CRCLEME

Cooperative Research Centre for
Landscape Environments
and Mineral Exploration

Annual Report 2003–2004

CRC

Established and supported
under the Australian
Government Cooperative
Research Centres Program

Contents

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.

Photograph: Ian Robertson

Regolith **is the surface 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.**

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 Industries
- Primary Industries and Resources South Australia
- The University of Adelaide

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2. Executive Summary

HIGHLIGHTS

- Groundwater geochemistry characterised by high content of isotopically light sulphur is an effective exploration tool for basemetals in thick transported regolith.
- The functional molecular structure of extracted DNA from microbes that dissolve and precipitate gold in regolith is close to identification.
- The first calcrete layer above the insitu silcrete layer is the optimum sampling medium, irrespective of state of burial, exhumation or degradation.
- Geochemical fractionation in redistributed ferruginous lags changes the suite of ore-bearing and pathfinder elements during the goethite-maghemite maturation process.
- Orientation biogeochemical studies show that anomalous gold, arsenic, copper and zinc report in leaves, twigs and bark of certain species of gumtree.
- Regolith-landform maps are being increasingly used to guide geochemical exploration, and provide the platform for new three-dimensional modelling.
- Microanalytical techniques map hydromorphic gold particles in transported regolith above a gold deposits.
- Regolith-landform models in the Eucla Basin identify palaeochannels with heavy mineral sand potential.
- New portable hyperspectral analyser identifies transported regolith and hydrothermal alteration in complex regoliths.
- New constrained inversion techniques integrating AEM, geology and borehole data, deliver spectacular results at Riverland and Lower Balonne.
- Groundwater investigations in southwest WA using seismo-electric method clearly imaged hydrogeological boundaries down to 120 metres.
- Sub audio magnetics successfully used for high definition regolith mapping which helps identify new gold targets at Songvang and Kambalda.
- New algorithms to minimise noise in ground surveys using electrical and electromagnetic methods will assist exploration and geo-technical surveys in areas of noisy infrastructure.
- Five Open File Reports and 105 regolith case histories are released on the LEME website.
- The student program supported 47 PhD students, and has 69 Honours graduates or graduands.
- Monograph published on proceedings for three Regolith Symposia held in November in Canberra, Adelaide and Perth.
- CRC LEME presented the *Minerals Exploration Seminar* in Perth, attracting 100 delegates.
- No lost time injuries or dangerous incidents were recorded during the reporting period.

Chairman's Report

George A Savell
Independent Chairman

It is appropriate to record, on behalf of the Board of both LEME 1 and LEME 2, our thanks to Dr Ross Fardon, for his contribution to both CRCs over a lengthy period. He relinquished the Chair to pursue his other business interests. We wish him well in these endeavours.

The content of my Report, therefore, covers the period November, 2003 to June, 2004 – the period during which I have been Chair of LEME 2.

CRC LEME is in excellent operational shape; working productively across five program areas and delivering on its set objectives.

An impressive team spirit prevails under the guidance of the program leaders which augurs well for the future. Indeed the CRC is well served by committed, professional team leaders dedicated to producing worthwhile, useable outcomes.

During 2004 there was a fundamental shift in Federal Government policy applying to CRCs.

At the June CRCA Conference held in Adelaide the Federal Minister for Science, the Hon Peter McGauran, delivered a powerful message that Government was placing greater emphasis on funding CRCs which were designed to achieve useable, commercial benefits. This can be interpreted to mean delivery of outcomes which will stimulate economic growth, export income, employment opportunities and benefit to the economy generally. In short, it will no longer be sufficient to demonstrate public good in bids for new CRCs, thus raising the entrance bar for CRCs such as LEME to be funded in future. This has serious implications for CRCs which seek refunding in terms of their objectives and outcomes.

One of CRC LEME's prime overarching objectives is to demonstrate the essential worth of Regolith Science in applications outside of its traditional fields. Progress to achieve this is being made in Natural Resource Management where the worth of this science is slowly being recognised.

The CRC is strategically positioned, literally astride the two great Australian primary industries – Mining and Agriculture. These highly productive industries are the natural recipients of LEME's scientific output and are able to readily flow the science into commercial applications.

An area which CRC LEME has been traditionally weak is profile building and public relations.

An example is the failure to connect with grass-root farmers, few of whom know anything of our work or how regolith science can help them with dryland salt, acid drainage and acid sulphate soil problems.

The CRC is now coming to terms with this facet of its business through the generation of articles in the Farm Weekly, The Countryman and Australia's Mining Monthly magazines. Strategic alliances with agricultural organisations are being formed. There is a long way yet to go before each and every farmer is routinely aware of the benefits of regolith science. When that happens our objectives will have been achieved.

The CRC's close connection with the minerals industry appears to be down-trending as a result of fundamental changes in the structure of the industry in recent years and the way big corporations conduct mineral exploration. The never ending round of takeovers, mergers and restructuring, the commercial emphasis on short-term results and shareholder returns has lessened emphasis on scientific research as a vital component of the long term commercial equation.

The fact that LEME's programs, which aim to better understand the mechanics and the processes which occur in the regolith, seem not sufficient enticement to attract substantial, long-term funding support is of real concern.

This is a particularly short-sighted approach which the mining industry will live to regret. Australia's future mining industry will rely on the identification of well hidden ore bodies. Regolith science provides the best chance of improving our 'mine finding' capacity which would enhance a future viable national mining industry.

Having said that, however, LEME's programs in mineral exploration are robust and are still well supported by some companies with long sight and a belief in the worth of research to their vision.

One very big immediate challenge confronts us and that is the future of the CRC itself.

CRCs are finite beasts with defined seven year lives. In this period they are expected to provide worthwhile results, be capable of renewal or, conversely, disappear at the end of the funding term.

CRC LEME is entering middle age and must now actively consider its future, if indeed it is judged to have a future beyond its current term.

This process is usually crystallised around the five year review, which occurs in 2006 for CRC LEME. By that time we must have a clear plan for either renewal, transition into a different form or an exit strategy to cleanly terminate the operation.

The LEME Board is addressing this issue in its broadest context and will have completed its deliberations well before the 5th year review in 2006.

Finally, it is my pleasant duty to thank the LEME Board for their efforts during the year, and the CEO, Dr Dennis Gee and his very able staff, team leaders and researchers for their valuable input.

The underlying strength of our CRC is this team effort which underpins our whole operation. Its importance cannot be overstated.

Chief Executive Officer's Report

R Dennis Gee

The year 2003-04 was everything it should have been for a successful CRC in the middle year of its second renewal. Our science is surging, and the management problems of the past are largely behind us. This satisfactory state was reflected in the positive outcomes of the Second Year Review, in which we received strong endorsement for the quality, relevance and delivery of our research. We were also complimented on the achievements made in the aftermath of some organisational difficulties of the first two years.

Finalising the Deed of Variation to reflect structural changes of Years One and Two seems to have been a never-ending process due to the ever-changing details of the in-kind resources offered by core parties. The process was also set back by proposed variations in cash contributions from some parties, the resolutions of which will be satisfactory, but must straddle the transition into the ensuing financial year.

