CRCLEME

Cooperative Research Centre for
Landscape Environments
and Mineral Exploration

CRC LEME Annual Report 2004 – 2005

Established and supported under the Australian
Government's Cooperative Research Centres Program

Regolith is the surficial blanket of material including weathered rock, sediments, soils and biota that forms by the natural processes of weathering, erosion, transportation and deposition. It has complex architecture, and may vary in thickness from a few centimetres to hundreds of metres. It hosts or hides valuable mineral deposits, we live on it, we grow our food in it, it is the foundation of many major engineering works, and much of our water supplies are stored in it. It underpins our economic, social and infrastructure systems.

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Cover photography: Steve Rogers Patrice De Caritat, Steve Hill and Ian Roach

Our vision is of an environmentally healthy, wealthy Australia, where regolith geoscience plays a fundamental role in mineral discovery and land management.

Our mission is to create breakthroughs in mineral exploration and environmental management through generating and applying new knowledge of the regolith. In doing so we will develop CRC LEME and its core participants to become global leaders in regolith research and its application to mineral exploration and natural resources management.

The objectives of CRC LEME are to:

- Provide the mineral industry with world-leading capabilities leading to breakthroughs in exploration in Australia's extensive areas of cover.
- Provide essential multi-disciplinary knowledge of Australia's regolith environments, to deliver this knowledge in readily useable forms, and ensure that it is transferred into practice in the minerals industry and environmental management.
- Provide high quality, geoscience-based education for those entering the minerals industry, land-care and environmental realms and to provide continuing education for those already involved.
- Inform and guide decision makers in the Federal and State policy areas about the relevance and contribution to Australia's future of the Centre's research.

The Cooperative Research Centre Program is funded by the Australian Government and has been running since 1990. The program exists to strengthen collaborative links between industry, research organisations, educational institutions and government agencies.

The Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME) is an unincorporated joint venture that brings together groups from the

- Australian National University
- CSIRO Exploration and Mining and CSIRO Land and Water
- Curtin University of Technology
- Geoscience Australia
- Minerals Council of Australia
- New South Wales Department of Primary Industry
- Primary Industries and Resources South Australia
- The University of Adelaide

Storm approaching Coyote prospect in far northeast WA, where Program 1 personnel are working in collaboration with Tanami Gold NL.

Photograph: Brad Pillans

Highlights

- Geochemical analysis of specific parts of the Mulga tree – especially ground litter – provide an effective method of detecting buried mineralisation below transported regolith where no other geochemical method will work.
- Prototype of a medium-weight bench-top automatic regolith logger using spectral technology is operational.
- Strikingly high values of dissolved nickel in groundwaters proximal to nickel sulphide mineralisation demonstrate another promising advance for groundwater hydro-geochemical exploration.
- Groundwater geochemistry characterised by high content of isotopically light sulfur is being used by base-metal explorers for exploration under thick cover.
- Regolith science and integrated geophysics has a major input to engineering evaluation initiatives in West Australian agricultural areas.
- First hydrogeochemical studies of acid drain waters in WA wheatbelt reveal extremely high values of dissolved cobalt, copper, zinc, uranium and rear-earth elements.
- A Hy-Map wide-band spectral pilot project at Kanowna shows maps of regolith and alteration minerals can be rapidly produced.
- The bacterial species responsible for natural gold precipitation is identified, and SEM shows gold precipitates onto the surface of the bacterial cells.
- Anomalous lead and zinc in parts of *E camaldulenses* discovers extension to mineralisation in the Broken Hill area.
- Experiments show that copper adsorption onto goethite is enhanced 30 times in the presence of NaCl under acidic and oxidised conditions. In contrast, adsorption of zinc is much less affected and even suppressed by NaCl under neutral pH conditions. Therefore copper dispersion will be much less than zinc under acidic, saline conditions.
- Integration of constrained inversions of AEM data with hydro-geochemistry and hydrogeology define recharge and aquifer parameters across three major NAPSWQ catchments, and explain mechanisms of salinisation.
- The value of low-density base-line geochemical surveys is demonstrated in by pilot studies in two contrasting regolith/landscape environments.
- CRC LEME technologies in the application of regolith science in natural resource management are presented at the International Salinity Forum in the US.
- The LEME website has a major restructure, and is now a more effective vehicle for the transfer of knowledge.
- Fifteen new Open File Reports were released; the web collection of *Regolith expressions of Australian ore systems* reaches 100 case histories; and the series on Regolith Landforms of Australia passes 50 case histories.
- The student program supported 39 PhD students, and has 80 Honours graduates or graduands.
- As deliverables are achieved, and outcomes emerge, our communication activities through presentations, publications, and representations have doubled in the last year.

Chairman's Report

CRC LEME is now a mature vehicle which continues in excellent operational state and is poised to deliver very real benefits to the industries it serves from its well managed and maturing research programs. Outcome delivery is expected to be a feature of the remaining three years of the CRC's existence.

Photograph: Brad Pillans

George Savell

During the past year the Board undertook a comprehensive review of the CRC's future, which resulted in a decision to not seek to re-fund the CRC at the end of its term. Changed circumstances, which emphasise commercial outcomes over the public good, now make it exceedingly difficult to fund CRCs of the nature of CRC LEME. Indeed, at the 2005 CRC Association's Conference held in Melbourne, real concern was expressed at Government's continuing obsession with commercial outcomes and its cool approach to knowledge-based CRCs. Government has clearly failed to perceive that unless the basic science fundamental to Australia's core industries is sound and at the cutting edge of the world's knowledge base, then Australia will quickly recede from "clever country" status to mediocre or worse. The CRC Association has commenced a study to address this increasing dilemma.

However, we are confident that we have embedded regolith science to the point where it is becoming an essential ingredient in mineral exploration, land matters generally and land use solutions across many disciplines. In this way we will have left a lasting practical legacy from the work pioneered by both CRC LEME 1 and CRC LEME 2 over the past decade.

During the rest of its term the CRC will pursue the conclusion of its long term programs, write up the scientific achievements of CRC LEME 1 and 2 and publish these results. A repository of this knowledge will be created for the future use of persons pursuing regolith studies. This considerable body of knowledge will, in effect, be CRC LEME's legacy to the community.

We can be proud of the fact that we have literally established a new science useable by many disciplines which are now realising how important regolith science is to their own work.

On this score it is now acknowledged that regolith science has a key role in the resolution of NRM problems, particularly dry land salt, acidic soils and acid drainage. This knowledge is the catalyst linking cause and effect and will enable solution of many vexed agricultural problems. Agricultural scientists will confidently be able to map lasting solutions which will begin to reverse environmental damage to farm lands, for example.

The CEO, Dr Dennis Gee, advised the Board that he would not seek re-appointment when his contract expired in November, 2005 but would leave to pursue other interests. The Board accepted this decision with regret, in view of Dr Gee's outstanding contribution to the CRC and research management generally during his term of office.

As a consequence, the Board conducted a comprehensive recruitment process which attracted an excellent range of applicants. Following an exhaustive interview period Dr Stephen Rogers from CSIRO's Land and Water Division, was selected and appointed to commence duties on conclusion of Dr Gee's contract period. He will guide the CRC to its termination in 2008.

While both the decision to allow the CRC to terminate and the upcoming change in leadership might have, in some organisations, proved disruptive, this has not been the case in CRC LEME. Indeed the CRC has strengthened considerably as a result of a stable management team.

Our on-going educational program is one of CRC LEME's proudest achievements. It is on course to deliver 70 Honours graduates and more than 60 PhD graduates over the life of LEME.

I cannot stress too strongly the ongoing benefits to the community and future science which this program delivers. We are proud to have been able to achieve such noteworthy results.

As a consequence of the decision to allow the CRC to terminate in 2008, the position of Deputy CEO held by Paul Wilkes became redundant and Paul left us at the end of his contract term in June 2005. He will continue to be associated with our NRM programmes and we wish him well in his future endeavours. His significant contributions to the CRC are much appreciated.

The CRC is fortunate in having staff and Program Leaders with such focussed commitment. The strength of purpose has flowed into the program and shows in the results. The Board extends its sincere thanks to everyone involved in the CRC's operations.

Finally, I want to pay tribute to Board members who have given the CRC such dedicated support during a busy year. Their knowledge is one of the "hidden assets" of the CRC.

All associated with CRC LEME look forward with confidence to the coming years.

G.A. Savell

INDEPENDENT CHAIRMAN

Photograph: Patrice de Caritat

Chief Executive Officer's Report

R Dennis Gee

This half-way year of the second term of CRC LEME, has been one of managerial stability, expanded clientele, accelerated research outputs, and significant research outcomes. Managerial stability was reflected in the eventual execution of the Deed of Variation – a legal requirement to formalise the major participatory changes during Years 1 and 2.

This process was delayed by significant subsequent changes in contribution status by a number of other participants. During this seemingly endless process, the CRC Program has kindly given "acceptance in principle", enabling us to accelerate and deliver on our research programs without any procedural encumbrances. A lesson from this process is that we need to recognise the requirement for some future flexibility to accommodate the ever changing situations of some of our participants.

Of profound significance for the future of CRC LEME, the Governing Board directed that rather than pursue a re-bid as part of the Fifth Year Review process, Executive should take LEME to a productive conclusion over the full seven years, and focus on full delivery of scientific programs and maximum uptake of regolith knowledge by stakeholders. This major decision clearly sets the strategy for the remaining three years of LEME.

There were a number of reasons for this unanimous decision by the participant representatives on the Governing Board. Basically, it was felt that any attempted re-incarnation of a public-good knowledge-based CRC would be high risk and distractive, when assessed against the new CRC Program guidelines that emphasise commercial outcomes. Also there is a difficulty for government geoscience agencies to create contingent liabilities over a time period of seven years – particularly in the recommended framework of an incorporated company. Overall there was a clear wish to achieve a successful finale, and then consider new partnerships under a variety of possible research structures. And finally it recognised that the twin stream of mineral exploration (MINEX) and natural resource management (NRM), although being outstandingly successful through LEME 2, was not a model to take forward into the future.

Far from being a negative, this decision recognises that our science has developed to the point where it is essential to a widening spectrum of applications. This years activities show that regolith knowledge is eagerly demanded from a diversifying range of stakeholders. At this mid point in LEME we can be absolutely confident that, in future years, some of our research themes will be picked up by current participants and other stakeholders under new alliances that can only be envisioned at this time. Equally, we can be confident that there will be further new exciting science outcomes over the remaining three years of LEME.

A simple breakdown of expenditures in 2004-05 shows $2.79m on salaries ($2.54m previous corresponding period), $0.77m on the student program ($1.08m), and $2.36m on research operating ($2.27m). External income tied to projects was $1.43m ($1.51m). The three year cash flow forecast shows that we can sustain adequate levels of project funding and staff support, in order to meet research objectives.

Levels of external income through commercial projects from both mineral explorers and natural resource management agencies continues at a sufficient level to deliver effective research. If there is any concern on the horizon, it lies with the ever-changing procedures for dispensing and managing NRM-type funds at national, state and local levels.

A core research objective with MINEX outcomes, is to develop new technologies for detecting geochemical signatures of undiscovered mineral deposits buried beneath significant thicknesses of transported regolith. Conventional and contemporary methods have so far failed this challenge, and this is the last frontier of geochemical exploration. Our Strategic Plan called for focus on the biological and groundwater processes that facilitate metal mobility in such environments. This strategic intent has now paid dividends. One fertile hypothesis is that deep-rooted trees in inland arid environments act as hydraulic pumps of dissolved metals drawn from groundwater. This is confirmed with the surprising revelation that enhanced metal signatures are preserved in specific products of certain trees. Specifically the ground litter of the Mulga tree, when analysed for a range of metals, gives chemical indications of buried mineralisation where no other geochemical methods will work. This is a revelation of breakthrough status. Similarly, great progress has been made in bringing new techniques in groundwater analysis and interpretation, in the search for hidden undiscovered mineral deposits.

A notable feature this year was the expansion of commercial

projects into Western Australia in both the Programs of *Salinity Mapping and Hazard Assessment*, and *Environmental Applications of Regolith Geoscience*. Many of these new projects fall under the Engineering Evaluation Initiative driven by the WA Department of Agriculture under the National Action Plan for Salinity and Water Quality. For example, in the agricultural areas on the Yilgarn Craton, models of acid sulphate soils previously developed within LEME are having a major input to assessing hazards associated with stimulated seepage of naturally occurring high-salinity groundwaters. An important new revelation is that disturbance and oxidation of such waters has released deleterious metals into solution. Drains sampled in the eastern agricultural areas have been shown to contain significantly elevated iron, aluminium, copper, zinc, uranium, and rare-earth elements.

Similarly, our integrated geophysical approaches to defining the location and geometry of palaeochannels provide a powerful demonstration of the value of regolith input to water resource assessment, and to engineering remediation of salinity problems in agricultural areas of WA.

As we transition from an output-based to an outcome-driven CRC, we have commenced processes to assess in a quantitative way the benefits of LEME research. Along with some other CRCs, we face challenges in this task because of the diversity of potential outcomes with a variety of stakeholders. It would seem that the quantification of benefits for the two different streams of LEME research – mineral exploration and natural resource management – each require different approaches.

For mineral exploration we can quantitatively define the actual value of past exploration success, and make good estimates of values of future developments. But because LEME is not directly in the exploration business, we then have to make qualitative assessments on how to apportion credits to R&D in making these discoveries. The apportionment of the LEME contribution to successful outcomes (mineral discovery) can vary from well above 50% where LEME information directly led to discoveries, to levels as low as 10% where LEME techniques were applied to previously identified occurrences. There are a number of econometric models which predict the leverage of government-sector funding on pre-competitive geoscientific information into GSP and other national benefits. But the difficulty lies in isolating and quantifying the R&D component where this does not manifest itself in commercial recoveries.

For NRM case studies, the best approach is to do cost-benefit analyses of specific projects, using real costs and quantitative estimates of reduction of 'damage cost' obtained by other economic and NRM agencies. At least one project could claim the have benefits through engineering savings of at least $40m. Many of our site studies are amenable to this approach, and benefits would aggregate to hundreds of millions of dollars.

Promotion and communication activities have stepped up a gear, commensurate with the flood of deliverables we are now enjoying. Our annual trilogy of Regolith Symposia has now settled on a successful formula. These are staged in November in the three nodes – Canberra, Adelaide and Perth. This series is about developing and sharing advances in the science; it is just as much a forum for students and researcher to deliver progressive findings to their peers, as it is for external people who have an interest in our science. I thank Dr Ian Roach who convenes these symposia, and edits the impressive volume of proceedings.

The well-patronised LEME annual MINEX seminar for mineral explorers is now firmly entrenched in the calendar of events for the industry. This year we also took the presentations to Kalgoorlie. LEME presentations have become a core component of many other mineral exploration events, staged by government and industry bodies. The *Minerals Brief*, a quarterly electronic newsletter succinctly outlining research results of relevance to mineral explorers, is now a prime communication tool with minerals explorers.

In the field of natural resource management, we instituted a partnership with CRC PBMDS to revamp the quarterly newsletter *Focus on Salt*. As our capabilities in salinity mapping, landscape analysis, 3-D groundwater flow modelling, and salt mobilisation gain national attention, we found it appropriate to take 14 presentations to the International Salinity Forum in California.

Our Education and Training Program, under the leadership of Dr Steve Hill (AU), is at its peak. We now have the maximum number of students under the Program, and our first three PhD graduands. The Program has three objectives: to contribute to the research themes, to deliver specialist training in regolith geoscience to practicing professionals, and to produce quality post-graduates for future national skill requirements. The end of 2004-05 will see the final intake of PhD students, although the Honours program will continue for the next two years. At present we have 18 Honours students and 50 PhD students within the Student Program. We look set to exceed our stated goals of graduating 60 Honours students, and 60 post-graduates during the life of LEME. It is gratifying to see that our graduates are getting quality employment. However in this respect I note the sad and untimely passing Honours student Peter Bamford who leaves his legacy in the form of a completed honours theses at ANU.

The LEME website – http://crcleme.org.au – is now an important repository of information, and with further growth will be one of the prime legacies of LEME. Its currency and timeliness is due to the efforts of Sue Game, who with along with other executive and centre-support duties, has taken on the management of the website.

This year will be my last as CEO of CRC LEME for I will, in the early part of the ensuing year, complete my agreed three-year appointment. It has been a privilege to be part of a research organisation that has now moved into top gear, and is delivering on its objectives. Credit for the science advances rest squarely with the quality cohort of Program Leaders, project leaders, and indeed, all researchers. I pay a fond tribute to my Executive team who have strongly advocated the interests of their host participants in a true spirit of collaboration. I thank Paul Wilkes for his contributions to the strength of LEME in his capacity of Deputy CEO – a position that will be discontinued. Especially, I thank Business Manager Gary Kong who has, in difficult circumstances, continued to deliver in a timely and professional manner.

Governance Structure and Management

Core Participants

CRC LEME operates as an unincorporated joint venture between its eight participants. They are signatories to the Commonwealth Agreement and Centre Agreements. Under those agreements, the CSIRO Exploration and Mining is the Centre Agent and assumes administrative responsibility. The core participants are:

- The Australian National University (ANU)
- CSIRO Exploration and Mining and CSIRO Land and Water
- Curtin University of Technology (CUT)
- Geoscience Australia (GA)
- Minerals Council of Australia (MCA)
- New South Wales Department of Primary Industries (NSW DPI)
- Primary Industries and Resources, South Australia (PIRSA)
- The University of Adelaide (AU)

Board of Management

The Governing Board is responsible for setting policy and strategy. It consists of representatives of core participants, Advisory Council Chairs, and independent members. Mr George Savell is the independent Chair. At the end of the reporting period the Governing Board membership was:

Prof Tim Brown, Australian National University

Ms Janet Dibb-Smith, Adelaide University

Dr David Garnett (independent)

Dr Dennis Gee, CRC LEME Chief Executive Officer

Mr Paul Heithersay, Primary Industries and Resources, South Australia

Mr Gary Kong, Board Secretary, CRC LEME Business Manager

Mr Adrian Larking, Association of Mining and Exploration Companies (independent)

Dr Steve Harvey, CSIRO

Mr Warwick Mc Donald (independent)

Dr Chris Pigram, Geoscience Australia

Mr George Savell, Chair (independent)

Mr Tony Tate, Curtin University of Technology

Dr Kevin Tuckwell, Minerals Council of Australia

Dr Ted Tyne, replaced by Mr Lindsay Gilligan in April 05, New South Wales Department of Primary Industries

Our Centre Visitor Prof Gerry Govett has a standing invitation to attend Board meetings.

The Board met on 10 September 2004 in Perth, 2 December 2004 in Canberra, and 18 March 2005 in Adelaide. Special Meetings via telephone hook-up were held on 5 August 2004 and 8 July 2005 for approval of the 2004-05 and 2005-06 Budgets respectively.

Photograph: Richie Hann

CRC LEME Board, taken 8 Sept 2005. L-R standing: Gary Kong, Steve Rogers (CEO Designate), Kevin Tuckwell, Gerry Govett, Steve Harvey, Adrian Larking, Tony Tate, Ian Lambert (replacing Chris Pigram GA), Richard Arculus (representing ANU), Lindsay Gilligan. L-R seated: Paul Heithersay, Janet Dibb-Smith, Dennis Gee, George Savell (Chair) and David Garnett.

In 2004–05 the Audit Sub-Committee comprised Mr George Savell (Chair), Dennis Gee, David Garnett, Chris Pigram and Gary Kong. The committee met prior to the Annual General Meeting on 10 September 2004 to discuss and accept the audit report for the previous financial year. They again met on 9 September 2005 to receive and accept the audit report for the year 2004–05.

Advisory Councils

The **Minerals Advisory Council** reviews research outcomes and advises on future priorities in line with industry and other user needs, primarily in mineral exploration. It reports directly to the Board through its Chair, Dr David Garnett. Most members attended the LEME Minerals Exploration Seminar on 25 May 2005, and the Council met the following day. A number of MAC members were invited to participate in the technical reviews of all projects in Perth, Canberra and Adelaide, in April 2005, in order to assist in developing LEME's research portfolio. There is frequent liaison between many LEME executives and MAC members on specific projects.

Members at the end of the reporting period were:

Chair: Dr David Garnett – Independent

Mr Paul Agnew – Rio Tinto Exploration Pty Ltd

Mr Peter Buck – LionOre Australia Pty Ltd

Prof Bob Gilkes – University of Western Australia

Dr Jon Hronsky – WMC Exploration Division

Dr Richard Mazzucchelli – Searchtech Pty Ltd

Mr Christopher Oates – Anglo American PLC, London

Mr Bill Peters – Southern Geoscience Consultants

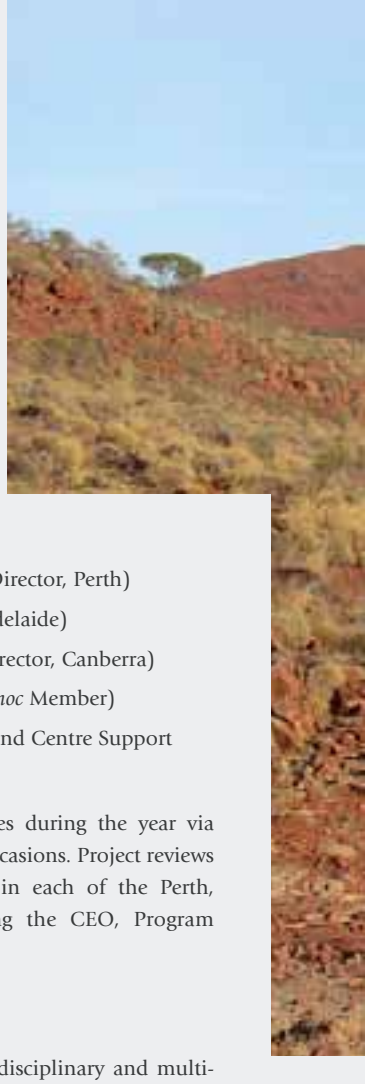
Dr Nigel Radford – Newmont Australia

Dr Bryan Smith – Bryan Smith Geosciences

Prof Peter Williams – University of Western Sydney

Dr Wally Witt – independent

The CEO and Board Chair are *ex-officio* members of MAC



The **Land Use Advisory Council** provides comment and advice on land use and environmental management issues. Its membership is drawn from governmental, semi-governmental and independent user groups, but does not necessarily represent any user group. It reports to the Board through its Chair, Mr Warwick McDonald. LUAC formally met on 15 November 2004, and at a workshop 2-3 March 2005 in Canberra with a follow-up telephone meeting on 14 March. Again there is frequent liaison with Executives on project generation matters.

Members at the end of the reporting period were:

Chair: Mr Warwick McDonald – Water for a Healthy Country, CSIRO

Mr John Bartle – Conservation & Land Management WA

Mr Murray Chapman – Rural Plan Pty Ltd

Dr Colin Chartres – CSIRO Land & Water

Dr Richard George – Dept of Agriculture WA

Mr Mike Grundy – Dept Natural Resource & Mines Qld

Mr Gavin Hanlon – North Central Catchment Management Authority

Dr Mike McLaughlin – CSIRO Land and Water (Waite Laboratories)

Dr Bruce Munday – CRC Plant Based Management of Dryland Salinity

Mr Bob Newman – independent

Mr Colin Simpson – Consultant

Mr Ross Williams – Dept Infrastructure, Planning & Natural Resources NSW

Mr Blair Wood – Land and Water Australia

The CEO, Board Chair are *ex-officio* members of LUAC. The Deputy CEO acted as Secretary.

Executive Committee

The Executive Committee is responsible for overall management of research programs, including the annual assembly of the portfolio of research projects and budgets for Board approval. The Executive Committee comprises CEO, Business Manager, Deputy CEO, Program Leaders, Assistant Directors whose responsibilities cover the three LEME nodes and, where appropriate, co-opted members for limited periods. At the end of the reporting period the membership of the CRC LEME Executive was:

Dr Dennis Gee, Chair (CEO)

Mr Gary Kong (Business Manager)

Mr Paul Wilkes (Deputy CEO)

Ms Lisa Worrall (Program 1 Leader)

Dr Ravi Anand (Program 2 Leader)

Dr Steve Rogers (Program 3 Leader)

Dr Ken Lawrie (Program 4 Leader)

Dr Steve Hill (Program 5 – Education and Training Leader)

Assoc Prof Lindsay Collins (Assistant Director, Perth)

Mr John Keeling (Assistant Director, Adelaide)

Assoc Prof Ken McQueen (Assistant Director, Canberra)

Dr Bear McPhail (Key Researcher – *ad hoc* Member)

Mrs Susan Game (Executive Secretary and Centre Support Officer)

The Executive Committee met eight times during the year via teleconference, and in person on several occasions. Project reviews were conducted throughout April 2005 in each of the Perth, Adelaide and Canberra nodes, involving the CEO, Program Leaders, and all Executives.

Centre Culture

LEME aims to develop and deliver multi-disciplinary and multi-party research that focuses on addressing stakeholder needs, consistent with the collaborative spirit of a Cooperative Research Centre. In planning and executing its research, governance and educational priorities, LEME acts as a cohesive entity in the best interests of the joint venture, whilst still recognising the needs for equitable returns for individual participants in the joint venture.

CRC Visitor

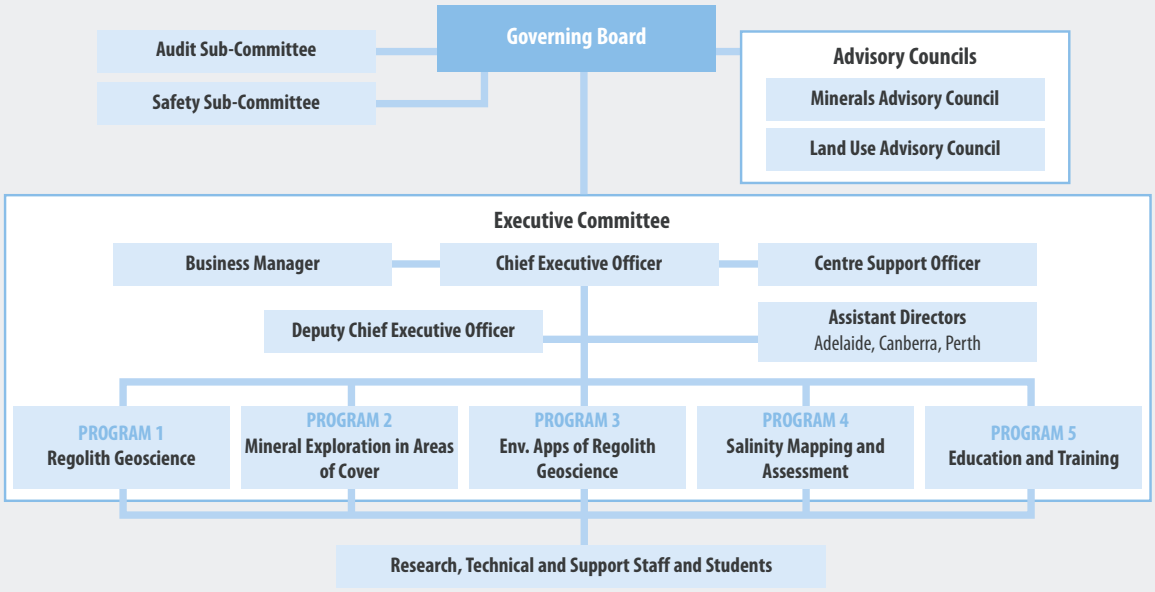
Under new procedures the CRC Program no longer requires or supports the Visitor concept. However over the years LEME had derived great counsel from its longstanding Visitor, Emeritus Professor Gerry Govett, and the Board has gladly continued his role. In this capacity he acts as mentor and independent advisor to LEME administrative staff, students, project staff, project leaders, Program Leaders, Executive and Board members. He is the thread of wisdom and support through the entire CRC. He provides written guidance to the CEO. He has a standing invitation to attend all Board and Advisory Council meetings, all project reviews and all scientific seminars and symposia.

Professor Gerry Govett

Photograph: Patrice de Caritat

Strategic Planning

The Strategic Plan 2002-2008 for CRC LEME, which was adopted by the Board on 14 March 2003, is still largely relevant. It remains consistent with the original concepts of the Commonwealth Agreement. It sets out objectives, and strategies to meet those objectives, and indicators to measure performance, all within a framework of strategic priorities. It focuses on outcomes as well as outputs. In the ensuing year, the Strategic Plan will need to be revisited to reflect the Board decision to run out to Year 7 and to define the expanded strategic direction of Program3.



Photograph: Steve Hill

Commercialisation, Technology Transfer and Utilisation

Intellectual Property

The Commercialisation and Intellectual Property Management Strategy aims to:

- protect and disseminate knowledge
- promote developments within Australia and overseas
- transfer knowledge on a fee-for-service basis
- identify marketing opportunities of technological developments with industry partners.

Where Centre projects generate knowledge that has potential economic or service value, it is considered **Centre Intellectual Property**. All Centre IP is owned by the core participants equally as tenants in common in proportion to equity. Each participant then has a non-exclusive royalty-free licence to use that Centre IP.

Projects receiving external resources or additional resources from a participant may generate **Project Intellectual Property**. Project IP provisions are set out in the relevant project agreements, on a case-by-case basis. This can provide for the IP to reside only with the participant(s) who have contributed resources to the project.

In regard to **student projects** not formally part of a Commercial Project, the student owns the IP unless there is a contractual arrangement between the student and the university, in which case the university owns the IP. However if the CRC invests resources into the student project, then the CRC must negotiate with the university to agree an interest in the student IP.

"National good" benefits

Opportunities for commercialisation of LEME knowledge are governed by LEME being a knowledge-based CRC which orients its research toward resource management in the "national good". It has less opportunity for discovery of patentable products and technologies with commercial value. Much of this knowledge provides assistance to industry and services to community sectors, including government agencies. It is significant that the original Commonwealth Agreement did not specify commercialisation milestones. However the utilisation of outputs was heavily emphasised in the Commonwealth Agreement, and are reported under Performance measures.

Some of our projects lie in the R&D niche of pre-competitive geoscientific information. Such information is generated by many other geoscientific agencies in order to make mineral exploration more effective and efficient. In this respect the objective is to release information expeditiously and freely in order to stimulate mineral exploration. This is the key driver of our knowledge transfer to the mineral exploration industry. Some Industry Projects generate knowledge which remains confidential to industry sponsors till the expiry of an agreed confidentiality period, as per the project agreement.

Fee-for-service opportunities have expanded in the fields of natural resource and environmental management, where our clients are government agencies, or organisations contracted to them. Currently we have two outstanding examples involving new geophysical technologies. Firstly we can model the dynamics of saline groundwater flow to assist salinity mitigation in the Riverland area of the Murray River. Water-borne and heli-borne electromagnetic systems have been developed that pin-point saline groundwater discharges into the Murray River, and identify preferred areas for irrigation on riverine plains to minimise those discharges. Secondly, integrated geoscientific approaches enable the construction of three-dimensional groundwater flow models in the Lower Balonne River in the headward region of the Murray Darling Basin.

Through its contracts of work and strategic research projects, CRC LEME is gaining credence for its methods for identifying salt stores above and below the watertable, and predicting saline movements, in both upland and lowland areas.

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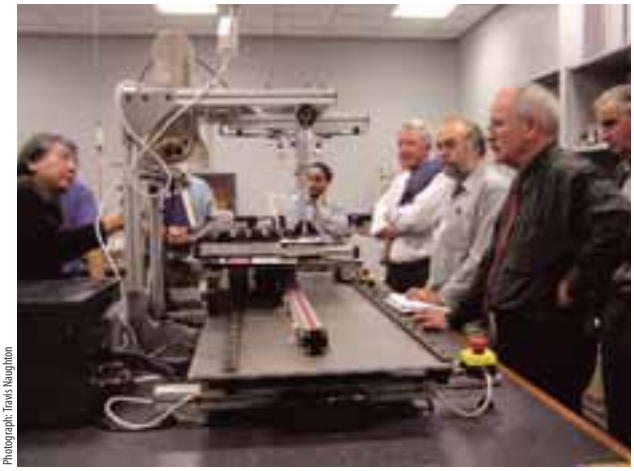


Photograph: Travis Naughton

Cajetan Phang demonstrates the use of the FieldSpec Pro Spectroradiometer (attached to the X-Y table) to members of the LEME Minerals Advisory Council. L-R: Cajetan Phang, Ravi Anand, David Garnett, Nigel Radford, Peter Williams and Richard Mazzucchelli.

Potential Commercial Projects

As part of its internal technical review process LEME compiles an interim list of potential projects warranting Centre or Project IP protection. These are described below.

Biota E

Dr Ravi Anand (100% in-kind from CEM) as leader of *Mineralogical and biological hosts* Project has demonstrated that certain parts of the Mulga tree give clear and reproducible chemical signatures of gold and base-metal deposits that occur under more that 20m of transported regolith – especially under cemented hardpan. This is entirely a Centre Project, and not reliant on company support. There are no confidentiality constraints. The IP therefore resides with LEME.

The mechanism of metal transfer is uncertain, but basically is due to hydraulic pumping up deep tree roots such that the anomalous metals report in various tissue types and products of the tree. Leaf litter on the ground was the fifth phase to be analysed (along with roots, bark, twigs and phyllodes) and gave the most dramatic geochemical signals – hence the term BiotaE.

BiotaE is a major research advance which lies at the core objective of Program 2 – "making geochemistry work through transported regolith". BiotaE delivers positive signals where all other geochemical approaches have failed. Current indications are that the method is applicable to the northern half of the Yilgarn Craton. However there is nothing special about the analytical and interpretations methods. The only innovation is the sampling of ground litter. It is unlikely this processes can be patented. The quality assurance and branding of this new process could be protected by a Registered Trade Mark®, which can then be licensed. To preserve this option the name BiotaE has been registered. Discussions are being held with one of the leading analytical laboratories with a view to developing a business model to give an imprimatur to a geochemical service provided by a commercial laboratory, under the banner of the registered trademark, using techniques and interpretations prescribed by LEME.

LEME Regolith Spectral Logger

This promising project aims to develop a new technology that will rapidly characterise regolith samples from exploration drill chips, by providing semi-quantitative mineralogical characterisation computed from wide-band spectral measurements. Since its inception in Year 2 as the Objective Logging Project, it has progressed to the stage where we now have a prototype of a medium-weight bench-top automatic unit ready for actual field trial.

Digital spectral data and associated mineralogical interpretations can then be directly imported into industry standard exploration drill-hole databases. This development should expedite and optimise the information gained from exploration drilling, particularly the discrimination of transported regolith from in situ regolith in the early stages of prospect evaluation. It will also enable the production of standard drill-hole cross sections used in mineral exploration at the resource drilling stage, and the production of three-dimensional mineral maps in the modelling of mineral deposits. The digital capture of spectral data would be made on-site, in a commercial analytical laboratory, or in a central drill store facility.

As of the end of end FY2004-05, LEME has invested some $274k in its development, by way of cash funded salaries and direct operating costs. In addition there has been $40k from the WA infrastructure funding scheme, deployed on the construction of the X-Y table. The X-Y table has the capacity to record automated spectral measurements of six standard chip trays (120 samples) in approximately five minutes. This has required substantial input to construction of the equipment, and modification of previously developed interpretation software by the Mineral Mapping Group of CSIRO E&M. The in-kind value this contribution from E&M is $70k.

This is a Centre Project, but CSIRO has been the sole participant. Rights to IP remain with the participant. This development is a complementary module of the potentially-commercial automated Hy-Logger developed by CSIRO. In this case CSIRO would have to apply to LEME participants for a license to develop the concept.

Photograph courtesy of Anton Kepic

CUT 3rd Yr students (L-R) Kyle Mair and Lee Davey 'breaking in' their new seismic/EKS system near Cue. They are conducting a seismic reflection test near some gold mineralisation.

Geophysical developments at Curtin University of Technology

As detailed in last years Annual Report, CUT are developing a number of innovative geophysical technologies. These mostly involve PhD students supported by LEME, complementing commercial projects. The exact ownership of the IP is yet to be negotiated.

Audio-magnetotellurics (AMT) is a ground-based method that uses reflected natural electromagnetic energy to measure the three-dimensional electrical structure of the earth. The enhanced system is capable of rapidly measuring the electrical structure of the earth down to 200 metres. Potential applications of the method are in mineral exploration, salinity mapping, and groundwater problems.

Electrokinetic seismic (EKS) groundwater exploration system works by measuring weak electrical impulses stimulated from an aquifer by seismic waves. The new system is being developed with ANSTO. It will be used to gather sub-surface hydraulic permeability data for numerical modelling. This can subsequently be used in salt interception schemes and groundwater assessments.

Signal processing algorithms have been developed to improve electromagnetic and electrical geophysical surveys in areas with high electrical noise. The software has widespread general applicability and outside groups are interested. It is expected that the algorithms may be patented or licensed.

EM image enhancement involves utilising innovative geophysical techniques, particularly airborne EM systems, and innovative data processing strategies for use in manganese exploration. Standard gravity methods can only identify manganese ore bodies close to the surface, and often miss deposits below 20 m, where the signal noise becomes comparable to the amplitude of the gravity anomaly. Reprocessing and editing of existing gravity data, along with careful analysis of topography, led to the identification of subtle gravity features, signifying "blind" manganese deposits. The Hoist EM system, being developed by Newmont Australia and GPX Services, has also been further refined and tested as a step towards acceptance and commercialisation of the technology. Conductivity depth inversions (CDIs) that show manganese ore and other conductive geological features have helped identify a number of high priority targets, and have improved the success rate of target drilling.

Knowledge and Technology Transfer

Since the full commencement of Programs 3 and 4 activities in 2002-03, we have successfully completed 12 contract and consultancy-type projects. Most of these have been with the South Australian NAP program and Queensland NRM agencies. In addition, another five projects commenced in the latter part of the year, involving Murray Darling Basin Commission, and Western Australian NRM agencies.

Projects of this nature are important because they establish credibility and competence in the eyes of NRM and catchment management agencies. They also provide a springboard for more strategic research. The successful strategy of initially engaging NRM agencies in the Murray-Darling Basin through contracts of work, before moving on to more strategic research, is being followed in the new initiatives in Western Australia. Without doubt, delivery of results through contracts of work is the most effective way to use and apply our research, and to transfer knowledge to end-users.

We have had one-on-one consultancies, including training courses, with a range of companies and government instrumentalities. Following are organisations that contributed financially towards LEME activities.

ANSTO

Alkane Exploration

Cameco Australia Pty Ltd

CRC for Freshwater Ecology

Dept Agriculture, WA

Dept Environment WA

Dept Water and Land Biodiversity SA

Dept Natural Resources and Mines, Qld

Jervious Mining Ltd

LionOre Australia Pty Ltd

MERIWA

Newmont Australia

Northern Territory Geological Survey

Peak Hill Gold Mines

Tap Oil Pty Ltd

Triako Resources

Technology Transfer and Utilisation

The following table lists organisations that were end users of LEME research outputs during the reporting period, or that collaborated with the Centre to secure those outputs. Most of these organisations contributed in-kind by meeting travel costs and provision of equipment.

