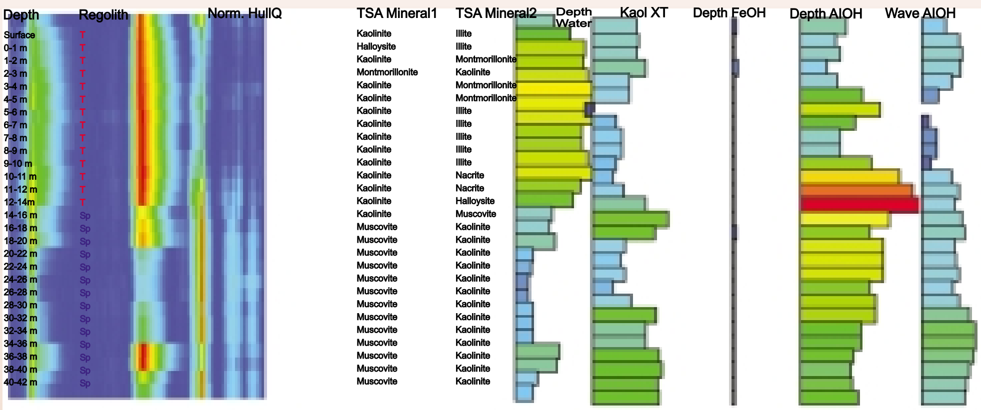


Figure 1. Drill hole CBAC 80 profile, Girilambone region, NSW, showing better identification of the unconformity using the 1900 nm water feature than kaolinite crystallinity”

Over-reliance on one parameter (kaolinite crystallinity) in determining the presence of an unconformity should be avoided.

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May 2003
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Acid sulfate soil seepage geochemistry: regolit

Rob Fitzpatrick and Marian (Swanny)

There are an estimated 40,000 km^2 of acid sulphate soils (ASS) in estuarine settings and coastal wetlands in Australia. They contain well over one billion tonnes of sulfidic compounds (pyrite) that, on exposure to air, form huge quantities of sulfuric acid. Coastal development around Australia is facing a $10 billion legacy resulting from inappropriate management of these soils. ASS, however, can also form under inland freshwater conditions in non-coastal Australian landscapes. This is especially so in higher rainfall (> 500 mm per annum) landscapes underlain by rocks or regolith containing sulfur where extreme changes in hydrology and geochemistry have occurred in saline discharge areas (i.e. where sulfur, iron and clay and have been mobilised and accumulated). Inland ASS develops as a result of contemporary land clearing, excess discharge of sulfate-rich saline groundwater and erosion. They form unsightly discharge areas with eroded "iron ochre scalds" (Fitzpatrick et al 1996).

Inland ASS occurs in seepages in the Mount Lofty Ranges and are within a region known to host base metal mineralisation. These seepages are contributing to degraded saline soil-landscapes and poor stream water quality. Consequently, both an orientation study in a small catchment with known mineralization (Skwarnecki et al 2002) and a regional study (Skwarnecki and Fitzpatrick 2003) has been undertaken to test the suitability of this medium as a new sampling tool in mineral exploration.

Characterising soil-regolith-water systems in acid sulfate soil seepages

Two questions most frequently asked by users of land resource information are: "*What soil-regolith-landform properties are changing spatially with time, and what are the most suitable tools for characterising, monitoring, predicting, and managing soil-regolith-landscape changes in ASS?*" We recognised that these questions could be solved by integrating pedology, geology, mineralogy, geochemistry and hydrology to develop various types of soil-regolith-landscape models. Such spatial and temporal models would enable issues of interest to farmers and mineral explorers to be better addressed. Being mechanistic or process driven, they would provide an excellent framework for the extrapolation of soil and water interactive processes operating across temporal and spatial scales from laboratory (micro-scale or mineralogical) to landscape (meso-scale or field) to regional/national (macro-scale or GIS-upscaling).

Laboratory scale: characterisation of poorly crystalline nano-particulate minerals

Poorly crystalline nano-particulate minerals are abundant in ASS soil environments and yet poorly understood. A remarkably wide range of poorly crystalline iron oxide and sulfide minerals (schwertmannite, ferrihydrites, pyrites, sideronatrite, tamarugite, jarosite, natrojarosite, plumbojarosite, sphalerite, galena, chalcopyrite) are formed in ASS by bio-mineralisation processes. These minerals are key indicators for predicting ASS processes. Recent work has shown they scavenge high amounts of As, Br, I, Pb, and Zn.

Element transport and the possibility of metals being adsorbed by these minerals is of fundamental importance to understanding ASS in degraded landscapes. Accordingly, laboratory experiments have been conducted to synthesise complex Fe, Al and Mn minerals under conditions that approach those encountered in nature.

Landscape scale: characterisation and classification of soils and landscapes

Most environmental land degradation problems associated with ASS requires detailed understanding of regolith below the limits of traditional soil surveys. Recognising this, we developed the underlying principles and methods used for identifying the best set of soil-regolith indicators for ASS in a specific region (Fitzpatrick et al 2003). This approach places great importance on using coloured cross sectional diagrams of soil-landscapes (toposequences) that schematically illustrate soil and regolith morphology and water flow paths (Figure 1). We have also developed several models to account for changes with time in biogeochemical and physical properties occurring in the various forms of land degradation. The models enable prediction and management of risk at scales from field, to farm, to regions.