The Review noted the potential for a lingering legacy of tightness in cash and in-kind resources. However I am confident with the resources at hand, and the expected growth in external funding, we can continue to effectively address our research priorities, and achieve the breakthroughs expected of us.

A simple breakdown of expenditures in 2003-04 shows $2.54m on salaries ($1.9m previous corresponding period), $1.08m on the student program ($0.54m), and $1.89m on research operating ($1.91m). External income tied to projects was $1.18m ($0.81m). The three year cash flow forecast shows we can sustain these levels of project funding from Centre funds for the out years of LEME, which will be augmented by external funds tied to projects.

In the latter part of the year we saw clear indications of substantial increases in committed external funding for a whole range of natural resource management (NRM) issues. This will manifest itself more strongly in the ensuing years. This increase is spread across all core programs, although salinity and environmental research is the business growth sector, despite the procedural difficulties of securing National Heritage Trust funds. These funds were specifically set aside for research in the NRM sector, but the decision by the Australian government to devolve disbursements to state and local agencies has created a difficult process.

To our credit, research aimed at injecting regolith science into environmental issues has blossomed, based mainly on the previously implemented tactic of engaging NRM stakeholders through contracts of work. This has successfully demonstrated our expertise, credibility and research capability. With the acceptance of the value of regolith science in NRM, we are now able to expand into more strategic research on processes related to regolith-water-salt interactions. We expect the current balance of contractual services and strategic research will continue.

The Riverland project was a stand-out example of the application of regolith science. Here we enjoyed the synergies of an area-specific project, technology developments, generic modelling – and most pleasingly – student research. This project pin-pointed high-saline discharges into the Murray River, and identified preferred areas for irrigation recharge which would ameliorate discharges. This is just one of several projects demonstrating substantial and quantifiable cost benefits for relatively modest research costs. We also made advances in geophysical interpretations of regolith architecture, understanding salt stores in and above and below the watertable, and regolith controls on groundwater flow models. This knowledge is applicable throughout the Murray-Darling Basin. New initiatives are being developed in the agricultural lands of southwestern Western Australia, where salinity and soil degradation issues are different, but the generic processes are the same.

There were significant changes in Program Leaders, triggered by the semi-retirement of Keith Scott, and return to the workface by Colin Pain. I thank those two colleagues for their excellent contributions to LEME management and research. Ravi Anand (CSIRO Exploration and Mining) shifted to lead the program on Mineral Exploration in Areas of Cover. Lisa Worrall (Geoscience Australia) came into LEME to lead Regolith Geoscience. Likewise, Steve Rogers rejoined LEME from CSIRO Land and Water to lead the revamped program on Environmental Applications of Regolith Geoscience. These new leaders were emplaced in time for them to participate in the 2004 round of project reviews, leading to the budget and portfolio of projects for the following year. As a result we continue to develop a range of multidisciplinary projects that involve many nodes that focus upon our research priorities.

Mineral exploration activity certainly picked up in 2003-04, but with the continuing emphasis on the 'bottom line' by the major companies, funds for research are still an order of magnitude lower than they were in the halcyon exploration days of the mid 1990s. Nevertheless we have engaged strongly with many mineral explorers, especially juniors. This has been done by the dual tactics of demonstrating capability by seed funding specific on-site projects with a view to evolution into industry-funded projects; as well as promotion of regolith applications across the spectrum of mineral explorers.

Regolith science still has a vital part to play in mineral exploration and we expect incremental breakthroughs to come in understanding metal mobility, especially in areas of transported regolith. Our three research priorities are; three-dimensional regolith architecture; understanding chemical, hydrological, mineralogical, physical and biological processes in regolith; and

Executive Summary

Photograph: Ian Robertson

dynamics of regolith processes determined by dating events. This year a strong biological theme has been introduced, involving the roles of vegetation, bioturbation and microbial transformations in metal mobility.

This year we instituted the *CRC LEME Minerals Brief* – a quarterly electronic newsletter succinctly outlining research results of relevance to mineral explorers. It goes straight to the desks of some 500 mineral explorers in Australia. The annual Mineral Exploration seminar in Perth, aimed at conveying the results of LEME research to mineral explorers, was again well attended.

The format of our Regolith Symposia continues to evolve and improve. These were staged in November in the three nodes – Canberra, Adelaide and Perth. This series is about developing and sharing the 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. But we also recognise that specific technically-based campaigns, focussed directly on our immediate stakeholders, are required to effectively promote the application of our science.

Our Education and Training Program received special praise from the Second Year Review panel. This is a compliment to the developmental work of our previous program leader – Prof Pat James. 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 requirements of the country. In 2003-04 we had 20 Honours students and 47 PhD students within the Student Program. Their research topics are closely integrated with core research priorities, and our students are making a major contribution to our objectives. Dr Steve Hill (AU) took over the leadership of this Program from Assoc Prof Pat James in April 2004.

A new participating agreement has been executed with the Minerals Tertiary Education Council (MTEC), to provide modular training courses to industry and graduates out till the end of Year 6. CRC LEME is clearly a lead player in the MTEC program.

The LEME website – http://crcleme.org.au – is becoming an increasingly important outlet for promulgating our activities and products. Together with the intranet, it is now a large website, consisting of some 360 file pages, and over 860 PDFs of technical papers. Content has been swelled this year by the incorporation of the case-history series on *Regolith expressions of Australian Ore Systems*, and *Regolith-Landscape Evolution across Australia*, and other monographs. Now that the website is an important reference centre, it is due for a structural revamp.

All Executives across the nodes, and the Perth Management team, are to be complimented for contributing to a productive year. Especially, I thank Business Manager Gary Kong who has, in difficult circumstances, continued to deliver in a timely and professional manner.

Photographs: Ian Robertson

Second Year Review

The Second Year Review was held in two stages in November 2003. Stage 1 Panel comprised Dr David Denham (FASTS President) and Christopher Oates (Anglo American). Stage 2 panel was Prof Max Brennan, Prof Roye Rutland and Prof Gerry Govett.

The Board and Executive of CRC LEME are pleased that both Review Panels recognised the achievements made in management and research, especially in the aftermath of the difficulties associated with the departure of Bureau of Rural Sciences (BRS) and the University of Canberra. These substantial problems are now largely behind LEME, although there will be a lingering legacy of tightness in cash over the remaining life of LEME – specifically relating to the departure of the Australian Government agency BRS.

Strategies are being set in place to redress the cash shortfalls and the Board and Executive are confident we will not be prejudiced in effectively and successfully addressing our stated objectives. We are indeed well placed to move forward in all aspects of the programs. We welcomed the comment that the Education and Training Program is of exceptionally high quality.

The recommendations and subsequent actions are summarised below.

Recommendation 1

The Panel recommends that the Board develop a framework and process that will enable it to obtain a credible estimate of the Centre's actual and potential contribution to Australia's sustainable economic and social development.

A considerable amount of background information on possible methodologies, together with several examples, has been collected. A paper entitled *Valuing LEME Research* was presented by CEO Dennis Gee at the CRC Association Annual Conference in June 2004, in the session entitled *Valuing Public Good CRCs*. The paper concluded that macro-econometric models would be useful for contributions in mineral exploration, by estimating the component of LEME research within the pre-competitive geoscientific effort of other agencies. It is widely recognised that such information quantitatively contributes to mineral exploration and discovery.