Technology Transfer and Utilisation 2004–2005

SMALL TO MEDIUM ENTERPRISES (generally less than 100 employees)

Research User	Activity/Project	Interaction	LEME Project Leader, Students and Supervisors
Adelaide Resources Ltd	Barns biogeochemistry project	Research collaboration	Mel Lintern
Adelaide Resources Ltd	Palaeo-shorelines and heavy mineral sands in Eucla Basin	Research collaboration	Baohong Hou
Adelaide Resources Ltd	The calcrete gold anomalies at Wudinna, Eyre Peninsular	Research collaboration	Andreas Schmidt Mumm, Mel Lintern, Malcolm Sheard, Steve Hill
Consolidated Minerals Ltd	Airborne EM	Research collaboration	Jayson Meyers
Dominion Ltd	CHIM method test at Challenger gold mine	Research collaboration	Baohong Hou, John Keeling, Malcolm Sheard
Dominion Ltd	Palaeo-shorelines and heavy mineral sands in Eucla Basin	Research collaboration	Baohong Hou
Echophyte Ltd	Electrical and EM studies	Research collaboration	John Joseph
Flinders Diamonds Ltd	Spectral mapping for kimberlite detection in the Terowie district	Research collaboration	John Keeling, Alan Mauger, Vicki Stamoulis
Flinders Diamonds Ltd	Dating sediments by palynology	Research collaboration	Liliana Stoian
Geoforce Ltd	Electrical and EM studies	Research collaboration	John Joseph
Giant Reef Mining Ltd	Palaeomagnetic dating of regolith	Research collaboration	Brad Pillans
Helix Resources Ltd	Hydrogeochemistry, geophysics and spectral logging, Tunkilla gold prospect	Research collaboration	David Gray, Lisa Worrall, John Keeling, Alan Mauger
Heathgate Resources Pty Ltd	Sedimentology, spectral logging, palynology	Research collaboration	Adrian Fabris, Liliana Stoian
Iluka Resources Ltd	Palaeo-shorelines and heavy mineral sands in Eucla Basin	Research collaboration	Baohong Hou
Iluka Resources Ltd	Study of the Jacinth and Ambrosia heavy mineral deposits	Research collaboration	Mark Paine, Luisa Ruperto, Baohong Hou, Lindsay Collins, Liliana Stoian, Sue Welsh, Lisa Worrall, Brad Pillans
Iluka Resources	Palaeomagnetic dating of regolith	Research collaboration-support	Brad Pillans
Jabiru Metals Ltd (formerly Pilbara Mines)	Yilgarn Regolith field studies	Research collaboration	Matthias Cornelius, Ian Robertson, Ravi Anand, Rob Hough, Amanda Cornelius
Jervious Mining Ltd	Lachlan Fold Belt – Miandetta Gold Project	Student research	Ken McQueen
Learning Curve Pty Ltd	Virtual Regolith Worlds	Research collaboration	Steve Hill
Leviathan Resources NL	Distribution of As in regolith above vein gold mineralisation	Research collaboration and Student research	**Ryan Noble**/Ron Watkins
LionOre Australia Pty Ltd	Using bacterial leach for geochemical exploration above VMS Ni deposits	Research collaboration and Student research	**Ryan Noble**/Ron Watkins
LionOre Australia Pty Ltd	Nickel hydrogeochemistry	Research collaboration	David Grey, Mark Pirlo, Patrice de Caritat, Dirk Kirste
Mars Society of Australia	MarsOz field trip: finding analogues for Mars research in the Flinders Ranges and Strzelecki Desert	Student research	**Kathryn Fitzsimmonds**/ John Magee
Metex Resources NL	Mineral and biological hosts	Research collaboration	Ravi Anand
New Potash Project Joint Venture	Potassium exploration Australian basins	Supporting participant	**Glen Bann**/John Field
Pilbara Mines Ltd	Mineral and biological hosts	Research collaboration	Ravi Anand
Quadrant Resources	Kangaroo Valley landform map with notes	Supporting participant	**Glen Bann**/John Field
Southern Cross Ltd	CHIM method test near Honeymoon mine	Research collaboration	Baohong Hou, John Keeling, Adrian Fabris
Sunseed Desert Technology, Spain	Dryland Management	Volunteer – Supporting participant	**Kathryn Fitzsimmonds**/ John Magee
Tanami Gold NL	Surface expressions of regolith 3D architecture	Student research	**Anna Petts**/Steve Hill
Tanami Gold NL	Palaeomagnetic dating of regolith	Field support	Brad Pillans
Tap (Shelfal) Pty Ltd	Aquifer parameters	Research collaboration	Anton Kepic
Triako Resources Ltd	Hera Orientation Study	Research collaboration	Keith Scott
Zonge Engineering and Research Organisation	Development of river-based geophysical surveys for salinity mapping	Student research	**Michael Hatch**/ Graham Heinson
Zonge Engineering and Research Organisation	Electrical and EM studies	Research collaboration	John Joseph

Technology Transfer and Utilisation 2004–2005 (cont'd)

LARGE COMPANIES

Research User	Activity/Project	Interaction	LEME Project Leader, Students and Supervisors
Alkane Exploration Ltd	Tomingley NSW biogeochemistry	Supporting participant	Peter Bamford, Ian Roach
Anglo American Exploration (Aust) Pty Ltd	Nickel hydrogeochemistry	Research collaboration	David Grey, Mark Pirlo, Patrice de Caritat, Dirk Kirste
Anglo American plc	Groundwater geochemistry, Calama, Chile	Research collaboration	Patrice de Caritat
Cameco Australia	Exploration under cover: regolith and uranium exploration in east Arnham land, NT	Consultancy	Mike Craig, Ian Robertson
Comalco Ltd	Weipa Bauxite	Supporting participant	Tony Eggleton, Graham Taylor
Inco Technical Services Ltd	Nickel hydrogeochemistry	Research collaboration	David Grey, Mark Pirlo, Patrice de Caritat, Dirk Kirste
Newmont Australia	Mineral and biological hosts	Research collaboration	Ravi Anand
Newmont Australia	Predictive petrophysics	Research collaboration	Nick Direen
Sons of Gwalia Ltd	Mineral and biological hosts	Research collaboration	Ravi Anand
Sons of Gwalia Ltd	Yilgarn regolith field studies	Research collaboration	Matthias Cornelius, Ian Robertson, Ravi Anand, Rob Hough, Amanda Cornelius
WMC Resources Ltd	Nickel hydrogeochemistry	Research collaboration	David Grey, Mark Pirlo, Patrice de Caritat, Dirk Kirste

GOVERNMENT ORGANISATIONS AND UNIVERSITIES

Research User	Activity/Project	Interaction	LEME Project Leader, Students and Supervisors
ANSTO	Aquifer parameters	Research collaboration	Anton Kepic
Australian Collaborative Land Evaluation Project	Member of Working Group for Land Resource Assessment – preparing national land maps and contributing to technical manuals	Collaboration with state and territory stakeholders in the Aust Soil Resource Information System	Colin Pain
ANU	Graduate Teaching Program	Teaching	**Kathryn Fitzsimmons**/ John Magee
Australian Water Environments	Development of river-based geophysical surveys for salinity mapping	Student research	**Michael Hatch**/ Graham Heinson
BRS	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**/John Field
BRS	AEM for salinity and groundwater mapping, Lower Balonne catchment	Research collaboration	Colin Pain
Ballarat University	Palaeomagnetic dating of regolith	Research collaboration	Brad Pillans
Catchment Management Authority, NSW	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**/John Field
China Ministry of Education	Chun-Hui Projects in Western China	Research collaboration	Baohong Hou
China University of Geosciences	Adjunct Research Fellowship for the China State Key Laboratory of Geological Processes and Mineral Resources	Research collaboration	Baohong Hou
CEM	Yilgarn Laterite Atlas	Research collaboration	Matthias Cornelius, Amanda Cornelius, Charles Butt
CLW	Rhizosphere microbial communities in forest soils from the southern Tablelands	Research collaboration	Steve Rogers, David Little
CLW	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	Glen Bann/John Field
CSIRO Water for a Healthy Country	WA Wheatbelt Drainage – Acid Drainage WA	Research collaboration	Steve Rogers, Bear McPhail, David Gray, Rob Fitzpatrick, Ron Watkins, Mark Pirlo.
CSIRO Water for a Healthy Country	Drawdown geochemistry – saline River Murray wetlands	Research collaboration	Simon Lamontagne, Warren Hicks, Steve Rogers, Rob Fitzpatrick
CSIRO Water for a Healthy Country	Lower Burdekin saline mapping	Research contract	Ken Lawrie, Andrew Fitzpatrick, Jon Clarke, Heike Apps
CSIRO Water for a Healthy Country	WA Rural Towns	Research contract	Paul Wilkes
CSIRO West Lindfield, Sydney	Development of magnetic gradient technology	Student research	**Philip Heath**/ Stewart Greenhalgh

Technology Transfer and Utilisation 2004–2005 (cont'd)

GOVERNMENT ORGANISATIONS AND UNIVERSITIES (cont'd)

Research User	Activity/Project	Interaction	LEME Project Leader, Students and Supervisors
DAWA	WA Wheatbelt Drainage – Acid Drainage WA	Research collaboration	Steve Rogers, Bear McPhail, David Gray, Rob Fitzpatrick, Ron Watkins, Mark Pirlo.
DAWA	Mineral and biological hosts	Research collaboration	Ravi Anand
DAWA	Yarra Yarra soil maps	Research collaboration	Paul Wilkes
DAWA – Rural Towns-Liquid Assets Program	WA Rural Towns	Research contract	Paul Wilkes
Dept of Environment WA	WA Wheatbelt Drainage – Acid Drainage WA	Research collaboration	Steve Rogers, Bear McPhail, David Gray, Rob Fitzpatrick, Ron Watkins, Mark Pirlo.
Dept of Environment WA	WA palaeochannels for salinity mitigation	Research contract	Paul Wilkes
DIPNR	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research – Research collaboration	**Glen Bann**/John Field
DWLBC SA	Electrical and EM studies	Research collaboration	John Joseph
DWLBC SA	Loveday Basin restoration project – biogeochemistry/hydrogeochemistry	Research collaboration	Sebastien Lamontagne
DWLBC SA	Soil Assessment of Tilley Swamp especially ASS	Research contract	Rob Fitzpatrick, Richard Merry, Steve Rogers, Mark Thomas
Environment ACT	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**/John Field
Geological Survey WA	Kanowna My-Map	Research collaboration	Tom Cudahy
Geological Survey WA	Yilgarn Laterite Atlas	Research collaboration	Matthias Cornelius, Amanda Cornelius, Charles Butt
Geological Survey of Norway	Element sources and cycles at the Earth's surface	Research collaboration	Patrice de Caritat
Geoscience Australia	Low-density geochemical survey, Riverina region and central Gawler region – RGS Pilots	Research collaboration	Patrice de Caritat
Graduate Earth Science students	Flinders Ranges Field trip	Teaching	**Kathryn Fitzsimmons**/ John Magee
Guilin Institute of Technology, China	CHIM project in South Australia	Research collaboration	Baohong Hou, John Keeling, Malcolm Sheard, Adrian Fabris
Jilin University, China	Adjunct Professorship	Teaching and Research	Baohong Hou
Land and Water Australia	National Land and Water Resources Audit (2)	Research contract	Ken Lawrie
Murray Darling Basin Commission	MDBC projects	Research contracts	Ken Lawrie
NAPSWQ	Inland ASS	Research collaboration	Rob Fitzzpatrick,
NT Geological Survey	NT regolith	Research collaboration	Mike Craig, Ian Robertson, Ravi Anand, Amanda Cornelius
NT Geological Survey	Palaeomagnetic dating of regolith	Research collaboration	Brad Pillans
Qld Dept Natural Resource Management	AEM for salinity and groundwater mapping, Lower Balonne catchment	Research collaboration	Colin Pain
South Burdekin Water Board	Lower Burdekin saline mapping	Research contract	Ken Lawrie, Andrew Kitzpatrick, Jon Clarke, Heike Apps
University of California, Berkely	Granite weathering	Research collaboration	Sue Welch
University of Melbourne	Regolith-landform evolution and geochronology	Research collaboration	Brad Pillans
University of Sydney	Low-density geochemical survey, eastern highlands and alpine regions	Co-supervision of PhD student	Patrice de Caritat
UWA, Botany Dept	Mineral and biological hosts	Research collaboration	Ravi Anand
UWA	Acid drain sediment mineralogy	Research collaboration	Bob Gilkes, Steve Rogers
UWA	WA Rural Towns	Research collaboration	Paul Wilkes
WA Chemistry Centre	WA Rural Towns	Research collaboration	Paul Wilkes
WA Engineering Evaluation Initiative	WA Wheatbelt Drainage – Acid Drainage WA	Research collaboration	Steve Rogers, Bear McPhail, David Gray, Rob Fitzpatrick, Ron Watkins, Mark Pirlo
Yarra Yarra Catchment Management Group	Yarra Yarra soil maps	Research collaboration	Paul Wilkes

Technology Transfer and Utilisation 2004–2005 (cont'd)

COOPERATIVE RESEARCH CENTRES

Research User	Activity/Project	Interaction	LEME Project Leader, Students and Supervisors
CRC PBMDS	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**/John Field
CRC PBMDS	Development and application of high resolution spatial diagnostic tools to aid in development of perennial systems at catchment scale	Student research	**David Mitchell**/ David Chittleborough
pmd*CRC	Geochemical modelling	Research collaboration	Bear McPhail

INDUSTRY ASSOCIATIONS

Research User	Activity/Project	Interaction	LEME Project Leader, Students and Supervisors
Southern Tablelands Farm Forestry Network	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**/John Field
Australian Water Environments Pty Ltd	Electrical and EM studies	Research collaboration	John Joseph
Greening Australia	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**/John Field
Environmental Research and Information Consortium	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**/John Field
Minerals and Energy Research Institute of WA (MERIWA)	Yilgarn Laterite Atlas Amanda Cornelius, Charles Butt	Research collaboration	Matthias Cornelius,
Minerals and Energy Research Institute of WA (MERIWA)	Kanowna Hy-Map	Research contract	Tom Cudahy

Phildappa Rock, near Minnipa in the Southern Gawler Region

Photographs: Patrice de Caritat

Research Programs

Program Structure

Research is reported under the four LEME 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**

Research within CRC LEME is conducted along a number of different themes, each of which has its own separate objectives, and often different stakeholders. However, all are interrelated by regolith geoscience. For administrative, management and reporting purposes, LEME activities are organised under four core research programs.

Program 1: Regolith Geoscience

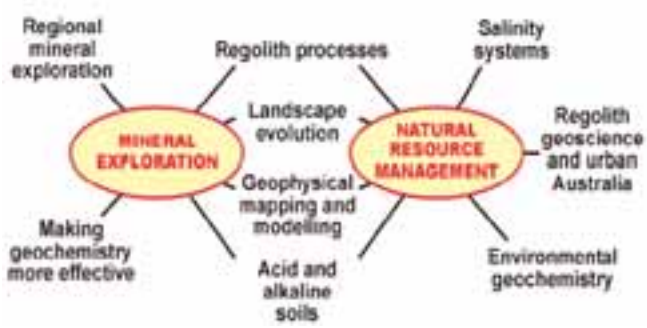
This program aims to understand the nature and timing of regolith processes, in both a detailed and regional context. It contributes strategic research in its own right, as well as forming the scientific foundation for other mineral exploration and environmental projects. It seeks to characterise and interpret regolith materials in different environments, develops landscape evolution models, and addresses the architecture and evolution of three-dimensional regolith models. In addition to a spread of regional focus projects, it looks at generic processes such as dating regolith events and history of aridity, as well as geophysical technology developments.

Program 2: Mineral Exploration in Areas of Cover

The aim of this Program is to provide new and improved tools for mineral exploration in areas of cover. This is achieved by understanding the chemical, mineralogical, biological and physical processes involved in metal mobility, and the formation of geochemical anomalies. There is a special emphasis on depositional regolith regimes. It addresses generic processes at a range of scales, involving micron-scale mineral hosts, calcrete genesis, and interactions with microbes and the general biota. Field sites are centred on key styles of mineral deposits. It pursues technology developments in hydrogeochemistry, spectral logging and remote mineral mapping.

Program 3: Environmental Applications of Regolith Geoscience

Program 3 researches environmental applications of regolith science, in themes such as assessment of regional geochemical baseline datasets, mechanisms in acid sulphate and alkaline soils, and microbiological processes in groundwater geochemistry. An important part of Program 3 is the application of microbiological and hydrogeochemical processes in other LEME Programs.



Program 4: Salinity Mapping and Hazard Assessment

Program 4 applies regolith science to the mapping, assessment and prediction of salinity stores and discharges, in both regolith materials and groundwater. The founding objective is to provide specialist geoscientific knowledge, technologies, datasets, interpretations and services to other agencies operating through the National Action Plan for Salinity and Water Quality (NAPSWQ). Research outcomes are applied to engineering mitigation proposals, land-use considerations, and landscape re-design strategies. Projects include both specialist contractual site studies generally funded under the NAPSWQ scheme and commissioned by NRM agencies; or strategic research into generic processes such as salinity hazard mapping, salt stores and mobility, aquifer parameters and groundwater flow models. A key component of research is application of electrical and electromagnetic technologies to mapping salt stores in regolith and groundwater

Research Themes

Themes are high-level groupings of multi-disciplinary research topics that have wide applications, and are unified by a common strategic direction within the overall objectives of LEME. Addressing designated themes ensures the best integration of research capabilities and resources across all nodes of LEME. All themes provide a direct focus on stakeholder interests, and many bind the two principle applications of NRM and MINEX. They therefore focus the individual research projects, and enhance their cohesion.

All projects must address one or more of these themes. Multi-party and multi-disciplinary projects have been consciously cultivated as the research programs develop, so the intellectual capital generated is effectively directed towards the needs of our diverse stakeholders in both mineral exploration and natural resource management. These theme statements are those currently on our website.

Theme 1. Understanding regolith processes

Theme 2. Models of regolith-landscape evolution

Theme 3. Acid and alkaline soils

Theme 4. Regional mineral exploration studies

Theme 5. Making geochemistry more effective

Theme 6. Geophysical mapping and modelling

Theme 7. Salinity systems in regolith and groundwater

Theme 8. Regolith geoscience and urban Australia

Theme 9. Environmental geochemistry and the regolith

Program Milestones

This section reports research progress against program milestones as stated in the Commonwealth Agreement, and as subsequently refined. The initial business plan in the Commonwealth Agreement specified milestones for **Programs 1 and 2**, which were applicable for the first three years. All of those specific milestones have now been met. The original plan also noted some longer term milestones of a strategic nature. As noted in last years Annual Report, specific milestones were developed for Year 4 and beyond. Some milestones in Program 1 and 2 have also been re-scoped to reflect scientific advances and participant requirements after Year 3. However all milestones relate to the original objectives, as set out in the Commonwealth Agreement.

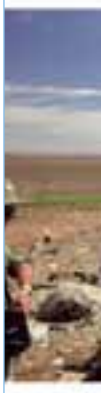
Program 3 set out to break new ground in regolith support for dryland salinity, and propose broader inputs of regolith knowledge to environmental issues. The original milestones for Program 3 were also broad and developmental. Program 3 now has an active focus on hydrogeochemistry, environmental geochemistry and biogeochemistry, whilst still providing cross-disciplinary support to Programs 1, 2 and 4. As noted in last years Annual Report, milestones were redefined, and these can now be reported against this year.

Program 4 milestones were not developed in the initial business plan, which simply referred to "intergovernmental agreements with State agencies". Program 4 conducts strategic research spanning commercial projects (either total or partial external contracts of work), and generic research as centre-funded collaborative projects. Commercial projects have their own defined milestones as recorded in the respective project agreements. In addition to their deliverables, commercial projects have substantial research outcomes regarding technology development and understanding regolith systems. In Year 3, milestones were set for the cluster of commercial projects and for the more strategic research projects, and these were stated in the last Annual Report.

Progress is reported below against all original and new milestones by way of important outputs and outcomes. For record purposes all delivered milestones from Years 1, 2 and 3, which were recorded in the 2003-04 Annual Report, are again recorded.

Program 1 Milestones

1. Publish monographs on *Regolith Geology of the Yilgarn Craton* and *Calcrete Manual* – delivered.
2. *Regolith-landscape case histories across Australia* – all modules released on LEME website.
3. Develop multi-disciplinary research teams involving staff from several Core Participants by end of Year 2 – achieved and teams are active.
4. Develop quantitative regolith-landscape models for key mineral areas in western New South Wales, Gawler Craton, Curnamona and Cobar mineral regions – major projects and reports are completed.
5. Complete initial studies in integrating three-dimensional geochemical and airborne electromagnetic modeling in Year 2 – delivered.
6. Initiate studies on dynamics, distribution and diagenesis of transported regolith in selected regions by Year 2 – completed.
7. Produce control reference sets for interpreting mineralogy from spectral signatures of regolith materials – delivered.
8. Extend quantitative regolith-landscape models into Lachlan Foldbelt and Northern Territory in Year 4 – well advanced.
9. Develop exemplar integrated 3D models of basinal areas of transported regolith surrounding key mineral provinces by July 2006 – completed in Cobar region.
10. Develop techniques for dating regolith and land surfaces, and publish new edition of handbook *Regolith Dating Methods* by June 2006 – He and U-Th techniques being developed for silcrete and laterite.
11. Synthesize quantitative framework for the history of aridity of Australia by June 2006 – initial quantitative framework using new dating techniques on dunes soils published in 2005.
12. Predict the geophysical responses of transported regolith and weathered rock, based on modeling of petrophysical data of regolith – by June 2006
13. Develop practical electrical and electromagnetic geophysical techniques for mapping regolith in three dimensions – by Year 5.



Program 2 Milestones

1. Compile case histories of *Regolith Expression of Australian Ore Systems* – 100 papers published on the website.
2. Deliver first results from integrated regolith projects in the Gawler and Cobar regions during Year 2 – reports completed.
3. Develop major interdisciplinary projects involving staff from several core participants in the Curnamona, Gawler, Lachlan and Yilgarn exploration regions – delivered.
4. Demonstrate the use of acid sulfate soils and saline discharges in mineral exploration – report delivered and theme transferred to P3.
5. Complete the *Base Metals Exploration Project* – achieved in Year 2.
6. Complete multi-client project in Pb isotope geochemistry in selective extraction analysis – completed and reported.
7. Assess all possible chemical, mechanical and biological processes leading to the formation of geochemical anomalies in regolith by June 2007 – definitive report completed June 2005, realigning this milestone with 8 below.
8. Identify dispersal mechanism of metals through transported regolith and develop practical deep-sensing geochemical exploration methods – promising breakthroughs using vegetation achieved by June 2006 – practical techniques by June 2008.
9. Quantify the role and kinetics of biological processes in rock weathering – by June 2006.
10. Determine the physical, chemical and biological processes in the mobilization and fixation of gold and other trace element in calcrete – by June 2008.
11. Demonstrate practical base-metal exploration methods in hydrogeochemistry, including isotope geochemistry – achieved for isotopes in June 2005 – now extended to nickel by Jun 2007.
12. Establish regional laterite geochemical patterns, and develop geochemical tracing methods using particles of residual regolith in eroding and buried regolith terrains – July 2006.
13. Develop prototype mineral maps of regolith, using remotely sensed spectra by June 2006 – Kalgoorlie test area completed June 2005.
14. Develop a production oriented, automatic regolith mineral logging technology based on spectral characteristics by June 2006 – prototype built and ready for field testing as at June 2005.

Photographs: Ian Roach

Program 3 Milestones

1. Discuss with NRM agencies and other CRCs collaborative research opportunities – discussions ongoing, partnerships identified, and collaboration initiated.
2. Identify and pursue research problems critical to the success of the dryland salinity work being undertaken in Program 4 – inputs delivered.
3. Identify and pursue environmental risks requiring regolith geoscience input – achieved and new projects developed.
4. Identify and assess geochemical datasets that can be used for baseline environmental geochemistry of selected regions – planning finished.
5. Complete pilot low-density baseline geochemical surveys in diverse regions – by Dec 2006 – technology successfully demonstrated and reported for Riverina, pilot study for Gawler in reporting stage.
6. Develop and apply methodologies for geochemical risk management of soils and groundwater at the catchment scale by Jun 2005 – development completed.
7. Establish the distribution, hydrochemical and biogeochemical processes involved in the formation of inland acid-sulphate soils and alkaline soils by Jun 2007.
8. Erect first model of acidity and metal toxicity in drainage water discharge in a Western Australian agricultural area, and participate in pilot engineering options for hazard remediation – June 2007.

Program 4 Milestones

1. Develop management and technical capability to generate and undertake state-based salinity projects, and provide technological transfer to clients, by December 2003 – achieved.
2. Develop new constrained inversion methodologies for modelling wide-band frequency domain helicopter EM data by December 2003 – achieved.
3. Develop and report on the application of geophysics-based methodologies for designing optimal recharge strategies, and developing hydrological models in lowland (for example irrigation) areas by December 2003 – achieved.
4. Evaluate and demonstrate the value of airborne geophysics (particularly AEM) for mapping salinity, regolith architecture and groundwater systems in various regolith environments; produce an evaluation report and site study by December 2003 – delivered.
5. Demonstrate and report on the application of three-dimensional regolith models based on integrated multi-disciplinary methodologies, to understand salt stores and groundwater dynamics in upland areas, by way of catchment-based projects – some industry projects delivered.
6. Apply and extend the use of use of new-generation geophysics and remotely-sensed technologies to case studies requiring regolith input to environmental problems by December 2004 – demonstrated at Lower Balonne and Riverland projects.
7. Develop theoretical and practical models for predicting salt mobilisation and water quality in various regolith landscapes; release information annually from July 2003 to July 2006.
8. Submit for publication a thematic volume on regolith input to South Australian NAP projects by June 2005, for publication in 2006.
9. Integrate salinity hazard and regolith inputs to the National Land and Water Resources Audit by December 2007 – input to national plan delivered, but Phase 2 on hold.
10. Deliver outputs on improved regolith frameworks for salinity modelling in upland landscapes and in-river salinity to the Murray Darling Basin Commission – released annually from June 2005 – June 2007.
11. Demonstrate the importance of acquisition, processing and interpretation of frequency domain AEM to deliver operational functionality in shallow regolith environments by June 2005, and impart this knowledge to NRM stakeholders over the period till June 2008.
12. Demonstrate the value of geophysically derived regolith frameworks to the distinctive environmental and NRM issues in Western Australia by June 2005, and have such inputs accepted as an integral part of NRM procedures by June 2008.

Program 1: Regolith Geoscience

Program Leader: Ms Lisa Worrall (Geoscience Australia)

Highlights

- **Uptake of metals in trees is seasonally dependent, and best anomaly enhancement of gold occurs in autumn.**
- **Trace metals in River Red Gum leaves discover an extension of the Pinnacles ore body underneath transported cover.**
- **Models of landscape evolution and bio-stratigraphy assist in discovery of high-grade zircon deposits in palaeo-coastal dunes of the Ooldea Range in South Australia.**
- **High abundance of zircon in sand may be the source of uranium in the Beverly uranium ore body, and can indicate vectors of palaeodrainages affected by post-Miocene tilting.**
- **OSL dating of sand grains indicates that dunes in the Strzelecki and Tirari Deserts were reworked in the last full glacial cycle (about 100,000 years before present), whereas Simpson Desert dunes contain preserved stacked sequences, with basal units as old as 400,000 years.**
- **New depth-to-basement map for the Curnamona Craton defines previously unrecognised structural features of significance to mineral exploration.**
- **Program staff successfully lobby the Working Group for Land Resource Assessment to include regolith as a fundamental data layer in Australian Soil Resource Information System.**

Overview

The aim of Program 1 is to understand the nature and timing of regolith processes, in both a detailed and regional context. It contributes strategic research in its own right, as well as forming the scientific foundation for other mineral exploration and environmental projects. It seeks to characterise regolith materials and regolith forming processes in three dimensions, and to develop models of regolith landscape evolution.

Projects within the Program have been grouped into regional-focus and generic-process projects. The regional focus projects are multidisciplinary and multiparty, and provide a focus for the generic-process projects.

Thematic Series – Regolith Landscape Evolution

54 case histories in the thematic series *Regolith Landform Evolution of Australia*, have been released on the web site, and the entire series is being prepared for publication as a LEME monograph.

Regional Focus Projects

Lachlan Fold Belt – **Ken McQueen**, Richard Greene, Keith Scott, Roslyn Chan, Peter Williams, Mike Hicks, Peter Buckley, Guy Fleming, Ben Maly, Anthony Senior, Kamel Khider, Joe Shifano, Susan Tate, Hugh Glanville, Paul Wilkes, Michael Whitbread, Adam Davey, John Joseph, Peter Bamford

This project consists of a number of modules incorporating the finishing phases of previous projects, and new industry-related research in the area of the Lachlan Fold Belt.

The outputs of the **Cobar Girilambone Synthesis** module include various LEME Reports on calcrete geochemistry of the Cobar region, a final report on the Cobar Girilambone Project (results and recommendations), and an Explorers Guide to assist industry explorers in Western NSW. Key results of the synthesis work were released as a paper presented at PACRIM 2004. The final report will be released at the end of calendar 2005 and the Explorers Guide will be released at the beginning of calendar 2006.

The key outcomes of this module are:

- a new understanding of the evolution of the Cobar-Girilambone landscape
- recognition of distinct lacustrine and fluvial facies in the transported regolith
- development of methods and protocols for routine regolith-landform mapping appropriate for state surveys
- potential for constructing derivative 'Go Maps'
- identification of background regolith controls on element dispersion, including regolith-related element associations.

John Greenfield (NSW DPI) and Jess Davey (Honours student AU) during collaborative fieldwork at Mt Poole, near Tibooburra.

Photograph: Steve Hill

The **Macquarie Arc** module is investigating the nature of transported regolith and the potential for biominex and other new methods for gold exploration in areas of thick cover over significant known gold mineralisation in the Peak Hill-Tomingley area. The project was initiated in 2004 with an Honours study, successfully completed by Peter Bamford. A biogeochemical study was completed over the Wyoming One gold deposit and an area south of Tomingley with positive results.

Key outcomes of this module are:

- demonstration of limits to dispersion in Wyoming cover
- recognition of tungsten as a pathfinder for Wyoming style mineralisation
- indications that biogeochemical sampling will work through this cover.

The *Lachlan Fold Belt* project also generated three industry-funded site studies. Detailed regolith landform mapping provided the context for a study of geochemical dispersion processes at the Illewong prospect in the southern portion of the Cobar goldfield. This was completed as an Honours project (Tom Woorych) with Peak Gold Mines Pty Ltd.

Dispersion controls on Au, As, Cu, Ni, Co and Sc in calcrete, soils, vegetation and saprock over deeply weathered ultramafic rock at Miandetta prospect were investigated with the assistance of LEME Summer Scholar (Simeon Hui) and Jervois Mining Ltd.

Dispersion controls and anomaly generation in soils over the Hera polymetallic deposit near Nymagee were investigated by Keith Scott (ANU Visiting Fellow). This work is funded by Triako and will be completed by the end of calendar year 2005.

Plans for the *Lachlan Fold Belt* project next year include; development of the derivative 'Go Map' concept; extension of biogeochemical investigations in areas of deep cover around Tomingley; application of emerging hydro-geochemical techniques to various regolith dominated areas; and process and technique studies involving regolith mineral hosts and objective logging.

Tibooburra – **Steven Hill**, Kingsley Mills, Barney Stevens, Tim Sharp, Bill Reid, Ian Roach, Karin Barovich, Nick Direen, Anna Petts, Karen Hulme, Tania Dhu, Robert Dart, Martin Smith, Nicole Anderson, Sarah Gibbons, Jess Davey

Last year the project team established that regolith mapping interpreted with reference to a good model of landscape evolution could be used to effectively track gold distribution in the enigmatic Tibooburra goldfield in western New South Wales. This year we have extended this approach to the whole of the western Thomson Orogen, focussing particularly on Mt Browne and Mt Poole Inliers. A regional geochemistry framework has also been established using regolith carbonates. A regional biogeochemistry sampling program, similar to that of the Curnamona Project, has provided new baseline data. It was shown that seasonal variations in plant biogeochemistry are important with respect to gold. Samples taken in autumn have the greatest metal content and background-anomaly contrast.

A report called *Regolith and Landforms of the Tibooburra-Milparinka Region* was prepared for a three-day field workshop which was held in May 2005. The field trip concentrated on Mesozoic sedimentary rocks and regolith landforms surrounding Tibooburra, Warratta, Mt Browne and Mt Poole basement inliers. The unconformity surface at the base of the Mesozoic is economically important because the basal Mesozoic units are prospective for placer gold. However, because the Mesozoic and subsequent Cenozoic stratigraphy is disrupted by recent tectonism it is difficult to trace the primary source of the gold. The project will focus on developing a better understanding of neotectonics in the region in the coming year.

The *Tibooburra* project has strong links to the Education and Training Program and has engaged with the undergraduate and short-course programs, as well as Honours and PhD students. The Project will continue as a component of the larger *Thomson Fold Belt* Project in 2005–06

Curnamona

Module 1 – **Adrian Fabris**, George Gouthas, Alistair Crooks, Steve Hill, Joel Brugger, Karen Hulme

Module 2 – **Patrice de Caritat**, Dirk Kirste, Luisa Ruperto

Thin regolith (<10m) covers much of the prospective Olary Block of the Curnamona Province. Regolith mapping in conjunction with detailed bedrock mapping at scales of 1:25k has identified large areas of prospective Proterozoic basement concealed by shallow regolith that could be explored by appropriate surface geochemical techniques. Mapping is continuing on the Mingary 1:100k and Kalabity 1:100k sheets. A student project on the application of biogeochemistry to exploration through shallow cover has highlighted the effectiveness of River Red Gum leaves as a sampling medium. This work has been responsible for the discovery of an extension of the Pinnacles ore body.

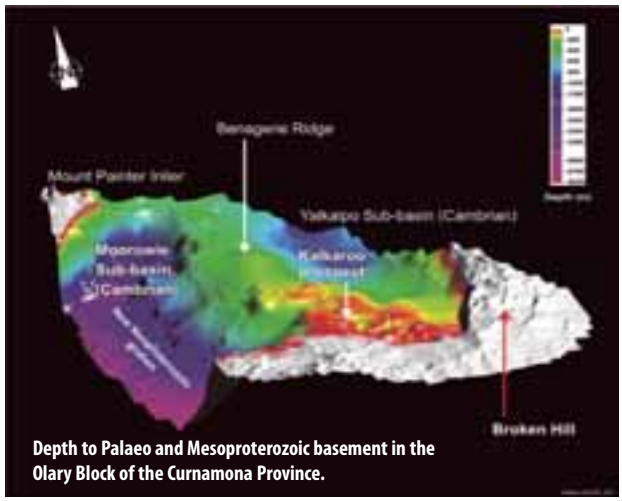
Thick sedimentary cover north of Kalabity and throughout the Callabonna Sub-basin conceals Proterozoic basement of lower metamorphic grade, but with potential to host Cu, Au and Pb-Zn mineralisation. Palaeochannels in the sedimentary cover host uranium deposits. A student project on the origin of the Beverley uranium deposit found that the palaeochannel sands have surprisingly high zircon content. Release of uranium from these zircons may be the source of the Beverley ore body. Multiple sources of the zircon grains have been located, one of which is currently draining to the west (away from the deposit), which may indicate tilting of the Flinders Ranges since the Miocene.

A depth-to-basement map of the Curnamona Province was created using an integrated, multi-data approach. This map is being used by mineral explorers to site drill holes in areas of deep cover. The study has indicated considerable errors in previous interpretations of regolith materials and thickness estimates in existing databases.

Data on the basin-fill material, together with the depth-to-basement map was used to generate a 3D model in Go-CAD. This will provide geological constraints for modelling groundwater flow and reactive transport thermodynamics and kinetics in the sediments of the Cainozoic Callabonna Sub-basin. The model incorporated a collation of textural and grain-size data from some 800 open-file drilling reports relating to the Callabonna Sub-basin, housed in the PIRSA library.

The 3D model outlines a series of sand and gravel horizons encased in a mud-filled basin. Aquifers do not form extensive layers that span the full width of the basin, but occur in perched sand ribbons and aprons of modest extent. This has implications for basin evolution and groundwater flow. The Go-CAD interface allows manipulation of the dataset and visualisation of the various components from any view angle and at any degree of vertical exaggeration.

The *Curnamona* project terminates this financial year, but aspects of the work will continue in 2005–06 in the new *CurnaMinEx* Project.



Depth to Palaeo and Mesoproterozoic basement in the Olary Block of the Curnamona Province.

Central Gawler Gold Landscapes – John Keeling, Mal Sheard, Mel Lintern, Baohong Hou, Alan Mauger, Wenlong Zang, George Gouthas, David Gray, Steven Hill, Lisa Worrall, Anna Mayo

The incorporation of regolith and geochemical data into the Central Gawler GIS continued in 2004-05, as a preliminary to establishing a regional regolith landscape evolution model. Company exploration geochemical data is being incorporated into regional datasets, but requires quality assurance – a task being provided by an external contractor. A final report for Boomerang gold prospect is in preparation, and a biogeochemical report for Barns gold prospect was completed as LEME Report 168.

An eight-metre thick dune over the Barns prospect was excavated and sampled to reveal the presence of dispersed gold halo of 9 ppb in carbonate accumulations. The dune, which lies on weathered saprolite, was dated by OSL technique at 27,000 years before present. The role of vegetation in transferring and fixing gold in the dune is being investigated at Barns, and at another site northeast of Wudinna. Four types of aeolian dunes have been recognised in the Wudinna area and there are significant differences in the associated vegetation and soil chemistry. The biogeochemical analyses are presently being interpreted as a part of an Honours project due for completion at the end of 2005.

The discovery in November 2004 by Iluka Resources of high-grade zircon deposits in palaeo-coastal dunes of the Ooldea Range in South Australia was assisted directly by models of landscape evolution, coastal stratigraphy and heavy-mineral accumulation, developed by Dr Baohong Hou and colleagues in the first year of this Project. This work is now being further developed in the *Eucla Margins* Project.

The aim of Program 1 is to understand the nature and timing of regolith processes, in both a detailed and regional context. It contributes strategic research in its own right, as well as forming the scientific foundation for other mineral exploration and environmental projects.

A major international study of mineralisation associated with palaeodrainage systems was accepted as an International Geological Correlation Program (ICCP) project. Dr Baohong Hou is co-leader and Australian co-ordinator. On invitation from various Chinese universities, Hou gave a series of lectures in China on the recognition and interpretation of palaeodrainage systems and their potential to host mineralisation. During the visit, Hou was given demonstrations of Chinese developments in electro-chemical prospecting techniques that will be tested under Australian conditions in a collaborative project with Chinese researchers and LEME in the latter half of 2005.

An update on the results of LEME research in the Central Gawler was included in presentations to industry in the GA/PIRSA Gawler Craton State of Play Conference in Adelaide on 4-6 August 2004.

Northern Territory Regolith – **Mike Craig**, Ian Robertson, Ravi Anand, Amanda Cornelius, Christine Edgoose, Roger Clifton, Masood Ahmad

This three-year project, funded by the Northern Territory Geological Survey, aims to establish a regolith-landform framework for the entire Northern Territory, as a guide to mineral explorers and land managers. A pilot palaeomagnetic age dating module in selected areas during 2004–05 showed it is possible to develop a well constrained timeframe for major weathering and preservation events across Northern Territory.

The Darwin coastal plains and adjacent profiles yield ages in the range 2 – 5Ma. Further south at Pine Creek ages range 5 – 10Ma. A road cutting at Tennant Creek yields an unexpected age of 295Ma. Further south, a weathering profile at Snake Head Dam, in the vicinity of Glen Helen George, yields an age of 47Ma. These ages are consistent with specific NT age data available from the LEME *Geochronology* Project. These encouraging results prompted further sampling at Tennant Creek and elsewhere. The results will enhance the emerging time frame of major weathering and regolith-forming events in NT.

As part of the NT project, a new system for collecting field data in digital form using a low-cost HP IPAQ Pocket PC is now fully developed. The system uses a wireless (Bluetooth) GPS device which allows speedy reliable collection of data, that can be easily uploaded into a corporate database and imported directly into commercial GIS software. This system is efficient during field operations, and allows early data analysis in the field, prior to full interpretation in office-based GIS systems. Digital data is integrated with national databases managed by Geoscience Australia.