A mechanistic model (Figure 1) developed to explain the formation of these sulfidic materials involves saline groundwaters enriched in sulfate (with elements such as Pb and Zn sourced from the mineralised zone) seeping up through soils, concentrating by evaporation and forming various precipitates. The combination of rising saline sulfate-rich groundwaters, anaerobic conditions associated with saturated soils and organic carbon in soils yielded pyrite-enriched or sulfidic material through anaerobic bacterial reduction of sulfate. Incipient oxidation of the sulfidic materials producs minerals such as jarosite and plumbojarosite in sulfuric horizons overlying mineralisation.

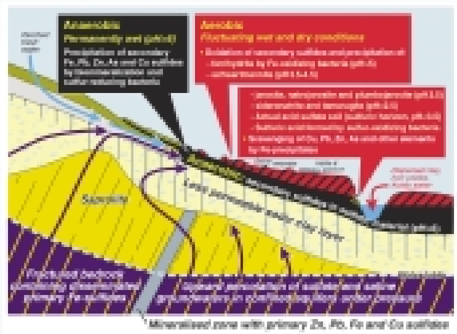

Figure 1. Soil-regolith model showing geochemical dispersion and erosion in saline landscapes, formation of secondary sulfides in potential acid sulfate soils in a perched wetland and actual acid sulfate soil along drainage lines (modified from Fitzpatrick et al 1996).

Regional/ national scale: spatially-based mechanistic models of soil and water processes

Natural resource assessment at regional scales is time-consuming and costly. It depends on local experience, knowledge, and personal judgement. We have developed an objective GIS-based approach that is efficient in assessing land degradation, overall catchment health and land use planning (Fitzpatrick et al 1999). Innovative approaches for constructing spatially and temporally based mechanistic models of soil and water processes enable

h processes, impacts and practical applications

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the prediction and management of risk at scales from field, to farm, to regions. These account for changes with time in biogeochemical and physical properties occurring in the various forms of land degradation. By combining soil-regolith models with digital terrain analysis, geophysical remote sensing, and direct field measurement, regional maps of waterlogging, acidity, salinity and catchment health have been developed (Fitzpatrick et al 1999).

Practical applications and Impacts: environmental

The accumulation and oxidation of iron- and sulfur-rich precipitates in acid sulfate soils from rising ground and surface waters in the Mt Lofty Ranges are causing less permeable soil layers to form in saline discharge areas. From an exploration viewpoint, such conditions carry indications of the presence of blind or concealed mineralisation. The geochemistry and mineralogy of the iron oxide and oxyhydroxysulphate precipitates forming in saline sulfidic soils are commonly anomalous in indicator elements, for which iron oxides have a high sorptive capacity. Saline scalds with associated acid sulfate soils containing iron precipitates, sulfidic materials and mottled sulfuric horizons provide a geochemical sampling medium for the detection of mineral deposits.

Practical applications: mineral exploration

Orientation and regional sampling of ASS (Skwarnecki et al 2002; Skwarnecki and Fitzpatrick 2003) has shown that a range of materials associated with acid sulfate soils (sulfidic materials, sulfuric horizons, salt efflorescences, and Fe- and Al-rich precipitates) are anomalous in As, Bi, Cd, Cu, Pb, Tl and Zn where they spatially relate to known mineralization, thus constituting a new sampling medium for mineral exploration (Figure 2).

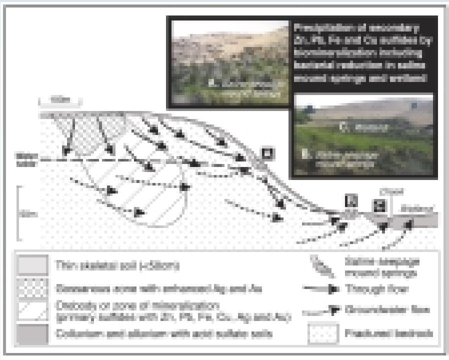

Figure 2. Model for geochemical dispersion from mineralized zones into acid sulfate soil materials in seeps, springs and wetlands, Mount Lofty Ranges (from Skwarnecki and Fitzpatrick 2003)

Conclusions

Seepages with ASS have been studied as part of linking CRC LEME environmental and mineral exploration investigations. Field and laboratory investigations in saline seepages have led to the construction of soil-water-landscape models, which incorporate biogeochemical, mineralogical, hydrogeological and biological mechanisms with implications for land management, water quality and mineral exploration.. These process models underpin the development of policy and manuals for regional land-use planning, risk assessment and environmental remediation.

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'. . regolith processes, impacts and practical applications'

The successes of MTEC

As much as we tried to leave them in Queensland, the students kept coming back! Regolith Mapping and Field Techniques 2003 students at the Warri Gate on the NSW-Queensland border during a field trip to Tibooburra.