Commercial projects in Program 4 admirably lend themselves to quantitative cost-benefit analyses. For example the LEME Riverland project on the Murray River in South Australia delivers a benefit/cost ratio of two orders of magnitude. All projects in 2004-05 will be assessed for cost/benefits. Initial discussions have been held with some consultants to progress the matter.

Recommendation 2

The Panel recommends that the Centre revise and strengthen its policies and procedures for Intellectual Property (IP) protection and commercialisation.

Policies and procedures for IP protection are discussed in Chapter 4 of this Annual Report.

Recommendation 3

The Panel recommends that the Centre explore ways in which improvements can be made to the acceptance and application of regolith and related groundwater research in salinity mapping and remediation programs including the possibility of joint programs with other CRCs.

Now that the salinity projects of Program 4 have successfully delivered, there is a pressing challenge in transferring knowledge to, and engaging with, research-users in the natural resource management (NRM) sector. This is a challenge as there is a lack of overarching coordination, at the national level, of the multitude of agencies involved in NRM research.

As noted elsewhere in this report, we have developed strategies for growing our research in natural resource management in the Murray-Darling Basin, into site studies in Western Australia, and into new generic research areas of a strategic nature. Clearly this requires closer cooperation with similarly oriented CRCs (for example Catchment Hydrology, Plant Based Management of Dryland Salinity, and Fresh Water Ecology). Discussion with those CRCs that were focussed on Round 9 renewals have effectively stalled. However we have developed strong links with CRC Plant Based Management for Dryland Salinity, which will result in collaboration at least at the sub-program level.

We have also developed a specific communication and transfer project to bridge the gap between our researchers, and the NRM managers who deal in engineering and farm-system mitigation projects.

3. Centre Structure and Management

CRC LEME operates as an unincorporated joint venture between its eight participants. The headquarters of CRC LEME are in Perth, Western Australia in the Australian Resources Research Centre (ARRC) at Technology Park, adjacent to Curtin University of Technology.

Core Participants

The core participants in CRC LEME are signatories to the Commonwealth Agreement and Centre Agreements under which the Centre was established, and undertake its research and management. Under those agreements, the CSIRO Division of Exploration and Mining is the Centre Agent and assumes administrative responsibility. The core participants at the end of the reporting period were:

- 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) (formerly Department of Mineral Resources)
- Primary Industries and Resources, South Australia (PIRSA)
- Adelaide University (AU)

Board of Management

The Governing Board is responsible for setting LEME policy and strategy. The Board consists of representatives of core participants, Advisory Council Chairs, and independent members. The Board is chaired by Mr George Savell, who is independent of the Core Participants.

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)

Prof Neil Phillips, CSIRO

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, New South Wales Department of Primary Industries

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

L-R Adrian Larking, Ted Tyne, Steve Harvey (Alternate for Neil Phillips), Dennis Gee, George Savell, Gerry Govett, David Garnett, Tony Tate, Warwick McDonald, Tim Brown, Janet Dibb-Smith, Chris Pigram, Kevin Tuckwell, Gary Kong and John Keeling (Alternate for Paul Heithersay)

A number of changes to the membership of the Governing Board occurred during the reporting period. Mr George Savell replaced the founding Chairman Dr Ross Fardon after eight successful years. Mr Tony Tate replaced Prof Graham Lodwick. and Mr Paul Heithersay replaced Dr Neville Alley. Mr Kevin Goss resigned in April 2004 to take up the position as CEO for the CRC for Plant Based Management of Dryland Salinity. He was replaced on the Board and as Chair of the Land Use Advisory Council (LUAC) by Mr Warwick McDonald in August 2004.

The Board met on 5 September 2003 in Perth, 25 November 2003 in Canberra, and 5 March 2004 in Adelaide. Special Meetings via telephone hook-up were held on 11 July 2003 for Budget approval and 3 May 2004, to discuss participant issues.

The Safety Sub-Committee, comprising Dr Chris Pigram (Chair), Adrian Larking and Dennis Gee, did not meet, but monitored the LEME Field Safety Procedures set in place last year.

In 2003-2004 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 accept the audit report for the year 2003-2004. They recommended to the Board that it be accepted.

Advisory Councils

Minerals Advisory Council

The Minerals Advisory Council reviews progress and advises on future directions and 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. The Council attended the LEME-AMEC Minerals Exploration Seminar on 2 June 2004, and then met the following day. A number of MAC members were invited to participate in the meetings (Perth, Canberra and Adelaide) during April 2004 to review research progress and develop the research portfolio. As well, LEME executives liaise on a one-to-one basis with MAC members on specific projects.

Current members are:

Chair: Dr David Garnett

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

Mr Mike Webb – Anglo American Exploration (Aust) PL

Prof Peter Williams – University of Western Sydney

Dr Wally Witt – Sons of Gwalia Ltd

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

Land Use Advisory Council

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, which for most of last year was Kevin Goss. Kevin accepted an appointment as CEO of the CRC for Plant Based Management for Dryland Salinity in April. He was replaced by Mr Warwick McDonald in August 2004. A meeting was held in Adelaide 11-12 March 2004. Current members are:

Chair: Mr Warwick McDonald

Mr John Bartle – Conservation & Land Management WA

Mr Shawn Butters – Earth Work Resources

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)

Ms Barbara Morrell – Regional Natural Resource Management Groups

Dr Bruce Munday – CRC Plant Based Management of Dryland Salinity

Mr Bob Newman – Murray Darling Basin Commission

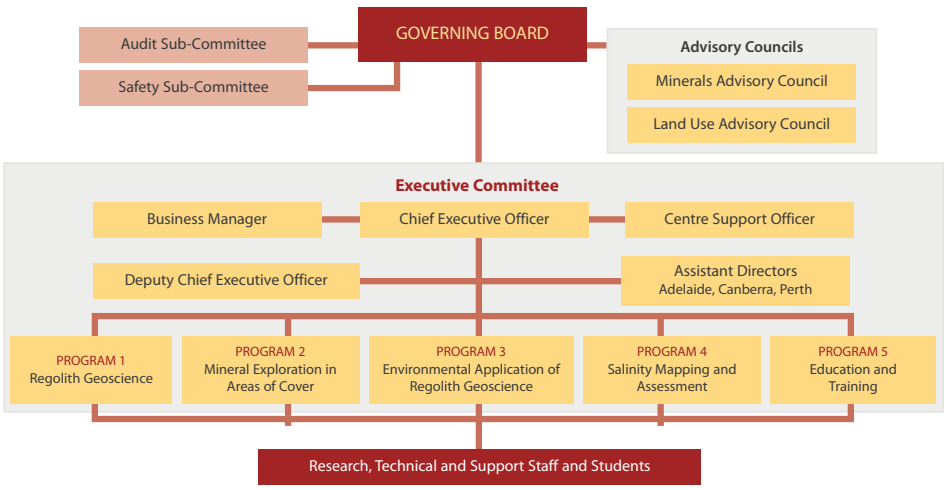
Ms Claire Rodgers – Fitzroy Basin Association