As prescribed in the project milestones, a progress report was presented at the NTGS AGES – 2005 Conference in Alice Springs. On conclusion, the *NT Regolith* Project will deliver a 1:2.5 million scale Regolith-landform map of NT, a comprehensive GIS package, a final report, and an atlas of regolith materials.

A spin-off from this years work in Northern Territory was a new industry project with CAMECO. The project evaluated the advantages of incorporating regolith concepts into CAMECO Australia's existing NT exploration strategies. This fully funded exercise resulted in a LEME report which will be released from confidentiality mid 2005. When the main *NT Regolith* Project concludes, it is likely that additional collaborative projects will be developed with CAMECO.

Eucla Margins – **Mark Paine**, Baohong Hou, Vicki Stamoulis, Liliana Stoian, Lindsay Collins, Brad Pillans, Sue Welch, Bear McPhail, Lisa Worrall, Steve Rogers

Activity in this project has been organised into two modules. One module, which is being funded in part by Iluka Resources, is focused on developing a better understanding of the character, geometry, age, and facies of mineralised sediments associated with the Jacinth and Ambrosia heavy-mineral sand deposits. The heavy-mineral suite is being characterised, heavy mineral domains are being established, and heavy mineral provenance studies are being undertaken. One of the outcomes of this module will be a better understanding of the prospectivity of the entire Eucla Basin margin.

The second module is focussed on testing the idea that Middle to Late Tertiary fluctuations in sea level in the Eucla Basin had a significant effect on the evolution of regolith and groundwater on the basin margins. Central to this idea is the hypothesis that organic pyrite rich estuarine sediments deposited during the Mid Eocene transgression were oxidised during the late Mid Eocene regression, resulting in production of sulfuric acid and the precipitation of haematite. Middle to Late Tertiary palaeochannel deposits in the area of Kalgoorlie and Norseman have been surveyed and sampled for mineralogical analysis and for dating (U-Th-He and palaeomagnetism). Early results of the mineralogical analyses support the possibility that the sampled sediments have undergone acid weathering.

Weipa – **Tony Eggleton, Graham Taylor**

This project researches the age of the Weipa bauxite and the processes by which it formed. In 2004–05 the bauxite section of the Weipa weathering profile was characterised. Mineralogy of some 50 bauxite samples of various size fractions was determined. Approximately 1000 individual pisoliths were examined and a descriptive scheme was developed. These results are being reported in the first of two manuscripts in a planned series on the Weipa bauxite. Activity is now focused on the genesis of the bauxitic profiles

Generic Process Projects

Geochronology and Quantitative Models of Landscape Evolution – Brad Pillans, Ed Rhodes, Andrew Christy, David Ellis, Jim Dunlap, Steve Eggins, Martin Smith

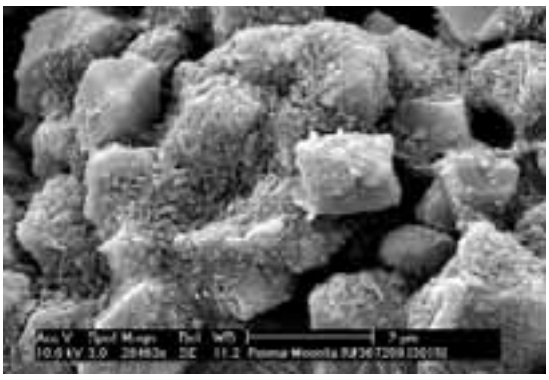
Paleomagnetic dating of oxidized regolith by Brad Pillans and Martin Smith continues to demonstrate the long history of weathering across the Australian continent. Sites sampled in 2004-05 include:

- Paddington, Norseman, Kambalda and Kanowna mines in the eastern Yilgarn, WA, as part of the *Eucla Margins* Project
- Coyote prospect in far northeast WA, as part of the *Tanami* Project
- Tennant Creek (including Nobles Nob mine), Darwin, Adelaide River and Alice Springs areas as part of the *NT Regolith* Project
- Challenger mine, Gawler Craton, SA
- Ballarat and Dundas Tableland areas (including Bondi mineral sands prospect) in western Victoria
- Broken Hill area, Tibooburra/White Cliffs area, Peak Hill mine, Mount Boppy mine and New Cobar mine in northwest NSW as part of Martin Smith's PhD project,nearing completion.

New results from these sites consolidate the continent-wide dataset from palaeomagnetic dating, and continue to support the hypothesis that major episodes of deep oxidation of the regolith occurred during Neogene (0-20 Ma), Early Paleogene-Late Cretaceous (50-80 Ma), and Early Permian-Late Carboniferous (290-320 Ma).

Martin Smith, Steve Eggins and Jim Dunlap have applied a multi-dating method to regolith in northwestern NSW, including oxygen isotope analyses of clay minerals, U/Pb measurements on silcrete and (U-Th)/He dating of iron oxides. While the U/Pb and (U-Th)/He results demonstrated that further work is required before reliable ages can be produced, the oxygen isotope data provided robust ages that compare favourably with palaeomagnetic ages from the region.

Jim Dunlap undertook $^{40}Ar/^{39}Ar$ dating of Mn oxides from the northern Flinders Ranges, and $^{40}Ar/^{39}Ar$ dating of alunite from the Poona mine at Moonta, SA. At the latter site, in conjunction with John Keeling, the ages are being used to place constraints on rates of copper dispersion in the regolith.



Poona Copper Mine, alunite crystals coated by halloysite from transported clay overlying the weathered copper lode.

History of Aridity – John Magee, John Chappell, Ed Rhodes, Brad Pillans, Derek Fabel, Kat Fitzsimmons

OSL dating of various phases of longitudinal dunes in the Strzelecki, Tirari and Simpson Deserts has progressed well during 2004–05. There are now sufficient dates to form the preliminary conclusion that Strzelecki and Tirari Deserts have no dune activity older than 100,000 years (100 ka). This suggests these dunefields were entirely reworked in the last full glacial cycle. On the other hand, Simpson Desert dunes are a complex of stacked stratigraphic units with basal units possibly as old as 400-500 ka. Reworking seems, therefore, to have been less destructive in the Simpson Desert during the cold dry phases of glacial climate cycles which would normally favour aeolian activity. This finding provides a first-order hypothesis which explains the difference between the pale (Strzelecki and Tirari) and red (Simpson, Great Sandy) deserts. These findings will have major implications for techniques of mineral exploration in dunefields, and for understanding evolution of arid landscapes and salinity.

Plans are well advanced for sampling red dunefields of the Eastern Great Sandy Desert and the Eastern Strzelecki Desert (near Cameron Corner) to specifically test hypotheses developed from previous results, and to further test aspects of dune reworking and sand sources as factors in dunefield evolution.

The OSL dating results have been presented at various national and international conferences and are being published in a number of national and international journals. The project team is also working on a major review paper which addresses the long-term evolution of the arid landscapes of Australia.

Physiographic Regions – Colin Pain

The Australian Collaborative Land Evaluation Program (ACLEP) provided funding to LEME in late 2004–05 to prepare a national map of physiographic regions. The map will form a basis for a new national regolith map of Australia, although that is not an objective of this project. This project will incorporate spatial information from other LEME regional projects, especially in NT and SA, into a map of physiographic regions.

Physiographic regions have already been compiled and digitised for LEME projects in QLD and NSW. The whole of NSW was compiled by mid June 2005 and will be digitised in early July. WA, VIC and QLD have agreed to compile the relevant data on their respective states

The Working Group for Land Resource Assessment was successfully lobbied during the year to include regolith as a fundamental data layer in the Australian Soil Resource Information System (ASRIS). The ASRIS has been expanded to include more realistic geology attributes, and LEME has been asked to contribute a new chapter on "the substrate" for a revised version of the Australian Land and Soil Survey Handbook (the Yellow Book) in 2005–06.

Innovative Electrical and Electromagnetic Methods for Improved Regolith and Sub-Regolith Exploration – **John Joseph**, Graham Heinson, Anton Kepic, Jayson Myers, Stewart Greenhalgh, Nick Direen, Paul Wilkes, Tania Dhu, Don Hunter, Margaritta Norvill, Anousha Hashimi, Lachlan Gibbins, Sukhyoun Kim, Adam Davey, Mohammad Rosid

Progress continues on understanding the spatial and temporal variation in the electrical properties of the regolith. Most research is being done by PhD students at Adelaide and Curtin Universities, resulting in numerous presentations and publications in national and international outlets.

In addition to the student activity a ground penetrating radar (GPR) survey was conducted for the *Central Gawler* Project in an effort to locate calcrete horizons. Several lines of 250MHz and 500MHz data were collected over a gold-in-calcrete anomaly. The top of the calcrete is detectable at both frequencies, but more clearly in the 250MHz data. Neither system seemed able to reliably pick any layers below one metre, despite apparently ideal conditions for radar. As the calcrete was typically within 50 cm of the surface, the limitation on depth of penetration did not prevent GPR from being able to detect areas useful for geochemical sampling.

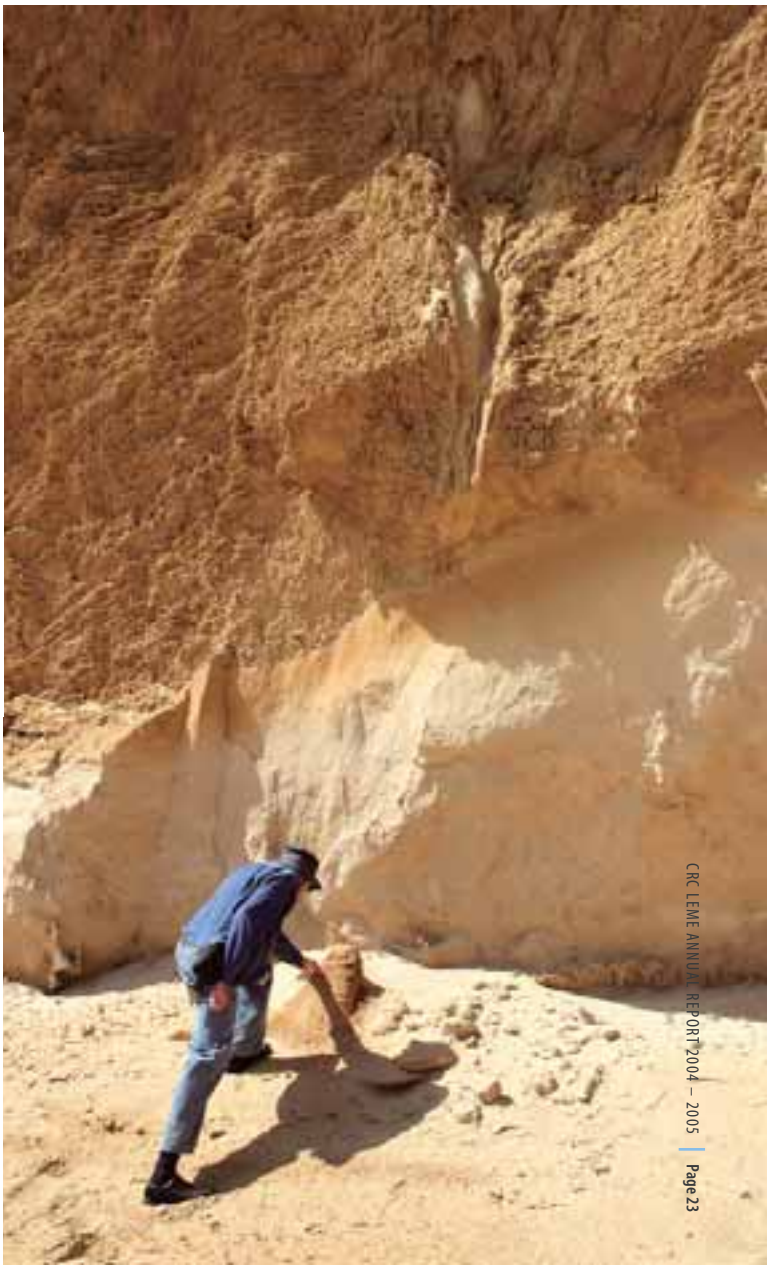
TEM surveys were also conducted for TAP Oil in an effort to detect dry sand channels in a clay-shale sequence. Logging of widely spaced boreholes had previously suggested that the upper strata were fairly uniform in the test area, and that subtle resistivity changes associated with dry sands might be detected with a TEM system. However, an ambitious attempt to detect the presence of gas rich sand channels at depths of 100 to 120 m within a buried river delta system was only partially successful. The data did show features that matched sand channels mapped from seismic reflection data, however there were other unanticipated changes closer to surface that could have been misinterpreted. Thus the TEM method was unable to reliably detect the sand channels in this area because the near surface variability masks the lower contrast features at depth.

Outlook for 2005–2006

Regional focus projects will continue to be the principal vehicle for delivery of research outcomes to minerals explorers through collaboration with Program 2, and to natural resource managers through collaboration with Programs 3 and 4.

In 2005–06 there will be three new regional focus projects in Program One; the *Tanami* (NT/WA), *Thomson Fold Belt* (NSW) and *Curnaminex* (SA/NSW) Projects. The *Tanami* Project is already off to an exciting start with the completion of a large multidisciplinary field program at the Coyote gold prospect. Early results suggest LEME will be able to develop new strategies for exploring through the cover in this highly prospective yet under explored terrain.

Photograph: Ian Roach



Program 2: Mineral Exploration in Areas of Cover

Program Leader: Dr Ravi Anand (CSIRO Exploration and Mining)

Highlights

- **Over a number of Yilgarn base-metal and gold deposits that are covered by thick transported regolith, certain *Acacia* organs and surficial organic materials, show unequivocal geochemical signatures of bedrock mineralization, in situations where no other soil or partial digest geochemical methods will work.**
- **Remobilised gold, possibly related to plant activity, is shown to be present in carbonate phases of 27,000 year old sand dunes on the Gawler Craton.**
- **New results confirm that biotic processes play an important role in bringing metals to the surface in areas with arid climate and deep watertable.**
- **Prototype of a medium-weight bench-top automatic regolith logger using spectral technology is operational.**
- **Soil dissolution experiments in organic acids show that organic compounds greatly increase release of major and trace metals, relative to inorganic ligands.**
- **Alunite, goethite and hematite in transported regolith are strong collectors of hydromorphic gold and pathfinder elements.**
- **New experiments show that solubility of native gold increases from 20 ppt in low salinity groundwater to more than 20 ppb in near-saturated chloride brines.**
- **Experiments show that copper adsorption onto goethite is enhanced 30 times in the presence of NaCl under acidic and oxidised conditions. In contrast, adsorption of zinc is much less affected and even suppressed by NaCl under neutral pH conditions. These results indicate that copper dispersion haloes around weathering ore bodies will be much smaller than zinc haloes under acidic, saline conditions.**
- **High concentrations of dissolved nickel in groundwater proximal to nickel sulphide mineralisation demonstrate another promising advance for groundwater hydro-geochemical exploration.**
- **Over one hundred case histories on regolith expression of Australian ore systems are released on the LEME website.**

Overview

The aim of Program 2 is to provide new and improved tools for mineral exploration in areas of cover, based on an understanding of metal transportation processes. This knowledge will provide guidelines for mineral explorers to assess which transported regolith environments permit metal dispersion, and what sampling techniques are most likely to detect the source of mobilised metals. The program involves a range of techniques such as chemical analysis of various plant species, metal geochemistry in the rhizosphere (plant-root zone) in relation to plant uptake, mass-balance studies, in-house laboratory and greenhouse studies; groundwater geochemistry, microbial characterization, isotope sourcing of metals, and soil desorption analysis to test for diagnostic gas migration. The researchers use a combination of *in situ* and *in vivo* spectroscopic techniques such as synchrotron, electron microprobe and laser ablation ICP-MS to determine the nano-scale location of metals in vegetation and regolith materials.

Mechanisms of Formation of Geochemical Anomalies

Metals mobility and microbes – **Bear McPhail**, and PhD students Alistair Usher, Frank Reith, Chris Gunton

A robust analytical method for measuring low level gold concentrations in groundwater is being developed. Experiments in native gold solubility have shown concentrations ranging from 22 ppt Au in 0.1 molal NaCl to 26 ppb Au in 5 molal NaCl brine, with AuCl(aq) or $AuCl_2^-$ as the likely dissolved species. These experiments indicate that much gold can be transported in groundwater through the regolith. Gold chloride and bromide complexes have been identified in UltraViolet-Visible spectrophotometric experiments under oxidised (Au^{III}) and acidic conditions. The results may lead to derivation of reliable thermodynamic properties for several gold complexes, which will be useful in predicting gold mobility in oxidised brines.

A metallophilic bacterium appears to play a key role in the formation of authigenic bacterioform gold grains. The organism is capable of accumulating Au on its own cell surfaces, and can also cover itself with biofilms of gold. Microscopic analyses show that active DNA-positive cells cover the surface of the biofilms. In the deeper areas of biofilms, gold encrusted cell-like structures resembling the gold-covered cells of the metallophile were detected.

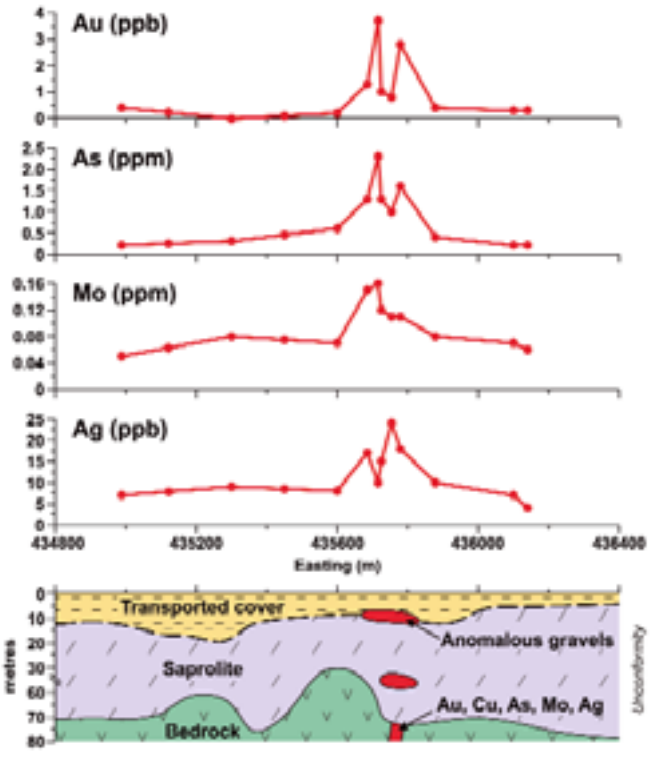
Photograph: Ian Roach

Experimental studies of metal adsorption onto goethite indicate that salinity has a strong effect on the transport of copper and to a lesser extent zinc. This is due to the formation of copper-chloride complexes on goethite surfaces. In contrast, zinc adsorption is much less affected, and at more neutral pH, zinc adsorption decreases with increasing chloride concentration. New experimental studies show little to no effect of dissolved sulphate on sorption of copper and zinc. This suggests that copper disperses less readily than zinc during weathering of base metal deposits in saline environments.

Mineral and biological hosts for gold and base metals – Ravi Anand, Rob Hough, Mel Lintern, Cajetan Phang, Ray Smith, Charles Butt, Steve Rogers, Ken McQueen

This year the project investigated the use of biota in generating the regolith expression of several gold and base-metal deposits in northern Yilgarn. At these locations, transported cover of Quaternary to Permian age is 7 – 25 m thick. Biota samples (phyllodes, branch wood, bark, litter and roots) were collected by Ravi Anand, Mathias Cornelius and Cajetan Phang. In addition, soil samples were taken 10-20 cm below surface and analysed using total, partial and selective digest methods, to cross-check for any surface chemical signature of bedrock mineralization. Soils from the rhizosphere were collected for bacterial investigations.

Whereas soil data is mostly ambiguous, biota geochemistry shows consistent evidence of buried mineralisation. Biota therefore appears to be a more effective medium than <250 µm soil and selective/partial soil analyses, in the studied locations. For example at Jaguar base metal deposit, the <250 µm soil results show a single high (Cu, Pb, Zn and Cd) above the interpreted up-dip surface projection of the deposit. Selective extractions (0.1 and 0.25M hydroxylamine hydrochloride and sodium dithionite) also show single point Cu and Zn highs without Cd. Enzyme Leach produces a marginally displaced (west of the mineralisation) strong, single high in Cu, Pb, Ni, As, Ga, Br, Rb, Y and Zr. By contrast, the biogeochemical survey shows a multi-point, multi-element signature in different ashed vegetation samples over the surface projection of the mineralisation. Zinc, in particular, is anomalous



in phyllodes, bark, branch wood, roots and litter. Cadium is anomalous in branchwood, bark and roots. Litter shows a multi-element (Zn, Cu, Pb, Cd, Ag and In) response over the surface projection of the mineralization that is particularly strong compared to other parts of the plant.

Our results on biota geochemistry are most encouraging and should lead to a practical method for locating mineralisation under transported cover in greenfields exploration, as well as providing clues to potential mechanisms for the transport of gold and pathfinder elements through cover. We consider this a highly prospective field for future research which LEME is therefore addressing as a matter of priority.

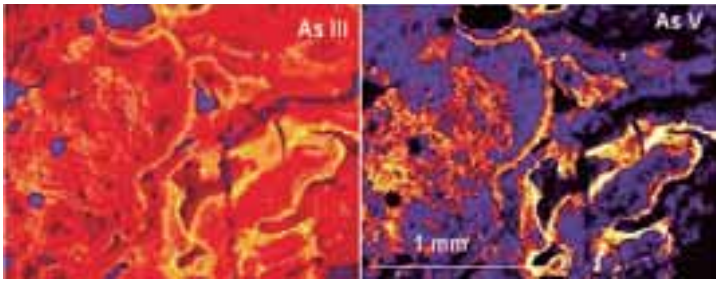
Detailed soil profile sampling at Jaguar shows that soil depth and soil properties (especially organic matter) control the metal distribution. Ore-related elements were extracted by sodium pyrophosphate and hydroxylamine hydrochloride at 0–4 cm depth. There is a significant drop in concentrations of zinc and copper at shallow sub-surface (> 4 cm). As most soil sampling is commonly done at 10-20 cm depth, the near-surface signature will be lost due to dilution.

We have also assessed the abilities of microbes to act as biomarkers for gold and base-metal deposits. Preliminary results suggest poor relationship between mineralisation and microbial populations. However, there appears to be some broad patterns of microbial communities evident at different sites.

An extensive geochemical survey of soils and vegetation at Barns prospect undertaken by Mel Lintern, indicates that gold and other elements associated with mineralization are found in leaves, bark and litter in both *Eucalyptus* and *Melaleuca*. Impressive anomalies occur in the organic-rich upper horizon of the soil, similar to the Jaguar deposit. A *Bacillus cereus* survey was completed in soils at ET prospect but, unlike some other documented studies, did not show a relationship with gold mineralization, gold anomalies in calcrete, or biogeochemical anomalies. This suggests other factors are involved in the distribution of this bacterium, such as clay content, or presence of soil nutrients. Early investigations of the role of non-specific soil biota (fungi and micro-organisms) on gold mobility in two soils from Bounty gold mine, indicate that relationship between gold mobilization, micro-organisms and other soil components is complex.

There is evidence of hydromorphic gold and pathfinder elements in hematite, goethite and alunite phases of transported overburden, possibly related to vegetation mechanisms. At Enterprise gold deposit and Moonta copper deposit, dispersion of gold was observed in alunite in Late Tertiary and Quaternary sediments by Rob Hough and John Keeling. Hydromorphic dispersion of gold and arsenic was observed in hematitic pisoliths formed in Tertiary sediments at Moolart Well gold deposit. At Rose Dam, Ravi Anand and Mel Lintern found the dispersion of copper in goethite of concentric pisoliths and gold in dolocrete developed in Tertiary palaeochannel sediments.

An investigation by Ray Smith of basal lateritic gravels that form the cover around the Golden Grove Gossan Hill VHMS deposit,



Speciation of Arsenic in ferruginous pisolith from Moolart Well, Yilgarn Craton WA.

establishes criteria to identify lateritic nodules and pisoliths derived from the ore deposit. These criteria include preserved tuffaceous textures with relict cassiterite (an associate of the ore zone sulphides), relict micron-scale Cu, Zn, As, or Pb sulphide inclusions in quartz grains of tuffs, micron-scale gold inclusions in nodules or clasts, ferruginous pseudomorphs after sulphides in nodules or clasts, and elevated indicators trace elements (Cu As Zn or more rarely Sb and Bi) in the core of nodules or clasts.

In the Cobar region of NSW, Ken McQueen has shown that different iron oxides and oxy-hydroxides play a role in chemical and mechanical fractionation of target and pathfinder elements during weathering of ore deposits, and the subsequent surface dispersal of the derived lags. This work has been linked with palaeomagnetic dating of ferruginous profiles to establish the element dispersion processes under different weathering and groundwater regimes through the Cainozoic.

Rob Hough and Charles Butt, in their continuing the work on gold nuggets, benefited from a kind donation from Mark Creasy (a renowned prospector) of a world-class collection of gold crystals and nuggets from over 30 localities. This study is providing important clues to the nature of gold in both primary and supergene forms, and how the internal structure and chemistry of gold relates to its weathering and accumulation in the regolith.

This year we were successful in gaining funding from the Australian Synchrotron Research Program to conduct Synchrotron based X-ray fluorescence and X-ray absorption spectroscopy experiments at the Advanced Photon Source in Chicago (USA). Rob Hough and Chris Ryan (both CSIRO Exploration and Mining) filled three days of beam time on polished blocks and thin sections of regolith samples from Mount Gibson and Moolart Well, analysing the distribution of Cu, As, Zn and Pb. They also determined the speciation of metals, and initial results point to the presence of both As (III) and As (V). Further synchrotron time is being sought.

Sampling of mulga tree at Moolart Well, Yilgarn Craton. Mineral and biological hosts project.

Photograph: Rob Hough

Biogeochemistry of calcrete – Andreas Schmidt Mumm

The genesis of calcrete and its association of gold and other trace elements were studied by reference to the microbial processes that may mediate the formation of carbonate. One such process is the enzymatic reaction of urease on urea to produce NH_3 and CO_2. It was shown that this enzymatic reaction can be activated through a profile 2.5m deep in aeolian sand dunes overlying mineralisation at the Barns prospect.

Biological weathering – **Sue Welch**, Sara Beavis, John Field, and Bear McPhail

Analysis of rhizosphere *vs* non-rhizosphere soils from the Mulloon Creek site which has co-occurring *Eucalyptus mannifera* and *Acacia falciformis* species, show differences in metal concentrations in the water and AAC extractable fractions, as well as in total concentrations in soils. Soil dissolution experiments in organic acids show that organic compounds greatly increase the release of major and trace metals relative to controlled inorganic experiments, very similar to the experiments with pure minerals. Results of rhizosphere *vs* non-rhizosphere organic dissolution experiments show similar trends, but generally higher metal mobilisation from rhizosphere soils. Soil bacterial and fungal community structure varies with plant species and soil horizon, and also there are noticeable differences between rhizosphere and non-rhizosphere communities.

Regional Focus Projects

Yilgarn laterite atlas – **Matthias Cornelius**, Amanda Cornelius, Charles Butt

Field sampling was completed in the southwest quadrant of the Yilgarn Craton. Some 2,000 samples were selected for analysis from field and existing collections. Analytical work commenced in July and will be complete in August. Preliminary results of the laterite geochemical mapping will be presented at the meeting of the International Geochemical Exploration Society in September 2005. The digital dataset for the southwest quadrant, and some interpretative maps will be published later in 2005.

Yilgarn Field Studies – **Matthias Cornelius**, Balbir Singh, Amanda Cornelius, Mark Pirlo, Ian Robertson, Merhooz Aspandiar

This project was discontinued because the industry collaborator, Sons of Gwalia, went into administration in late 2004. However research outcomes to date will be applied to other related projects. An annual technical report was submitted in February 2005, summarizing studies at Whirling Dervish and McGrath gold deposits. In the Carosue Dam mine corridor, calcrete is an effective regional surface exploration medium for gold. At McGrath mine, gold in biogeochemical samples indicate the presence of gold mineralization under cover. In areas of thick transported cover, ferruginous materials, in particular magnetic detrital gravel beds, at or near the base of the cover, may indicate the presence of regional geochemical anomalies of As and Sb. Ferruginous gravels at the base of transported cover overlying gold mineralization in fresh rock, may also act as a sink for transported Au, Cd, Hg and other pathfinder elements, and thus show the signature of underlying and nearby mineralization. Selective sampling of ferruginous nodules and pisoliths, either by magnet or visual separation after sieving, is recommended.

Hydro-geochemistry for mineral exploration – **Patrice de Caritat**, Dr David Gray, Mark Pirlo, Dirk Kirste

This new umbrella project successfully raised awareness of the use of groundwater chemistry as a tool for mineral explorers in areas of regolith cover. This awareness was enhanced by communication with stakeholders, publication of scientific and promotional articles, and short-courses. This has resulted in new industry funded projects.

Work on the *Ni hydro-geochemistry* project commenced along the Leonora-Wiluna belt, one of the world's premier nickel sulphide provinces. This externally funded project aims to develop cost-effective groundwater-based techniques to enhance discovery of NiS deposits in weathered terrains. The initial stage involves various sampling approaches at four sites along this belt.

Work has progressed despite unforseen sampling and logistical issues. Initial sampling was on (then) WMC and Lionore tenements in the Wildara area, including Waterloo nickel mine, but was cut short due to loss of down-hole sampling equipment. Return access has been difficult, but will resume in August 2005. Further sampling was at the (then) WMC Camelot prospect immediately north of Harmony nickel mine, which was previously sampled prior to mining. Unfortunately many of the critical bores had particularly narrow tubing, requiring the construction of special samplers, and a further visit. This has been successful, and data has been sent to BHP-Billiton. So far we have demonstrated kilometre-scale variations in groundwater chemistry around the mineralised area. Research is also addressing the value of S-isotope hydro-geochemistry.

Initial work has demonstrated the potential to use activated carbon sorption for semi-quantitative Mo W Au Pt Pd and potentially Ag.

Technology Development Projects

Objective regolith logging – **Tim Munday**, Cajetan Phang, David Gray, Mehrooz Aspandiar, Alan Mauger, John Keeling, Ravi Anand

This year the *Objective Regolith Logging* project applied spectrometric techniques to determining mineralogy of regolith materials, leading to the rapid automated logging of drillhole material in the regolith. Collation of reference material documenting the nature and variability of spectral responses in the visible and shortwave infrared spectrum in different regolith and landscape environments, was successfully progressed.

With a view to developing better processing software for estimating mineral abundances from spectral measurements, a detailed examination of a large number of regolith samples was undertaken with the assistance of the Mathematical and Information Sciences section of CSIRO. This showed that major mineral constituents of drill-chip material could be identified, provided that they were referenced to a carefully constrained spectral library. The threshold of identifiability will certainly vary from mineral to mineral. The study recognized the need to develop new ways of defining a common low-frequency background across the 400 to 2500 nm spectral range simultaneously with the automated identification of various mineral components in mixed materials. This work is ongoing.

Considerable promise was demonstrated in the application of readily derived spectral indices for automatically logging regolith stratigraphic horizons from drill chips. The trial involved a statistically-based algorithm developed for petrophysical data. The procedure is being rigorously tested with the specific goal of identifying a suite of indices that would have relevance to exploring through regolith.

The project also took delivery of a logging table designed and constructed by CSIRO Exploration and Mining which allows for the rapid automatic spectral recording of drill chips, pulps and core. The logging table is being trialled in a study of how spectral mineralogy might be incorporated into the exploration workflow.

Mineral mapping – South Australia – **Alan Mauger**, John Keeling, Graham Heinson

Sampling by hand auguring of selected targets from the HyMap image discovered new occurrences of kimberlite at Pine Creek. HyLogging of holes from Barns Prospect identified an association between phengitic (white) mica and gold mineralisation. Analysis of diamond drill holes that had been twinned with RC drill holes revealed that alteration associated with mineralisation could be linked to white mica distribution in the regolith.

The intensity of sericite alteration can now be quantified using spectral responses recorded by HyLogger, as has been shown in the Yarlbrinda Shear Zone. Correlations of white mica with distribution of gold in the shear zone are being established.

The basic elements of a 3D model are being built for the Tarcoola Goldfield with surface HyMap and HyLogger data, deep diamond drill holes, and underground drilling in old workings. Samples are being analysed to quantify the geochemical variations identified in the hyperspectral datasets.

Directions for 2005-2006

Generic process research will continue to be an important part of Program 2. We can now confidently expect major advances in understanding metal dispersion processes which will benefit the mineral exploration industry. Emphasis will focus on biotic and abiotic processes, using a combination of field and analytical techniques derived from soil science, botany, molecular microbiology, geochemistry, plant chemistry, hydro-geochemistry and regolith geology. Studies will be done at sites that show a surface geochemical signal over bedrock mineralization (true positive), at sites that show no known surface signature over mineralization (false negatives) and at sites with surface signature over no mineralization (false positives). Industry collaboration is expected through an ambitious new project entitled *Predictive geochemistry in areas of transported overburden*. We will be seeking industry funding to support part of this research.

Research on the application of hydro-geochemistry to gold and base-metals exploration will continue, with emphasis on developing cost-effective sampling and analytical methods. Digital datasets of laterite geochemistry and some interpretative maps for the southwest Yilgarn Craton will be published later in 2005. Sampling will continue in the northwest Yilgarn. Much of this area is difficult to access and the sample coverage may be less dense than that in the southwest. Nevertheless, broad geochemical trends are expected to be apparent even at spacing wider than the ideal nine-km grid. Work is expected to be completed by June 2006 with the release of a final interpretation report.

A significant technological development is expected with the spectral logging of mineralogy and chemical analysis by portable XRF. The regolith logger will be ready for field trialling in 2005–06.

Program 3: Environmental Applications of Regolith Geoscience

Program Leader: Dr Steve Rogers (CSIRO Land and Water)

Highlights

- Acid drainage waters in the WA wheat belt have concentrations of trace elements, metals and metaloids orders of magnitude higher than current Australian water quality guidelines.
- Potential U and Au anomalies have been identified in acid drainage water samples.
- Following a LEME submission, inland ASS is recognised as a *significant geohazard to environments of the world* by an international working group of the International Union of Geological Sciences.
- Significant accumulation of reduced sulfur has occurred at the Loveday wetland (River Murray) during 30 years of use as an irrigation disposal basin.
- Program leader and scientific staff were involved in the organisation of the 8th ICOBTE meeting, Adelaide April 05 (LEME Sponsor)
- LEME sponsored International Workshop and Conference on "Clay Mineralogy and Geophysics for Environmental Management and Mineral Exploration (ClayGEMME 2004) September 2004 in Adelaide.

Overview

The aim of Program 3 is to apply regolith geoscience and geochemistry skills of the CRC core parties to environmental management issues. The focus is on inland and floodplain acid sulfate soil (ASS) conditions, including geochemistry, mineralogy, trace element transport and transformations in sulphidic environments of the regolith. These will develop techniques for geochemical risk assessments, understanding biological (both faunal and microbial) processes across all four LEME research Programs, and demonstrating the value of low-density biogeochemical surveys. Projects not only involve a range of skills and partners from within the CRC, but in most cases projects involve active collaboration with external research groups and agencies.

WA Wheat belt Drainage – Acidic Groundwater: Geochemical Risk Assessment and Evaluation of Management Options – Steve Rogers, David Gray, Mark Pirlo and Rob Fitzpatrick (CRC LEME); Richard George, Adam Lillicrap (Agriculture Department Western Australia), John Ruprecht, Brad Degens, Jane Filmer (WA Department of the Environment); Grant Douglas, Jason Kirby (CSIRO Land & Water)

In response to the increasing incidence of salinity, and the current lack of viable plant-based options for salinity management, over 24,000 km of deep open drains have been installed in the WA wheat belt. Some of these drains have been found to export waters with a pH of 2-3, a flow of 50 kL/km/day and a salinity of 30,000-50,000 mg/L. Drainage waters in some areas have also been shown to have increased concentrations of aluminium, lead, copper, cadmium, manganese and radionuclides.

This multi-agency project managed by LEME aims to:

- understand the processes of acidic groundwater in the natural or pre-disturbed regolith, and beneath the cleared landscape
- forecast the impacts of engineering drainage on the transport and transformation of trace elements in undrained and drained areas
- assess feasible management options.

A review of historic pH data from 3,065 water bores shows that in nearly every landscape in the agricultural area, acidic groundwater (< pH 4.5) is present. Groundwater in the eastern wheat belt is the most acidic. By contrast, a stream and lake sampling program found that surface waters were neutral to alkaline in most areas.

Some 54% of samples collected were acid with a pH below 4.0. The geographical distribution of acidity in drains was similar to that of acid groundwater. However, some drains were characterised by a downstream change from alkaline to acid, indicating that geochemical changes are taking place in the drain irrespective of groundwater characteristics.

Geochemical analyses of drain waters for heavy metals, trace elements, rare earths, and major elements (S, Al, Fe) were performed using ICP-OES and ICP-MS. Analytical quality control and quality assurance was achieved using international-standard certified reference material. The presence of high chloride concentrations in samples (up to four times seawater) presented significant analytical challenges.

In general concentrations of heavy metals in drains with pH greater than 5.0 were below the limits of detection. In contrast

Location of acid and alkaline bores based on historical records

concentrations of heavy metals and major elements such as aluminium were significantly elevated in acid drains. When compared to Australian water quality guidelines, 70% of acid drain samples exceeded the upper limit for aluminium (solution phase aluminium is probably one of the most toxic elements to aquatic life), 100% of acid drain samples exceeded the upper guideline for both nickel and lead, 70% of samples exceeded the upper guideline for copper, and 45% exceeded the upper guideline for zinc.

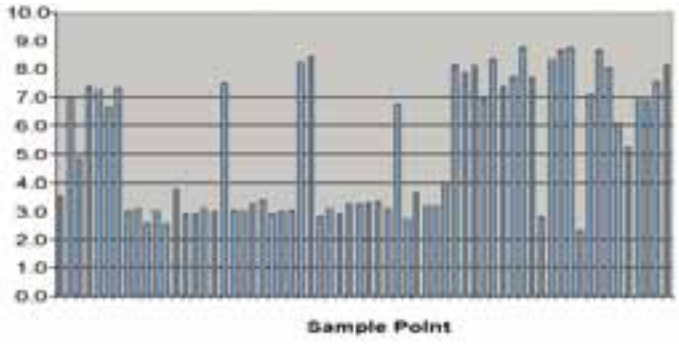
Elevated concentrations of economically important metals were also observed in drain waters. The REE elements cerium and lanthanum were elevated in acid drains with concentrations of cerium up to 2500 ppb. Uranium in acid drains and adjacent groundwaters was up to 900ppb, with all elevated samples in a single catchment, indicating a potential uranium mineralisation 'hot spot'. In addition elevated concentrations of gold up to 10 ppb in solution were observed. The significance of these findings with respect to potential mineralisation in the wheat belt is being investigated.

The presence of waters with elevated trace elements, aluminium and heavy metals that exceed current Australian water quality guidelines, has management implications which need to be addressed. However, the presence of elevated concentrations in the drains themselves does not necessarily indicate environmental risk. It is the impact of these elements on aquatic ecosystems, and their behaviour in the receiving areas, that present potential risks of acid drainage.

Loveday basin Floodplain Sulfidic Sediments

As reported in the 2003–04 Annual Report we made the decision to focus all our acid sulfate soil projects at a single site. Following discussions with Department of Water Land and Biodiversity Conservation (DWLBC), the *Loveday Basin* site in the SA Riverland was selected. This former ephemeral wetland was used as an irrigation disposal basin between 1970 and 2000. The site has also been selected by DWLBC to trial an adaptive management pilot for floodplain restoration, with the aim of restoring the basin to an ephemeral River Red Gum dominated wetland.