CRC LEME is an important contributor to the Minerals Tertiary Education Council (MTEC) through the National Geoscience Teaching Network initiative, supported by one of the CRC LEME core parties - the Minerals Council of Australia. MTEC's goal is to create better graduates for the minerals industry by bringing together select Australian universities and research organisations with world-class skills and knowledge in the geosciences.

Since early 2002 the Education & Training Program has conducted Honours- and Masters-level courses structured to raise awareness of regolith geoscience for students and minerals industry professionals. Courses include:

- Environmental Mineralogy (EMN)—5 days at Honours-level taught at the ANU by Professor Tony Eggleton (ex-CRC LEME1 Synthesis Program Leader) which introduces participants to regolith mineralogy and quantitative and qualitative analysis of these materials using X-Ray Diffraction
- Introduction to Hydrogeochemistry (HGC)—5 days at Honours-level taught at the University of Melbourne by Dr Dirk Kirste (ANU) and Dr Patrice de Caritat (Geoscience Australia) describing the geochemistry of Australia's groundwaters for salinity and pollution mapping and amelioration and mineral exploration purposes.
- Regolith Mapping and Field Techniques (RMF)—5 days at Honours-level taught by Dr Steve Hill (Adelaide University), Dr Ian Roach (ANU) and Ms Kylie Foster (Geoscience Australia) around Broken Hill. This course takes participants through the process of creating regolith-landform maps from planning to completion, introducing them to basic concepts in regolith mapping and making them aware of the "holisitic" nature of the discipline.
- Regolith Geology and Geochemistry (RGG)—5 days at Honours-level taught by Dr Steve Hill (Adelaide University), Dr Mehrooz Aspandiar (Curtin University of Technology) and Dr Ian Roach (ANU) in Victoria. This course offers participants introductory knowledge of the discipline of regolith geoscience, as a foretaste of things to come!
- Hyperspectral Remote Sensing for Geological and Regolith Interpretation (HRS)—5 days at Honours-level taught in Adelaide by Dr Alan Mauger (PIRSA), Dr Vicki Stamoulis (PIRSA) and Ms Megan Lewis (Adelaide University), providing participants with an insight into one of the newest and most innovative remote sensing methods for regolith and geological mapping.

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For more information please contact:
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WHAT'S ON THE WEB?
http://crcleme.org.au

Since September 2002 we have been developing the CRC LEME web site to provide a reference facility for our stakeholders and general public, as well as a promotional and communication tool for LEME. At the coal face is Jennie Campbell with the web skills, with ideas and assistance coming from LEMErs all around Australia. This article provides a guide as to **what's on the LEME web site**:

FROM THE HOME PAGE

- Contact - Head Office details plus links
- LEME Strategic Plan (draft) - whole document outlines aims and strategies to achieve those aims within the next few years; the framework for LEME operations
- Board Members and Executive Committee/Program Leaders and CVs)
- Advisory Councils - Minerals and Land Use - terms of reference and council members
- Staff Directory - full contact details.
- Core Parties and Links - eight Core Parties and direct links to their sites

RESEARCH

- Under the four **RESEARCH PROGRAMS**

  PROGRAM 1: Regolith Geoscience.
  PROGRAM 2: Mineral Exploration in Areas of Cover.
  PROGRAM 3: Environmental Applications of Regolith Geoscience.
  PROGRAM 4: Salinity Mapping and Hazard Assessment.

  Summary of personnel, aims, objectives and milestones on the current research projects, along with updates/news/results from project leaders.

EDUCATION AND TRAINING

- Student Register, includes students and their study projects
- Education and Training Committee and contacts
- LEME shortcourse program for the year, including the Minerals Tertiary Eduction Council (MTEC) courses
- Announcements - news and views relating to the E&T Portfolio and info directed to the students
- Scholarship advertising happens here at year end
- LEME study projects fitting strategic directions will be listed here for selection by potential students

PUBLICATIONS

- Open File Reports covering over a decade of regolith science including abstracts. Hard copies are available to purchase, and more recently CDs.
- Annual Reports - LEME 1 and LEME 2
- LEME Conference Proceedings and other monographs authored by LEME researchers,
- REGOLITH LANDFORM MAPS - available to order

EVENTS / PROMOTION

- Lists LEME participation in conferences and symposiums
- LEME Seminar Series - information on monthly talks held at ANU

NEWS

- Stories and photos of LEME personnel awards, achievements and happenings
- Reports on LEME events
- Links to research project updates
- Staff vacancies
- Archived stories
- Advertisements - LEME seminars and symposiums

LEME STAFF INTRANET (password required)

Reports on Board Meetings, Quarterly Project research reports, Financial Reports; Executive Minutes; internal communiqués; full project details; staff news; policy documents; and document proformas and guidelines. Also we use the intranet for posting specific reference material to our Executive and Advisory Councils.

Over the next few months, we will be designing a 'new look' web site, with additional features leading directly into our core business - regolith geoscience.

Sue Game and Jennie Campbell, CRC LEME Head Office, crcleme-hq@csiro.au