Mr Colin Simpson – Consultant

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

Mr Blair Wood – Land and Water Australia

The CEO, Board Chair and Deputy CEO are *ex-officio* members of LUAC



Centre Structure and Management

CRC Visitor

Emeritus Professor Gerry Govett is the CRC Visitor for LEME. In this capacity he acts as mentor and independent advisor, and provides a link between LEME and the CRC Committee. Prof Govett's significant contribution to LEME affairs is much appreciated. The following shows the breadth of his involvement:

- Meetings with LEME staff at CSIRO Exploration and Mining and NSW Dept of Mineral Resources – 17 July 2003
- Meetings with LEME staff at ANU and GA, Canberra – 4 August 2003
- Second Year Review, Stage 1, Perth – 21-23 October 2003
- Second Year Review, Stage 2, Canberra – 20-21 November 2003
- Board Meeting, Canberra – 25 November 2003
- Board Meeting, Adelaide – 5 March 2004
- Land Use Advisory Council, Adelaide – 11-12 March 2004
- Non-Salinity Project Reviews, Canberra and Adelaide, 8 and 20 April 2004
- LEME Minerals Exploration Seminar, Perth – 2 June 2004
- Minerals Advisory Council, Perth – 3 June 2004

Prof Govett provides written reports to the CEO and the CRC Program Committee on his visits.

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 (*ad hoc* Member)

Dr Mirko Stauffacher (*ad hoc* Member)

Mrs Susan Game (Executive Secretary)

The Executive Committee met eight times during the year via teleconference, and in person as opportunities arose. Project reviews were conducted throughout April 2004 in each of the nodes (Perth, Adelaide and Canberra), involving in each case the CEO, Program Leaders, and Executives and senior researchers in the respective nodes.

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.

Strategic Planning

The Strategic Plan 2002-2008 for CRC LEME was adopted by the Board on 14 March 2003. In effect it was the second-year update of the initial Strategic Plan as prescribed in Schedule 1 of the Commonwealth Agreement. It sets out objectives, strategies to meet those objectives, and indicators to measure performance, all within a framework of strategic priorities. Special emphasis is given to research themes. It focuses on outcomes as well as outputs. The strategic plan will need to be revisited late in the ensuing year.

Photograph: Ian Robertson

4. Commercialisation, Technology Transfer and Utilisation

Intellectual Property

The Commercialisation and Intellectual Property Management Strategy was approved by the Board on 14 March 2003, and modified slightly after the Second Year Review in November 2003.

The overall objectives of the strategy are to manage Centre Intellectual Property by:

- protecting and disseminating knowledge
- promoting developments within Australia and overseas
- transferring its knowledge on a fee-for-service basis
- identifying opportunities for marketing technological developments with a range of strategic industry partners.

Where Centre projects generate knowledge that has potential future economic or service benefits, it is then considered **"Centre Intellectual Property"**. All Centre IP is owned by the Core Participants equally as tenants in common in accordance with their participating shares. Each participant then has a non-exclusive royalty-free licence to use that Centre IP.

Projects involving 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.

From time to time, as part of normal technical reviews of projects, LEME Executive carries "opportunity audits" in order to:

- identify specific Centre Intellectual Property and review the commercial opportunities against market driven criteria
- identify projects with the greatest commercial potential
- identify networks to projects to introduce industry partners
- reinforce commercialisation as part of our culture.

Potential Commercial Projects

Potential projects warranting Centre or Project IP protection are described below.

Audio-magnetotellurics

Audio-magnetotellurics (AMT) is a ground-based method that uses reflected natural electromagnetic energy to measure the three-dimensional electrical structure of the earth. However, this analytical method is slow and prone to errors. Anton Kepic and LEME Honours students Barrett Cameron and Brendan Corscadden (all based at CUT) have updated the old technique with new technology – a laptop computer and less than $1000 of electronics. Their ingenuity has produced a system that is now capable of measuring the electrical structure of the earth down to 200 m in less than two minutes. The rapid AMT system can be used in situations where an airborne survey is expensive, and where a ground-based survey would not normally cover a sufficient area. Potential applications of the method are in mineral exploration, salinity mapping, and groundwater problems.

No current work is being done on this development, and it awaits more student availability. Results to date, via two Honours projects in 2002 and 2003, look good and worth further development. This appears to be a significant advance in producing a cheap, fast, capable system. We are not aware of a comparable system. This is either a Centre Project, or a student project subject to negotiation.

Electrokinetic seismic

Anton Kepic of CUT is collaborating with the Australian Nuclear Science and Technology Organisation (ANSTO) to develop an electrokinetic seismic (EKS) groundwater exploration system. The system works by measuring weak electrical impulses stimulated from the aquifer by seismic waves. The system 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.

Multi-channel hardware is being assembled by Scintrex Auslog in Brisbane with design input from Anton Kepic. This equipment will be capable of both seismic and EKS data acquisition. Field tests of this new equipment are planned within the next three months. ANSTO advise they are planning further financial support for this project (about $45,000) in addition to the current project (also worth $45,000) to add more channels and more software capability. Field tests in areas where we have other complementary datasets are planned in WA and Queensland. Technical potential looks promising and ANSTO are keen to talk to LEME on commercialisation. The new system should be a considerable advance on currently available systems.

This is regarded as Project IP, to be shared between ANSTO and CUT. The exact terms of equity have not yet been defined.

Photograph: Ian Robertson

Signal processing algorithms

Margarita Norvill, a LEME PhD student at CUT, has developed novel signal processing algorithms to improve electromagnetic and electrical geophysical surveys in areas with high electrical noise. Electrical noise can cause interference within 100 km of a city. The project was initially undertaken to improve data quality from MIMDAS, used by MIM Exploration Ltd (now Xstrata Pty Ltd), but the algorithms to improve signal-to-noise ratio can also be applied to other geophysical systems. Tests done in both urban and country areas have shown that many common geophysical methods can now be made to work in previously difficult urban areas. Remote locations now also yield improved resolution at greater depth.

Margarita expects to complete her PhD by end calendar 2004. The software has widespread general applicability and outside groups are interested. It is expected that the algorithms may be patented or licensed. Various options are under consideration for commercialisation. This is regarded as student project , with IP subject to negotiation.

EM image enhancement

Jayson Meyers (CUT) has been working with Pilbara Manganese to develop novel methods of finding manganese ore below regolith. This involves innovative geophysical techniques, particularly airborne EM systems, and innovative data processing strategies. 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 the "blind" Camp East deposit at Woodie Woodie.

The Hoist EM system, being developed by Newmont Australia and GPX Services, has also been further refined and tested at Woodie Woodie, 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. One of the Hoist EM discoveries sits below 30 m of Permian cover and contains a manganese resource in excess of 1.5 million tonnes. This blind discovery would not have been identified using conventional EM techniques. Induced polarisation methods are also being trialled as a means of identifying potential ore bodies that do not have an electromagnetic response. This work is ongoing, to further optimise both the Hoist EM system, in association with other surveying methods and data processing strategies. LEME has supported this project with a PhD scholarship and operating funds.