The site is characterized by sulfur oxidation during dry seasons producing noxious odors, characteristic of oxidizing acid soils. LEME has entered into a Memorandum of Understanding with DWLBC to provide regolith biogeochemical and hydro-geochemical inputs to the rehabilitation of the site. Sebastien Lamontagne (LEME Project Co-ordinator) is a member of the Loveday Rehabilitation Steering Committee



Drain water sample pH October 2004

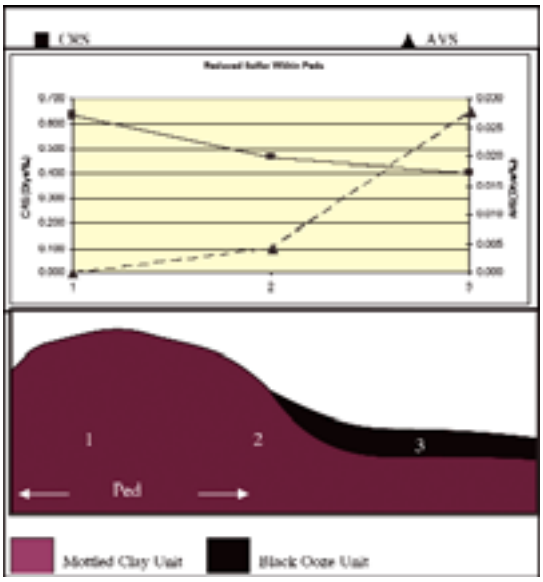
1. Drawdown Geochemistry – Sebastien Lamontagne, Warren Hicks

The *Draw-down Geochemistry* project aims to develop tools that will enable a safer management of the water regimes in Loveday Basin. One management issue is the presence of sulfidic materials, which can create environmental problems when disturbed (in particular, through the production of noxious smells). This LEME project will contribute to the rehabilitation effort by:

- Reconstructing historical water, salt and sulfur balances for the wetland between 1970 and 2000 (when the wetland was used as a disposal basin);
- Monitoring surface water quality to follow the impacts of water level variations over the next two years;
- Reviewing previous work on mechanisms causing noxious smells over sulfide–rich wetlands;
- Estimate gaseous sulfur losses from the wetland in partnership with the DWLBC *Odor control program*.

Water and salt balance models show that historically, irrigation drainage water and groundwater inflow are responsible for the majority of salt inputs to Loveday Basin. Irrigation drainage water contributed 46% of the water inflow and 47% of the salt. Groundwater inflows from the highland (groundwater mound) while only contributing 5% of the water contributed 51% of the salt input. Consequently even in the absence of irrigation that ceased in 2000, some 50% of salt input to the basin continues.

Salt accessions were converted to sulfur using indicative values for water composition based on pit water analysis at the site, compiled from River Murray data and Loxton rainfall data. This gave a sulfur accession rate of 750 t y^{-1}. An estimate of 8,700 t for the total basin sulfur loading was made using the preliminary survey data. This converts to a 30 year accession rate of 290 t y^{-1}, which is 40% of the estimated accession rate based on the water balance model. Further detailed sediment sampling and analysis is expected to close the gap in the estimates.



Distribution of AVS and CRS across a ped. The surface of the peds is coated with a gypsum crust

2. Geomicrobiology and Geochemistry of Acid Sulfate Soils –

Sue Welch, Sara Beavis, Dirk Kirste, Bear McPhail

Students: Luke Wallace, Sarah Tynan

Initial work shows that sulfur is concentrated in the upper 40 cm of sediments as gypsum, pyrite, monosulfides and jarosite. Gypsum is prominent at the sediment surface along sediment cracks and as salt efflorescence, where it comprises up to 10% of the surface sediments. The distribution of reduced sulfur is highly variable with organic-rich sediments containing up to 1% chromium-reducible sulfur (CRS) and 0.1% acid volatile sulfur (AVS). Pyrite (CRS) is concentrated within clay peds whilst monosulfide (AVS) is abundant at ped exteriors. Jarosite is common in small quantities associated with pyrite oxidation. Although there is abundant sulfidic material in the uppermost sediments at the site, analysis of water and sediment-water extracts show that most of the material analysed is not currently acidic, with pH ranging from 6-8. Jarosite mottles and acidic conditions (pH< 5) are associated with high concentrations of organic material.

The potential acidity stored in sediments was estimated from the rapid oxidation of sulfidic material by the peroxide test, and from incubating sediments in the laboratory under intermittent wetting and drying cycles. The results of rapid oxidation showed that although the sediments contained abundant sulfidic material, only sediments collected from 5-25 cm below the surface (ped material) routinely became acidic (pH 2-5). This is consistent with the results of the long-term sediment incubations. Slurry experiments were conducted with sediment collected from the surface of the ped, middle of the ped, and surface of the crack. The major element analysis of the solutions shows that the sulfur flux from the sediment appeared to be controlled by gypsum dissolution and not sulfide oxidation.

Microscopic analysis of the different sediment horizons focused primarily on sulfur-bearing minerals. Gypsum is abundant in the uppermost part of the sediment column as euhedral crystals, where it infills micro-cracks within the sediments, and encrusts the surface of the peds. Diatoms and filamentous alga or cyanobacteria are associated with the gypsum crusts. Jarosite and alunite are scarce. Framboidal pyrite was found throughout the sediment column, most often associated with decaying plant material. The morphology of framboidal pyrite was variable indicating it would not be useful as a redox indictor. Preliminary analysis of sediments by laser ablation ICP-MS show relative enrichment in Sr, Ba and Zr associated with Ca in cracks within the ped.

Hydrogeochemical analysis of water samples (surface water, pits and piezometers) comprised major, minor and trace species as well as isotopes of O and H in H_2O, S and O in SO_4 and C and O in CO_3. The waters are saline with chloride content ranging from 9,000 to 58,000 mg/l suggesting groundwater, near-surface water and surface water are compositionally distinct. Sulfate in pit waters have sulfur and oxygen isotopic signatures typical of sulphide oxidation, while the groundwaters generally have isotopic composition that suggests they are a residual of sulfate reduction.

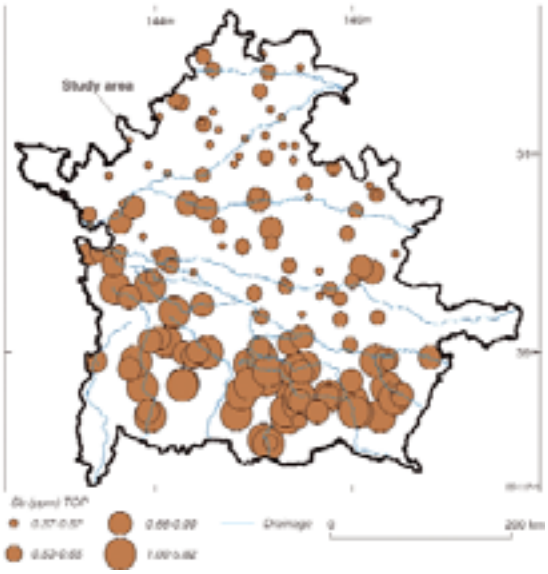
Low-density geochemical surveys – Patrice de Caritat, Megan Lech, Amy Kernich

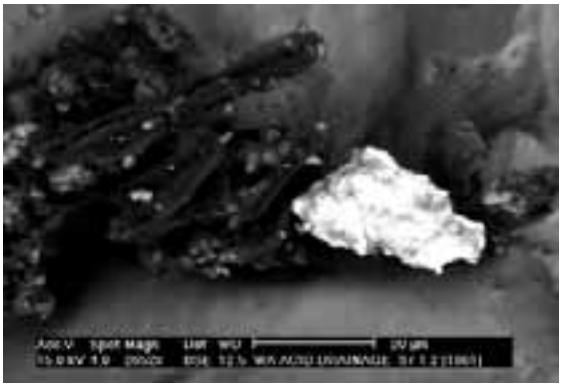
Following the completion of pilot baseline geochemical surveys in the Riverina (reported in LEME 2003-04 Annual Report), the methodologies were applied to the central Gawler region of South Australia, a contrasting geological and regolith environment. A reconnaissance field trip in October-November 2004 took samples of regolith and groundwater to fine tune preparation and analytical protocols.

The bulk of the regolith and groundwater samples were collected in April-May 2005. Overall 84 surface sediment samples, 25 groundwater samples and 1 rainwater sample were collected. All samples were prepared at GA and then dispatched to external laboratories for analysis.

Data interpretation is well advanced for the Riverina pilot project. This resulted in the publication of a LEME Open File Report and an article in AusGeo News, the Geoscience Australia magazine for news and highlights. A presentation on geo-health implications in the Riverina was made at Regolith 2004 in Canberra (24–26 November 2004). Almost all analytical results were at hand by June 2005, so that full data analysis and interpretation can be done in 2005–06.

Example of output for Riverland baseline geochemical surveys Sb distribution





Scanning electron micrograph of Cu and Zn sulphide minerals in iron oxyhydroxide gels sediments in Acid drains WA wheatbelt

Inland acid sulfate soils: distribution and regolith processes – Rob Fitzpatrick

This year we organised a highly successful multi-disciplinary International Workshop and Conference on Clay Mineralogy and Geophysics for Environmental Management and Mineral Exploration (ClayGEMME 2004) from 27–29 September 2004 in Adelaide. The meeting drew on the unique expertise of LEME in the emerging field of forensic soil science, and mineral exploration geophysics.

Our initiative has established the extent and severity of inland ASS as a major environmental issue in both public and government arenas. This position has been achieved through leading the debates, and providing the scientific basis of public policy. Consequently inland ASS is now recognised as a *significant geo-hazard to environments of the world*, by the Geohazards Working Group of the four major geoscience organisations of the world (International Union of Soil Sciences (IUSS) with members from the International Geographical Union (IGU), International Union of Geological Sciences (IUGS) and International Union of Geodesy & Geophysics (IUGG)). Examples of degraded inland ASS from Australia were used as international case studies.

We have continued to demonstrate that inland ASS generates anomalous concentrations of Cu, Pb, Zn, Se, As and Sr, thus introducing a new geochemical sampling medium for mineral exploration. Original research was conducted in South Australia but recent case studies in WA and Victoria verify this approach is widely applicable in the WA wheat belt. We have identified occurrences of: (i) new sulfate minerals (eugsterite, thenardite, bloedite, sideronatrite, tamarugite, copiapite, pentahydrite, starkeyite, bischofite, bassanite, carnallite, rozenite and barite) in salt efflorescences and (ii) iron oxides (ferrihydrite, goethite, schwertmannite and akaganéite). These iron oxide minerals act as a major sink for potentially toxic trace elements in drained ASS soils in new case studies in SA, WA and Victoria. Sulfidic sediments studied jointly with the SA Department of Water Land and Biodiversity Conservation in the Upper SE drainage region contain up to 9000 ppm As bound in iron oxide minerals. (An evaluation of the soils of Tilley Swamp and Morella Basin, South Australia by Richard Merry and Robert Fitzpatrick for South Australian Department of Water, Land and Biodiversity Conservation, LEME Open File Resport).

These unique phenomena relate to the specific geochemistry of the combined groundwater, drainage water and drained soils. The soluble sulfate minerals result from the oxidation and evaporation of saline sulfitic drainage water. During rainfall these soluble sulfate minerals play an important role in the transient storage of components (Na, Ca, Mg, Cl, Sr and SO_4), which will dissolve to form saline monosulfidic black ooze in the drains. Much of this work is made possible by the development of new XRF laboratory methods for determining major elements (fusion method) and trace elements. Methods have been refined to determine high concentrations of Se (>1ppm), Br, I, Cl and U. The final objective to develop an XRD standard under Standards Australia is also progressing (Mark Fritz – MSc). Progress has been made in exploiting the speciation potential of XRF for the characterisation of pyrite minerals in ASS. We have obtained good correlations with the chromium-reducible method for pyrite determination.

Delivery of scientific outcomes to clients has involved the development of new integrated mechanistic models using the toposequence approach, which integrates pedological, mineralogical, hydrological, biogeochemical, geological, climatic and land-use information for 31 case studies in Mt Lofty Ranges (South Australia), wheat belt in WA, and Dundas Tableland (Victoria). This mechanistic model can be used in natural resource management to predict how soil-water-landscape properties change with management intervention. Consequently implications for infrastructure and NRM planning, water quality management and mineral exploration need to be determined.

Directions 2005–2006

All projects will continue next year. The low-density geochemical survey will be completed at both the Riverina and Gawler, and final reports written. The key delivery will be a synthesis report on the applicability of low-density geochemical methodologies in two different regolith-landscape environments, and assessing if the approach is 'market ready' for adoption by government agencies or the commercial sector, in other regions.

The inland ASS project will provide further input to both the floodplain and drainage geochemistry projects, and develop a web-based National Inland ASS map. A key focus will be the development of a *National ASS Knowledge* project, funded by the Natural Heritage Trust involving a consortium of CRC LEME, University and State Government agencies. An ASS risk assessment consultancy for DWLBC will also be completed in the first quarter of 2005–06.

Site biogeochemical characterisation for the *Loveday basin sulfidic sediment* project will be complete by June 2006. LEME and DWLBC have commenced a site monitoring program to assess hydrological and geochemical changes during flooding and drying cycles. The installation of a permanent monitoring network will be a significant task. Laboratory studies will involve the reactivity of different sulfur phases, isotopic analysis of the different sulfur fractions, sulfur redox experiments and molecular analysis of microbial populations involved in sulfur reduction and oxidation.

The focus of the current *WA wheat belt drainage* project will be to assess the impact of acid, trace element and mineral-rich drainage waters on receiving areas such as wetlands, playas and salt lakes. We will also model the geochemical changes when acid waters mix with alkaline, hypersaline waters in receiving areas. A new wheat-belt risk assessment project will commence in the first quarter 2005-06, involving the existing consortium. This will expand the geochemical knowledge from the current Avon catchment to other areas of the wheatbelt, (Yarra Yarra catchment in the north, the lower southeast, and the Blackwood catchment). It will also develop predictive methodologies based on pilot drain studies prior and after drain installation.

A geochemical reconnaissance project will follow up.

Program 4: Salinity Mapping and Hazard Assessment

Program Leader: Dr Ken Lawrie (Geoscience Australia)

Highlights

- Deliverables from South Australian and Queensland NAPSWQ projects integrated into models to enhance salinity management and land use activities.
- New methods developed to map and predict regolith complexity and model salt movements in upland catchments in the Murray-Darling Basin.
- DEM-based methods by themselves cannot be used to predict regolith thickness, salt stores and mobility due to disequilibrium between current landscapes and buried regolith landscapes.
- Petrophysics of drill core from river bed sediments validates nano-TEM conductivity mapping and interpretation of river bed salinity.
- Improved methods for calibrating frequency domain helicopter AEM data (AMIRA P407B project) significantly enhance the accuracy of conductivity mapping by AEM.
- Identification of a buried fan-delta under the Lower Burdekin irrigation area by sedimentological studies, and mapping of salt water intrusion by EM techniques has major implications for surface-groundwater and salinity management.
- New methods of integrating AEM, regolith and hydrogeological data improve the modelling of salt stores and metal and salt reaction pathways.
- Gravity and TEM combined with borehole geophysics used to map and confirm palaeo-channel aquifers, enabling the targeting of groundwater pumping to lower water tables in salinised landscapes of WA.
- Regolith geology, climate change and groundwater pumping are important factors in modifying salt load and salinity hazard predictions.
- Communication of project results in regional and national workshops and conferences, and the inaugural International Salinity Forum in California.

Photograph: Patrice de Caritat

Overview

Several NAPSWQ projects in SA and Queensland were finished, and new externally-funded and Centre-funded projects commenced. Over 40 LEME staff and 10 students were involved in program activities. Externally-funded projects are typically multi-agency, with increased collaboration with other CRCs and salinity research groups.

Over 80 papers were presented at regional, national and international conferences. Several papers are being peer reviewed for international journals. A highlight was the presentations at the inaugural International Salinity Forum in California, at which Ken Lawrie presented the keynote address on salinity mapping methods.

We developed new products for mapping regolith and adding value to existing groundwater flow systems in upland landscapes of the Murray-Darling Basin. Unexpected complexity in buried regolith landscapes is revealed in many upland landscapes, necessitating innovative ways to map and predict this variability. This work demonstrated problems in using DEM-based approaches alone to predict regolith thickness, because of landscape disequilibrium and buried landscapes.

Research in salinity dynamics aims to develop dynamic models of salt movement in upland catchments. These products will be integrated into hydrogeological models for salinity and water management through collaboration with CRC PBMDS and CRC Spatial Information.

Progress was made in developing new geophysical techniques for aquifer mapping, particularly with seismo-electric techniques. Advances in the calibration of AEM, by way of AMIRA P407b project, are increasing the accuracy of these products. A petrophysical study of drill core from river bed sediments of the Murray River validated nano-TEM conductivity mapping techniques.

The 3D distribution and hydraulic properties of differently-textured regolith materials are important inputs to mapping salinity hazards, yet are rarely considered. However recently

completed petrophysical studies have characterised the various porosity types within a range of regolith materials. These can be used to generate look-up tables for mapping and predicting rates of groundwater movement through regolith. These data have been incorporated into a new method of interpreting AEM and hydrogeological data, to better model salt stores and element reaction pathways. Regolith petrophysics, palaeo-climate change and historical groundwater pumping are recognised as important factors in modifying salt load and salinity hazard predictions.

Previously we have identified significant cost savings for time domain AEM surveys. However these approaches cannot be applied to frequency domain AEM, because of corrections for drift and levelling problems require close line spacing.

In Western Australian, gravity, TEM and borehole geophysics have been used to map palaeochannel aquifers, to enable groundwater pumping to lower water tables in salinised landscapes. A methodology has also been developed to define methods, scales and line spacing for detailed mapping of soils using radiometrics and DEMs in the WA Wheat Belt.

In the Lower Burdekin irrigation area a buried fan-delta has been identified. Ground and borehole EM surveys can map salt water intrusion and water quality variations in the fan-delta. These findings have major implications for surface-groundwater and salinity management.

Extensive consultation with clients and research partners through the year, and workshops with the Land Use Advisory Council and CRC Board, have helped shape a research plan for the remaining three years.

Collaborative Projects with Murray-Darling Basin Commission – Ken Lawrie, John Wilford, Colin Pain

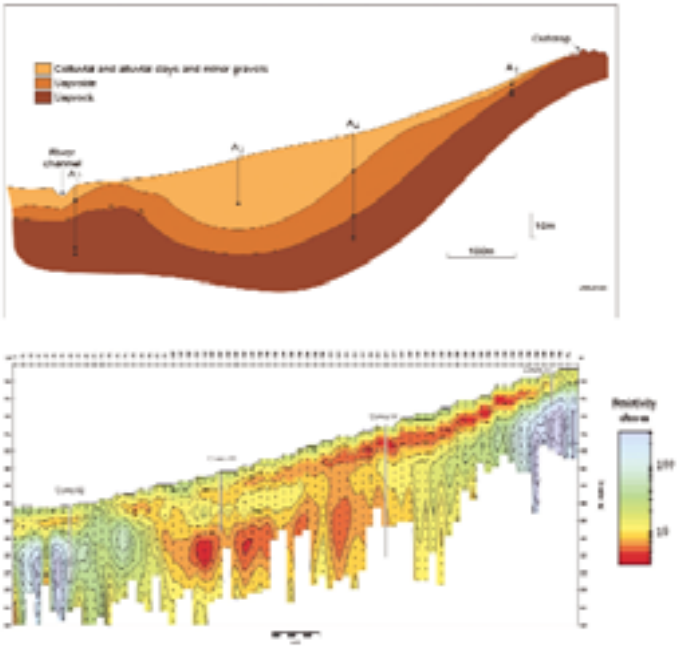
Modelling salt movements in Upland Landscapes

This project aims to demonstrate how subsurface information can be used to develop groundwater flow systems at sub-catchment scales in upland landscapes. There are two focus areas, Waugoola Creek catchment near Cowra, and Mitchell Creek catchment near Wellington, both in Central-West NSW.

The specific objectives are to:

- improve GFS models by incorporating information on subsurface regolith, hydrogeology, and salt stores
- provide surface and subsurface data to better delineate mappable units at catchment scales
- describe mobilisation pathways of salt stores in the shallow subsurface of each mappable unit
- link existing salinity and salt export models with DIPNR matrix farming trial studies for salinity and recharge management.

Analysing physiographic regions of the Eastern Highlands of the Murray-Darling Basin has revealed previously unmapped areas and boundary conditions of complex landscapes. Variations occur at scales ranging from hundreds to tens of kilometres. These variations are not recorded on any existing maps, yet this information has the potential to add significant value to GFS maps. One important consequence of these findings is that models that predict regolith from DEM and terrain indices alone, do not adequately predict sub-surface regolith landscapes, salt stores and groundwater movements. An hierarchical, multi-scale approach is required to map the extent of regolith units with complex regolith characteristics.



Cross-section (bottom image) showing ground EM conductivity image revealing highly conductive saline groundwaters (red) in a buried channel, mid-slope. Regolith unit interpretation in section above.

As regolith is the main store for salts and groundwater, resolving regolith architecture is essential for calibrating salinity models. Innovative approaches are required to extrapolate biophysical data from limited field calibration sites. New tools for depicting alluvial thickness, saprolite thickness, and physiographic regions help predict the distribution of salt stores in regolith.

Modelled regolith units and erosional scarps in upland landscape near Cowra. Salt scalds are associated with highly weathered regolith (dark red hues).

In areas of Palaeozoic fractured bedrock aquifers, further complexity is introduced by differential weathering of bedrock mineral systems. Key components of the latter are not commonly recorded in publicly available geology maps, and this has necessitated development of value-added bedrock products, and saprolith maps that reflect the underlying heterogeneity. This has been achieved through examination of existing publicly available geoscientific datasets, and traditional air photo interpretation.

Conclusions arising from this study are:

- An integrated, multi-disciplinary geoscience approach for upland landscapes will provide a reliable basis for salinity planning and water management.
- A multi-scale, hierarchical approach to regolith-landscape mapping provides a means for predicting potential salt stores and sub-catchment response times.
- Regolith data needs to be integrated with a wider range of biophysical data, including stream EC values, and electromagnetics to link salt stores and exports.
- Further trials of the methodology in a range of landscape types are needed.
- Salinity and groundwater management at sub-catchment scales requires more data on the 3D character of the regolith.

In-river nanoTEM conductivity mapping

LEME at Geoscience Australia was tasked by the Murray Darling Basin Commission to determine the suitability of nanoTEM to define salt fluxes into the River Murray. This necessitated analysis of borehole materials sampled from the river bed. From these studies it is concluded:

- Predicted and measured electrical conductivities of sediments correlate positively
- In the top 4 m of river sediments, nanoTEM measurements reflect pore fluid salinity, and there is little porosity variation in the sediment (Monoman Formation). In comparison, the electrical conductivity at 4 – 10 m depth is a function of both salinity and porosity of the muddy sand of the Bookpurnong Formation.
- Conductivity in sediment of less than 1 m depth does not correlate with pore fluid salinity, being less conductive than high salinity pore fluids.

Overall, it was found that in-stream nanoTEM measures the salinity of the river sediments, and can define the distribution of salt accession along the Murray River. This is important information for siting salt interception bores, and mapping gain and loss intervals in rivers.

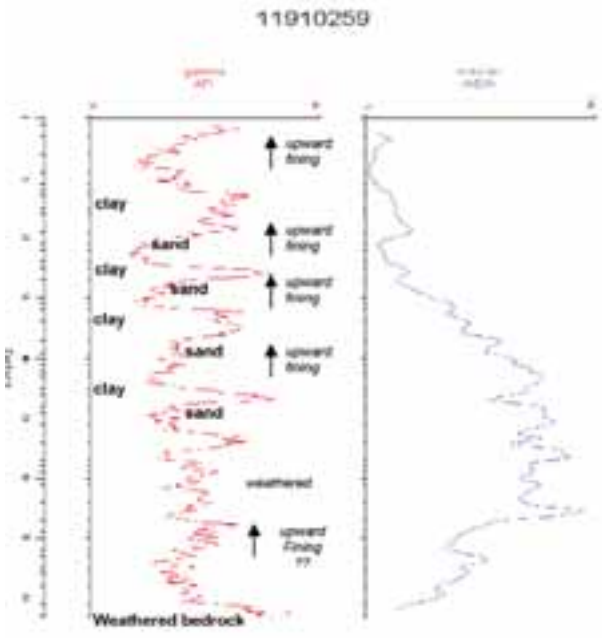
Lower Burdekin – Ken Lawrie, Andrew Fitzpatrick, Jon Clarke

Salt water intrusion is a growing hazard in Australian coastal landscapes. The phenomenon is poorly understood, with few long-term hydrograph records in affected areas. There is little understanding of sub-surface distribution of the salt-fresh groundwater interface, and rates of groundwater movement.

The Burdekin Irrigation District in north Queensland is the oldest irrigation area in Australia. Natural flows along the river have been modified by dams, barrages and groundwater extraction. This has resulted in marine-water intrusion into sub-surface aquifers, despite extensive artificial recharge. Effective management of salt-water intrusion in the coastal zone, and management of surface-groundwater interactions in the irrigation district, is not possible without a 3D understanding of aquifers and aquitards, as well as knowledge of the dynamics of surface-groundwater interaction.

In 2004-05, studies of borehole materials, geophysical logs, and high resolution digital elevation models (DEM) reveal new detail on the present-day and past river morphology. Previous workers who studied only the coastal zone, variously classify the Burdekin as a wave, wave-and-tide, and tide-dominated system. However based on sedimentological analysis, we have recognised it as a fan-delta system. This has implications for modelling groundwater flow, resource estimation, recharge actions, and salinity management in the irrigation region.

On-ground electromagnetic traverses show these techniques can map variations in water quality in the irrigation district, which reflect the scale of textural variability in the sub-surface.



Borehole gamma (on left) and conductivity (on right) from Burdekin Irrigation District, revealing aquifer stratigraphy (using gamma logs) and saline groundwater (viewed on conductivity image)

WA Ground Geophysics Projects

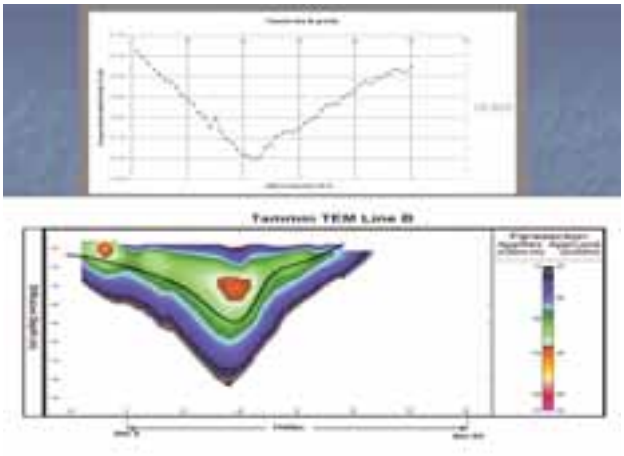
Palaeochannels Project – Paul Wilkes, Anton Kepic, Simon Abbott

This research project is funded under the Engineering Evaluation Initiative (EEI) of the WA Department of the Environment. Our role is to map palaeochannels in salinised agricultural land using geophysical methods, as a guide to siting groundwater pumps to lower the water table and thereby enhance agricultural production. Palaeochannels can be precisely defined by gravity and time-domain EM methods because of the low density conductive of the in-fill material. Two test areas were selected – Tammin 200 km east of Perth and Dumbleyung 300 km southeast of Perth.

At Tammin, gravity and EM successfully predicted a palaeochannel 60 metres deep, one km east from that indicated by the current landscape. The first groundwater pump delivered 40,000 mg/l of water at 120 cubic metres per day. The bore was logged to provide conductivity information to assist the EM interpretation. The success at Tammin was presented at the first National Salinity Engineering conference in Perth in November 2004. A related paper has been submitted to the *Australian Journal of Water Resources*. Further articles have been presented in the agricultural press and in *Focus on Salt*.

The Dumbleyung test site has been recommended for a groundwater pump, but this has not yet been installed.

Taking gravity observations, Rural Towns Project.



Cross-sections showing palaeochannels in gravity and conductivity images, Tammin, WA.

Rural Towns Project – Paul Wilkes, Anton Kepic, Simon Abbott

LEME is a research partner in this multi-disciplinary project involving WA Department of Agriculture, and CSIRO Land and Water. It tackles water management plans for 16 salt affected towns in WA. Its aims are:

- protection of townsite infrastructure from salinity
- integration of town water management methods
- implementation of new water supply and recycle schemes
- reduced reliance on town scheme water
- promotion of high-value water-dependent industries
- protection of biodiversity around townsites.

The *Rural Towns* project began in July 2004, involving geophysics, groundwater drilling, test pumping, catchment run-off and water quality analysis at Wagin, Lake Grace, Nyabing and Woodanilling. The role of LEME is to provide inputs on regolith and bedrock geology, and facilitate integration in this multi-disciplinary project. Work is in progress on the next group of towns, which will include Merredin and Moora.

Yarra Yarra Project – Paul Wilkes

This is a collaborative project with WA Department of Agriculture, and the Yarra Yarra Catchment Management Group, using NAP/NHT funds. The project aims to develop paddock-scale soil mapping methods using airborne geophysical data, satellite data, digital elevation data, and soil analyses. There is a current proposal to acquire high-resolution low-level airborne geophysics over a large part of southwestern agriculture area of WA, so as to apply the new mapping methods. The Yarra Yarra Catchment Management Group has made soils maps by traditional methods, but is now keen to trial more rapid methods as part of their plans to construct drains to combat salinity.

In 2003, Geoscience Australia acquired new airborne geophysical data over the southeastern part of the catchment, including radiometric data suitable for soil mapping. Concurrently, WA Department of Agriculture is revising soil maps for this area.

From the new radiometric images, some 900 sites have been selected for checking by shallow augur. For these sites we interrogated the geophysical and Landsat images. New soil maps have been produced using a decision-tree approach. These will be provided to local farmers for their assessment using *Catchman* software provided by the Catchment Management Group

A palaeochannel study using gravity and EM methods investigated linkages between present surface drainages and deeper drainages at Yarra Yarra. Six transects have been selected at key locations, and gravity data measured. It is planned to follow up with ground or airborne EM methods.

Wallatin Project – Paul Wilkes

This is a Catchment Demonstration Initiative working on salinity mitigation in Wallatin and O'Brien catchments near Kellerberrin, 300 km east of Perth. It is a collaborative project with Wallatin Wildlife and Landcare Inc, WA Department of Agriculture and CSIRO Sustainable Ecosystems. Trials involve groundwater pumps and syphons, drainage engineering and plant-based solutions.

Existing aeromagnetic and radiometric coverage provide a regolith framework for this project. New data was acquired with vehicle-based frequency-domain EM (EM31) and gamma radiometrics. Vehicle-borne GPR was acquired in one area. Gravity and ground time-domain EM was acquired on selected transects. The project has diverse skills and is now working on defining targets to be drilled in September 2005. Communication with farmers is an important part of this project.

Salinity Dynamics – Richard Cresswell, Jim Cox, KP Tan, Dirk Kirste

This is the third year of a major multi-party project, initially designed to bring the expertise of CSIRO Land and Water into Program 4 activities. Understanding system response times of salt mobilisation is important in identifying salinity risks, development of secondary salinisation, amelioration of salinised land, and long-term effects of landscape salinisation. We are now in the process of synthesising and extending our research, which will continue into next year as a unified multi-party multi-disciplinary project called *Salinity Dynamics*.

In 2004-05 we continued to develop methodologies and interpret data from across the Murray-Darling Basin under three modules, discussed below.

Salt mobilisation and water quality – Richard Cresswell

The aims of the module are to:

- Consolidate the NAP work of the past 2 years in upland systems throughout the Murray-Darling Basin.
- Apply a range of integrated hydrogeological, geochemical and modelling tools to priority catchments for the purpose of preventing salinisation.
- Develop fundamental science on mobilisation and transport processes of salts in the regolith.

All components of the (in-part) NAP-funded South Australian salt mobility project have been completed under the auspices of the SA-SMMSP. CRC LEME Open File Reports and DWLBC Technical Reports have been produced.

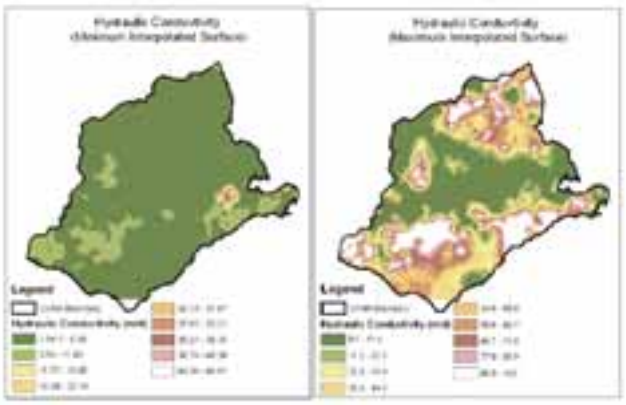
In the Bremmer Hills in SA, reports were produced on modelling salinity distribution and transport. This study found a relationship between regolith attributes and salt storage, although this was overprinted by rainfall gradient across the hills. Rainfall is the primary factor governing present-day salt stores, while the depth of weathering governs the actual amount of salt available to be mobilised. FLOWTUBE modelling confirms that major salinity-prone areas correspond to constrictions in the underlying geology and confluences of surface streams. Sub-surface palaeochannels generally correspond to present-day creeks. A notable exception is north of Jamestown where sub-surface groundwater flows south down the eastern valley, while surface waters cross the divide and compound salinity problems in the Bundaleer valley. Here, moderate recharge will result in elevated groundwater levels, bringing saline groundwater into the root-zone and affecting crop growth.

A number of initiatives have been developed with the Queensland Department of Natural Resources to address salinity risk mapping. These will incorporate hydrogeochemical modelling using HYDRUS 2D, and FLOWTUBE. Refining the decision support tools is a high priority for the QDNRM Group. These initiatives include:

- hydrogeochemical investigations in Condamine, Moonie, Border Rivers, Pioneer, Lower Balonne catchments
- salinity variability and transport in Hodgson Creek and Condamine Catchment
- assessment of salinity in bores of the Goondoola Basin, Moonie
- evaluation of anomalous bores in the Border Rivers
- assessment of parameters defining seawater intrusion in the Pioneer
- recharge rate determination from radio-isotopes in the Lower Balonne
- integration with the Queensland Salinity Modelling Team.

The long-awaited Corangamite Project in western Victoria commenced in 2004-05. It aims to develop a 3D model of the groundwater system associated with the Victorian Volcanic Plains. This study will re-interpret existing bore records and geophysical surveys to constrain the various hydraulic parameters describing water flow. It will develop a 3D model of the hydrostratigraphy. Hydrogeological data have been assessed and incorporated into numerical model. This provides constraints on the limits of various hydraulic parameters describing water flow.

In the Coonawarra region of SA, the performance of drains has been examined by specifically modelling the Bald Hill Drain.



Minimum and maximum hydraulic conductivity determined for the main aquifer across the Corangamite region, western Victoria.

MODFLOW results combined with analysis of rainfall and water-level trends, indicate that drains will provide the necessary diversion of water for the region, provided there is a near-surface impermeable barrier to facilitate movement of water along drains. An assessment report on the impact of drains in southeast SA is currently under review. This has generated a calibrated groundwater model that incorporates various drain scenarios to predict seasonal and annual changes in groundwater level.

In addition to the laboratory work described in other modules, the Brisbane Laboratory of CSIRO Land and Water has now been equipped for field and sample preparation support. In Adelaide, John Dighton has developed a novel, yet simple, methodology for the collection and analysis of stable sulfur ($\delta^{34}S$) isotopes in waters and sulfurous minerals. This has applications across a number of LEME projects, including mineral exploration.

The accession of salts to the landscape is a necessary input to modelling salinity risks. A revised chloride accession map for Australia has been created and compared to limited radionuclide data (^{36}Cl). Patterns are similar, but data coverage is still poor. A new national rainwater collection network is being established to help rectify this deficiency.

Chemistry of salt and metal mobility NSW – Dirk Kirste

This module aims to understand the:

- sources of salt in the regolith, how it has accumulated, and the reactive transport effects during mobilisation
- mobility of metals in the regolith in relation to chemical environments (salinity, redox, acidity), roles of regolith mineralogy in metal dispersion and reactive transport modelling.

This is fundamental to assessing salinity risks and remediation strategies. Reactive transport modelling examines the level of mobility of ions in regolith materials, and whether we can distinguish the roles that pore waters play in the unsaturated and saturated zone. Column experiments with pore waters will provide constraints on model parameters.

Water-rock interaction and salt transport have been studied in cores from the GILMORE project. Isotopes and chemistry are revealing quasi-equilibrium within thick illite-smectitie sequences, juxtaposed with intercalated sandy lenses that transport the fresher, younger waters and salts. As part of these studies, the mobility of Cu and Au is being modelled in 3D.

Cyclic salts are the major contributor of chloride and sodium to groundwaters, particularly in shallow systems. Calcium, magnesium, potassium and sulphate may come from a variety of sources and the contribution from rainfall can be ambiguous, particularly considering the paucity of rainfall data across the country.

Chloride mass balance is a method of evaluating recharge rates in semi-arid environments. The input value for chloride is estimated from real data, but sometimes it is not from a relevant location. Isotopic methods to evaluate chloride transport are well established, but there are few studies that compare the two approaches at the same location. Good agreement has been found at one such site in Queensland, and evaluation of GILMORE data is yielding important constraints on chloride transfer rates.

Current laboratory column experiments will investigate transport through low-permeability clay, flow systems in 3D layer models, ion-exchange and adsorption reactions, simulated evapo-transpiration, dissolution and precipitation.

Analysis of pore waters is crucial and a pore water extraction system has been constructed. This required special inserts being made for use in a centrifuge. A method has been tested for the extraction and analysis, which works well for sands, silts and silty clays. For more clay-rich materials, pore waters will be extracted using compression equipment at BRS.

Regolith controls on salt stores and mobility – K P Tan, Richard Cresswell

Objectives for this third module are:

- determine permeability and porosity of various textured materials
- derive a look-up-table characterising regolith materials and their permeability and storability values

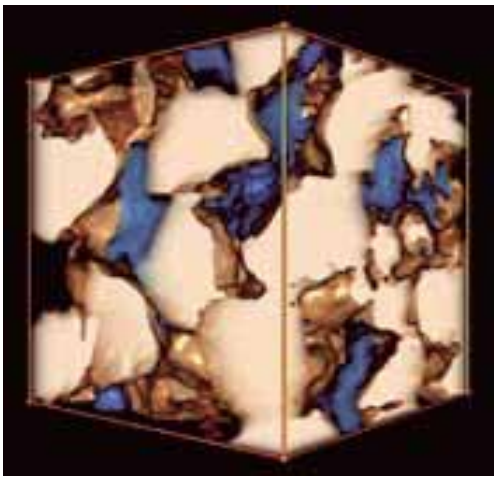
Activities have focused on literature reviews and examining soil profiles in NSW and Victoria wheat areas. Experiments have been set up to measure total porosity, water content at wilting point (15 bar) and permeability. The focus is on material properties rather than macro-landscape analysis, although these parameters can in future be applied to landscape analysis.

Salt mobility in the regolith is by way of fluid movements through soil, sediment, saprolith and fractured rocks. The rates of flow are governed by permeability, and the storability of fluids is controlled by porosity. Permeability is essentially controlled by the dimensions of pore-necks and pore connectivity, and is strongly influenced by texture, mineral abundances, porosity and compaction. Clay is defined as less than 4 µm. Since texture is a function of mineral composition, the abundances of various minerals will also control the permeability.

Porosity can take three forms – physical (total) porosity, effective porosity and chemical porosity. Physical porosity is the ratio of void volume to total volume and includes both isolated and connected pores. Effective porosity refers to connected pores only and is used when describing the movement of fluids and solutes through rock. Chemical porosity includes all porosities that allow chemical reaction to take place. For coarse-grained regolith, physical, effective and chemical porosities are very similar. In contrast, fine textured materials are very different, with the effective porosity having a much smaller ratio compared to total porosity.

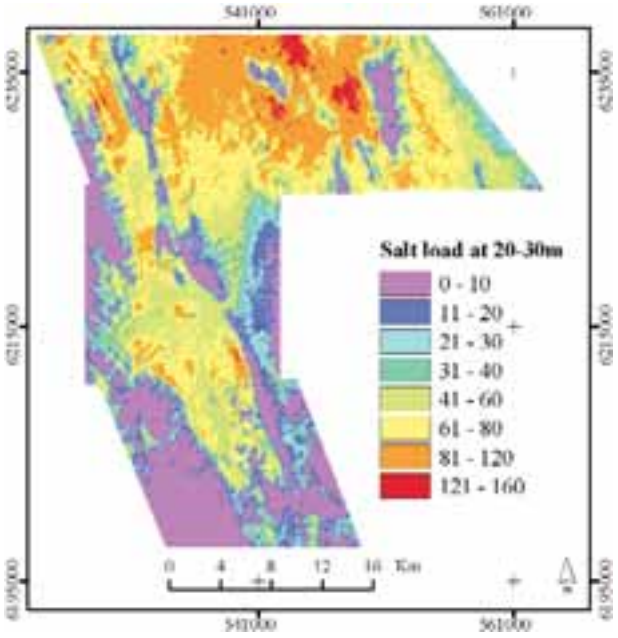
Data reviews of clay effects on porosity, and location of salt within minerals, pores and fluids has been undertaken and significant data gaps identified, particularly for materials with low (10-30%) clay content. Also, different clays are known to behave differently with respect to salt retention and transport, but this is poorly documented. Samples with appropriate clay mineralogy and content have been submitted for analysis by Hg-porosimetry, and for the new technique of CT micro-tomography. Each technique preferentially targets pore geometry at different scales, allowing a complete picture of pore distribution in the samples

Soils from NSW and Victoria wheat belts show a wide range of sand, silt and clay fractions. In these soils the total porosity does not show any correlation with clay or mud abundances.



CT micro-tomography of regolith sample with pore spaces in blue.

Map of salt load in tonnes/pixel. Each pixel is 30 x 30 m or 900 m². From GILMORE project area, NSW



Petrophysics and Geophysics

Physical properties from electrical conductivity – KP Tan

Electrical conductivity responses of regolith materials primarily depict the amount of water and its electrolyte concentration. The water content depends on degree of saturation, and at saturation the content depends on porosity and texture. Knowing the salinity and ranges of moisture content of regolith is imperative in interpreting AEM and borehole conductivity data.

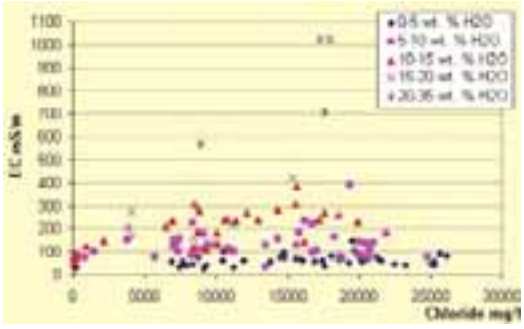
The functions between electrical conductivity and water content for a range of regolith textures, at saturation and at -15 bar, have been established for the first time. This has been achieved by examining volumetric water content, pore fluid salinity, textures and electrical conductivity in various drill cores. This has established relationships between electrical conductivity, water content, porosity, texture, pore-water salinity and salt store. Results highlight the upper and lower limits for moisture contents found in most regolith materials.

Together with pore fluid concentrations, these functions form a look-up-table that will aid validation of EM products and calibration of EM data in new areas. For example, unsaturated sand with low moisture content (< 5 vol %), and high pore fluid salinity of 20,000 mg/l TDS, does not give a conductivity response greater than 100 mS/m. Such low conductivity responses from airborne data are commonly interpreted as electrically resistive sand with low salt load. However, the electrically resistive units may contain saline pore fluids representing a potential salinity hazard.

These data were applied to estimating salt loads in the Bland Basin in NSW. This involved integration of data from borehole materials, and analysis of conductivity depth slice (CDI) images. Results show the amount of salt stored in the regolith profile as estimates of salt loads, and displayed as tonnes of total dissolved solutes (TDS) per pixel (900 m²) per CDI thickness (5 or 10 m).

Results from this project provide a reference for more accurate interpretation of AEM data. They enable the precision of down-hole induction logs to translate into salt store by taking into account heterogeneity of regolith materials.

EC-chloride scatter plot showing relationship between texture, moisture and salinity of pore fluids.



Seismo-electric developments – Anton Kepic

LEME has previously collaborated with ANSTO in developing electro-kinetic sounding (EKS). This is a hybrid method that uses a seismic source (P wave) to produce differential movement of dissolved ions in pore water against surrounding mineral grains. It is the only geophysical technique with potential to directly measure aquifer permeability. This is the basis for the *Aquifer Parameter* project.

This year, seismo-electric data was collected in collaboration with Tap Oil, at two locations along a seismic line near Karratha. EKS data at both locations agreed extremely well with the seismic data. This was unexpected as the seismic source used was a small shotgun cartridge, which provides minimal energy. Repeat shots at each location confirmed that the seismo-electric data was indeed caused by the shot. Surprisingly, some signals were from layers 150m deep. This is a new observation. Additionally, the partially saturated gas-rich sands gave a distinctly stronger signal, which is in accordance with an observation reported by Exxon-Mobil.

Tests of the ANSTO prototype seismo-electric acquisition system in Dec 2004 showed that it was still not effectively operational, with numerous software and hardware problems. The acquisition system had problems interfacing with the Curtin University pre-amplifiers. Another pre-amplifier interface with the ground stakes is needed.

A new acquisition method was used in further seismo-electric tests in the Blackwood River area near Nanup (WA), but it was found that surface waves produce interfering signals. This was particularly strong near laterite, where the hard surface layer traps the seismic energy producing reverberations within the data. Such signals can be filtered with F-K algorithms if a dense array of sensors is deployed. However our limited number of sensors (24) over a small area limits ability to see deeper signals. Possibly only 50% of soundings at Nanup have produced interpretable data. A solution is to move the seismic source position incrementally within the array. This approach appears to work if the regolith material does not change much over depths of 10-20 cm, but the relative phase of the interfering signals changes greatly. This allows the F-K post-processing filter to remove the interference. This development was presented at the SEG conference in Denver in Oct 2004. In addition, the case histories were presented by M Rosid (PhD candidate) at the ASEG (Aug 2004) meeting in Sydney and published as a paper in the *Exploration Geophysics Journal*.

Nuclear Magnetic Resonance – Don Hunter

Don Hunter (PhD candidate) examined the effects of natural magnetic gradients on the nuclear magnetic resonance (NMR) signal from groundwater. Gradients detune the NMR signal producing a more complex decay. However, it appears that NMR can still be used in areas with strongly magnetic basement rocks (iron formation, dolerite), but the magnetic field at the transmitter loop corners should be measured or inferred. This work and other recent studies on the sensitivity of survey configuration for water at different depths was presented at the ASEG conference (Aug 2004), SEG (Oct 2004, expanded abstract) and published in *Exploration Geophysics Journal*.

Seismic Reflection – Anton Kepic

The main aim of the *Aquifer Parameterisation* project in 2004-05 was to apply the high resolution seismic reflection method to regolith problems. This method excels where there are horizontal layers of varying thickness, enabling better hydrogeological modelling. It was planned to test areas south of Karratha (with Tap Oil) and in the Lower Burdekin delta in Qld. However seismic equipment for the Burdekin work was not available before the end of the reporting year.

The seismic reflection method worked fairly well in the Tap Oil project despite using an old seismic system, a weak seismic source, and experiencing more variation in the overlying material than expected. The aim was to map sand channels 5-15m thick in a layer of buried hardpan that is approximately 120 m deep, sitting upon crystalline basement rocks. The sand is part of an old river delta system, and is overlain by shale. The sand channels have potential to trap natural gas that may have has seeped in from offshore. Two seismic lines 3km long produced reasonable cross-sections. The landward line showed five or six sand channels, but 5 km to seaward, the line sees only one large sand channel. Ground TEM supported this picture, but it remains inconclusive.

It is concluded that 2-D seismic reflection is not good enough, and a full 3-D survey is needed to resolve the distribution of channel sands, before any commercial testing can be done.

Geologically-constrained interpretation of AEM – Tim Munday

AMIRA P407b commenced in August 2003, and finishes in September 2006. Its objectives are to:

- improve the accuracy and resolution of imaging quasi-layered conductivity structures
- develop 2Dand 3D models and interpretation methods
- document the software developed over several previous collaborative research projects.

LEME sponsorship of this project gives us access to cutting-edge software for analysing, processing and interpreting EM data for a wide range of applications. Specifically it gives access to the research version of *EMFlow* which handles all data from ground and airborne EM systems. It has been successfully applied to several of our environmental projects, and complements other processing software LEME has developed.

These new methods for calibrating frequency-domain helicopter AEM data improve the accuracy of conductivity mapping, which is of benefit to land management. LEME sponsorship enables us to influence new research directions, and leverage new funding opportunities.

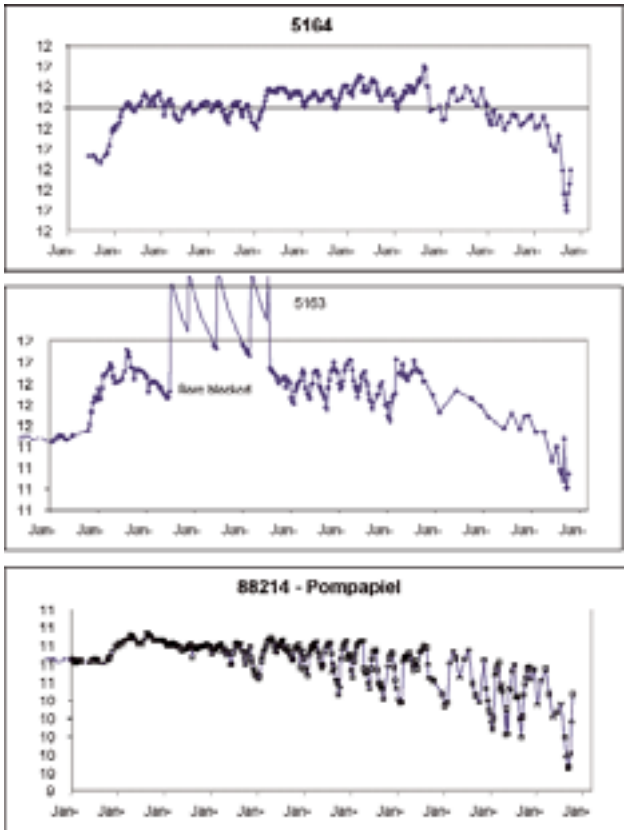
Frequency Domain HEM – Andrew Fitzpatrick

LEME research in 2002–03 demonstrated that significant cost reductions in the use of time-domain AEM surveys for natural resource management could be achieved through a combination of landscape knowledge, increasing flight line spacings and innovative grid displays.

In 2003–04 we further assessed whether similar reductions could be achieved for frequency-domain AEM. Increasing line spacings on drift-corrected and levelled HEM data for the *Riverland* Project dataset were initially promising, suggesting that line spacing could be widened 4-5 times (600-750m) without losing useful details on landscape elements of hydrogeological significance at sub-catchment scale.

However in 2004–05, an analysis of drift and levelling errors in frequency-domain HEM data, identified a number of problems requiring further analysis. In particular, errors associated with different orders of drift and levelling corrections applied to DIGHEM RESOLVE data were identified for the Riverland survey, which could not be adequately removed. First-order corrections can be addressed by routinely re-zeroing the FDHEM coils at high altitude every 20 minutes during surveying. However, correction of second and third-order drifts and levels still requires closely spaced flight lines.

It is concluded that frequency-domain EM surveys should not be flown at line-spacings greater than 300 metres. In order to reduce the cost of regional FDHEM surveys, a swath approach is suggested.



Hydrographs from Loddon Catchment, Victoria. Variations in water table are primarily due to climate effects and groundwater pumping.

Salinity and Landscapes

Salinity Hazard Mapping – Ken Lawrie

Research into predictive salinity hazard mapping continued in 2004-05, addressing the issue of lack of spatial sub-surface geoscience data. Previous work on *Lower Balonne* project shows that knowledge of catchment geometry and regolith attributes are necessary to correct hydrograph data and forecast watertable trends. A better understanding of porosity, moisture content and hydraulic conductivity of a range of regolith materials is necessary for salt load predictions. This knowledge has not yet been injected into any hazard maps in Australia. We are now quantifying such effects in a number of project areas.

Research into climate-change and anthropogenic influences on salinity hazards was done on borehole data from the Loddon Catchment in Victoria. Data in Australia point to increasing temperatures, decreasing precipitation, and increasing evaporation over the next century. This may result in a climate different from that of the Holocene and late Pleistocene, where increased salinity levels in southeastern Australian riverine systems appear to relate to a cold dry climate, rather than hot and dry. It is therefore likely that future impacts of salinity in riverine systems will be quite different to those recorded in the late Quaternary geological record.

Assessing the contribution of human impact on salinity and groundwater changes is difficult because of current data limitations. Research in 2004-05 looked at maximizing the use of existing data, using other proxies, and assessing the data gap. This will have a bearing on future data acquisition strategies, management policies and investment planning.

All current predictive methods are limited by data availability particularly at sub-catchment scales, and may have only 5 – 20% confidence levels. They are heavily weighted towards present-day climate data and surface datasets, but do not incorporate groundwater flow models. A paucity of sub-surface spatial data severely constrains our present predictive ability.

Landscape Analysis – Colin Pain

The *Landscape Analysis* project is in its second phase. The first phase examined line-spacing and gridding of airborne EM and magnetic data, and successfully demonstrated a way of reducing costs of airborne EM surveys for salinity mapping. The second phase develops models of regolith-landscape architecture for Cainozoic basins – initially the Murray-Darling Basin.

In combination with the *MDBC* project, we have developed procedures for extrapolating from small pilot studies in the Wellington-Cowra area, to broader regions of similar physiographic aspect. This involved:

- compiling of regional physiographic framework maps
- documenting characteristics of small study areas
- extrapolating using remotely sensed datasets.

This project made significant progress with State partners through the Working Group for Land Resource Assessment, in collaboration with Program 1. The plan for next year is to apply the methods to new areas, by producing maps of hierarchical land units elsewhere in the Murray-Darling Basin, and linking hierarchical land units to groundwater flow systems.

Plant-based Solutions for Hostile Regolith – Ken Lawrie

To date, farm-system approaches to improving water efficiency have taken little account of the regolith below the top few decimetres of soil. A particular issue has been the inability to map and predict sub-soil moisture and 'hostile' regolith units, including hardpans, which can potentially restrict the success of plant-based strategies for recharge control and salinity management.

Discussions in 2004-05 with CRC PBMDS, Division of Plant Industry at CSIRO, and State NRM agencies have shown the potential for LEME expertise to add value to existing management strategies in planted landscapes. This has led to further work in the Bet Bet Catchment in Victoria, involving the injection of new 3D hydrogeomorphic response maps to hydrogeological models, to assess their contribution to water balance studies and salinity management. Useful outcomes are anticipated in early 2006. It is likely new joint projects in WA with CRC PBMDS and CRC Spacial Information will attract external funding.

NRM Communications

With the conclusion of many projects after the first three years, the year 2004-05 required an emphasis on report writing and knowledge transfer. Over 80 papers were presented at regional, national and international conferences. Many were subject to peer review which is important for enhancing our science profile. Reports that incorporate LEME work with that of South Australian and southern Queensland NAPSWQ work have been released. Our work has been integrated with hydrogeological models to refine salinity management strategies and land-use activities. A number of LEME papers will contribute to a thematic issue on SA NAPSWQ work in *Australian Journal of Earth Sciences*.

Regional workshops were held in most States. Presentations were given at the LIMPACS workshop on climate change in Mildura, highlighting the importance of past climate change in predicting future salinity hazards. Presentations at the Murray-Darling Basin 3rd Salinity Modelling Workshop, and a DEM-Landscapes Workshop in Perth, highlighted our work in modelling regolith complexity and salinity mapping in upland landscapes. Presentation at the CRC Spacial Information Landscapes Systems Workshop in Melbourne has attracted new collaborative projects.

Several papers were presented at ASEG-PESA in Sydney, the 1st National Salinity Engineering Conference in Perth, the 8th Australasian Environmental Isotope Conference in Melbourne and the Inaugural Australasian Hydrogeology Research Conference in Melbourne.

A total of 13 papers and a keynote address were given at the inaugural International Salinity Forum in California. This conference was followed by a field trip with CRC PBMDS staff to view dryland and irrigation salinity issues in Utah. LEME plans to co-host, with CRC PBMDS, the 2nd International Salinity Forum in 2008. Papers were also given at the EGU in Vienna and at the SEG in the USA. Full peer-reviewed papers are being developed from most of these presentations.

NAPSWQ project results were also highlighted in radio and printed press articles, and newsletter articles in trade magazines, and the *Focus on Salt* newsletter. New work is continually posted on the LEME website. Our added communication effort is attracting new opportunities for contract research.

Outlook for 2005–2006

NRM clients now range across Australia, and include MDBC, the Centre for NRM in SA, many State agencies, Catchment Management Authorities and Irrigation Boards. We expect to be involved in a new round of airborne geophysical acquisition with salinity management objectives, currently being developed at the Australian Government level.

Projects in the remaining three years will continue to include Centre-funded and externally-funded co-investment projects in the following priority areas:

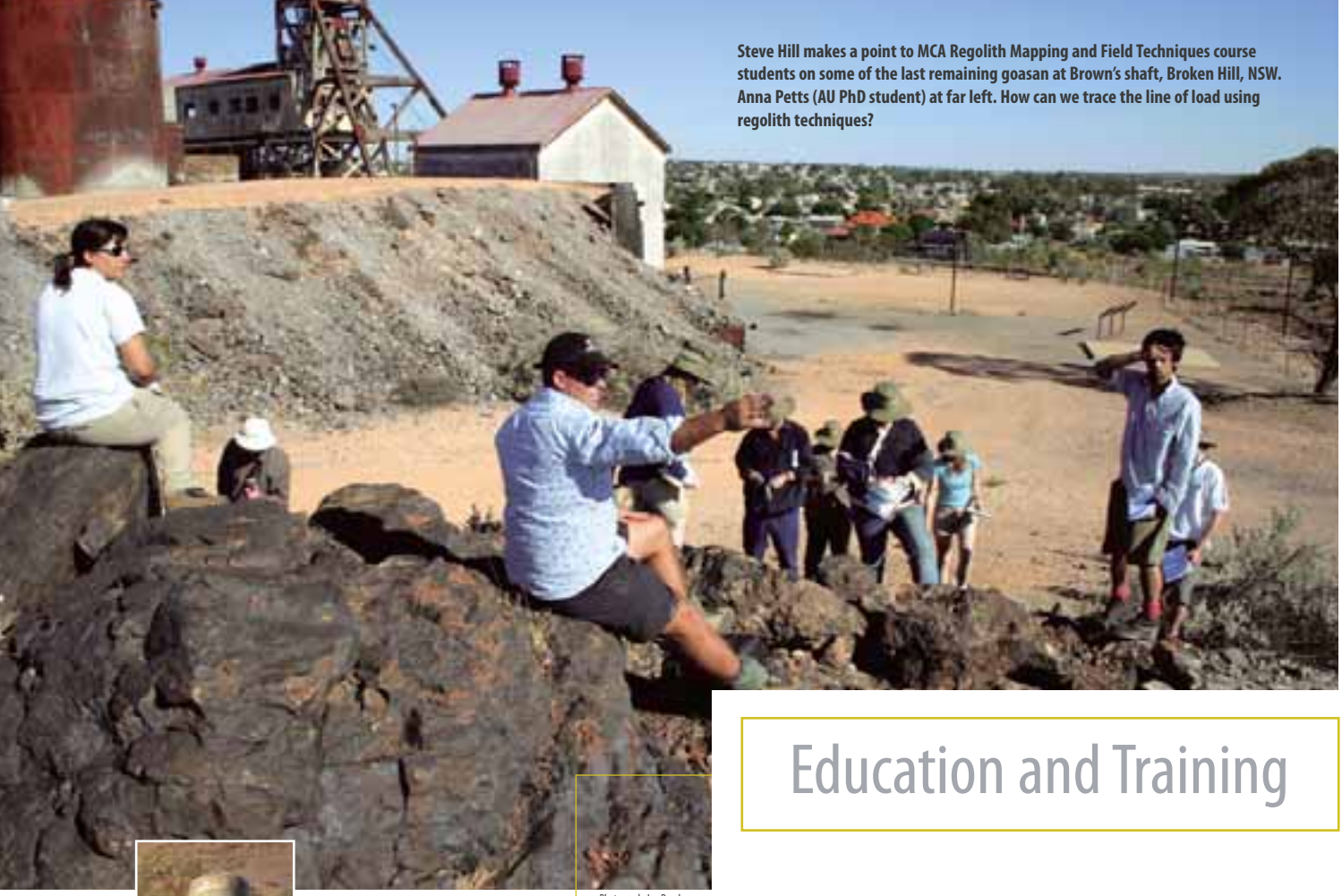
- salinity and groundwater management in floodplain landscapes
- salt export from upland landscapes
- salinity mapping and mitigation in ancient landscapes
- communication
- salinity assessment methodologies
- technology refinement and development.

In floodplain landscapes, projects will focus on spatial and temporal characteristics of groundwater systems and surface-groundwater connectivity. These studies are required to manage resources, protect high value assets, and reduce river salination. Collaborative multi-party studies will focus on NAPSWQ priority areas in the southern Murray Basin, Burdekin-Fitzroy, Eyre Peninsula and Ord Irrigation area.

Reducing salt export from upland landscapes is a continuation of existing MDBC co-funded projects and new NAPSWQ-funded projects. LEME will provide new landscape evolution models and 3D hydrogeomorphic response unit maps for input to hydrogeological models developed with other agencies. These will be used for plant-based and engineering salinity management. Work will include Corangamite catchment in Victoria and the Burdekin-Fitzroy in Qld, plus catchments in NSW.

Salinity and acidity mapping (jointly with Program 3) in ancient salinised landscapes with high water tables will be done in WA. This will help mitigate salinity in rural lands, reduce impacts of acid drainage and locate additional groundwater resources. Research will continue on a suite of projects under the Rural Towns-Liquid Assets Consortium. New projects in the WA Wheat Belt are being developed jointly with DAWA, CRC Spatial Information and CRC PBMDS. Outputs will include 3D Hydrogeomorphic Response Unit maps, soil maps, maps and reports on groundwater pumping strategies.

Photograph: David Gibson



Steve Hill makes a point to MCA Regolith Mapping and Field Techniques course students on some of the last remaining goasan at Brown's shaft, Broken Hill, NSW. Anna Petts (AU PhD student) at far left. How can we trace the line of load using regolith techniques?

Photograph: Ian Roach

Education and Training

Program Leader: Dr Steve Hill (Adelaide University)

Highlights

- The total number of students in the program is at a peak, and we are on target to well exceed performance indicators as set out in the Strategic Plan.
- This year we have had the highest number of both graduated and continuing postgraduate students so far within the term of LEME. These student numbers rank CRC LEME as having one of the highest postgraduate student teams of any CRC.
- Student research contributes strongly to outputs and outcomes, including significant breakthroughs and discoveries in regolith geoscience, particularly in biogeochemistry research.
- Undergraduate regolith courses are now in place at core party universities and student numbers in these undergraduate courses have increased.
- Short courses continue to provide an important part of the Minerals Tertiary Education Council (MTEC) program for the Minerals Council of Australia, ensuring that Australia produces regolith experienced industry-ready graduates and quality post-graduates.
- Regolith Symposia held in Adelaide, Perth and Canberra during November 2004, attracted large numbers of LEME staff, students and clients. Symposia Proceedings (*Regolith 2004*) was published in printed and electronic form. LEME students made a major contribution to the scientific outputs.

Overview

The Education and Training Program aims to be recognised as a national world-class provider of quality graduates and researchers to satisfy the growing demand for regolith and environmental geoscientists. The specific aims are:

- Provide funds, scientific supervision and institutional support for graduates by granting, on a competitive basis, scholarships in regolith geoscience at the BSc(Hons) and PhD levels. Our quantitative measure is to provide at least 60 new PhD graduates and 60 Honours graduates over the life of LEME.
- Provide workshops, seminars and training courses on regolith geoscience and related disciplines, directed at students, industry, government and institutional professionals.
- In cooperation with industry and other agencies, contribute regolith content to university courses.

A major emphasis of the E&T Program has been to bring to full delivery all strategic aims this year, and to ensure this will continue over the next three years. This also includes continued engagement of new regolith students beyond the LEME scholarship program in the final years of LEME and beyond.

To manage the E&T Program, the leader (Dr Steve Hill) seeks assistance and recommendations from the E&T Committee, which includes Dr Ian Roach (Deputy and MCA Lecturer), and representatives of the core party universities, Dr Karin Barovich (AU), Dr Richard Greene (ANU), and Dr Mehrooz Aspandiar (CUT).

This year we have had the highest number of both graduated and continuing postgraduate students so far within the term of LEME. These student numbers rank CRC LEME as having one of the highest postgraduate student teams of any CRC.

LEME students at the CRC Minerals and Energy Sector Student – Industry Symposium, Feb 05, Pinjarra WA. *L to R:* Frank Reith, Tania Dhu, Karen Hulme, Ryan Noble.

Student Scholarship Program

LEME offers a range of scholarships to students within its research programs:

- Full PhD stipend and operating scholarship ($18.5 k stipend plus up to $10 k operating expenses / year)
- PhD top-up stipend and operating scholarship ($5 k top-up plus up to $10 k operating / year)
- PhD operating only (up to $10 k operating / year)
- Honours scholarship and operating ($5K plus up to $5K / year)

The LEME student cohort has a growing number of post-graduate and Honours students who are not receiving LEME scholarships, but are receiving other forms of support. They are supervised by LEME staff and contribute to the research program. This will ensure that the student research program continues as a key component in Australian geoscience training, following the initial investment through LEME.

Post-graduate Students

Our post-graduate students make important contributions to LEME research programs as well as generating research leaders of the future.

This year has seen our highest number of post-graduate students complete their research programs (10 completed post-graduates). We also have sustained the high level (59 post-graduate students) of last year. We are presently on target to graduate over 70 post-graduate students. In addition it is expected we will continue to attract further post-graduate students to our research programs from other funding sources, even though they would complete their studies after the term of LEME. These students will contribute to the ongoing development of regolith geoscience post-CRC LEME.

All of our completed post-graduate students have moved into employment within industry (30% of graduates), government (40%) and academia (30%). This is a strong endorsement of the relevance and quality of our post-graduates. Our post-graduate students have also achieved high quality research results. Most notably Annamalai Mahizhnan received the Krishna and Pamela Sappel Award at CUT, for his outstanding PhD thesis on red-brown hardpans in the Yilgarn Craton.

Congratulations are also extended to Karen Hulme, who is one of our PhD students at the University of Adelaide. Karen was awarded the 2005 Eric Rudd Memorial Prize for Economic Geology. This competitive award provides $5,000 for Karen to travel to Canada in July 2005, where she will visit biogeochemistry researchers and laboratories, including Dr Colin Dunn and Becquerel Laboratories, who have serviced some our biogeochemical research.

A group of our post-graduate students were selected to attend the Student-Industry-CRC Symposium sponsored by the Minerals and Energy Sector of the CRC Association. This symposium was held in Pinjarra, WA on 20-25 February 2005. It provided opportunities for students to network, share experiences, present their work to industry, as well as learn that research extends outside their immediate discipline. It was organised by Dr Dan Churach from the CRC for Sustainable Resource Processing and the AJ Parker CRC for Hydrometallurgy. Participants came from the six mining and energy CRCs as well as Rio Tinto, Anglogold Ashanti, Alcoa, WMC, Ti-west, Hi-smelt, Voice4u, Minrisk and Executive Search. Tania Dhu, a LEME PhD student at Adelaide University won a $300 prize for her presentation at this symposium.

Honours Students

Our Honours program delivers a large number of post-graduate research students, as well as "industry-ready" graduates for employers. A notable outcome from this program has been the high recruitment levels of our Honours graduates, where for this year, all of our Honours students actively seeking employment with stakeholders have been successful (90% employed in industry and 10 % in government agencies).

This year has seen 17 Honours students complete their degrees, with 13 new students continuing. This places us well above target to exceed our KPI of 60 graduated Honours students. Indeed, we expect to have over 90 Honours students graduate within the term of LEME!

MCA Lecturer, Dr Ian Roach (ANU)

Photographs: Ian Roach

Photograph: Ian Roach

AU Honours student collecting Pearl Bluebush at Fowlers Gap, NSW during ANU-AU undergraduate regolith field school at Fowlers Cap NSW. Samples used to demonstrate biogeochemical mineral exploration techniques.

Undergraduate Students and Teaching

The undergraduate teaching program enables a wide range of emerging geoscientists and environmental scientists to gain their first insights into the importance of the regolith. Undergraduate regolith courses are now in place at all of the core party universities. Each of UA, ANU and CUT offered third year courses specifically teaching regolith geology, as well as associated courses in geophysics, remote sensing, pedology, geochemistry and sedimentology. These courses are convened and taught by LEME staff from universities and other core parties, ensuring that students experience up-to-date and high quality regolith course content. For 2005, Adelaide University developed a new undergraduate course with a regolith geoscience subject offered in second year and two within third year. The high enrolment numbers in these new undergraduate courses (including 50 students in the new second year undergraduate regolith course at AU) indicate the popularity, quality and relevance of these new courses.

A major achievement for undergraduate teaching of regolith geoscience has been the ambitious development of a joint UA-ANU regolith field school. The field school, run by LEME staffers Steve Hill (UA) with Ian Roach (MCA) and Dr John Field (ANU), is incorporated into undergraduate teaching programs at each university. It was run at Fowlers Gap Arid Zone Research Station, 100 km north of Broken Hill, during September 2004. Students gain their first experience of regolith field skills including regolith-landform mapping, documenting and interpreting regolith materials, as well as experiencing first-hand the role of regolith in mineral exploration and land management. The next regolith undergraduate field school is July 2005.

Minerals Council of Australia Courses (MTEC Program)

LEME provides regolith geoscience course material and staff for the Minerals Tertiary Education Council (MTEC) of the MCA. MTEC is a network of tertiary learning and research institutions linked to industry and delivering minerals education to the global minerals industry, so ensuring an adequate supply of suitably qualified geoscientists, mining engineers and metallurgists for the Australian industry. Associated with this the MCA covers a large part of the salary of Ian Roach, the MCA lecturer, as well as operating costs for selected short courses. Short courses run by LEME staff contribute to the MCA geoscience Honours program coordinated by the Victorian Institute of Earth and Planetary Sciences (VIEPS), and the Minerals Geoscience Masters program jointly run with University of Tasmania, University of Western Australia and James Cook University. These courses ensure that Australian geoscience students gain essential skills and knowledge in regolith geology.

The courses conducted during 2004–05 include:

- *Regolith Geology & Geochemistry* (RGG), Wilsons Promontory, Victoria, 21-25 February 2005
- *Regolith Mapping and Field techniques* (RMF), Fowlers Gap, 14-18 March 2005
- *Introduction to Hydrogeochemistry* (HGC), 4-8 April 2005, University of Melbourne
- *Advanced Remote Sensing* (RSM), 6-10 June 2005, University of Adelaide.

These courses, as well some additional offerings, are again planned for 2006 and are outlined with enrolment details on the LEME website.

Photographs: Steve Hill

Silicified Eyre Formation sediments northeast of Innaminka, SA.

LEME on the move on a rainy day at Fowlers Gap, NSW during the joint ANU-AU 3rd year regolith field school.

Anna Mayo (Honours student) sampling mallee leaves near Wudinna, for biogeochemistry analysis within the Central Gawler landscape project.

Regolith Symposia

The annual series of Regolith Symposia are now well established in Australia. They disseminate and showcase our research across the three main nodes. They facilitate annual outputs from core research and student projects that complement other stakeholder-focussed presentations. The trilogy of symposia was held during successive weeks of November 2004 in Adelaide, Perth and Canberra.

Symposia proceedings were published in a volume *Regolith 2004* edited by Ian Roach in both hard copy and digital format (available on the CRC LEME website and on CD-ROM). It includes 97 papers and 417 pages of emerging regolith science. Over 50 of these papers were authored by LEME students, demonstrating their major contribution to core research programs. Awards for excellent presentations (see awards table in report) were made. *Regolith 2005* will be held in November 2005, in a similar format to the one that has been successfully employed since 2003.

Virtual Regolith Worlds

This project aims to develop regolith teaching materials and to impart knowledge for students and professionals of the future. There is a limited but growing arsenal of teaching materials available for regolith geoscience, the paucity of which has restricted its incorporation into undergraduate university courses in Australia. Deliverables from this project, which will support the MTEC shortcourse and undergraduate teaching programs at core party universities, will be a major legacy of LEME. They will be an important part of the transfer of skills and knowledge. Outputs for this year have included:

- *Radiometrics Computer Aided Learning* (CAL) modules developed by John Wilford (LEME / GA)
- contributions to "*Learning Curve*" CAL modules, largely by Ian Roach (LEME/MCA)
- *Fowlers Gap Regolith GIS*, which includes the latest remote sensing techniques and the latest regolith-landform maps developed in conjunction with student teaching exercises by Steve Hill and Ian Roach
- undergraduate teaching notes and materials by Steve Hill, Mehrooz Aspandiar and Ian Roach

Outlook for Next Year

For the year 2005-06, the program will continue to deliver according to its strategic aims. There will be an expansion of the *Virtual Regolith Worlds* Project with the further development of teaching materials. These will under-pin the expansion of the undergraduate field camp program to accommodate the increased enrolments in undergraduate regolith geology courses, particularly at the University of Adelaide. Emphasis will be on further development and completion of teaching materials. A continuation of the successful regolith symposia program is also planned for November 2005.

Although the recruitment of students within the formal PhD scholarship program must now cease, engagement of graduate students through alternative scholarship programs will ensure the vibrancy of the LEME student culture into the future. Already the signs are that the highly successful postgraduate student program established within LEME will continue with solid recruitment. This is a pleasing trend, especially as demand for our undergraduates and Honours graduates from industry and government stakeholders is now reducing the number of students pursuing post-graduate research opportunities.