Spectral logging of regolith

This project commenced as the Objective Logging Project in Year 1 and has progressed into a true technology development project. It aims to rapidly log regolith samples (core, drill chips, pulps), by measuring physical properties of regolith samples, predominantly through spectral analysis. This will require specially developed software by the Mineral Mapping Group of CSIRO E&M. Digital spectral data and associated mineralogical interpretations can then be directly imported into 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 commercial model is that mineral explorers would "zap" the samples at one of three possible locations:

- at the drill site
- in the core store, or
- at the commercial analytical laboratory.

The raw data would be processed and interpreted either by the exploration company under licence, or by an authorised service bureau under licence. This is a Centre Project, but CSIRO has been the sole participant. Rights to IP remain with the participant. A spectral logging workshop was organised at CSIRO Exploration and Mining in Perth in May 2004 to progress software development and paths to commercialisation. It was recognised that this development could be 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.

"National good" benefits

It is emphasised that LEME is a knowledge-driven CRC, and orients its research more toward the applications of scientific knowledge to resource management for the 'national good". It has less opportunity for discovery of patentable products and technologies with material commercial benefits. Much of this knowledge relates to special methodologies which are not immediately patentable, but provide assistance to industry and services to community sectors, including government agencies.

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 our information expeditiously and freely, in order to stimulate mineral exploration. Some Industry Projects generate knowledge which remains confidential to industry sponsors till the expiry of an agreed confidentiality period, as per the project agreement. In the present exploration climate, there is limited opportunity for fee-for-services in the mineral exploration.

In contrast, fee-for-service opportunities are growing in the fields of natural resource and environmental management. One outstanding example is the development of software and methodologies for assisting salinity mitigation in the Riverland area of the Murray River. Water-borne and heli-born 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. This project alone contributes quantifiable benefits of the order of hundreds of millions of dollars, for outlays of hundreds of thousands of dollars.

Through its contracts of work and strategic research, 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. We can confidently predict that this growing capability will be in great demand by catchment management authorities and natural resource management agencies in the future.

Knowledge and Technology Transfer

Since the full commencement of Program 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 apply our research, and to transfer knowledge to end-users.

On the minerals side we have had one-on-one consultancies, including training courses, with a range of mineral exploration companies. Shown below are organisations that contributed financially towards LEME activities, a total of $1,183K during the reporting period:

ANSTO

Bureau of Rural Sciences

Cobar Management

CRC for Freshwater Ecology

Dept of Agriculture WA (Rural Towns Liquid Assets)

Dept of Environment WA

Dept of Water, Land & Biodiversity Conservation SA (Loxton-Boorapurnong)

Dept of Natural Resources, Mines and Energy Qld

Dominion Mining Ltd

Geological Survey of Western Australia

Murray Darling Basin Commission (MDBC Projects)

NT Government

St Ives Gold Mining Company Pty Ltd

Triako Resources (Talingaboolba)

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.

Table 4 – Technology Transfer and Utilisation 2003-2004

Research User	Activity/Project	Interaction	LEME Project Leader, Students and Supervisors
SMALL TO MEDIUM ENTERPRISES (generally less than 100 employees)			
Adelaide Resources Ltd	Alteration mineralogy, weathering and Au mobilisation into transported cover	Research collaboration	Alan Mauger, John Keeling, Mel Lintern, Andreas Schmidt-Mumm
Adelaide Resources Ltd	Biogeochemistry at Barns Gold Prospect, SA	Research collaboration	Mel Lintern
Biotrack Pty Ltd	Dryland salinity, biodiversity and geodiversity	Student research	**Glenn Bann**, John Field
Flinders Diamonds Ltd, Amona Mining and Exploration Pty Ltd	Airborne hyperspectral techniques in kimberlite detection, Pine Creek, SA	Research collaboration	John Keeling, Alan Mauger
Heathgate Resources Ltd	Source of uranium in sediments	Student research	**Pierre-Alain Wulser**, Joel Brugger, John Foden
Helix Resources Ltd	Au in calcrete anomalies	Student research	**Robert Dart**, Karin Barovich
Helix Resources Ltd	Spectral core logging, hydrogeochemistry, regolith logging	Research collaboration	Alan Mauger, John Keeling, Lisa Worrall, David Gray
HyVista Corporation	Kanowna Hy-Map demonstration	Research contract	Tom Cudahy
Iluka Resources Ltd	Palaeodrainage and models for heavy mineral accumulation in Eucla Basin strandlines	Research collaboration	Baohong Hou
Intrepid Geophysics	Regional geophysical study of crustal architecture near Challenger Mine, Gawler Craton	Student research	**Alan Cadd**, Nick Direen
Metex Resources NL	Mineral and biological hosts	Research collaboration	Ravi Anand, Cajetan Phang
Minotaur Resources NL	Development of down hole geophysics for exploration under cover	Student research	**Hashim Carey**, Graham Heinson
Mithril Resources NL	Distribution of metals in regolith profiles	Student research	**Amy Lockheed**, Karin Barovich
Xstrata Plc	Electrical and EM regolith studies	Research collaboration	Graham Heinson
MPI Mines Ltd	Using bacterial leach for geochemical exploration above VMS deposits	Research collaboration and Student research	**Ryan Noble**, Ron Watkins
Oroya Mining Ltd	Mineral and biological hosts	Research collaboration	Ravi Anand, Rob Hough
Pasminco Ltd	Using lithogeochemistry to map cryptic alteration, Elura and Century case studies	Student research	**Michael Whitbread**, Ken McQueen
Perilya Ltd	Use of hyperspectral techniques to aid exploration for zinc at Beltana, SA	Student research	**Alexandria Pengelly**, Alan Mauger, Pat James
Perilya Ltd	Palaeomagnetic dating of regolith at Beltana, SA	Research collaboration	Brad Pillans
Pilbara Mines Ltd	Mineral and biological hosts	Research collaboration	Ravi Anand, Matthias Cornelius
Pilbara Mines Ltd	Northern Yilgarn	Research collaboration	**Matthias Cornelius** and team
Stawell Gold Mine Ltd	Distribution of As in regolith above vein gold mineralisation	Research collaboration and Student research	**Ryan Noble**, Ron Watkins
St Ives Goldfields	Spectral logging of the regolith	Research collaboration	David Gray, Balbir Singh
Tensor Geophysics	Development of down hole geophysics for exploration under cover	Student research and teaching	**Hashim Carey**, Graham Heinson
Triako Resources Ltd	Geochemical investigation of deep cover sequences, Mineral Hill, Talingaboolba	Research consultancy	Keith Scott
Zong Engineering Research Organisation	Development of river based geophysical surveys for salinity mapping	Student research	**Brian Barrett,** Graham Heinson
LARGE COMPANIES			
Gold Fields Australia Pty Ltd	Spectral logging of the regolith	Research collaboration	Balbir Singh, David Gray, Ravi Anand
Newmont Australia	Palaeomagnetic dating of regolith in Yilgarn and Tanami areas	Research collaboration	Brad Pillans
Newmont Australia	Objective logging of the regolith.	Research collaboration	Ravi Anand, Cajetan Phang
Newmont Australia	Mineral and biological Hosts	Research collaboration	Ravi Anand, Cajetan Phang
Newmont Australia	Predictive petrophysics in regolith-covered Au-hosting proterozoic terranes, Tanami	Student research	**Kate Pfeiffer**, Nick Direen
Newmont Australia	Development of down-hole geophysics for exploration under cover	Student research	**Hashim Carey**, Graham Heinson
Sons of Gwalia Ltd	Northern Yilgarn	Research collaboration	Matthias Cornelius
Sons of Gwalia Ltd	Au anomaly formation in areas of cover at Karari and northern Leonora and implications for exploration	Research contract	Matthias Cornelius
Sons of Gwalia Ltd	Mineral and biological hosts	Research collaboration	Matthias Cornelius
Sons of Gwalia Ltd	Weathering of sulphides	Student research	**Christopher Buxton**, Mehrooz Aspandiar, Ravi Anand
GOVERNMENT ORGANISATIONS AND UNIVERSITIES			
ANSTO	Radiocarbon dating of samples from Coorong coastal lakes	Student research	**Aija Mee**, David McKirdy, Martin Williams
ANSTO	Direct seismic-electric layer detection	Research collaboration	Anton Kepic
ANSTO	Riverland SA – HEM for groundwater recharge mapping	Research Collaboration	Tim Munday
ANSTO	Parameter of aquifer systems	Research collaboration	Ken Lawrie