Honours Students 2004–2005

Student	Project	Program	Supervisor(s)	Funding	Year	University
Honours Degree – completed						
Nicole Anderson*	Tectonic controls on the landscape evolution of the Olepoloko-Wahratta fault system and Mesozoic placer Au systems, Tibooburra, NSW	2	Nick Direen Steve Hill	LEME	2004–	AU
Peter Bamford (deceased)*	Geochemical dispersion and under-cover expression of gold mineralization at the Wyoming deposit, Tomingley, NSW	2	Ken McQueen Bear McPhail	LEME	2004–	ANU
Adam Davey*	Innovative electrical and electromagnetic methods for improved regolith and sub-regolith exploration	1	John Joseph Graham Heinson	LEME	2003–	AU
Tim Hamilton	Sources, sinks and pathways of iron and manganese in the Cotter River Catchment, ACT	3	Bear McPhail	ACTEW	2004–	ANU
Marion Kehoe*	The role of Thiobascillus ferroxidans in the oxidation and weathering of pyrites in ASS.	3	Susan Welch Sarah Beavis	LEME	2004–	ANU
Vjekoslav Matic*	Integrating geophysics for regolith landform characterisation in part of the Fitzroy Basin, Qld, and application to natural resource management	4	Prame Chopra	LEME	2003–	ANU
Liam McEntegart	Where is the gold in calcrete bearing regolith? A selective and sequential leaching approach	1	Andreas Schmidt-Mumm	Nil LEME	2004	AU
Dougal Munro	Regolith controls on geochemical dispersion in the CSA area, Cobar NSW	2	Ken McQueen	CSA Project funding	2003–	ANU
Benjamath Pewkliang	Opalisation of fossil bone and wood: clues to the formation of precious opal		Allan Pring Joel Brugger	Nil LEME	2004	AU
Kate Pfeiffer*	Predictive petrophysics in regolith-covered Au-hosting proterozoic terranes with specific reference to the Callie-DBS-Granites area, Tanami Au Province	2	Nick Direen	LEME	2004–	AU
Tim Raggatt	Spectral discrimination of soil-regolith attributes over a lead-zinc mineralisation and an area of known acid sulphate condition in Herrmann's Catchment, Mt Lofty Ranges, SA	3	Rob Fitzpatrick	Nil LEME	2004	AU
Anne Riesz*	Hydrogeochemistry and regolith properties of the Harden-Boorowa Region, NSW	4	Dirke Kirste	LEME	2004–	ANU
Peter Somerville*	The role of cyclic salts & minerals weathering in salinisation in the Boorowa Catchment	4	Sara Beavis, Ian White Richard Greene	LEME	2003–	ANU
Luke Tylkowski*	The development of calcretes in the Murray Basin	1	David Chittleborough	LEME	2004–	AU
Michael Whitford*	Electrical and seismic properties of the regolith above gold mineralisation in saline lake environments	2	Jayson Meyers	LEME	2004–	CUT
Paul Wittwer*	Calcrete gold anomalies in the Curnamona Province	2	Karin Barovich	LEME	2004–	AU
Thomas Woolrych*	Regolith controls on geochemical dispersion in the Cobar gold field NSW	2	Ken McQueen Ian Roach	LEME	2004–	ANU
Honours Degree – commenced or continuing						
Fern Beavis*	Mobilisation of anthropic Pb in the regolith	3	David Ellis, Sue Welch	LEME	2005	ANU
Kieran Coupe*	Acid generation and chemical release from the south Undup dredge spoils storage facility : scale and environmental sig.	3	Ron Watkins	LEME	2005	CUT
Jessie Davey	Regolith and landscape evolution of the Mt Browne and Mt Poole inliers, Thompson Fold Belt, NW, NSW	1	Steve Hill	Nil LEME	2005	AU
Jennifer de Livera*	Copper and Zinc mobility in the regolith	2	Bear McPhail, Dirk Kirste	LEME	2005	ANU
Sarah Gibbons	Gold nuggets and calcretes in the Tibooburra-Milparinka goldfields, NW, NSW	1	Steve Hill	Nil LEME	2005	AU
Rochelle Irwin	Mineralogy of acid drain sediments in the WA Wheatbelt	3	Bob Gilkes (UWA) Steve Rogers (CSIRO)	Nil LEME	2005	UWA
Cameron Jones*	Modelling and visualization of geology, regolith and geophysics to assist nickel exploration in the Kambalda area, WA	2	Paul Wilkes	LEME + Independence Group	2005	CUT
Kevin Kinnison	Partition of acid in acid sulphate soils		Dirk Kirste, Sue Welch Sara Beavis	Nil LEME	2005	ANU
Jennifer Leonard*	Vegetative uptake of gold and pathfinder minerals by native dry schlerophyll forest		John Field	LEME	2004–	ANU
Stefania Madonna	Regolith geochemistry and calcretes across the Archean/Proterozoic terrain boundary near Wudinna, Gawler Craton, SA	2	Andreas Schmidt-Mumm, Steve Hill	Nil LEME	2005	AU
Anna Mayo	Plant biogeochemistry in the Central Gawler Gold Province, SA	1	Steve Hill	Nil LEME	2005	AU
Michael Neimanis*	Mine site rehabilitation at Mt Boppy Mine. NSW	3	Ken McQueen Richard Greene	LEME	2005	ANU
Jacob Paggi*	Regolith investigations using geophysical methods for mineral exploration in the Cue Region, Western Australia	2	Paul Wilkes	LEME + Independence Group	2005	CUT

* Denotes LEME Scholar

Postgraduate Students 2004–2005

Student	Project	Program	Supervisor(s)	Funding	Year	University
Master of Science (MSc) Graduated						
Ralph Kreige	Determination of interfaces within the regolith structure of the Whirling Dervish site (Yilgarn) using near surface geophysical and petrographic methods	2	Anton Kepic	LEME Op.	2005	CUT
Master of Science (MSc) Commenced or Continuing						
Katie Dowell*	Silicification in the regolith using opal as an indictor	1	John Mavrogenes John Chappell	APA + LEME Top-up	2003–	ANU
Doctor of Philosophy (PhD) – Graduated						
Leanne Hill*	Chemical dispersion pathways in a variety of landscapes	1	Tony Eggleton + LEME Top-up	APA	1999–2003	ANU
Ian Lau*	Minerals, lithologies and structural mapping using integrated technologies incorporating hyperspectral, airborne magnetics, and radiometrics of regolith covered terrains (Olary Domain, South Australia)	1	Patrick James	LEME/AU	2002–2005	AU
Annamalai Mahizhnan	Red-brown hardpans on the Yilgarn	1	Ravi Anand	APA, Robe River Mines	1997–2004	CUT
Wendy McLean*	Groundwater quality, recharge and sustainability in the lower Namoi Valley	3	Jerzy Jankowski Patrice de Caritat	APA, Cotton Growers, DLWC LEME Top-up	1999–2003	UNSW
Andrew McPherson*	Salts sources and development of the Regolith Salt Store in the Upper Billabong Creek Catchment, SE NSW	3	Tony Eggleton	LEME	2000–2004	ANU
Mark Paine*§	Regolith and landscape evolution of the Dundas Tableland, Western Victoria, with implications for salinity management and heavy mineral exploration	1	Mehrooz Aspandiar	CUPS + LEME Top-up	2001–2005	CUT
Greg Shirtliff §	Weathering of wasterock at Ranger Uranium Mine, NT, Australia	1	Tony Eggleton	EWL Sciences Pty Ltd	1999–2004	ANU
Michael Whitbread	Using lithogeochemistry to map cryptic alteration: Elura and Century case studies	2	Ken McQueen Leah Moore	PASMINCO + LEME Top-up	1999–2005	UC
Doctor of Philosophy (PhD) – commenced/continuing/graduand						
Abbott, Simon*	Application of geophysical technologies for 3D visualization of palaeochannels and use of this information for management of dryland salinity in Western Australia	4	Jayson Meyers Anton Kepic Keith Smettem	CUPS + LEME Top-up	2004–	CUT
Baker, Andrew*	Isotopic and geochemical studies of soil-regolith-rock interactions with ground waters, stream waters and base metal mineralisation: implications for mineral exploration and the environment	1	Rob Fitzpatrick John Foden	APA + LEME Top-up	2002–	AU
Bann, Glen*	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	4	Colin Pain	LEME	2003–	ANU
Bayat, Bahman	Indirect exploration of ore deposits in weathered terrains with airborne gravity gradiometry	2	Anton Kepic Jayson Meyers	LEME Op. only	2005–	CUT
Beckett, Kirsty*	Multispectral analysis of high spatial resolution, 256-channel radiometrics for soil and regolith mapping	3&4	Jayson Meyers Anton Kdepic Richard George	CUPS + LEME Top-up	2002–	CUT
Brown, Aaron*	Regolith geochemistry and biogeochemistry of the White Dam Cu-Au deposit, Curnamona Province, SA	1	Steve Hill	LEME	2002–	AU
Carlile, Paul*	Development of semi-distributed catchment hydrology model for simulation of land-use change, streamflow and groundwater recharge within the Little River Catchment, NSW	3	Tony Jakeman Brian Lees	LEME	2004–	ANU
Cook, Troy*	Geochemical investigation into the acid generating potential of wetland sediments of the Gnaugara and Jandakot Mounds : Implications for long-term water quality	3	Ron Watkins	APA + LEME Top-up	2004	CUT
Cotter, Steven*	The nature, origin and geochemistry of chert breccias at Mt Isa	1	Graham Taylor Ravi Anand	APA + LEME Top-up	1998–	UC
Craig, Mike	Regional regolith and landscape evolution in the eastern Goldfields, Yilgarn Craton, Western Australia	1&2	Ken McQueen Graham Taylor Colin Pain	GA	1998–	UC
Dart, Robert*	Research the origin and distribution of calcrete in Southern Australia	2	Karin Barovich David Chittleborough	LEME/AU	2004–	AU
Dhu, Tania*	Electrical and EM studies of regolith and sub-regolith structure	1	Graham Heinson Stewart Greenhalgh	LEME/AU	2003–	AU
Drewry, John*	Modelling nutrient generation in Australian catchments: land use, regolith and management factors affecting surface and groundwater quality	3	Tony Jakeman	ANU + LEME Top-up	2004–	ANU
Durkey, Michael	Effect of drains on soil properties in SE SA	4	David Chittleborough Steve Hill	AU/DWLBC	2003–	AU

Postgraduate Students 2004–2005 (cont'd)

Student	Project	Program	Supervisor(s)	Funding	Year	University
Doctor of Philosophy (PhD) – commenced/continuing/graduand (cont'd)						
Fitzsimmons, Kathryn*	Relationships between regional landform patterns and landscape history in the Lake Eyre Basin dunefields	1	John Magee	APA + LEME Top-up	2003–	ANU
Foster, Luke*	Landscapes, geochemistry, and GIS at Marlborough Qld	2	Tony Eggleton Colin Pain	LEME	1997–	ANU
Fritz, Mark*	Baseline geochemistry of South Australian saline and acid sulfate soils	1	Rob Fitzpatrick	LEME/AU	2003–	AU
Gibbins, Lachlan*	Measuring hydraulic conductivity with streaming potentials	1	Graham Heinson	LEME/AU	2004–	AU
Gunton, Chris*	Element dispersion and mobility in the regolith	2	Bear McPhail	APA + LEME Top-up	2002–	ANU
Hashemi, Anousha*	Innovative geophysical exploration for high-grade manganese ore under regolith and sedimentary cover in the East Pilbara of Western Australia	2	Jayson Meyers Anton Kepic Tim Munday	LEME	2003–	CUT
Hatch, Michael	The use of shallow geophysical techniques to help characterise hydrological parameters	4	Graham Heinson	Nil LEME	2005	AU
Heath, Philip*	3-D automated inversion of potential field tensor data	2	Stewart Greenhalgh Nick Direen	LEME/AU	2003–	AU
Hulme, Karen*	Biogeochemistry of river red gums (*Eucalyptus camaldulensis*) in the Curnamona Province and adjacent parts of SA and NSW	1&2	Steve Hill Steve Rogers	LEME/AU	2003–	AU
Hunter, Donald*	Surface NMR for hydrogeological applications in Australia	2	Anton Kepic Jayson Meyers	APA + LEME Top-up	2002–	CUT
Khider, Kamal*	Regional chemical dispersion processes in the regolith of Cobar Nymagee area, Central West, NSW	2	Ken McQueen Bear McPhail	LEME	2002–	ANU
Kim, Sukhyoun	Electrokinetic groundwater exploration	4	Graham Heinson	Nil LEME	2004	AU
Lee, Sam*	Hydrogeology of the Cape Range karst and coastal plain aquifers, Exmouth, NW Australia	3	Qadeer Rathur Lindsay Collins	APA + LEME Top-up	2002–	CUT
Lenahan, Matthew*#	Origin, nature and mobility of salt in the regolith	2	Bear McPhail Dirk Kirste	LEME	2003	ANU
Lintern, Mel	The role of biological and non-biological factors in the formation of Au anomalies in calcrete	2	Lindsay Collins Mehrooz Aspandiar Ravi Anand	Nil LEME	2001–	CUT
Little, David*	Investigate, quantify and model rhizosphere in regolith formation in temperate landscapes in SE Australia	1	John Field	LEME	2003–	ANU
Mahoney, Sean	Evaluation and development of use of multitemporal imagery for water condition monitoring, environmental and wetland management in the SE of SA	4	Megan Lewis Dr Bertram Ostendorf	AU/DWLBC	2003–	AU
Mee, Aija*	Lacustrine and soil organic matter as proxies for mid-latitude Holocene environmental change in SE Australia	1	David McKirdy Martin Williams	APA + LEME Top-up	2003–	AU
Mitchell, David	Increasing spatial resolution of soil maps using geophysics and GIS	4	Megan Lewis Bertram Ostendorf	AU/PBMDS	2003–	AU
Noble, Ryan*	Dispersal mechanisms of arsenic and antimony in regolith and surface deposits in the vicinity of buried gold ore bodies, northwest Victoria: implications for gold prospectivity and environmental management	2	Ron Watkins	APA + LEME Top-up	2003–	CUT
Norvill, Margarita*	The use of distributed sensor arrays in electrical imaging	2	Anton Kepic Jayson Meyers	APA + LEME Top-up	2002–	CUT
Petts, Anna*	Termitaria and other landscape indicators of sub-surface regolith	2	Steve Hill Lisa Worrall	LEME/AU	2004–	AU
Reid, Nathan	Biogeochemistry of regolith associated with Au deposits in the Tanami, WA and NT	1	Steve Hill David Lewis	Nil LEME	2005	AU
Reilly, Mark*	Evolution and internal architecture of ephemeral streams and delta/splay complexes, Umbum Creek, Lake Eyre, Central Australia	1	Simon Lang Steve Hill	LEME/AU	2003–	AU
Reith, Frank*	Interactions of microbes and gold in regolith in moderate, arid and tropical climates	1	Bradley Opdyke Bear McPhail	IPRS + LEME Top-up	2002–	ANU
Rosid, Mohammad	Groundwater investigations using the seismo-electric method	3	Anton Kepic Jayson Meyers	Nil LEME	2001–	CUT
Simons, Suzanne*	U-Th-Pb systematics of opaline silica: implications for the dating of surface processes	1	Alexander Nemchin	LEME	2002–	CUT
Smith, Margaret	Groundwater acidification process with the Lake Muir-Unicup natural diversity recovery catchment, Western Australia	3	Ron Watkins David Gray	APA + LEME Top-up	2005–	CUT
Smith, Martin*	Geochronology of long-term landscape evolution, North Western NSW	1	Brad Pillans	ANU + LEME Top-up	2002–	ANU

Postgraduate Students 2004–2005 (cont'd)

Student	Project	Program	Supervisor(s)	Funding	Year	University
Doctor of Philosophy (PhD) – commenced/continuing/graduand (cont'd)						
Smith, Michael*	The geochemical evolution of alkaline salt-affected soils on the western slopes of northern New South Wales	4	Bear McPhail Dirk Kirste	ANU + LEME Top-up	2003–	ANU
Somerville, Peter	Dryland salinity in the Widden Creek Valley in the Upper Hunter Valley NSW	4	Ian White	LEME Op. only	2005–	ANU
Soongpankhao, Siriporn	Mineral hosts and biogeochemistry for gold and trace element in regolith	2	Mehrooz Aspandiar	LEME OP. only	2005–	CUT
Sorensen, Camilla	Mapping of the regolith using Passive Seismics in combination with other geophysical methods	4	Ken Lawrie	Nil LEME	2005–	ANU
Street, Greg	Interpretation of geophysics for catchment management	3	Jayson Meyers	Nil LEME	2000–	CUT
Thomas, Mark*	Combining remote sensing and terrain analysis with conceptual toposequence models in two dry saline land affected areas (Jamestown and Mt Lofty Ranges) for up-scaling root zone constraints	3	Graham Heinson Rob Fitzpatrick Megan Lewis	LEME/DWLBC/ PIRSA	2002-	AU
Turner, Michael*	3 Dimensional pore scale characterisation of the permeability and porosity of regolith materials	4	Bear McPhail	APA + LEME Top-up	2002–	ANU
Tynan, Sarah	Geochemistry of heavy metals in coastal and inland sediments		David Ellis	LEME	2005	ANU
Usher, Alistair*	Gold mobility and geochemistry in hypersaline solutions	2	Bear McPhail	APA + LEME Top-up	2003–	ANU
Waclawik, Victor*	The regolith geology and landscape evolution of Umbum Creek, West Lake Eyre, South Australia	1	Simon Lang Steve Hill	LEME/AU	2003–	AU
Wallace, Luke*#	Geochemistry and hydrogeology of inland acid sulphate environments	3	Bear McPhail	LEME	2004	ANU
Wilkes, Paul	Geophysics in the search for diamonds	2	Jayson Meyers Simon Wilde	Nil	2000-	CUT
Wong, Vanessa*	The effects of salinity and sodicity on soil carbon stocks and fluxes	3	Richard Greene Graham Farquhar	ANU + CRC Greenhouse + LEME Top-up	2004	ANU
Worthy, Martin	Major water quality degrading events in the Cotter River Catchment : characteristics and management	3	Robert Wasson Mike Hutchinson	ACTEW + LEME Operating	2004	ANU
Wulser, Pierre-Allain*	Mobility of uranium and rare earth in the Mt Painter-Lake Frome-Curnamona Craton Regions, SA : Geochemical and temporal controls	2	Joel Brugger John Foden	IPRS + LEME Top-up	2003–	AU

* denotes LEME Scholar # denotes upgraded to PhD from MSc § denotes thesis submitted, awaiting assessment

Three New PhD Graduates

Annamalai Mahizhnan (supervised by Dr Ravi Anand CSIRO Exploration and Mining) completed his thesis at Curtin University, on the red-brown hardpans of the Eastern Goldfields. These form extensive partially cemented sheets of old colluvium, occurring below the soils, sands alluvium and gibber plains in the northern Yilgarn. They are cemented by disordered kaolin and opal A, are chemically impervious, but contain significant detrital gold particles. As such they present both challenges and opportunities for geochemical sampling. He received the Krishna and Pamela Sappal prize for his research. Anna is now working for BHP Billiton at the giant Mt Keith nickel mine.

Mark Paine (supervised by Dr Mehrooz Aspandiar of Curtin University) studied the landscape morphology and mineral components of ancestral stranded marine shorelines in the eastern Murray Basin – an important heavy-mineral sand province of Australia. In so doing he developed a rapid method to quantify a diverse suite of heavy minerals grains using the AutoGeoSEM. The SEM can identify and count 10,000 mineral grains per hour. Mark is now a LEME-funded Research Fellow at Curtin University, continuing work on heavy-mineral deposits, and regolith dating.

Ian Lau (supervised by Dr Graham Heinson of Adelaide University), successfully submitted his thesis on hyperspectral airborne and hand-held spectral techniques in mapping regolith landforms and detailed mineral dispersion patterns, over a copper-gold system in the Olary Province of South Australia. He showed that detailed characterisation of mineral dispersion patterns can be done by spectral methods, when supported by digital elevation and radiometric data. Ian is now a post-doctoral researcher with CSIRO Exploration and Mining in Perth.

Collaboration

With our significant scientific advances, and the increased uptake by stakeholders, the level of collaboration, both internal and external, has also risen noticeably. LEME now has effective collaborative linkages between its eight core participants, the users of its research in industry, the scientific research community, government authorities and community stakeholders in general.

LEME/NSW DPI Thomson Orogen Regolith Field workshop party at the "Warratta Au-reefs", northwest NSW. L-R: John Watkins, Tim Sharp, Kingsley Mills, Bob Brown, John Greenfield, Nancy Vickery and Bull Reid (NSW DPI-Geological Survey), Jess Davey, Karen Hulme (AU), Lisa Worrall (GA), Sarah Gibbons and Steve Hill (AU)

Photograph: Steve Hill with automatic timer!

Internal Research Linkages

Cross-program linkages have developed dramatically as the new microbiological, geochemical and hydrogeochemical initiatives of Program 3 have had spin-offs into Programs 1 and 2. For example the new acid-drainage studies in Western Australia are providing insights to the nature of metal mobility, and some anomalously high metal occurrences, which are relevant to understanding geochemical exploration anomalies. Also the low-density geochemical surveys provide evidence of regional metal anomalies, as well as base-line surveys. Similarly the accelerated work on acid-sulphate processes is finding applications in Programs 2 and 4. The regional focus projects of Program 1 provide a useful framework for some of the generic-process projects in Program 2.

Multi-party and multi-disciplinary projects are now an integral part of LEME research. This ensures that regolith knowledge is focused on the needs of diverse stakeholders in both mineral exploration and natural resource management. Of the 45 projects funded by the Centre, 33 had participation from more than one core participant. Most so-called 'one-party' projects focussed on technology developments (for example, geochronology dating methods) or specialist services that will, in the ensuing years, be applied across the full spectrum of LEME research.

Student Program Linkages

Honours and PhD research projects are integrated into our research projects, and LEME staff members supervise students. However for ease in financial and IP management, they are not formally brought into individual projects in the core research programs. LEME students make significant contributions to the overall research effort. They benefit from networking with LEME staff, industry and government organisations.

Student projects benefit from support and linkages with CALM (WA), WA Department of Agriculture, DWLB South Australia, ANSTO, as well as Gold Fields Australia, Tanami Gold, Dominion Mining, Sons of Gwalia, Newmont Australia, Helix Resources, Agincourt Gold, Independence Gold, and Zong Engineering. Details of many of these linkages are provided in the Commercialisation, Technology Transfer and Utilisation Section, as well as the Education and Training sections of this Annual Report.

The Education and Training Program joins with the Minerals Council of Australia to provide regolith science training to industry geoscientists throughout Australia.

Linkages with Industry and other End Users

Of our 45 core research projects, 20 are classified as industry/commercial projects. They draw cash contributions from a wide range of Australian and State government NRM agencies, as well as some major mining companies for mineral-related projects. In addition to the cash contributions, there is a significant in-kind contribution to several other mineral-related projects.

Program 3 and 4 personnel in particular have continued their productive engagement with NRM agencies. A significant number of contracts have come to fruition during the period with work continuing into 2005–06. Our clientele in NRM research has expanded mainly with the flow-on from completed contracts, and new growth of NRM projects in Western Australia. A table detailing this collaboration is shown under the Commercial, Technology Transfer and Utilisation Section. Effective delivery on these projects has cemented relationships with many clients.

During the reporting period we have kept an active liaison with AMIRA International (formerly Australian Minerals Industry Research Association) with a view to undertake a major multi-client industry project on *Deep Sensing Geochemistry* in collaboration with eight of the world's premier mining companies. Formal planning meetings have been held and details are yet to be finalised. However to give impetus to this project LEME completed the initial phase of this project in 2004-05 as a stand-alone Centre project. This action has contributed to the significant progress we have made with developing new sampling geochemical techniques in parallel running projects that also involve industry partners. One potential stumbling block in taking this emerging science forward as a full AMIRA project, is confidentiality requirements that may constrain the wider dissemination of this knowledge to the exploration industry.

Our two interactive advisory groups – Minerals Advisory Council (MAC) and Land Use Advisory Council (LUAC) provide external stakeholders in mineral exploration and natural resource management with opportunities to contribute to research themes. In this way networks with stakeholders are continuously expanded, which facilitate research cooperation and technology.

Of particular note is the credit given to Baohong Hou – a LEME in-kind geologist with PIRSA – and his colleagues, for their palaeographic reconstructions of the Eocene shorelines of the Eucla Basin. This reconstruction has played a significant part in the recent discovery of the Jacinth and Ambrosia heavy-mineral sand deposits in South Australia.

Linkages with users of Centre research are also promoted through staff and student participation in conferences and industry workshops. This publicises LEME research and facilitates networking. Details of these activities are provided in the section on Communication Strategy. LEME personnel presented at 13 international conferences, and 32 public conferences/seminars within Australia during the reporting period. LEME was also involved in conducting or sponsoring 13 seminars and symposia that attracted a gross audience of 890 attendees.

International Linkages

LEME has not developed many strong international linkages at the project level, because all our research is directed at the challenges of the distinct Australian regolith environment.

However, as an aid to understanding our own regolith, it may be useful to compare regolith processes in different parts of the world, shaped by different climates and time scales. Knowledge of international examples provides keys for developing our own models of regolith evolution.

At at this mid-stage of LEME our pioneering work, especially in salinity research, is being increasingly recognised overseas. Consequently we were invited to give 14 presentations, including a keynote from Dr Ken Lawrie, at the International Salinity Forum in California in March 2005.

Under the Direction of Program Leader Dr Steve Rogers, LEME was a significant organiser, sponsor and contributor to the International Conference on Biochemistry and Trace Elements in Adelaide. LEME is also a sponsor and lead player in the forthcoming biennial International Geochemical Exploration Conference in Perth later in 2005. Details of international conference participation are shown in the accompanying table.

Along with collaborators in Russia and Canada, Baohong Hou (a LEME geoscientist in PIRSA) was instrumental in getting up an International Geological Correlation Program (IGCP) project called *Continental Fluvial Palaeosystems – Evolution and Mineral Deposits.* In May-July 2004, Baohong undertook an exchange lectureship with five Chinese universities to speak on regolith work in Australia, and learn of CHIM electro-geochemical techniques in China. And to cap off his notable work, he has been awarded a Churchill Fellowship. Baohong will use his fellowship to interact with colleagues in US, Canada and Russia on palaeodrainage and electro-geochemical techniques of exploration through cover. Baohong will probably do this travel in the second half of 2005.

Plans have been set in place to host Prof Cliff Stanley – an eminent Canadian litho-geochemist from Acadia University, Nova Scotia – to have his sabbatical with LEME in calendar year 2005.

Collaboration with CRCs and other research providers

Two major projects dealing with geochemical signals in transported regolith generate close collaboration with other research agencies. The *Mineral and Biological Hosts* project has initiated an involvement for Prof Pauline Grierson of Botany Department UWA, to assist with tracking metal mobility through the entire tree system. This involvement is expected to grow in subsequent years. The Geological Survey of Western Australia (GSWA) and the Minerals and Energy Research Institute of WA (MERIWA) are collaborators with the *Yilgarn Regolith Atlas* project. Similarly MERIWA is a collaborator with a developmental project involving remote mapping with airborne spectral platforms.

In an important promotional move, LEME has joined with CRC PBMDS to resurrect the fortunes of the highly successful technical newsletter *Focus on Salt*, following near demise with the passing of the National Dryland Salinity Program (NDSP). *Focus on Salt* had a circulation list of some 5000 recipients. PBMDS has production responsibility, and LEME contributes some 15% of editorial material and production costs. Its contributions may well rise in future years.

Two student projects have been undertaken jointly with CRC PBMDS on *Dryland salinity, biodiversity and geodiversity* (Glen Bann ANU) and *Predictability of surface soil properties from geophysical remote sensing and regolith information* (David Mitchell AU).

The joint research project involving Bear McPhail (LEME-ANU) and Dr Evgeniy Bastrakov (pmd*CRC), is continuing with the aim of developing reliable geochemical modelling methods for element transport in regolith and ore-forming environments.

LEME remains a co-bidder to participate in Stage 2 of the *Catchments to Coasts Scoping Study Plan* by the National Land and Water Resources Audit 2. Collaborators would be AFFA, CRC e-Water, and CSIRO – Water for a Healthy Council Flagship Project and CRC LEME (Ken Lawrie). The aim of this major national project is to develop methods for assessing biophysical indicators and trends of catchment conditions across Australia.

Deputy CEO Paul Wilkes contributes a LEME perspective to the planning of an ambitious initiative of several WA government NRM agencies and CRC PBMDS. This may involve the acquisition and interpretation of a high-resolution airborne geophysical (magnetic, EM, radiometric and DTM) survey over much of the agricultural areas of the Yilgarn Craton. This could generate collaborative project opportunities for LEME in the final three years. LEME has an involvement in the planning and promotion of this major initiative.

CRC LEME participates in the Minerals and Energy Sector activities within the Cooperative Research Centre Association activities. The CEOs undertake joint promotional material and monitor the opportunities for strategic alignments in long-term strategic research projects. Dennis Gee joined with other CRC Chief Executive Officers from the Minerals Sector to participate in the Minerals Week 2005 of the Minerals Council of Australia.

Specified Personnel and Staff Matters

Photograph: Steve Hill

Business Manager, Mr Gary Kong CPA

Staff complement

LEME has world-class expertise in regolith geoscience, and supporting disciplines such as mineralogy, geochemistry, hydrogeochemistry, sedimentology, geophysics and geochronology. In this fourth year of funding, LEME had a total complement of 134 staff, of whom 123 were professional geoscientists. This distilled down to 70.3 FTE scientists, made up of 45.1 in-kind and 25.2 cash funded scientists.

Additionally, other staff members provide technical, administrative, cartographic, illustrative, laboratory and field support. Staffing resources, in terms of FTEs, are shown in the accompanying tables.

Specified Personnel

Specified personnel are the science leaders and managers, as required by the Commonwealth Agreement. There were no changes in specified personnel during the reporting period. They form the core of the Executive, and comprise the following:

Dr Ravi Anand, Program Leader, CSIRO, 100%
Dr Charles Butt, Key Researcher, CSIRO, 70%
Dr R Dennis Gee, Chief Executive Officer, CSIRO, 100%*
Dr Steven Hill, Program Leader, AU, 100%*
Dr Ken Lawrie, Program Leader, GA, 100%
Dr D.C. (Bear) McPhail, Key Researcher, ANU, 100%
Dr Colin Pain, Key Researcher, GA, 100%
Dr Steve Rogers, Program Leader, CSIRO, 85%
Mr Paul Wilkes, Deputy CEO, CUT, 100%*
Ms Lisa Worrall, Program Leader, GA, 100%

**Paid from the CRC Grant*

Staff OH&S Matters

Being an unincorporated joint venture, CRC LEME is not a direct employer of staff and relies on the personnel services of Core Participants or the Centre Agent as appropriate. However in the course of carrying out research activities, staff and students frequently operate in remote and difficult environments. Consequently LEME aims to instil an awareness of safety in the field, especially for students who must learn to work safely in remote areas. The Board has a duty of care in all safety matters, but since LEME is an unincorporated joint venture, the primary duty of care in respect of all occupational health and safety matters rests with the Core Participants, who are the designated employers. LEME follows the occupational health and safety policies and procedures of its Core Participants. The employing agency has an obligation to develop and implement safe working procedures, and to provide necessary training and instruction.

A manual entitled *CRC LEME Policy and Procedures on Field Safety* has been prepared by Geoscience Australia – in consultation with the Occupational Health and Safety representatives from the other Core Participants. This manual draws together best-practice material from companies in the exploration industry, providing essential reference material for all LEME staff and students. An abridged manual *The Glove Box Guide to Health and Safety in the Field* has also been produced, enabling critical safety information to be easily taken into the field.

These publications do not supplant the requirements stipulated by the Core Participants for their staff, but prescribe minimum procedures where they may not be stipulated by the host agency. They have been endorsed by the Board, drawn to the attention of all staff by way of the LEME intranet, and have now been implemented.

Essential components of the safety procedures have been stated in the CRC LEME 2003-04 Annual Report. There is a standing directive that all accidents and incidents that are reportable under Core Participant requirements are also reported to the LEME Head Office. **During the reporting period, no lost time injuries or dangerous incidents were recorded.**

Research Staff In-kind Contribution

Name	Main Activity	Total % of Time	% Spent on Research Program					% Spent on CRC		
			Regolith geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
The Australian National University (ANU)										
Beavis S	R	20		5	5	10	20			
Chappell J	R	50	50				50			
Chopra D	R	20					0	20		
Cristy A	R	10	5	5			10			
Croke B	R	20				20	20			
DeDeckker P	R	20				20	20			
Dunlap J	R	25	25				25			
Eggins S	R	20	20				20			
Ellis D	R	15	10	5			15			
Fabel D	R	20	20				20			
Field J	R	40		25		15	40			
Fifield K	R	5	5				5			
Gingele F	R	75					0	75		
Greene R	R	30				30	30			
Jakeman T	R	20				10	10	10		
Lees B	R	40				40	40			
Magee J	R	25	25				25			
McPhail D	R	100	15	65	15	5	100			
Norman M	R	5	5				5			
Opdyke B	R	20				10	10	10		
Pillans B	R	50	50				50			
Reeves J	R	40	40				40			
Rhodes E	R	25	25				25			
White I	R	20				20	20			
		715	**295**	**105**	**20**	**180**	**600**	**115**	**0**	**0**
Geoscience Australia (GA)										
Apps H	R	100				100	100			
Chan R	R	100	100				100			
Craig M	R	100	100				100			
Gibson D	R	100				100	100			
Lawrie K	R	100				100	100			
Pain C	R	100	25			75	100			
Ruperto L	R	50				50	50			
Wilford J	R	100	5			95	100			
Worral L	R	100	95			5	100			
		850	**325**	**0**	**0**	**525**	**850**	**0**	**0**	**0**
Curtin University of Technology (CUT)										
Aspandiar M	R	50		45			45	5		
Collins L	R	70	35	10			45	25		
Collins PLF	R	30		30			30			
Fagan R	R	20					0	20		
Kepic A	R	50	10	5		35	50			
Meyers J	R	50	25			25	50			
Wartho J	R	15					0	15		
Watkins R	R	70			10		10	60		
Watling J	R	20					0	20		
Wilde S	R	35					0	35		
		410	**70**	**90**	**10**	**60**	**230**	**180**	**0**	**0**
Adelaide University (AU)										
Barovich K	R	70	30	40			70			
Brugger J	R	10		10			10			
Chittleborough D	R	5		5			5			
Direen N	R	70	45	15	10		70			
Foden J	R	30					0	30		
Greenhalgh S	R	25	10				10	15		
Heinson G	R	55	20	5	5	20	50	5		
Lang S	R	15					0	15		
McKirdy D	R	25		10			10	15		
Schmidt-Mumm A	R	45		35			35	10		
Williams M	R	10					0	10		
		360	**105**	**120**	**15**	**20**	**260**	**100**	**0**	**0**

Research Staff In-kind Contribution (cont'd)

Name	Main Activity	Total % of Time	% Spent on Research Program					% Spent on CRC		
			Regolith geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
The Australian National University (ANU)										
Beavis S	R	20		5	5	10	20			
Chappell J	R	50	50				50			
Chopra D	R	20					0	20		
Cristy A	R	10	5	5			10			
Croke B	R	20				20	20			
DeDeckker P	R	20				20	20			
Dunlap J	R	25	25				25			
Eggins S	R	20	20				20			
Ellis D	R	15	10	5			15			
Fabel D	R	20	20				20			
Field J	R	40		25		15	40			
Fifield K	R	5	5				5			
Gingele F	R	75					0	75		
Greene R	R	30				30	30			
Jakeman T	R	20				10	10	10		
Lees B	R	40				40	40			
Magee J	R	25	25				25			
McPhail D	R	100	15	65	15	5	100			
Norman M	R	5	5				5			
Opdyke B	R	20				10	10	10		
Pillans B	R	50	50				50			
Reeves J	R	40	40				40			
Rhodes E	R	25	25				25			
White I	R	20				20	20			
		715	**295**	**105**	**20**	**180**	**600**	**115**	**0**	**0**
Geoscience Australia (GA)										
Apps H	R	100				100	100			
Chan R	R	100	100				100			
Craig M	R	100	100				100			
Gibson D	R	100				100	100			
Lawrie K	R	100				100	100			
Pain C	R	100	25			75	100			
Ruperto L	R	50				50	50			
Wilford J	R	100	5			95	100			
Worral L	R	100	95			5	100			
		850	**325**	**0**	**0**	**525**	**850**	**0**	**0**	**0**
Curtin University of Technology (CUT)										
Aspandiar M	R	50		45			45	5		
Collins L	R	70	35	10			45	25		
Collins PLF	R	30		30			30			
Fagan R	R	20					0	20		
Kepic A	R	50	10	5		35	50			
Meyers J	R	50	25			25	50			
Wartho J	R	15					0	15		
Watkins R	R	70			10		10	60		
Watling J	R	20					0	20		
Wilde S	R	35					0	35		
		410	**70**	**90**	**10**	**60**	**230**	**180**	**0**	**0**
Adelaide University (AU)										
Barovich K	R	70	30	40			70			
Brugger J	R	10		10			10			
Chittleborough D	R	5		5			5			
Direen N	R	70	45	15	10		70			
Foden J	R	30					0	30		
Greenhalgh S	R	25	10				10	15		
Heinson G	R	55	20	5	5	20	50	5		
Lang S	R	15					0	15		
McKirdy D	R	25		10			10	15		
Schmidt-Mumm A	R	45		35			35	10		
Williams M	R	10					0	10		
		360	**105**	**120**	**15**	**20**	**260**	**100**	**0**	**0**

Research Staff In-kind Contribution (cont'd)

Name	Main Activity	Total % of Time	% Spent on Research Program					% Spent on CRC		
			Regolith geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
Primary Industries & Resources, South Australia (PIRSA)										
Crooks A	R	10	10				10			
Fabris A	R	100	100				100			
Gouthas G	R	100	100				100			
Hou B	R	100	100				100			
Keeling J	R	80	65	10	5		80			
Mauger A	R	80		75			75	5		
Painter J	R	30	20	10			30			
Sheard M	R	100	100				100			
Stoian L	R	50	50				50			
Zang Wen Long	R	50	50				50			
Stamoulis V	R	50	50				50			
		750	**645**	**95**	**5**	**0**	**745**	**5**	**0**	**0**
New South Wales Department of Primary Industries (NSW DPI)										
Buckley P	R	50	50				50			
Dawson M	R	75	75				75			
Hicks M	R	33	33				33			
Mills K	R	65	65				65			
Sharp T	R	30	30				30			
Stevens B	R	25	25				25			
Triggs S	R	75	75				75			
		353	**353**	**0**	**0**	**0**	**353**	**0**	**0**	**0**
Commonwealth Scientific and Industrial Research Organisation (CSIRO)										
Barns S	R	25		25			25			
Butt C	R	75		60	15		75			
Carr G	R	5		5			5			
Cudahy T	R	25		25			25			
Gray D	R	100	10	80	10		100			
Robertson I	R	80	30	50			80			
Anand R	R	100	20	80			100			
Cornelius M	R	100		100			100			
Evans N	R	15		15			15			
Hewson R	R	5		5			5			
Hough R	R	90		90			90			
McDonald B	R	15		15			15			
Munday T	R	90		65	25		90			
Pirlo M	R	100	10	80	10		100			
Fitzpatrick R	R	50			40	10	50			
Cox J	R	25				25	25			
Cresswell R	R	20				20	20			
Davies P	R	20				20	20			
Dighton J	T	15				15	15			
Gildfedder M	R	10				10	10			
Hicks W	R	20			20		20			
Lamontagne S	R	20			20		20			
Rogers S	R	60			60		60			
Stenson M	R	10				10	10			
		1075	**70**	**695**	**200**	**110**	**1075**	**0**	**0**	**0**
TOTAL RESEARCH STAFF: IN-KIND CONTRIBUTIONS		**4513**	**1863**	**1105**	**250**	**895**	**4113**	**400**	**0**	**0**

Key: 100 = 1 person year

Research Staff – CRC LEME Funded

Name	Employer	Main Activity	Total % of Time	% Spent on Research Program					% Spent on		
				Regolith geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Applications	Admin-istration
CRC Grant Funded											
Kirste D	ANU	R	100	30	20	15	35	100			
McQueen K	ANU	R	75	50	25			75			
Pillans B	ANU	R	50	50				50			
Roach I	ANU	R	100	15				15	85		
Welch S	ANU	R	100	15	55	30		100			
de Caritat P	GA	R	100	15	40	40		95	5		
Young M	GA	R	10			10		10			
Aspandiar M	CUT	R	50		45			45	5		
Paine M	CUT	R	100	50	50			100			
Wilkes P	CUT	R	100	5			95	100			
Hill S	AU	R	100	60			5	65	35		
Joseph J	AU	R	100	80			10	90	10		
Cornelius A	CSIRO	R	75	15	60			75			
Lintern M	CSIRO	R	100	10	90			100			
Phang C	CSIRO	R	100		100			100			
Singh B	CSIRO	R	100		100			100			
Cox J	CSIRO	R	50				50	50			
Cresswell R	CSIRO	R	80				80	80			
Davies P	CSIRO	R	10				10	10			
Gildfedder M	CSIRO	R	20				20	20			
Hicks W	CSIRO	R	15			15		15			
Lamontagne M	CSIRO	R	5			5		5			
Rogers S	CSIRO	R	10			10		10			
Stenson M	CSIRO	R	10			10		10			
			1560	**395**	**585**	**135**	**305**	**1420**	**140**	**0**	**0**
Industry or Externally Funded											
Tan K P		ANU	R	20				20	20		
Cahill K		GA	R	25				25	25		
Clarke J		GA	R	100				100	100		
Coram J		GA	R	5				5	5		
Fitzpatrick A		GA	R	100				100	100		
Halas L		GA	R	100				100	100		
James J		GA	R	100				100	100		
Lane R		GA	R	20				20	20		
Roberts L		GA	R	100				100	100		
Ruperto L		GA	R	50				50	50		
Tan KP		GA	R	80				80	80		
Harris B		CUT	R	40				40	40		
Caccetta M		CSIRO	R	40		40			40		
Cudahy T		CSIRO	R	40		40			40		
Hackett A		CSIRO	R	50		50			50		
Hewson R		CSIRO	R	25		25			25		
Robertson I		CSIRO	R	20	20				20		
Wells M		CSIRO	R	40		40			40		
			955	**20**	**195**	**0**	**740**	**955**	**0**	**0**	**0**
TOTAL RESEARCH STAFF: CRC GRANT AND EXTERNAL FUNDS			**2515**	**415**	**780**	**135**	**1045**	**2375**	**140**	**0**	**0**

KEY: 100 = 1 person year

Summary of Research Staff Resources

	Total Equivalent Person Years	Person Years Spent on Research Program					Person Years Spent on		
		SUBPROGRAM							
		Regolith geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
TOTAL IN-KIND CONTRIBUTED	45.13	18.63	11.05	2.5	8.95	41.13	4	0.0	0
CRC GRANT FUNDED	15.6	3.95	5.85	1.35	3.05	14.2	1.4	0.0	0
INDUSTRY FUNDED	9.55	0.2	2.0	0.0	7.4	9.55	0.0	0.0	0
TOTAL FUNDED BY CRC LEME	25.15	4.15	7.8	1.35	10.45	23.75	1.4	0.0	0
GRAND TOTAL	70.28	22.78	18.85	3.85	19.4	64.88	5.4	0.0	0
Proportion of total professional staff resources in each activity (100%)	100	32	27	5	28	92	8	0	0

Administration and Technical Staff

Name	Position	Main Activity	Total % of Time
In-kind Contributions			
CRC Grant Funded			
Australian National University			
Edwards D	Research Support Officer	T	10
Bordeau D	Education Support Officer	A	50
			60
Geoscience Australia			
Walsh M	Program Support Officer	A	50
			50
Adelaide University			
Blake M	Program Support Officer	A	50
			50
CSIRO			
Campbell J	Admin Support Officer	A	20
Game S	PA to CEO/Centre Support Officer	A	100
Hink H	Program Support Officer	A	50
Kong G	Business Manager	A	100
Gee D	Chief Executive Officer	A	100
Mills J	Financial Accountant	A	80
Tyrell S	Admin Support Officer	A	50
			500
			660
Industry or Externally Funded			
Geoscience Australia			
Walsh M	Program Support Officer	A	50
			50
TOTAL ADMINISTRATION AND TECHNICAL STAFF:			710

KEY: 100 = 1 person year

Photograph: Steve Hill

Publications

Photograph: Steve Hill

Publications

Publications by LEME staff and students have surged this year, as the research outputs have gained momentum. The increase in outputs is partly related to a successful mentoring program instituted by Prof Ken McQueen and Dr Ian Roach at the Canberra node, designed to facilitate the publication process by students.