Table 4 – Technology Transfer and Utilisation 2003-2004 (cont'd)

GOVERNMENT ORGANISATIONS AND UNIVERSITIES (cont'd)

Research User	Activity/Project	Interaction	LEME Project Leader, Students and Supervisors
Auckland University	Sinter opals and how their origin can be used as a prefix for precious opals	Student Research and visit	**Katie Dowell**, John Chappell, Brad Pillans
Ballarat University	Palaeomagnetic dating of regolith in western Victoria	Research collaboration	Brad Pillans
Bureau of Rural Sciences	Angas Bremer Hills – regolith and salt	Research Collaboration	John Wilford
Bureau of Rural Sciences	Angas Bremer Plains regolith	Research collaboration	David Gibson
Bureau of Rural Sciences	Jamestown – regolith and salt	Research collaboration	John Wilford
Bureau of Rural Sciences	Lower Balonne airborne geophysics salinity projects	Research collaboration	Ken Lawrie
Bureau of Rural Sciences	SA Salinity mapping and monitoring support project (SA SMMSP)	Research collaboration	Tim Munday
Bureau of Rural Sciences	Riverland SA – HEM for groundwater recharge mapping	Research Collaboration	Tim Munday
Bureau of Rural Sciences	Salt mobilisation and water quality	Research collaboration	Andrew Herczeg
Canadian Geological Survey	Mackenzie Corridor Project, NW Territories	Scientific Exchange	Roslyn Chan
CSIRO – Water for a Healthy Country Flagship Project	Catchments to coasts project: scoping study plan, national land and water resources audit 2	Research contract and collaboration	Ken Lawrie
CSIRO Land and Water	Organic C&N isotopic analysis of Holocene sediments from Coorong coastal lakes	Student research – non LEME Supervisor E S Krull	**Aija Mee**, David McKirdy, Martin Williams
CSIRO Land and Water	Soil mapping with geophysics	Student Research	**David Mitchell**, David Chittleborough
CSIRO Mineral Mapping Technology Group	Objective regolith logging	Research collaboration	Ravi Anand
Dept of Agriculture WA	Inland acid sulfate soils and acid seeps	Research collaboration	Mehrooz Aspandiar, Arthur Rathur
Dept of Agriculture WA	WA rural towns	Research contract	Paul Wilkes
Dept of Agriculture, WA	Yarra Yarra catchment WA – soil maps from airborne geophysics and DEMS	Research contract	Paul Wilkes
Dept of Conservation and Land Management WA (CALM)	Spectral mineralogy, soil and water chemistry associated with the Narembeen Drain Network and Seagroatt Nature Reserve	Research collaboration	Ian Tapley, David Gray, Mark Pirlo
Dept of Environment WA	WA Palaeochannels salinity mitigation	Research contract	Paul Wilkes
Dept Infrastructure Planning and Natural Resources NSW (DIPNR)	Groundwater flow systems in the central west of NSW	Collaborative development of project	**Dave Gibson**, John Wilford, Louise Roberts, Susan Tate, Ken Lawrie
DIPNR	Dryland salinity, biodiversity and geodiversity	Student research	**Glenn Bann**, John Field
DIPNR	Dryland salinity hazard mitigation along the Booberoi-Quandialla Transect Central West NSW	Student Research	**Michael Holzapfel**, Xiangyang Chen
Dept of Land and Water Conservation NSW (DLWC)	Regional geochemistry surveys MDB pilot	Research collaboration	Patrice de Caritat
Dept of Natural Resources, Mines and Energy (DNRME), Qld	Lower Balonne airborne geophysics salinity project	Research collaboration	Ken Lawrie
DNRME Qld	Upper Burdekin regolith	Research collaboration	Colin Pain
DNRME Qld	Salt mobilisation and water quality	Research collaboration	Andrew Herczeg
Dept of Water, Land and Biodiversity Conservation SA (DWLBC)	Soil mapping with geophysics	Student research	**David Mitchell**, David Chittleborough
DWLBC SA	Effects of (artificial) drainage on the hydrology and physio-chemistry of soils in the southeast of SA	Student research	**Michael Durkey**, David Chittleborough
DWLBC SA	Evaluation and development of use of multitemporal imagery for water condition monitoring, environmental and wetland management in the southeast of SA	Student research	**Sean Mahoney**, Pat James
DLWBC SA	Loxton-Bookpurnong	Research collaboration	Tim Munday
DLWBC SA	SA Salinity mapping and Monitoring Support project (SA SMMSP)	Research collaboration	Tim Munday
DLWBC SA	Riverland SA – HEM for groundwater recharge mapping	Research collaboration	Tim Munday
DLWBC SA	Tintinara SA – AEM for groundwater recharge and condition mapping	Research collaboration	Tim Munday
Environment ACT	Dryland salinity, biodiversity and geodiversity	Student research	**Glenn Bann**, John Field
Geological and Nuclear Sciences, NZ	Exposure dating of balanced rocks	Consultancy	Derek Fabel
Geological Survey WA	Yilgarn laterite atlas	Research collaboration	Matthias Cornelius
Geological Survey WA	Kanowna Hy-Map demonstration	Research contract	Tom Cudahy
Geoscience Australia	Upper Burdekin regolith	Research collaboration outside LEME contribution	Colin Pain
Institut des Matériaux de Nantes, France	Trace element concentrations of Mexican red fire opal and Hungary common opal	Research collaboration	**Katie Dowell**, John Chappell, Brad Pillans

Table 4 – Technology Transfer and Utilisation 2003-2004 (cont'd)