Highlights of the publication record include:

- 40 journal papers
- 24 full conference papers
- 38 conference extended abstracts
- 14 presentations at the International Salinity Forum in California
- 26 LEME Open File Reports
- 15 case studies added in the series *Regolith Expression of Australian Ore Systems* to bring the total to over 100
- 4 *Minerals Briefs* electronic newsletters released.
- 5 case studies added to the series *Regolith-Landscape evolution across Australia*, bringing the total to over 50.
- Regolith 2004 volume printed containing 97 papers by LEME staff and students.

Patents

No patents or provisional patents were lodged by the Centre during the reporting period

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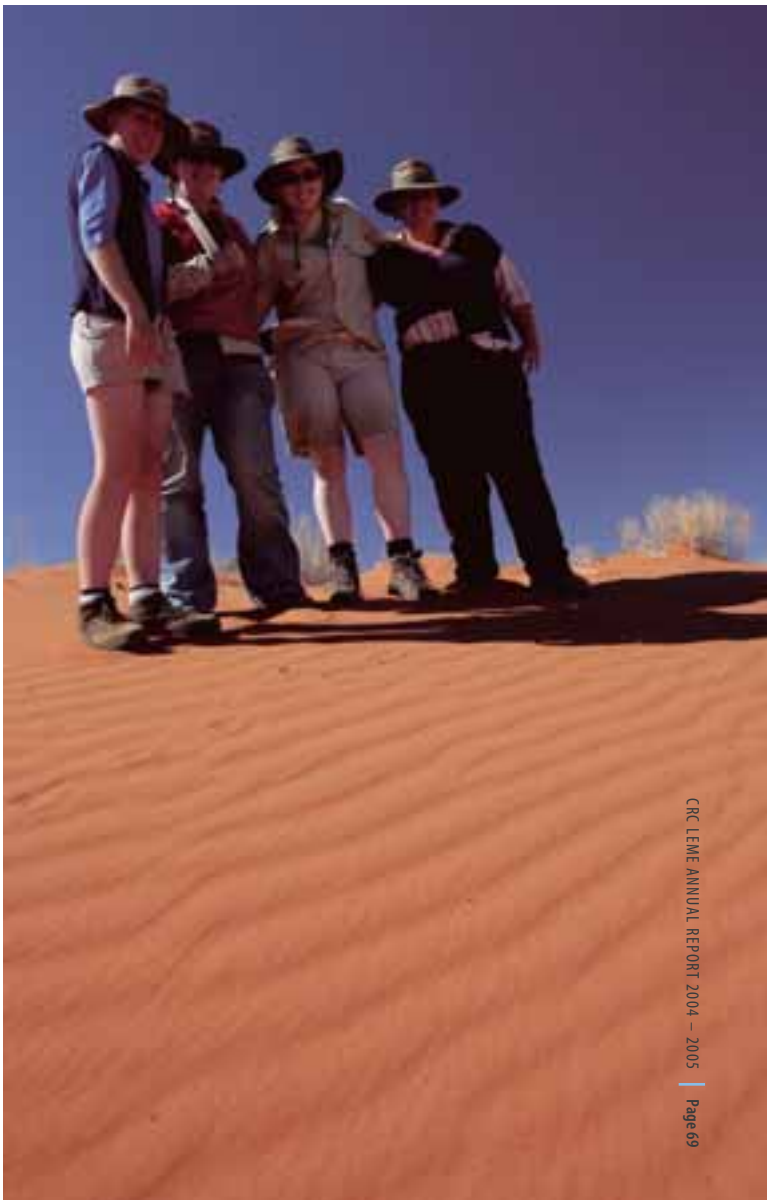
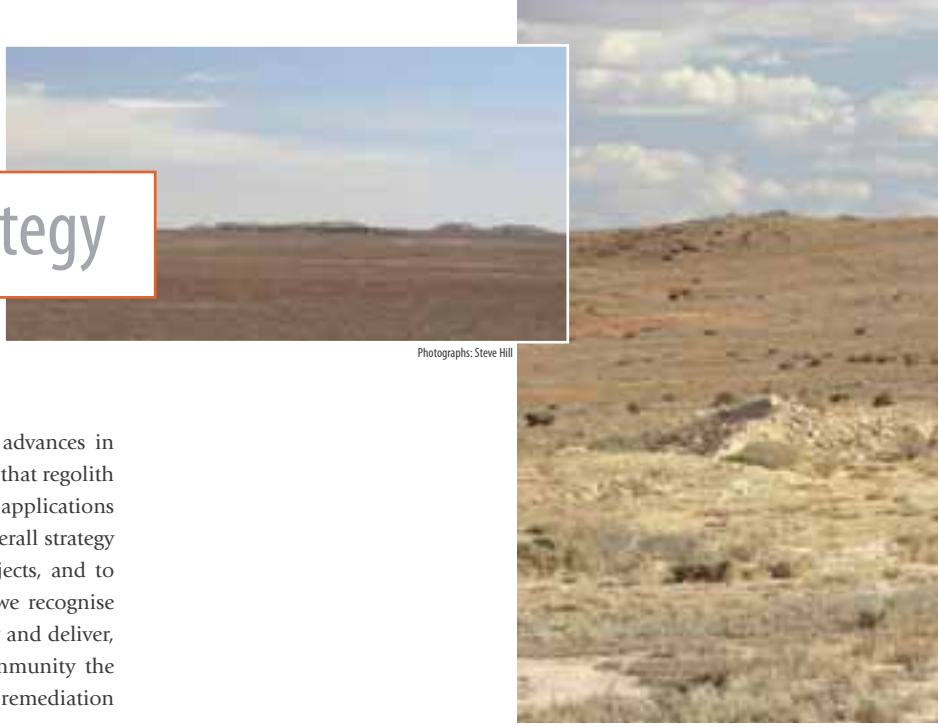


Communication Strategy



Photographs: Steve Hill

Communication Policy

CRC LEME aims to promote and communicate its advances in regolith knowledge to its **immediate end-users**, such that regolith science becomes an accepted and integral part of new applications in mineral exploration and land management. The overall strategy to optimise uptake is by way of demonstration projects, and to promote on **delivery** rather than **intent**. However, we recognise that as the salinity and environmental programs grow and deliver, there will be a need to promote to the general community the widening application of regolith geoscience in land remediation schemes and environmental applications.

LEME communication of research activities and scientific results is through the following mechanisms:

- Updates of the website, http://crcleme.org.au and its contained intranet site, so that it is an outlet for interim and final releases of information.
- Production of an Annual Report which not only satisfies the reporting needs of the CRC Secretariat, but delivers summaries of activities and achievements to a mailing list of over 800 recipients.
- Release of comprehensive technical reports through the LEME Open File Report series and various monographs.
- Publication of scientific communications in national and international scientific journals.
- Staging conferences, seminars and workshops under the LEME banner, for example Mineral Exploration Seminars, and the tri-partite Regolith Symposia held annually in Canberra, Adelaide and Perth.
- LEME researchers presenting their findings at national and international events.
- Distribution of the quarterly electronic newsletter *Minerals Brief* to over 500 recipients.
- Contribution to *Focus on Salt* – a widely circulated newsletter to NRM stakeholders, produced jointly with CRC PBMDS.
- Sponsoring multi-disciplinary multi-agency scientific and technical events.
- Technical articles in special interest journals and industry magazines.
- Issuance of media releases on significant research advances.

Photograph: Rob Fitzpatrick

LEME booth at the International Conference on Biogeochemistry of Trace Elements (ICOBTE), Adelaide, April 05. L to R: Ravi Anand, Aaron Brown, Frank Reith, Steve Rogers and Rob Fitzpatrick.

Publication Policy

LEME is committed to the rapid production of high quality publications and information products, in digital and hardcopy form, as a means of knowledge transfer to stakeholders. Expeditious production of publications is achieved by in-house desktop practices, generally with limited print runs, and increasing availability in digital form. New reports and other significant publications will go onto the LEME web site in PDF form, where they will remain freely available for a few months. Thereafter they are listed in the web-index of Open File Reports, through which they can be purchased at cost price, as either CD or hard copies.

LEME also aims to release, after appropriate quality control, other information, data, interim results and technical presentations.

Publication guidelines, addressing format and style for technical publications have been developed. They are based on the premises of clear written communication and continuous disclosure. The basis of this will be the continued delivery of progress summaries on the website, and LEME Reports via CD, observing the constraints imposed by confidentiality and intellectual property issues.

LEME Website (http://crcleme.org.au)

With the enormous growth material suitable for the website, we found it necessary to completely restructure the website and rewrite virtually all the text during 2004-05. We have moved away from the old 'frames' structure, and the new look site has a search engine. It now contains over 700 PDF files of technical papers, and is the main medium for conveying LEME activities and research to staff and stakeholders. It contains project descriptions, research results, abstracts for Open File Reports and monographs. Recent reports in their entirety are downloadable as PDF files. Order forms for the range of LEME publications are also available from the site.

The website contains personnel directories (staff, students, Board, Advisory Councils), the LEME Strategic Plan, news and events,

Photograph: Ian Roach

upcoming conferences, as well as links to Core Participant and collaborator websites. The Education Section advertises MCA courses, scholarships and proposed student projects and also provides a forum for LEME students to report progress.

The staff intranet is central to internal LEME communication, and is used to post minutes from Executive meetings, reports to staff, procedures and templates, policy directives, and the approved Project Summaries of the entire research portfolio of LEME.

Publications

The main publication outlets are Open File Reports, monographs, papers in scientific journals, and Internet releases. LEME reports and monographs are *publications* in the literal sense, in that they are works of scientific merit, produced on a recurring basis that carry author and organisational attribution, are internally refereed, are citable, and are subject to copyright. LEME scientists also publish research papers in refereed external journals.

LEME has a series of some 190 Open File Reports, dating back to LEME 1. An impressive total of 26 new OFR Reports were published during the reporting period, and these are listed in the Publications section of this report. Three new monographs were produced in the year.

Conferences, Seminars and Meetings

In November 2004, CRC LEME Regolith Symposia were staged in Canberra, Adelaide and Perth. Principally these are an opportunity for researchers, including students, to present updates on their work, deliver results in advance of more formal publication, and to share their evolving science with peers. This enhances the quality of research, and promotes cross-fertilization of ideas. Presentations cover the full spectrum of LEME research and therefore are of relevance to a wide range of stakeholders with interests in regolith science. The symposia are attracting an increasing number of external research end-users. Fully reviewed extended abstracts are published as the 420-page *Regolith 2004* in the LEME monograph series. These are available in hard copy, PDF on CD.

The annual LEME Minerals Exploration Seminar was held in Perth in May 2004, and attracted 120 attendees. This successful series conveys timely and relevant research results to the mineral explorers, and has become embedded in the calendar of events for mineral explorers in Western Australia. As part of the expanded promotion effort, a similar seminar was also staged in Kalgoorlie in February 2005.

Dennis Gee was an invited key-note speaker at the AusIMM Pacrim 2004 Conference in Adelaide in August 2004, and also at the AMIRA biennial Exploration Managers Conference in Newcastle in April 2005.

As a confident signal of the coming-of-age of LEME science in salinity management, Program Leader Ken Lawrie led a LEME delegation to the International Salinity Forum in California in April 2005. An impressive total of 14 papers were presented, and the impact was sufficient to secure the Second International Salinity Forum for Australia in 2008. Ken is to be complimented for his leadership and endeavour in this important communication initiative.

Visitors

LEME personnel maintain their individual connections with colleagues abroad and at home. The tables show the extent of this important interaction.

Media Releases

Commensurate with the acceleration of LEME science deliveries, promotion has been stepped up, mainly through special industry journals and industry magazines, and also through press releases. Two press releases under the CRC Association program were produced on *Gum trees and Mulga* and *Pin-pointing Riverland Salinity.*

Early in the year the CEO wrote a series of six articles on LEME's regolith science that appeared in the Research section of the leading industry journal *Australian Mining Monthly*. This was followed by a series of seven articles produced collectively for the six CRCs comprising the Mining and Energy Sector of the CRC Association. These were done under a contractual arrangement with Professor Julian Cribb, the leading Australian science journalist. These were a populist integration of the recent work of the Mining and Energy Sector, appearing under catchy headings such as *Re-discovering Australia, Letting bugs do the work, Mining the mother lode, Wizards of Oz and Future technologies.*

Conferences, Seminars and Meetings – Presentations by LEME Personnel

Event	Location	Date	LEME Presenters	LEME additional involvement
Gawler Craton: State of Play 2004 Conf	Adelaide SA	4-6 Aug 04	Alan Mauger, John Keeling	LEME minor sponsor
ASEG-PESA Conference and Exhibition:	Sydney NSW	15-18 Aug 04	Richard Cresswell, Tania Dhu, Andrew Fitzpatrick, David Gibson, Philip Heath, Anousha Hashemi, Don Hunter, John Joseph, Anton Kepic, Richard Lane, Jayson Meyers, Tim Munday, Margarita Norvill, Vicki Stamoulis, KP Tan, John Wilford – total 19	LEME booth
32nd International Geological Congress	Florence Italy	20-28 Aug 04	Mark Paine	
Acid Sulfate Soils Workshops	Perth and Mandurah WA	1-2 Sept 04	Rob Fitzpatrick – Keynote address and another presentation, Steve Rogers	
AIG Seminar: Leading Edge Geophysical Technology	Perth WA	6 Sept	Jayson Meyers organiser and presenter, Tom Cudahy, Alan Mauger, M Rosid	
Near surface 2004: 10th European meeting of Environmental and Engineering Geophysicists	Utrecht, The Netherlands	6-9 Sep 04	Margareta Novill	
NAP/NHT NSW Workshop on State Level Priorities	Sydney NSW	8 Sep 04	Ken Lawrie – invited presentation	
6th International Symposium on Applied Isotope Geochemistry	Prague, Czech Republic	11-16 Sep 04	Matthew Lenahan	
Global Workshop on Digital Soil Mapping	Montpellier France	15-17 Sept 04	Mark Thomas	
GSA – ACT Branch	Canberra ACT	21 Sept 04	Brad Pillans	
AusIMM PACRIM 2004 Sessions: Discovery techniques and regolith, and Exploration Case Histories	Adelaide	19-22 Sept	Dennis Gee – Keynote speaker. John Keeling – session chair, Keith Scott, Ken McQueen, Patrice de Caritat, KP Tan, Dirk Kirste, Tony Eggleton, Alan Mauger	LEME minor sponsor
SEG/SGA 2004: Predictive Mineral Discovery Under Cover	Perth WA	27 Sept – 1 Oct	Charles Butt – Keynote speaker and Session Chair. Ray Smith on Planning Committee, Ravi Anand and Jayson Meyers workshop organisers	LEME minor sponsor
Aust Clay Mineralogy & Geophysics for Environmental Management and Mineral Exploration – ClayGEMME	Adelaide SA	27 Sept – 3 Oct 04	Rob Fitzpatrick – Convenor, John Keeling, Alan Mauger, Graham Heinson, Balbir Singh, John Joseph, Ian Lau, Andrew Baker, Mark Fritz, Mark Thomas, Anna Petts, Tania Dhu	LEME Workshop, conference presenters, field demonstrations, lecturers (55 delegates)
3rd International Workshop on Chemical Bioavailability in the Terrestrial Environment and Contaminated Site Management, September 2004, Adelaide,	Adelaide, SA	Sept 04	Rob Fitzpatrick – Keynote speaker – Acid Sulphate Soils symposium	
LIMPACS International Workshop on Climate and Palae-climate Change and Impacts	Mildura Vic	30 Sep to 3 Oct 04	Ken Lawrie – invited presenter	
Volcanic hosted Cu-Zn deposits in WA: an update	Perth WA	2 Oct 04	Charles Butt, Matthias Cornelius, Ravi Anand, Ray Smith, Tom Cudahy	LEME support
SEG International Exposition and 74th Annual Meeting	Denver, Colorado USA	10-15 Oct 04	Don Hunter, Anton Kepic, Tim Munday	
12th Australasian Remote Sensing & Photogrammetry Conference (12ARSPC)	Fremantle WA	18-22 Oct 04	Alan Mauger	
17th Int Workshop on Electro-magnetic Induction in the Earth	Hyderabad, India	18-23 Oct 04	Tania Dhu	
Dust Workshop: CSIRO Marine and Atmospheric Research	Melbourne, Vic	8-10 Nov 04	Richard Greene	
1st National Salinity Engineering Conference	Perth WA	9-12 Nov	Tim Munday, Jayson Meyers, Don Hunter, Paul Wilkes, Greg Street, Mohammad Rosid	
Geoscience Australia Minerals Exploration Seminar	Pert WA	29 Nov	Lisa Worrall	
8th Australasian Environmental Isotope Conference	Melbourne Vic	29 Nov to 1 Dec 04	Matthew Lenahan, Dirke Kirste	
Aust Society for Limnology, 43rd Annual Congress	Adelaide SA to 3 Dec 04	29 Nov	Sebastien Lamontagne presenter, Rob Fitzpatrick and other LEME attendees.	
Inaugural Australasian Hydrogeology Research Conference	Melbourne Vic	2-3 Dec 04	Dirk Kirste, KP Tan, R Cresswell	
Aust Society of Soil Science Inc: SuperSoil2004 Conference	Sydney NSW	5-9 Dec 04	Rob Fitzpatrick, David Little and Vanessa Wong	
National Committee for Acid Sulfate Soils (NatCASS)	Perth WA	Jan 05	Rob Fitzpatrick – presentation of report: National Atlas for Inland and Coastal ASS	
GSWA Annual Lecture Series MrVBF and SW Australia's landscapes	Perth Perth WA	8 Feb 05 18 Feb 05	Dennis Gee Ken Lawrie, Colin Pain	

Conferences, Seminars and Meetings – Presentations by LEME Personnel (cont'd)

Event	Location	Date	LEME Presenters	LEME additional involvement
Student-Industry-CRC Symposium	Pinjarra WA	20-25 Feb 05	Ryan Noble, Frank Reith, Tania Dhu and Karen Hulme	
Presentation to HRH Prince Charles: Salinity mapping and hazard-risk assessment in Australia	Perth WA	1 Mar 05	Ken Lawrie	
Conceptual Models for regolith thickness workshop	Canberra ACT	4 Mar 05	Colin Pain convenor	
AIG Seminar: Spurious or anomalous geochemical innovation in the exploration for blind orebodies in Australia	Perth WA	14 Mar 05	Dennis Gee, David Gray, Ravi Anand	
AGES 2005	Alice Springs NT	22-23 Mar 05	Mike Craig	
Aerosol Workshop	Sydney NSW	30 Mar – 1 Apr 05	Keith Scott	
8th ICOBTE (International Conference on Biogeochemistry of Trace Elements)	Adelaide SA	3-7 Apr 05	Steve Rogers on organising committee, Ravi Anand, Frank Reith, David Little	LEME major sponsor
3rd Murray Darling Basin Salinity Management Strategy and Modelling Forum	Canberra ACT	5-6 Apr 05	Ken Lawrie KP Tan, T Munday	
AMIRA 6th Biennial Exploration Managers Conference	Hunter Valley SA	5-7 Apr 05	Dennis Gee	
Economic Geology Seminar Series: Calcrete Geochemistry in Gold-Exploration – Biogeochemistry of Carbonate Formation	Freiberg, Germany	7 Apr 05	Andreas Schmidt Mumm – invited speaker	
International Salinity Forum: Managing saline soils and water – science technology and social issues.	California, USA	25-27 Apr 05	Ken Lawrie and Rob Fitzpatrick – keynote addresses. 14 LEME presentations and posters	
European Geosciences Union General Assembly – EGU2005	Vienna, Austria	24-29 Apr 05	Jon Clarke and Andrew Fitzpatrick – 4 papers	
SA Resources and Energy Investment Conference: Plan for Accelerating Exploration technical day (PACE)	Adelaide SA	4 May 05	John Keeling, Lilian Stoian, Baohong Hou, Alan Mauger, Adrian Fabris	
CRC Association Conference	Melbourne Vic	18-20 May 05	Dennis Gee and Board Chair George Savell participants	
15th Annual Goldschmidt Conference	Moscow, Idaho, USA	20-25 May 05	Keith Scott	
MCA Innovation Forum	Canberra ACT	3 Jun	Dennis Gee	
CRC for Spatial Information Landscape Systems Workshop	Melbourne Vic	8 Jun 05	Ken Lawrie	
National Committee for Acid Sulfate Soils (NatCASS) conference	Cairns Qld	12 Jul 05	Rob Fitzpatrick – presentation of report: National Atlas for Inland and Coastal ASS	

Conferences, Seminars and Meetings – Conducted or Sponsored by LEME Personnel

Event	Location	Date	LEME Involvement	No of attendees
ANU-LEME Seminar Series	Canberra ACT	18 Oct 04	Brad Pillans presenter: Geochronology of ancient Australian landscapes	30
ANU-LEME Seminar Series	Canberra ACT	30 Nov 04	Kamal Khider presenter: Regional chemical dispersion processes in the regolith of the Cobar-Nymagee area NSW	30
4th Asia Pacific Symposium on Environmental Geochemistry	Perth WA	18-20 Jan 05	Ron Watkins Chair, Ryan Noble, Troy Cook, Ron Watkins Organising Committee. Kirsty Beckett, Mark Pirlo, Troy Cook, Ryan Noble, Ron Watkins, John Watling presenters*. Hosted by CUT, supported by LEME	85
CRC LEME Regional Regolith Symposia (3)	Adelaide, Perth and Canberra	10-12, 18-19 and 24-26 Nov	97 LEME presentations*	110
Commemorative Address – Butt Smith Medallist Richard Mazzucchelli	Kalgoorlie	14 Feb 05	Sponsored by LEME	75
ANU-LEME Seminar Series	Canberra ACT	17 Feb 05	Michael Smith presenter: The physicochemical evolution of alkaline salt-affected soils on the western slopes of northern NSW	30
LEME-GSWA Mineral Exploration Seminar	Kalgoorlie WA	15-16 Feb 05	24 LEME presentations*	85
Commemorative Address – Butt Smith Medallist Richard Mazzucchelli	Sydney Minerals Exploration Discussion Group (SMEDG) Meeting NSW	28 Apr 05	Sponsored by LEME	30
LEME Mineral Exploration Seminar	Perth, WA	25 May 05	18 LEME presentations*	130
Postgraduate Shortcourse: Advanced remote sending for mineral exploration and natural resource management	AU, SA	6-10 Jun 05	Alan Mauger – lecturer	12
HyLogging Workshop	Adelaide SA	23 Jun 05	Alan Mauger – presenter other LEME attendees	12
Mineral Exploration Through Cover Seminar	Adelaide	24 June 05	7 LEME presentations*	130
Commemorative Address – Butt Smith Medallist Richard Mazzucchelli	Adelaide (at above event)	24 Jun 05	Sponsored by LEME	130

*Please refer to respective Abstracts and Proceedings Volumes under Publications.

Visitors from the Centre

Name and Core Party	Host Organisation and Location	Host Staff	Project/Activity	Date – from – to
Baohong Hou PIRSA	Dept. of Sciences & Technology, Inner Mongolia Province, China	Education Dept. of Inner Mongolia Province, China	Giving presentation on CRC LEME program	6 Sept 04
Baohong Hou PIRSA	Inner Mongolia University, China	Education Dept. of Inner Mongolia Province, China	Giving lecture, Exchange program	7 Sept 04
Baohong Hou PIRSA	Inner Mongolia Normal University, China	Education Dept. of Inner Mongolia Province, China	Giving lecture, Exchange program	8 Sept 04
Baohong Hou PIRSA	Inner Mongolia University of Sciences & Technology, China	Education Dept. of Inner Mongolia Province, China	Giving lecture & taking course, Exchange program	10 Sept 04
Baohong Hou PIRSA	Shihezhi University of Xinjiang, China	Deputy President & other uni. staff	Giving lecture & taking course, Exchange program	14 Sept 04
Bear McPhail ANU	Geological Survey of Canada, Ottawa, Ontario	Dr Rob Berman	Research discussions and presentation	Oct 04
Bear McPhail ANU	Queens University, Kingston, Ontario	Dr Heather Jamieson, Dr Jim Lee, Dr Kurt Kyser, Dept of Geological Sciences and Engineering	Research discussions and presentation	Oct 04
Bear McPhail ANU	University of British Columbia	Dr Greg Dipple, Dr Mati Raudsepp, Dept of Earth and Ocean Sciences	Research discussions	Apr 05
Ken Lawrie, John Wilford, KP Tan – GA	Utah Dept of Agriculture, USA	Representatives from Utah and US Depts Agriculture, Utah Dept Natural Resources and CRC PBMDS	Research discussions and field trip	29 Apr to 3 May 05

Visitors to the Centre

Visitor	Organisation	LEME Host	Location	Date – from – to
Prof Rosa Poch	University of Lleida, Spain	Rob Fitzpatrick	CLW, Adelaide	Feb to Jul 04 sabbatical
Dr Geoff Hunston	Heritage Branch, Yukon Provincial Government, Canada	Ken KcQueen	ANU, Canberra	20-27 Jul 04
Richard Langford	Geological Survey of WA	Colin Pain, Lisa Worrall	GA, Canberra	24 Sept 2004
Dr Abbas Farshad	International Institute for Geo-Information Science and Earth Observation, The Netherlands	Colin Pain	GA, Canberra	15 Nov 2004
Mr Jose Luis Perez Jimenez	National Museum of Natural Sciences, Madrid, Spain	John Keeling	PIRSA, Adelaide	15 Jan to 15 Apr 05
Prof Tom Ammons	The University of Tennassee	Ryan Noble and Ron Watkins	CUT, Perth	May – July 2005
Prof Jonathan Phillips	Department of Geography, University of Kentucky	Colin Pain	GA, Canberra	20 June 2005

Media Reports and Releases

Subject	CRC LEME Contact	Publication	Date
Stalking a killer in an invisible landscape	Ken Lawrie	CRCA Media release	July 04
Fields of Attraction	Jayson Meyers and Anousha Hashemi	R&D Now – Research highlights 04, CUT	July 04
Reading the Regolith	Dennis Gee	Australian Mining Monthly	Aug 04
Great Youth Hunt	Amy Lockheed, Honours student	The Sunday Mail	Oct 04
Regolith research underpins discovery of Zircon-rich HMS in the Eucla Basin	Baohong Hou	PIRSA Media Release	Nov 04
Re-discovering Australia (CRCA Mining and Energy Sector initiative)	"Chasing bugs" – Frank Reith	Australian Mining Monthly	Nov 04
Geologist's gem win	Rob Hough	Scarborough Community News	Nov 04
Portable spectroscopy proving its worth	Dennis Gee	Gold Mining Journal	Oct-Dec 2004
Robot Age (CRCA Mining and Energy Sector initiative)	Automated drill logging – Dennis Gee	Australian Mining Monthly	Jan 05
New Airborne sensors fight Australia's big salt problem	Ken Lawrie	CRCA Media release	Feb 05
Bugs do the Work (CRCA Mining and Energy Sector initiative)	"Microbe explorers" – Ravi Anand	Australian Mining Monthly	April 05
Improved drain design and management	Steve Rogers	CSIRO: A major partner in CRCs. Research Achievements brochure	May 05
Mining the mother lode (CRCA Mining and Energy Sector initiative)	"Golden insights" – Dennis Gee	Australian Mining Monthly	May 05
Mining the mother lode – Part 1 and 2	LEME Minex programs – Dennis Gee	MiningNews – electronic newsletter	May 05
Gumtrees and mulga: signposts to minerals	Biological mineral exploration – Dennis Gee	CRCA Media release	May 05
Exploration Trees	Steve Hill	ABC radio	June 05
Wizards of Oz (CRCA Mining and Energy Sector initiative)	"Golden Trees" – Dennis Gee	Australian Mining Monthly	June 05

Grants and Awards

Photograph: Patrice de Caritat

Butt Smith Medal

CSIRO Exploration and Mining, together with CRC LEME have instituted the Butt Smith Medal, to be awarded every two years, to geoscientists who have made outstanding and sustained contributions linking regolith science to mineral exploration in Australia. The award honours the contribution of Dr Charles RM Butt and Dr Raymond E Smith to research and development related to the mineral industry. The inaugural award was made to Dr Richard Mazzucchelli at the President's Dinner of the international Society of Economic Geologists which held its biennial conference in Perth on 28 September 2004.

The Butt Smith Medal award recognizes the contributions of two great Australian geoscientists – both of whom could be regarded as founding-fathers of LEME. It is appropriate therefore to quote from the testimonial honouring Ray and Charles:

> **Dr Charles Butt and Dr Ray Smith have played a significant role in the development of the Australian mineral industry in the past three decades. Much of the industry's rapid growth in that time has resulted from exploration success. For example the feat of discovering almost 10,000 tonnes or 300 million ounces of gold in 25 years has rarely been matched.**
>
> **Many ingredients go into exploration success. Research scientists such as Charles and Ray make a substantial contribution by providing new ideas and exploration methods and by instilling vital confidence in exploration methodologies. Charles and Ray have won respect in Australia and internationally. They are excellent scientists who tackled the perplexing topic of the Australian regolith and provided exploration solutions in clear terms.**
>
> **Thanks to Charles and Ray, we now understand that metals can be dispersed in the regolith that some materials are more important to sample than others, and that different landform settings require different exploration strategies. These are simple but vital messages based on very complex concepts. Charles and Ray are skilful communicators who have helped the industry understand these messages and improve exploration processes.**
>
> **CSIRO Exploration and Mining and the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME) are proud to honour two great Australians through the Butt Smith medal.**

Neil Phillips
CSIRO Exploration and Mining

Dennis Gee
CRC LEME

Similarly it is appropriate to quote the citation in favour of the recipient.

> **Dr Richard Mazzucchelli has been at the leading edge of geochemical exploration in Australia since beginning his doctorate in 1962. His frontier research into geochemical methods and application of regolith geochemistry has directly contributed to successful exploration programs for nickel, gold and copper. Richard introduced geochemical methods into the exploration programs of Western Mining Corporation including sampling and analysis for gold, nickel, copper-lead-zinc and uranium.**
>
> **His work in developing geochemical exploration techniques has been important to the success and growth of exploration companies both through discoveries and cost effective testing and rejecting of unmineralised areas. Richard describes himself as a bullet maker, not a bullet firer.*"People have applied the exploration methods I have developed, and come up with something."***
>
> **Great grandfather Mazzucchelli emigrated from Switzerland and joined the Victorian gold-rush. The whole family moved to the WA Goldfields in the 1890s after the Coolgardie discovery. Richard's grandfather started the jewellery business in Kalgoorlie which moved to Perth in the 1920s. Richard was born in Nedlands, but moved back to Kalgoorlie on graduation from UWA. *"My father, four children and two grandchildren were all born in Kalgoorlie-Boulder and now, with five of my six descendants living there, you could say we have reverted to our Goldfields roots!"***
>
> **Richard's career with WMC spanned almost 25 years and included appointments as Chief Geochemist and Regional Exploration Manager. In 1987 he established the geochemical consultancy, Searchtech Pty Ltd. He has extensive experience in all facets of geochemical exploration for a wide range of commodities in Australia, North and South America, Africa, Asia and the Pacific.**
>
> **Publications he has written or co-authored document the use of laterite as a sampling medium and the arsenic-gold association in rocks, soils, streams and lake sediments. In 1999, the West Australian Division of the Geological Society of Australia awarded Richard the Gibb Maitland Medal for his contribution to geoscience in Western Australia.**

Dr Richard Mazzucchelli, recipient of the inaugural Butt Smith Medal.

Baohong Hou receiving his Churchill Fellowship Award. From L to R Baohong Hou, Governor of South Australia, Her Excellency Marjorie Jackson-Nelson, AC, CVO, MBE, and Juan Li (Baohong's wife)

In acknowledgement of the award Richard has given commemorative public lectures at the Kalgoorlie MINEX Seminar, the Sydney Mineral Exploration Discussion Group, and South Australian *Mineral Exploration through Cover* symposium. His lecture tour will conclude with a Commemorative Presentation at the prestigious International Geochemical Exploration Symposium in Perth in September 2005.

Awards and Appointments

LEME staff activities have been recognised at a number of national and international forums during the reporting period, as shown in the accompanying tables. Most notable is the impressive list of chair and presidential appointments of Dr Rob Fitzpatrick. He demonstrates an admirable capacity to take on organisational leadership roles, and still retain his scientific productivity.

We offer our congratulations to our LEME icon Dr Charles Butt who was elected Fellow of the Australian Academy of Technological Sciences and Engineering in November 2004.

We also congratulate Dr Baohong Hou who was awarded the Churchill Fellowship for the ensuing year. This will enable him to expand the already impressive list of international linkages he has developed, as noted in the Chapter 9 – Collaboration.

Awards and Appointments

Awardee	Core Party	Name /Description of award	By	Received
Rob Fitzpatrick	CLW	Chairman – Soil Mineralogy Commission – four year appointment	IUSS	2003
Rob Fitzpatrick	CLW	President – Australian Mineral Society – one year appointment	ACMS	2004
Rob Fitzpatrick	CLW	Appointment – Member of International Geohazards Working Group	IUSS, IGU. IUGS, IUGG	May 2004 – two years
Tom Cudahy, and Amanda Cornelius, plus others from CSIRO	CEM	CSIRO Divisional Award for Teamwork – Next Generation Mineral Mapping, plus $5000 to be shared amongst the team	A/Chief Cliff Mallet CEM	2004-2005
Rob Fitzpatrick	CLW	Director – Centre for Australian Forensic Soil Science	Board of CAFSS	Jul 04
Baohong Hou	PIRSA	Chun-Hui Fellowship for outstanding China-born Australian scientist to visit to western China	China Ministry of Education	Sept 04
Nick Direen	AU	Elected Fellow of the Geological Society of London	Geological Society of London	Sept 04
Rob Fitzpatrick	CLW	Promotion – Chief Research Scientist	CLW	Sept 04
Baohong Hou	PIRSA	Adjunct Research Fellow – China State Key Laboratory of Geological Processes and Mineral Resources	China University of Geosciences	Oct 04
Nick Direen	AU	Early Career Symposium Fellowship – to attend Annual Symposium of the AATSE, Adelaide	AATSE	Nov 04
Mark Paine	CUT	Appointed Research Fellow, Dept Applied Geology	CUT	Nov 04
Robert Hough	CEM	WA Premier's Prize for Early Career Achievement in Science 2004	WA Government	Nov 04
Charles Butt	CEM	Elected Fellow of the AATSE	AATSE	Nov 04
Tim Munday	CEM	Best Technical presentation at National Salinity Engineering Conference. Paper entitled *"Combining geology and geophysics to develop a hydrogeological framework for salt interception in the Loxton Sands aquifer, Central Murray Basin"*	National Salinity Engineering Conference Committee	Nov 04
Graham Heinson	AU	Appointment – Associate Dean of the Faculty of Sciences (Education)	VC, AU	Nov 04
Rob Fitzpatrick	CLW	President – two year appointment	Royal Society of South Australia	Nov 04
Keith Scott	CEM	Appointed Honorary Research Fellow	CEM, Sydney	Nov 04
Baohong Hou	PIRSA	Co-Leader – IGCP Project 514 – Palaeochannels and Mineral Deposits	International Geological Correlation Program Committee	Apr 05
Baohong Hou	PIRSA	Visiting Professor – Research and Teaching	Fujian Normal University, China	May 05
Baohong Hou	PIRSA	Promotion to Principal Geoscientist	PIRSA	May 05
Baohong Hou	PIRSA	2005 Churchill Fellow and Fellowship – rewarding Australians striving for excellence	The Winston Churchill Memorial Trust	Jun 05

Student Success

Our students also made their mark during the year, winning a number of awards at conferences.

Student Prizes

- Philip Heath, (AU)- Bob Crompton award in Physics for best poster describing research project, plus $500 prize (shared), Dec 04
- Rosa Poch, Brett Thomas, Rob Fitzpatrick, Richard Merry, CLW – Best Poster Award, Acid Sulfate Soils Symposium, Sydney, Dec 04
- Tania Dhu (AU) – Students presentation Runner Up – Technical Content and Presentation – $300 prize, Student-Industry-CRC Symposium, Pinjarra WA, Feb 05
- Annamalai Mahizhan (CUT) Krishna and Pamela Sappal Prize for the Best Higher Degree Research Graduate in Geoscience, May 05

2004 CRC LEME Regolith Symposia – held in Adelaide, Canberra and Perth – Student Awards

- Taylor & Eggleton Book Prize for Best Overall Oral and Written Presentation: Vanessa Wong (ANU), Kirsty Becket (CUT) and Andrew Baker (AU).
- Editor's Choice Award for Best Written Work: Chris Gunton (ANU), Ryan Noble (CUT) and Paul Wittwer (AU).
- Outstanding Oral Presentation Prize: Michael Smith (ANU), Rick Jones (ANU), Duanne White (UWS), Anne Riesz (ANU), Simon Abbott (CUT) and Kate Pfeiffer (AU).
- Editor's Award for Excellence: Chris Gunton (ANU)

Grants

LEME staff and students were again successful in winning a number of Australian Research Council and other grants during the reporting period. These grants were awarded for core research, but do not include consultancies or research contracts.

Grants to CRC LEME Personnel

Name of Researcher	Core Party	Title of Project	Source of grant	Period of grant	Amount	Relationship to CRC research
Glen Bann	AU	Dryland salinity, biodiversity and geodiversity	Southern Tablelands Farm Forestry Network	Jul 04 to Jul 05	$5,000	PhD project support
Don Hunter	CUT	Student Prize	ASEG	Dec 04	$500	Travel to the SEG Int Exposition, Denver, Colorado
Karen Barovich	AU	Regolith carbonate profile development and association with underlying gold mineralisation. White Dam Prospect, Curnamona Province SA	PIRSA	2005	$5,500	PhD project support
Rob Fitzpatrick	CLW	Travel grant USA trip presenting Keynote address "Global overview on saline inland acid soils"	International Salinity Forum	24-27 April 05	$3,500	Program 3 project – Inland ASS
Karen Hulme	AU	Eric Rudd Memorial Prize for Economic Geology	AU	June 05	$5,000	Travel to Canada to visit biogeochemistry researchers and laboratories.

Photograph: Ryan Noble

Photograph: Ryan Noble

Performance Measures

Performance Measures/Indicators (PIs), along with milestones and outputs, provide a numerical measure of performance against our stated objectives. Our PIs are those itemised in Schedule 6 of the Commonwealth Agreement, for which quantitative measures were developed and presented in the 2001–02 Annual Report. By including those numerical scores from previous years, we now have some time-series charts to develop benchmarks and compare annual performances.

Objectives of the Centre

Broad indicators of progress towards Centre objectives are:

- The Centre will provide the mineral industry with world-class capabilities leading to breakthroughs in exploration in Australia's extensive areas of cover.
- The Centre will produce essential multi-disciplinary knowledge of Australia's regolith areas, package this knowledge in readily useable forms, and ensure that it is transferred into practice in the minerals industry and environmental management.
- The Centre will provide high quality, geoscience-based education for those entering the minerals industry, landcare and environmental realms and provide continuing education for those professionals.
- The Centre will inform and guide decision-makers in Australian and State policy arenas about the relevance and contribution of regolith research to Australia.
- The Centre will increase the number of companies, agencies and institutions using LEME outputs and participating in LEME projects.
- The Centre will attract overseas researchers to work in LEME and encourage visits by LEME staff to counterpart institutions overseas.
- The Centre will encourage requests for LEME collaboration from companies, agencies and institutions overseas.