Research User	Activity/Project	Interaction	LEME Project Leader, Students and Supervisors
GOVERNMENT ORGANISATIONS AND UNIVERSITIES (cont'd)			
Institute of Geochemistry, Mineralogy and Ore Formation, National Academy of Sciences, Ukraine	Carbon content variation in precious opals from northern and southern hemisphere using GC-MS	Student research	**Katie Dowell**, John Chappell, Brad Pillans
Institute of Geological and Nuclear Sciences. Rafter Stable Isotope Laboratory, NZ	Using stable isotopes to understand low temperature amorphous silica precipitation	Student research	**Katie Dowell**, John Chappell, Brad Pillans
Macquarie University	Palaeomagnetic dating of regolith, Blue Mountains, NSW	Research collaboration	Brad Pillans
Macquarie University	Dryland salinity, biodiversity and geodiversity	Student research	**Glenn Bann**, John Field
Murray Darling Basin Commission	Groundwater flow systems in the central west of NSW project	Collaborative development of project	**Dave Gibson**, John Wilford, Louise Roberts, Susan Tate, Ken Lawrie
National Parks and Wildlife Service NSW	Dryland salinity, biodiversity and geodiversity	Student research	**Glenn Bann**, John Field
Northern Territory Geological Survey	Regolith landscape evolution of the NT	Research collaboration	Mike Craig, Ian Robertson, Ravi Anand,
PIRSA	Mineral mapping at White Dam, SA	Student research	**Ian Lau**, Pat James, Alan Mauger, Graham Heinson
PIRSA	Soil mapping with geophysics	Student research	**David Mitchell**, David Chittleborough
Resource and Conservation Assessment Council (RACAC) NSW	Regional geochemistry surveys MDB Pilot	Research collaboration	Patrice de Caritat
Rural Lands Protection Board NSW	Dryland salinity, biodiversity and geodiversity	Student research	**Glenn Bann**, John Field
University of California, Berkeley	Granite weathering	Research collaboration	Susan Welch
University of Canberra	Dryland salinity, biodiversity and geodiversity	Student research	**Glenn Bann**, John Field
University of South Australia	Palaeomagnetic dating of regolith, Fleurieu Peninsula, SA	Research collaboration	Brad Pillans
University of Wollongong	Regolith dating in WA and SA	Research collaboration	Brad Pillans
Upper Lachlan Catchment Management Authority	Dryland salinity, biodiversity and geodiversity	Student research	**Glenn Bann**, John Field
Yarra Yarra Catchment Management Authority	Yarra Yarra catchment WA – soil maps from airborne geophysics and DEMS	Research contract	Paul Wilkes
COOPERATIVE RESEARCH CENTRES			
CRC for Plant Based Management for Dryland Salinity (PBMDS CRC)	Dryland salinity, biodiversity and geodiversity	Student research	**Glenn Bann**, John Field
PBMDS CRC	Predictability of surface and subsurface soil properties from geophysical remote sensing and regolith information	Student research	**David Mitchell**, David Chittleborough
CRC for Predictive Mineral Discovery (pmd* CRC)	Development of reliable geochemical modelling: database of thermodynamic properties and software	Research collaboration	Bear McPhail
CRC for Freshwater Ecology; CRC for Catchment Hydrology CRC for Coastal Zone, Estuary & Waterway Management	Catchments to coasts project scoping study plan, national land and water resources audit 2	Research contract and collaboration	Ken Lawrie
INDUSTRY ASSOCIATIONS			
AMIRA International	Isotopic discrimination of partial leach anomalies on covered terrains (CRC LEME AMIRA Project 618)	Research collaboration	Geoff Denton
Australian National Seismic Imaging Resource (ANSIR)	Parameter of aquifer systems	Research collaboration	Ken Lawrie
Australian Water Environments Pty Ltd	Development of river based geophysical surveys for salinity mapping	Student research	**Brian Barrett**, Graham Heinson
Australian Water Environments Pty Ltd	Riverland SA – HEM for groundwater recharge mapping	Research collaboration	Tim Munday
Greening Australia	Dryland salinity, biodiversity and geodiversity	Student research	**Glenn Bann**, John Field
Landcare Groups	Dryland salinity, biodiversity and geodiversity	Student research	**Glenn Bann**, John Field
Lightning Ridge Miners Association	Low temperature silicification in the regolith using black opal as a primary example	Student Research	**Katie Dowell**, John Chappell, Brad Pillans
Minerals & Energy Research Institute of Western Australia (MERIWA)	Kanowna Hy-Map demonstration	Research contract	**Tom Cudahy**
Outside the Box Consortium Pty Ltd	Riverland SA – HEM for groundwater recharge mapping	Research collaboration	Tim Munday
Quilpie miners & Bolder Opal Association	Low temperature silicification in the regolith using black opal as a primary example	Student research	**Katie Dowell**, John Chappell, Brad Pillans

5. Research Programs

Photo by Jennifer Henry-Lawson

Members of the multi-party, collaborative, Program 4 Lower Balonne Airborne Geophysics Project Technical Working Group at their final meeting in Brisbane in June 2004. L-R: Rick Evans (Sinclair Knight Mertz), Justine Claridge (QDNRM&E), Andrew Fitzpatrick (LEME), Jon Clarke (LEME), Andrew Biggs (QDNRM&E), Kate Wilkinson (QDNRM&E), Greg Grainger (Smart Rivers), Ian Mullen (BRS), Tessa Chamberlain (QDNRM&E), Mike Grundy (QDNRM&E), Ian Heiner (QDNRM&E), Colin Pain (LEME), Bruce Pearce (QDNRM&E), Jim Kellett (BRS)

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 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, plus the Education and Training Program which is reported in Chapter 6.

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 such areas as assessment of regional geochemical baseline datasets, mechanisms in acid sulfate 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

Salinity and groundwater resource issues are national research priorities in Australia. Program 4 applies multi-disciplinary geoscience to mapping, assessment, prediction, prevention, and mitigation of salinity and related groundwater issues. It develops methods and indicators for monitoring and evaluating catchment condition. The founding objective of the program is to provide specialist geoscientific knowledge, technologies, datasets, interpretation products and services across a range of government initiatives tackling salinity and groundwater-related issues within Australia's regolith landscapes. These initiatives include the National Action Plan for Salinity and Water Quality (NAPSWQ), the National Heritage Trust (NHT), the National Land and Water Resources Audit (NLWRA). Projects are also funded by State and Commonwealth NRM agencies including the MDBC, GA, the Living Murray Initiative, and CSIRO's Flagship Program 'Water for a Healthy Country' (WfHC). Clients range across Commonwealth, State and other NRM agencies and, with the increasing devolution of funding and responsibility for NRM issues, regional Catchment Management Agencies and Boards.

Projects deliver strategic science both through Centre-funded projects and through externally-funded contract research. Centre-funded projects include salinity hazard mapping techniques, salt mobilisation and groundwater dynamics, the use of perennial woody vegetation to reduce salinity, aquifer parameterisation and value-adding to the groundwater flow systems framework. A key component of research is the application of a range of geophysical techniques including electromagnetics.

Research Themes

Themes are high-level groupings of multi-disciplinary research topics that may have wide applications, but are unified by a common strategic direction within the overall objectives of LEME. Themes ensure the best integration of research capabilities and resources across all nodes of LEME. All themes provide a direct focus on stakeholder interests, and many of them bind the two principle applications of NRM and MINEX. They therefore focus the individual research projects, and enhance the cohesion of LEME. All projects adopted by LEME must address one or more of the nine 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 MINEX and NRM.