Objectives of the Centre

Performance Indicator	2001–2002	2002–2003	2003–2004	2004–2005
Number of external research collaborators	47	86	75	80
Number of sponsors and the annual value of sponsorship	13 $756,540	13 $616,000	14 $1,183,000	16 $1,662,000
Number of overseas researchers visiting LEME sites	4	10	10	6
Number of overseas visits by LEME staff	19	7	8	9
Number and value of overseas research projects	1 $27,489	0	0	1 $12,000

This time-series shows we have seen significant growth in the level of external funding, and have sustained a high level of research collaboration with external organisations. Also of note is that we continue to resist the opportunities for conducting research in overseas countries. Whereas we are confident that much of our research can be applied to other countries, Centre Objectives clearly are aimed at addressing the challenges facing Australia.

Quality and Relevance of the Research Programs

To ensure the quality and relevance of its Research Programs, CRC LEME will:

- Develop a best-practice benchmark for the number of articles accepted for publication in leading national and international scientific journals, and in refereed conference proceedings.
- Accept invitations to contribute chapters in books; and to present keynote addresses, papers and workshops at national and international conferences.
- Record the number of eminent scholars choosing to undertake sabbatical visits to LEME centres.
- Recognise the significance of LEME research as measured by the bestowal of honours and awards upon Centre staff.
- Record the number of companies and agencies using LEME-developed protocols for exploration in regolith-dominated terrains.
- Promote LEME innovations in airborne salinity mapping for management and remediation of dryland salinity and in other land-care issues.
- Obtain acknowledgement of the roles played by LEME concepts, methods and technologies in mineral discoveries by exploration and mining companies.
- Obtain acknowledgement of the roles played by LEME concepts, methods and technologies in environmental issues by Australian, state and local government bodies and by environmental and engineering companies.

Quality and Relevance of the Research Program

Performance Indicator	2001–2002	2002–2003	2003–2004	2004–2005
Number of published journal articles per year	54	23	18	40
Number of conference papers presented per year	50	134	186	210
Number of books or chapters in books	20	40	41	28
Other forms of publications includes maps, short course notes, field guides, electronic newsletters	28	21	19	16
Number of LEME Technical Reports released, includes Open File Reports	36	6	10	26
Number of confidential reports, maps	18	9	8	8
Number of keynote addresses given	4	2	6	7
Number of sabbatical leaves taken by overseas personnel at LEME sites	3	2	2	3
Number of awards to LEME researchers and educators	3	8	8	9
Number of professional appointments awarded to LEME researchers and educators	7	5	9	15

This year we have seen a surge in the number of journal publications, conference presentations, and technical reports in the LEME Open File Series. This is a pleasing reflection of the accelerating outputs that we are now delivering from our impressive portfolio of projects. We can expect to see these indicators to grow further in the next three years.

Strategy for Utilisation and Knowledge Transfer of Research Outputs

To realise the benefits flowing from LEME research, the Centre will:

- Record and benchmark the number of technology transfer courses, workshops, public displays and media releases.
- Increase the distribution of open file reports, course notes, manuals, maps, special publications, text books and other materials.
- Ensure that concepts, methods and technologies developed within the Centre are adopted by industry, university and government agencies.
- Record the number of articles published in industry journals.
- Prepare and distribute LEME publications and information documents to companies and organisations in the mineral and environmental industries.
- Actively pursue the development of collaborative research projects with industry and organisations.
- Secure adequate funding from companies, agencies and institutions for Centre projects.

As part of the strategic plan, LEME aims to produce scientific outputs (refereed papers and book chapters, monographs, conference publications, technical reports, short course notes, maps) that total an average of three outputs per full-time-equivalent staff per year. It also aims to increase external revenues from contract research over the life of the Centre.

Strategy for Utilisation and Knowledge Transfer of Research Outputs

Performance Indicator	2001–2002	2002–2003	2003–2004	2004–2005
Number of short courses and workshops	7	11	6	4
Number of media reports and releases	8	9	21	17
Number of items sold (open file reports, manuals, course notes)	120	75	101	119
Number of articles in prospecting magazines	3	1	9	11
Number of reports to sponsors and companies	15	9	13	8
Number of collaborative projects with industry users and user organisations	49	48	56	60
Annual external research income	$782,000	$616,000	$1,183,000	$1,662,000
Number of scientific outputs per FTE staff	2.4	3.4	4.2	4.4
Increase in external revenues from contract research	NA	-21%	+92%	+41%

Here again we see steady growth in the promotional and liaison activity with stakeholders and users of regolith science. The potential outcomes from this promotion activity are described in the chapter on Commercialisation, Technology Transfer and Utilisation.

Education and Training

To enhance the regolith knowledge of current and future geoscientists in Australia, CRC LEME Education and Training program will:

- Maximise the number of postgraduate research scholars undertaking their degrees within the Centre or through universities associated with the Centre, within the constraints of the budget.
- Produce a continuing stream of Bachelor Degree Honours graduates from the Core Participant universities and other universities associated with the Centre.
- Ensure postgraduate research and Honours students have access to generic training courses during their studies in the Centre.
- Allocate an advisor for all postgraduate research and Honours students outside their enrolled university and preferably in a non-university core participant or other external partner.
- Develop a formal Masters by Coursework Degree in Regolith Studies.
- Provide and market professional short courses and workshops to research users and increase awareness of the Centre's research in the community at large.

As part of the strategic plan, CRC LEME aims to produce at least 60 new PhD graduates and 60 Honours graduates throughout the lifetime of the Centre. For the purpose of meeting PIs, we define a LEME student where:

- LEME has given financial support either by way of scholarship or contribution to stipend and operating cost, or
- a LEME in-kind or cash-funded staff has been a primary supervisor on a regolith project that aligns with LEME program objectives.

We are well on our way to achieving this goal.

Education and Training

Performance Indicator	2001–2002	2002–2003	2003–2004	2004–2005
Number of postgraduate students working on LEME research projects	38	51	50	59
Number of MSc and PhD completions, each year/cumulative	1	7/8	7/15	5/20
Number of BSc Honours graduates completing LEME projects	16	11	21	17
Number of BSc Honours students commenced/continuing LEME projects	37	20	10	13
Number of external supervisors of research students	20	12	16	21
Number of student class hours of instruction in Masters by Coursework degrees related to the regolith	80	80	80	80
Number of Honours graduates produced over the lifetime of LEME (incl graduands)	16	27	58	75

Collaborative Arrangements

To ensure that the research and educational programs have access to adequate resources and expertise to meet their objectives, the Centre will:

- Maintain an appropriate mix of staff, in terms of disciplines and function, within the core participants, and across the nodes.
- Develop multi-disciplinary project-based research teams involving staff from several core participants and supporting participants.
- Establish a culture of collaboration between core participants, such that collaboration will continue beyond the life of the Centre.
- Ensure that the mineral industry, environmental agencies and other user groups participate in the functioning of the Centre, including the Board and Advisory Councils, in project generation, support and collaboration, education, technology transfer and application of research findings.
- Develop collaborative projects where overseas researchers participate in Centre research to the benefit of its staff and students.
- Attract leading scientists from overseas for sabbatical study.
- Develop collaboration with appropriate bodies such as other CRCs.
- Increase the extent of PhD and Honours student involvement in research activities.
- Develop and extend an Associate network of Supporting Participants.
- Support the interchange of personnel among different sites within the Centre.

The figures show we have maintained a high level of cooperation through the assembly of multi-disciplinary multi-party research project teams

Collaborative Arrangements

Performance Indicator	2001–2002	2002–2003	2003–2004	2004–2005
Number of Centre-funded projects involving staff from more than one core party	28 (of 30)	27 (of 29)	38 (of 59)	33 (out of 45)
Number of external stakeholders involved in the direction of LEME through the Governing Board and Advisory Councils	14	27	26	22
Number of projects involving international collaborators	6	0	5	1

Resources and Budget

Performance Indicator	2001–2002	2002–2003	2003–2004	2004–2005
Total resources (cash and in-kind excluding CRC Grant)	$17.6M	$16.7M	$19.8M	$17.4M
FTE research staff (excluding students)	73.3	63.1	70.0	63.3
FTE technical and other support staff	11.1	6.35	7.05	6.9

Safety

As part of the Centre strategic plan and safety policy, CRC LEME aims to have a Lost Time Injury Frequency Rate (an industry standard measure) of zero throughout the life of the CRC. There were no reportable incidents or accidents involving LEME staff working in any of the Core Participants in 2004-05.

Financial Information

Photograph: Ian Roach

As at 30 June 2005, all Core Participants met or exceeded their in-kind contribution target defined in the Commonwealth Agreement and the Deed of Release and Variation. The total cash income received for collaborative activities from industry and other users in Year 4 is $1.3M.

The leverage of actual contributed resources to CRC Program funding from the Commonwealth is 6.2:1, for the reporting year.

Actual contributed resources:

- Total Cash from Industry and other users, and from Core Participants: $5.91M
- Total In-Kind resources from participants $14.64M,
- Total contributed cash and in-kind resources: $20.55M
- CRC Program funds: $3.3M.

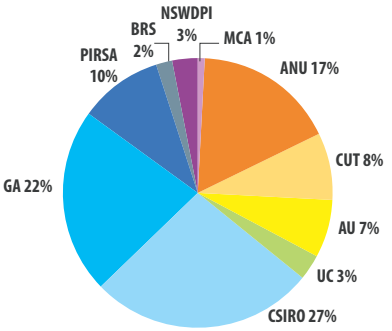
All figures for the reporting year of 2004–05 only.

Financial Reports for 2004–2005

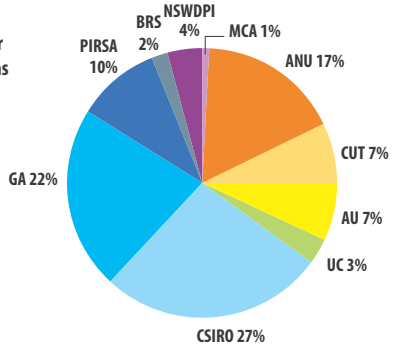
The following statements and accounting policy notes represent the known financial status as at 30 June, 2005.

Core Participant equity positions are summarised as follows:

Core Participant Actual Cumulative Equity as at June 2005 (Years 1-4)



Core Participant Equity as per Commonwealth Agreement as at 30 June 2005 (Years 1-4)



Total External Income

	Year 1 $'000	Year 2 $'000	Year 3 $'000	Year 4 $'000	Cumulative $'000
Budget	765	1,080	1,658	1,869	5,372
Actual	892	811	1,509	1,294	4,506
Variance	127	-269	-149	-575	-866

Significant Accounting Policies

The attached financial statements are prepared specifically for the CRC Secretariat and are presented in a format which enables reporting consistent with the Centre Budget as contained in the Commonwealth Agreement and any subsequent revisions as approved by the CRC Secretariat.

Income

Income is fully credited on invoicing. In general, all income is received by CSIRO, the Centre Agent, and distributed to Core Participants to reimburse expenditure incurred in line with the Centre's Budget.

Expenditure

All Core Participants operate with some form of accrual accounting system. Expenditure is recorded on an accrual basis.

Intellectual property

Any intellectual property, as defined in Clause 9 of the Commonwealth Agreement dated 13 August 2001, which is generated under the projects currently undertaken, is only recognised when capable of being separately identified as being of commercial value.

Capital expenditure/other expenditure commitments

There were no capital expenditure commitments approved and/or entered into as at 30 June 2004, and for which goods had not been receipted at 30 June 2005.

TABLE 1: IN-KIND CONTRIBUTIONS FROM CORE PARTICIPANTS (Dollars in '000s)

	IN-KIND CONTRIBUTIONS					CUMULATIVE TOTAL TO DATE					GRAND SEVEN-YEAR TOTAL			
	YEAR 1 2001–02 Actual	YEAR 2 2002–03 Actual	YEAR 3 2003–04 Actual	YEAR 4 2004–05 Actual	YEAR 4 2004–05 Agreement	Actual	Agreement	YEAR 5 2005–06 Agreement	YEAR 6 2006–07 Agreement	YEAR 7 2007–08 Agreement	Actual Total Seven Years	Revised Agreement Seven Years	Difference Seven Years	Original Agreement Seven Years
THE AUSTRALIAN NATIONAL UNIVERSITY														
SALARIES	474	431	765	798	767	2,468	2,306	809	834	859	4,970	4,808	162	3,127
CAPITAL	-	-	-	-	–	–	–	–	–	–	–	–	–	–
OTHER	1,126	1,169	2,336	2,352	2,383	6,983	6,784	2,512	1,723	1,687	12,904	12,706	199	8,289
TOTAL	1,600	1,600	3,101	3,150	3,150	9,451	9,090	3,321	2,557	2,545	17,874	17,513	361	11,416
UNIVERSITY OF CANBERRA														
SALARIES	314	81	–	–	–	395	343	–	–	–	395	343	53	2,289
CAPITAL	-	-	–	-	–	–	–	–	–	–	–	–	–	–
OTHER	852	329	–	–	–	1,181	1,114	–	–	–	1,181	1,114	68	4,339
TOTAL	1,166	410	–	–	–	1,576	1,456	–	–	–	1,576	1,456	120	6,628
GEOSCIENCE AUSTRALIA														
SALARIES	974	839	814	846	827	3,473	3,172	785	741	764	5,763	5,462	301	5,627
CAPITAL	-	-	–	-	–	–	–	–	–	–	–	–	–	–
OTHER	1,973	1,928	2,457	2,600	2,595	8,958	9,203	2,304	2,012	1,942	15,216	15,461	(245)	14,812
TOTAL	2,947	2,767	3,271	3,445	3,422	12,430	12,375	3,089	2,753	2,706	20,978	20,923	55	20,439
CURTIN UNIVERSITY OF TECHNOLOGY														
SALARIES	329	423	433	486	469	1,671	1,560	483	497	512	3,163	3,052	111	2,694
CAPITAL	-	-	–	-	–	–	–	–	–	–	–	–	–	–
OTHER	469	646	629	765	773	2,509	2,333	788	670	689	4,656	4,480	176	4,126
TOTAL	798	1,069	1,062	1,251	1,242	4,180	3,893	1,271	1,167	1,201	7,819	7,532	287	6,820
ADELAIDE UNIVERSITY														
SALARIES	314	403	400	363	349	1,480	1,415	427	522	538	2,967	2,902	65	2,868
CAPITAL	-	–	–	-	–	–	–	–	–	–	–	–	–	–
OTHER	373	626	753	728	712	2,480	2,450	813	691	710	4,694	4,664	30	4,565
TOTAL	687	1,029	1,153	1,091	1,061	3,960	3,865	1,240	1,213	1,248	7,661	7,566	95	7,433
PRIMARY INDUSTRIES & RESOURCES, SOUTH AUSTRALIA														
SALARIES	506	523	551	594	567	2,174	1,915	584	601	619	3,978	3,719	259	3,161
CAPITAL	-	-	–	-	–	–	–	–	–	–	–	–	–	–
OTHER	1,984	521	584	627	600	3,716	3,478	617	634	652	5,619	5,381	238	4,651
TOTAL	2,490	1,044	1,135	1,220	1,167	5,889	5,393	1,201	1,235	1,271	9,596	9,100	496	7,812
BUREAU OF RURAL SCIENCES														
SALARIES	193	16	–	–	–	209	208	–	–	–	209	208	1	1,563
CAPITAL	-	-	–	-	–	–	–	–	–	–	–	–	–	–
OTHER	139	12	–	–	–	151	150	–	–	–	151	150	1	1,126
TOTAL	332	28	–	–	–	360	358	–	–	–	360	358	2	2,689
NEW SOUTH WALES DEPARTMENT OF PRIMARY INDUSTRIES														
SALARIES	224	235	223	318	312	1,000	983	364	373	382	2,119	2,102	17	1,783
CAPITAL	-	-	-	-	–	–	–	–	–	–	–	–	–	–
OTHER	29	30	63	76	75	198	195	81	83	84	446	443	3	228
TOTAL	253	265	286	393	387	1,197	1,178	445	456	466	2,564	2,545	19	2,011
MINERALS COUNCIL OF AUSTRALIA														
SALARIES	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CAPITAL	-	-	–	-	–	–	–	–	–	–	–	–	–	–
OTHER	–	–	35	35	35	70	70	35	35	35	175	175	–	–
TOTAL	–	–	35	35	35	70	70	35	35	35	175	175	–	–
CSIRO														
SALARIES	1,333	1,398	1,169	1,285	1,263	5,185	4,772	1,144	1,202	1,263	8,794	8,381	413	7,670
CAPITAL	-	-	-	-	-	–	–	–	–	–	–	–	–	–
OTHER	2,559	2,457	2,511	2,772	2,603	10,299	10,285	2,405	1,904	1,987	16,595	16,581	14	21,026
TOTAL	3,892	3,855	3,680	4,058	3,866	15,485	15,057	3,549	3,106	3,250	25,390	24,962	428	28,696
SUPPORTING CONTRIBUTIONS														
SALARIES	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CAPITAL	-	-	-	–	–	–	–	–	–	–	–	–	–	–
OTHER	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TOTAL	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TOTAL IN-KIND CONTRIBUTIONS														
SALARIES	4,661	4,349	4,355	4,689	4,554	18,054	16,673	4,596	4,770	4,937	32,356	30,976	1,381	30,782
CAPITAL	–	–	–	–	–	–	–	–	–	–	–	–	–	–
OTHER	9,504	7,718	9,368	9,954	9,776	36,544	36,062	9,555	7,752	7,786	61,637	61,154	483	63,162
GRAND TOTAL (IN-KIND)	14,165	12,067	13,723	14,643	14,330	54,598	52,735	14,151	12,522	12,722	93,993	92,130	1,864	93,944

TABLE 2: CASH INCOME AND EXPENDITURE (Dollars in '000s)

	ACTUAL					CUMULATIVE TOTAL TO DATE					GRAND SEVEN-YEAR TOTAL			
	YEAR 1 2001–02 Actual	YEAR 2 2002–03 Actual	YEAR 3 2003–04 Actual	YEAR 4 2004–05 Actual	YEAR 4 2004–05 Agreement	Actual	Agreement	YEAR 5 2005–06 Agreement	YEAR 6 2006–07 Agreement	YEAR 7 2007–08 Agreement	Total Seven Years	Revised Agreement Seven Years	Difference Seven Years	Original Agreement Seven Years
ANU	100	150	200	200	200	650	650	200	100	100	1,050	1,050	–	700
CURTIN UNI	100	100	100	100	100	400	400	100	100	100	700	700	–	700
ADELAIDE UNI	100	100	100	100	100	400	400	100	100	100	700	700	–	700
UNI OF CANBERRA	100	50	-	–	–	150	150	–	–	–	150	150	–	700
CSIRO	150	100	150	200	200	600	600	200	100	100	1,000	1,000	–	750
GEOSCIENCE AUST	100	150	100	100	100	450	450	100	100	100	750	750	–	700
PIRSA	–	–	-	100	100	100	100	100	100	100	400	400	–	–
BRS	810	–	-	–	–	810	810	–	–	–	810	810	–	3,794
NSW DPI	250	250	250	100	100	850	850	100	50	–	1,000	1,000	–	1,400
MCA	100	100	105	80	80	385	380	80	40	–	505	500	5	300
TOTAL CASH FROM PARTICIPANTS	1,810	1,000	1,005	980	980	4,795	4,790	980	690	600	7,065	7,060	5	9,744
Supporting Participants	–	300	–	141	141	441	441	10	–	–	451	451	-	450
OTHER CASH														
Non Participants	–	–	-	-	400	–	1,900	–	–	–	–	1,900	(1,900)	1,900
External Grants	–	–	-	-	–	–	–	–	–	–	–	–	–	–
Contract Research	696	599	1,286	1,075	800	3,656	2,100	900	1,325	1,100	6,981	5,425	1,556	5,100
Commercialisation	–	–	-	-	520	–	1,025	640	640	640	1,920	2,945	(1,025)	2,945
Education	86	17	24	33	120	160	273	120	120	120	520	633	(113)	633
Interest Income	110	195	199	187	29	691	74	15	15	15	736	119	617	105
TOTAL	892	811	1,509	1,435	1,869	4,647	5,372	1,675	2,100	1,875	10,297	11,022	(725)	10,683
CRC GRANT	2,754	3,300	3,300	3,300	3,300	12,654	12,654	3,300	2,700	1,546	20,200	20,200	–	20,200
TOTAL CRC CASH CONTRIBUTION (T2)	5,456	5,411	5,814	5,715	6,290	22,396	23,257	5,965	5,490	4,021	37,872	38,733	(861)	41,077
Cash carried over from previous year (Note a)	777	2,504	3,566	3,492	3,566	-	-	3,071	2,437	2,692	-	-	-	-
Less Unspent Balance	2,504	3,566	3,492	3,087	3,071	-	1,830	2,437	2,692	1,241	-	-	-	-
TOTAL CASH EXPENDITURE	3,729	4,349	5,888	6,120	6,785	20,086	21,427	6,599	5,235	5,472	37,392	38,733	(1,341)	40,074
ALLOCATION OF CASH EXPENDITURE BETWEEN HEADS OF EXPENDITURE														
SALARIES	1,916	1,898	2,541	2,794	3,166	9,149	10,529	2,913	1,254	1,162	14,478	15,858	(1,380)	17,238
CAPITAL	–	245	–	190	206	435	451	–	–	–	435	451	(16)	467
OTHER	1,813	2,206	3,347	3,136	3,413	10,502	10,447	3,686	3,981	4,310	22,479	22,424	55	22,369

Note a Balance brought forward at 1.7.01 relates to excess funds from CRC LEME 1 brought into CRC LEME 2

TABLE 3: SUMMARY OF RESOURCES APPLIED TO ACTIVITIES OF CRC (Dollars in '000s)

	ACTUAL					CUMULATIVE TOTAL TO DATE					GRAND SEVEN-YEAR TOTAL			
	YEAR 1 2001–02 Actual	YEAR 2 2002–03 Actual	YEAR 3 2003–04 Actual	YEAR 4 2004–05 Actual	YEAR 4 2004–05 Agreement	Actual	Agreement	YEAR 5 2005–06 Agreement	YEAR 6 2006–07 Agreement	YEAR 7 2007– 08 Agreement	Total Seven Years	Revised Agreement Seven Years	Difference Seven Years	Original Agreement Seven Years
GRAND TOTAL (IN-KIND) From Table 1 (T1)	14,165	12,067	13,723	14,643	14,330	54,598	52,735	14,151	12,522	12,722	93,993	92,130	1,864	93,944
GRAND TOTAL (CASH EXPENDITURE) from Table 2 (T3)	3,729	4,349	5,888	6,120	6,785	20,086	21,427	6,599	5,235	5,472	37,392	38,733	(1,341)	40,074
TOTAL RESOURCES APPLIED TO ACTIVITIES OF CENTRE (T1 &T3)	17,894	16,416	19,611	20,764	21,115	74,685	74,162	20,750	17,757	18,194	131,386	130,863	523	134,018
ALLOCATION OF TOTAL RESOURCES APPLIED TO ACTIVITIES OF CENTRE BETWEEN HEADS OF EXPENDITURE														
TOTAL SALARIES (CASH AND IN-KIND)	6,577	6,247	6,896	7,483	7,720	27,203	27,202	7,509	6,024	6,099	46,835	46,834	1	48,020
TOTAL CAPITAL (CASH AND IN-KIND)	–	245	–	190	206	435	451	–	–	–	435	451	(16)	467
TOTAL OTHER (CASH AND IN-KIND)	11,317	9,924	12,715	13,091	13,189	47,047	46,509	13,241	11,733	12,096	84,116	83,578	538	85,531

TABLE 4: ALLOCATION OF RESOURCES BETWEEN CATEGORIES OF ACTIVITIES

PROGRAM	RESOURCE USAGE			
	CASH ('000s)	IN-KIND ('000s)	CONTRIBUTED (IN-KIND) STAFF (FTEs)	CRC FUNDED RESEARCH STAFF (FTEs)
RESEARCH	4,051	12,615	41.13	23.75
EDUCATION	1,008	1,290	4.00	1.40
EXTERNAL COMMUNICATIONS	-	-	-	-
COMMERCIALISATION/TECH. TRANSFER	-	-	-	-
ADMINISTRATION	1,061	738	-	-
TOTAL	6,120	14,643	45.13	25.15

OTHER NOTES

Costing of contributions

Costing of salaries and on-costs contributed by the Core Participants is as reported to LEME by each Core Participant. In no case does the reported amount of salary on-costs exceed the agreed valuation of on-costs shown in Schedule 4 of the Commonwealth Agreement, viz:

Core Participant	Salary on-costs as a multiple of base salary
The Australian National University	0.2889
Curtin University of Technology	0.2806
Adelaide University	0.2942
CSIRO (CSS Superannuation)	0.3185
CSIRO (PSS Superannuation)	0.2205
Geoscience Australia	0.2050
Primary Industries & Resources, SA	0.2590
NSW Dept. Of Primary Industries	0.3300
Minerals Council of Australia	N/A

The in-kind contributions of infrastructure overhead costs have been costed as multiples of the base salaries of in-kind and LEME funded staff, in accordance with Schedule 4 of the Commonwealth Agreement and the Deed of Release and Variation, viz:

Core Participant	Infrastructure overheads as a multiple of base salary	
	For in-kind staff	For CRC funded staff
The Australian National University	2.3656	2.3656
Curtin University of Technology	1.2800	1.2800
Adelaide University	1.5400	1.5400
CSIRO	1.3400	1.3400
Geoscience Australia	2.1500	2.1500
Primary Industries & Resources, SA	1.2550	1.2550
NSW Dept. Of Primary Industries	0.1700	0.1700
Minerals Council of Australia	N/A	N/A

The Budget and Financial report was prepared with the assistance of the Centre Accountant, John Mills.

Photograph: Patrice de Caritat

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Independent audit report to the Cooperative Research Centres Program, Department of Education, Science and Training representing the Commonwealth in respect of Cooperative Research Centre for Landscape Environments and Mineral Exploration

Audit opinion

In our opinion, the financial information set out in Tables 1 to 3 for the Cooperative Research Centre for Landscape Environments and Mineral Exploration presents fairly, in accordance with Australian Accounting Standards and the provisions of the Commonwealth Agreement dated 13 August 2001 (specifically those provisions referred to in the CRC Program Guidelines for Annual Reports June 2005, section 17), the sources of funding and the application of that funding for the year ended 30 June 2005.

This opinion must be read in conjunction with the rest of our audit report.

Scope

The financial information and the responsibility of board of management

The financial information comprises the statement of in-kind contribution from partners, the statement of cash income and expenditures, and the summary of resources applied to activities of the centre for the Cooperative Research Centre for Landscape Environments and Mineral Exploration (the CRC LEME) for the year ended 30 June 2005. It has been prepared for distribution to the Cooperative Research Centres Program, Department of Education, Science and Training (the Commonwealth) for the purpose of fulfilling the requirements of the Commonwealth Agreement dated 13 August 2001 ("the Agreement").

The board of management is responsible for the preparation and presentation of the financial information in accordance with the Agreement. This includes responsibility for the maintenance of adequate accounting records and internal controls that are designed to prevent and detect fraud and error, and for the accounting policies and accounting estimates inherent in the financial information.

The board of management have determined that the accounting policies used, including the basis of accounting are appropriate to meet the requirements of the Agreement and the needs of the Commonwealth.

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Audit approach

We conducted an independent audit of the financial information in order to express an opinion to the Commonwealth. No opinion is expressed as to whether the accounting policies used are appropriate to the needs of the Commonwealth. We disclaim any assumption of responsibility for any reliance on this audit report or on the financial information to which it relates to any person other than the Commonwealth, or for any purpose other than that for which they were prepared.

Our audit was conducted in accordance with Australian Auditing Standards. The nature of an audit is influenced by factors such as the use of professional judgement, selective testing, the inherent limitations of internal control, and the availability of persuasive rather than conclusive evidence. Therefore, an audit cannot guarantee that all material misstatements have been detected. For further explanation of an audit, visit our website http://www.pwc.com/au/financialstatementaudit.

We performed procedures to assess whether in all material respects the financial information presents fairly, in accordance with the Agreement and the accounting policies, a view which is consistent with our understanding of the CRC LEME's sources of funding and the application of funding. These policies do not require the application of all Accounting Standards and other mandatory financial reporting requirements in Australia.

We formed our audit opinion on the basis of these procedures, which included:

- examining, on a test basis, information to provide evidence supporting the financial information, and
- assessing the reasonableness of significant accounting estimates made by the board of management.

Our procedures include reading the other information included with the financial report to determine whether it contains any material inconsistencies with the financial report.

While we considered the effectiveness of management's internal controls over financial reporting when determining the nature and extent of our procedures, our audit was not designed to provide assurance on internal controls.

Our audit did not involve an analysis of the prudence of business decisions made by the board of management.

Independence

In conducting our audit, we followed applicable independence requirements of Australian professional ethical pronouncements.

PricewaterhouseCoopers

PricewaterhouseCoopers

S.T. Maher

S T Maher
Partner

Perth
24 August 2005

Glossary*

Acid sulfate soils – soils characterised by low pH (<3.5), deriving their acidity from the presence of oxidised sulfur

Aeolian – pertaining to wind; said of rocks, soil and deposits whose constituents were transported by the wind, or of sedimentary structures, erosion and deposition accomplished by the wind

Aerobic – requiring or utilising free oxygen in air for metabolic purposes

Alluvial – said of a placer formed by the action of running water; also, said of the valuable mineral (gold or diamond) associated with an alluvial placer

Anaerobic – capable of living without free oxygen

Aquifer – a permeable layer carrying accessible water

Base metals – a term for copper, nickel, lead and zinc, often considered as a group because of their long history of use

Basement – a complex unit, generally of igneous and metamorphic rocks, unconformably overlain by sedimentary strata

Breccia – a composite rock consisting of angular fragments of stone, cemented together by some matrix, such as calcium carbonate

Calcrete – used broadly to refer to regolith carbonate accumulations, forming more or less-well cemented aggregates composed largely of calcium carbonate

Colluvial – pertaining to colluvium – heterogeneous material of any particle size, generally composed of soil and/or rock fragments, accumulated on the lower parts of slopes, transported there by gravity, soil creep, sheet flow, rainwash or mudflow

CHIM – Electro-chemical method of prospecting using direct electric current that attracts metal iron onto the cathode.

Cover – see Regolith

Craton – a relatively immobile section of the Earth's crust, generally of large size

Duricrust – regolith material that has been hardened by a cement occurring at or near the surface

Facies – general appearance, composition or nature of one part of a rock body as contrasted with another. A lateral subdivision of a stratigraphic unit

Felsic – of or pertaining to such light-coloured minerals as the feldspars, the feldspathoids, quartz, and muscovite, or to rocks containing a high proportion of these or similar minerals

Ferruginous – pertaining to, or containing iron

Goethite – Common, yellow-brown iron oxide mineral

Hematite – Black/Blue-Black or red mineral, hexagonal close-packed structure

Hyperspectral – having many narrow spectral bands, used in remote sensing

In situ – in its original place

kaolinite – Clay mineral

Karst – terrain with distinctive characteristics of relief and drainage arising primarily from a higher degree of rock solubility in natural waters than is found elsewhere

Lacustrine – pertaining to, produced by, or formed in a lake

Lag – Surface accumulation of divers materials, eg reolith, rock.

Mafic – rock or mineral of high magnesium and iron content

Magnetite – Mineral of the spinel family, strongly ferromagnetic

Mahegmite – Magnetic mineral formed by the oxidation of magnetite

Morphology – shape, form, external structure or arrangement

Nanoparticulate – made up of particles with dimensions of a few nanometres (10^{-9} m)

Palaeo – a prefix used to relate subjects to earlier periods of time, eg. palaeoclimatology, palaeodrainage Pathfinder elements of little intrinsic interest that aid in the discovery of valued minerals

Pedology – the study of soil morphology, genesis and classification

Permeability – the capacity of a rock for transmitting fluid

Placer – a mineral deposit formed by the accumulation of weathering resistant materials, usually in alluvium or on a shore

Playa – vegetation-free, flat area at the lowest part of an undrained desert basin, underlain by stratified clay, silt or sand, and commonly by soluble salts, dry most of the time

Porosity – the amount of pore space present, expressed as a percentage of the total volume of the material

Porphyry – igneous rock containing conspicuous phenocrysts (large crystals, generally of feldspar) in a fine-grained groundmass

Radiometric – of, pertaining to, or involving the measurement of radioactivity or ionising radiation

Regolith – the entire unconsolidated or secondarily re-cemented cover that overlies more coherent bedrock, that has been formed by weathering, erosion, transport and/or deposition of older material

Saprolite – weathered rock in which the fabric of the parent rock is retained

Surficial – at the surface, especially the surface of the earth

Tdhem – time domain helicopter electromagnetic

Transect – a line or a belt of land along which a survey is made; a survey of this kind

Traverse – a line surveyed across a plot of ground

Ultramafic – of an igneous rock: composed chiefly of mafic minerals

* The principal source for this glossary is *The Regolith Glossary – surficial geology, soils and landscapes*, edited by Richard A. Eggleton, published in 2001 by CRC LEME.

Acronyms

3D – three-dimensional

4D – four-dimensional (spatial + time)

4WD – four-wheel drive

AEM – airborne electromagnetic

AFFA – Australian Government Department of Agriculture, Fisheries and Forestry

AGC – Australian Geological Convention

AGES – Annual Geoscience Exploration Seminar

AGIA – Australian Geoscience Information Association

AIG – Australian Institute of Geoscientists

AusIMM – Australasian Institute of Mining and Metallurgy

AINSE – Australian Institute of Nuclear Science and Engineering

AJES – Australian Journal of Earth Sciences

AM – Aeromagnetic

AMEC – Association of Mining and Exploration Companies

AMIRA – Australian Mineral Industries Research Association (International)

AMT – Audio-magnetotellurics

ANU – The Australian National University

ANU RSES – ANU Research School of Earth Sciences

ANSTO – Australian Nuclear Science and Technology Organisation

ANZGG – Australia New Zealand Geomorphology Group

APA – Australian Postgraduate Award

APAI – Australian Postgraduate Award (Industry)

ARC – Australian Research Council

ARRC – Australian Resources Research Centre

ASCILITE – Australasian Society for Computers in Learning in Tertiary Education

ASEG – Australian Society of Exploration Geophysicists

ASS – Acid Sulfate Soils

ASSS – Australian Society of soil Science Inc

ATSE – Academy of Technological Sciences and Engineering

AU – Adelaide University

BRS – Bureau of Rural Sciences

BRS – bacterial sulfate reduction

CALM – Western Australian Department of Conservation and Land Management

CDI – Conductivity Depth Inversion

CD – Compact Disc

CEM – CSIRO Exploration and Mining

CLW – CSIRO Land and Water

CMA – Catchment Management Authority

CNRM SA – Centre for Natural Resource Management South Australia

COGEO-ENVIRONMENT – International Union of Geological Sciences Commission on Geological Sciences for Environmental Planning

CRC – Cooperative Research Centre

CRC PBMDS – CRC for Plant-based Management of Dryland Salinity

CRC SI – CRC for Spatial Information

CRM – chemical remnant magnetism

CSIRO – Commonwealth Scientific and Industrial Research Organisation

CUPS – Curtin University Postgraduate Scholarship

CUT – Curtin University of Technology

DAWA – Department of Agriculture, Western Australia

DNA – Deoxyribonucleic Acid

DEH – Department for Environment, Heritage in South Australia

DEM – Digital Elevation Model

DIPNR – NSW Dept of Infrastructure Planning and Natural Resources

DLWC – NSW Dept of Land and Water Conservation

DNRM – Department of Natural Resources and Mines Queensland

DTM – Digital Terrain Mapping

DWLBC – Department of Water, Land and Biodiversity Conservation (South Australia)

EGU – European Sciences Union

EKS – Electrokinetic Seismic

EM – Electromagnetic

FDHEM – Frequency Domain Helicopter Electro-Magnetics

FTE – Full Time Equivalent

GA – Geoscience Australia

GAB – Great Artesian Basin

GFS – Groundwater Flow Systems

GIS – Geographic Information System

GPS – Global Positioning System

GSWA – Geological Survey of Western Australia

HEM – Helicopter Frequency Domain Electromagnetic

HGU – Hydrogeomorphic Units

HRU – Hydrogeomorphic Response Unit

ICPMS – Inductively Coupled Plasma Mass Spectrometry

IGCP – International Geological Correlation Program

IGU – International Geographical Union

IP – Induced Polarisation

IP – Intellectual Property

IPRS – International Postgraduate Research Scholarship

IUGG – International Union of Geodesy and Geophysics

IUGS – International Union of Geological Sciences

IUSS – International Union of Soil Sciences

LA – Laser Ablation

LEME – Cooperative Research Centre for Landscape Environments and Mineral Exploration

MCA – Minerals Council of Australia

MDBC – Murray-Darling Basin Commission

MERIWA – Minerals & Energy Research Institute of WA

MINEX – Minerals Exploration

MTEC – Minerals Tertiary Education Council

NAPSWQ – National Action Plan (for Salinity and Water Quality)(NAP for short)

NGTN – National Geoscience Teaching Network

NHT – National Heritage Trust

NSW DPI – NSW of Primary Industries (formerly Mineral Resources)

NLWRA – National Land and Water Resources Audit

NMR – Nuclear Magnetic Resonance

NRM – Natural Resource Management

NTGS – Northern Territory Geological Survey

OSL – Optically Stimulated Luminescence dating method

PESA – Petroleum Exploration Society of Australia

PIRSA – Primary Industries and Resources South Australia

pmdCRC – CRC for Predictive Mineral Discovery

PDF – Portable Document Format

PIMA – Portable Infrared Minerals Identifier

PURSL – Productive Use and Rehabilitation of Saline Lands

REE – Rare Earth Elements

RIRDC – Rural Industries Research and Development Corporation

RNA – Ribonucleic acid

RTMAP – Regolith Terrain Mapping

SEG – Society of Economic Geologists

SEG – Society of Exploration Geophysicists

SEGH – International Society of Environmental Geochemistry and Health

SEM – Scanning Electron Microscopy/Microscope

SHRIMP – Sensitive High Resolution Ion Microprobe

SIS – Salt Interception Scheme

SMMSP – Salinity Mapping and Management Support Project

TSA – The Spectral Assistant (computer software)

TSG – The Spectral Geologist (computer software)

TEM – Transient Electro-Magnetics

TIMS – Thermal Ionisation Mass Spectrometry

UC – University of Canberra

UNSW – University of New South Wales

UWA – The University of Western Australia

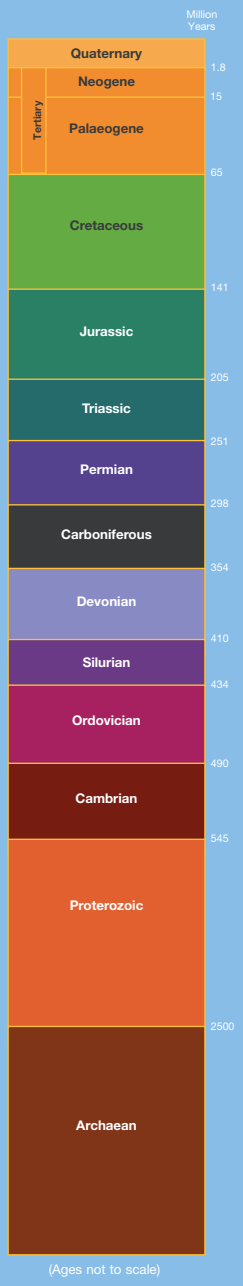
VHMS – Volcanic hosted massive sulphide (deposit)

VSWIR – Visual to Shortwave Infra red

WRI – Water-rock interaction

XRD – X-Ray Diffraction

XRF – X-Ray Fluorescence



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