The themes remain broadly similar to those adopted in the first two years of LEME. However in some areas they have been re-scoped to reflect new opportunities, changing stakeholder focus, and scientific advancements in the early years. 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

Full theme statements are on our website http://crcleme.org.au

Program Milestones

The initial business plan in the Commonwealth Agreement specified certain milestones for Programs 1 and 2, which were generally applicable for the first three years. Almost all of those specific milestones have now been met. The original plan also noted some longer term milestones of a strategic nature. Following the successful Second Year Review, these milestones were able to be more precisely defined and implemented in 2003-04 (Year 3). Milestones have also been re-scoped to refect scientific advances made in the first three years. In some instances we now find some projects more naturally lie in other programs. Consequently some milestones have shifted between programs. However all milestones relate to the original objectives, and the original style of projects, as set out in the Commonwealth Agreement.

Program 3 had a developing role in the new LEME, embracing both regolith support for dryland salinity, and proposing broader investigations into environmental geochemistry and environmental hazards. Consequentially its milestones were also broad and developmental. The geophysical development role now resides with Program 4. After three years, Program 3 now has a focus on hydrogeochemistry, environmental geochemistry and biogeochemistry, whilst still providing cross-disciplinary support to Programs 1, 2 and 4. Its milestones have been re-defined in line with these changes, although the fundamental aspects of the original milestones are preserved, as noted below.

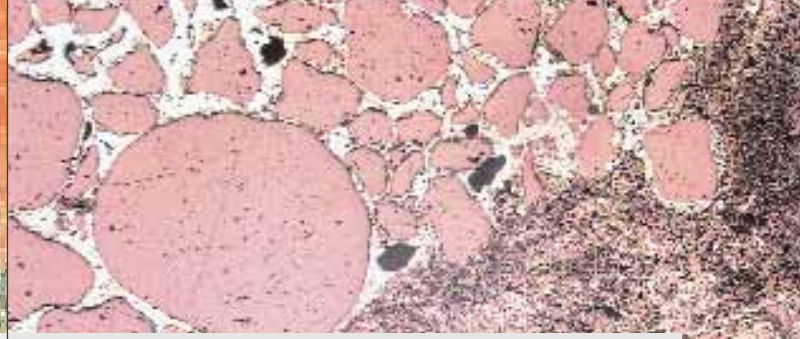
Similarly, as noted in last years Annual Report, milestones for the new projects in Program 4 were not developed in the initial business plan, which simply referred to "intergovernmental agreements with State agencies". Program 4 conducts strategic research within a spectrum between two end-member types of projects – commercial projects (either totally or partially external NAP 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. Therefore milestones can be set for the cluster of commercial projects, and for the more strategic research projects. The major milestones in terms of strategic intent and deliverables are listed below.

Progress is reported against the outputs and milestones as follows:

Program 1 Milestones

1. Regolith geology of the Yilgarn Craton – published.
2. *Regolith-landscape case histories across Australia* – published on the website.
3. Develop multi-disciplinary research teams involving staff from several Core Participants and/or Supporting Participants and Associates by end of Year 2 – achieved.
4. Develop quantitative regolith-landscape models for key mineral areas in western New South Wales, Gawler Craton, Curnamona and Cobar mineral region – some projects 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 training sets for the interpretation of mineralogy from the spectral signatures of regolith materials – delivered.
8. Extend quantitative regolith-landscape models into other areas of mineral significance – in the Lachlan Fold Belt and the Northern Territory by Year 5.
9. Develop exemplar integrated 3D models of basinal areas of transported regolith surrounding key mineral provinces – by July 2006.
10. Develop techniques for dating regolith and land surfaces, and publish new edition of handbook *Regolith Dating Methods* – by June 2006.
11. Deliver quantitative framework for the history of aridity of Australia – June 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 deposits* – 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 exploration use of acid sulfate soils and saline discharges in mineral exploration – delivered.
5. Complete the first phase of the *Base Metals Exploration Project* by Year 2 – completed.
6. Complete multi-client projects in isotope geochemistry in selective extraction analysis – completed.
7. Determine the chemical, mechanical and biological processes leading to the formation of geochemical anomalies in regolith – June 2007.
8. Identify the dispersal mechanism for transport of metals through transported regolith and propose deep sensing geochemical exploration methods – June 2007.
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 mobilisation and fixation of gold and other trace elements in calcrete – by June 2006.
11. Demonstrate practical base-metal exploration methods in hydrogeochemistry, including isotope geochemistry – June 2005.
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 – June 2006.
14. Develop a production oriented, automatic regolith mineral logging technology base on spectral characteristics – June 2006.

Program 3 Milestones

1. Discuss with potential collaborators such as the CRC for Catchment Hydrology and Plant-based Management of Dryland Salinity, to plan collaborative research projects – discussions in progress.
2. Identify and pursue research problems critical to the success of 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 regional baseline geochemistry studies in three diverse regions – Riverina, Gawler and WA Grainbelt – by Dec 2006.
6. Develop methodologies for geochemical risk management of soils and groundwater at the catchment scale – by Jun 2005.
7. Establish the distribution, conditions of formation, and management options of inland acid-sulfate soils, and alkaline soils – June 2007.

Program 4 Milestones

1. Develop management and technical capability to generate and undertake State-based salinity projects, and to provide for 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 new-generation geophysics and remotely-sensed technologies to case studies requiring regolith input to environmental problems – December 2004.
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 2005.
8. Submit for publication a thematic volume on regolith input to South Australian NAP projects by June 2005.
9. Integrate salinity hazard and regolith inputs to the National Land and Water Resources Audit – by December 2007.
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. Refine the acquisition, processing and interpretation of frequency domain AEM to deliver operational functionality in shallow regolith environments – by June 2005.

Program 1: Regolith Geoscience

Program Leader: Ms Lisa Worrall

Highlights

- In the Central Gawler Gold Province, the first calcrete layer above the *in-situ* silcrete layer is the best exploration sampling medium.
- Prototype 3D derivative maps are developed in areas of complex palaeo-landforms.
- Newly recognised chemical fractionating trends in mature ferruginous lags enhances geochemical anomaly interpretation.
- Soil geochemical signals are enhanced by screening out the 70micron aeolian fraction.
- 44 case studies in the series *Regolith-landscape evolution of Australia* posted on the LEME website.
- Four 1:100k regolith-landform maps released for Cobar-Girilambone region.
- Release of the Tibooburra 1:25k regolith-landform map.
- Successful staging of Cobar-Girilambone Field Workshop.
- Release of Central Gawler Gold Province Data Catalogue.
- Release of the Lake Harris Greenstone Belt Report and GIS.

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 in three dimensions and to develop models of regolith landscape evolution. In addition to regional focus projects, it looks at some generic processes, and aims to advance the development of some geophysical technologies.

Thematic Series – Regolith Landscape Evolution

All 44 case histories supplied by authors have been finalised and posted on the LEME website during the reporting period. These studies describe regolith-landform development in a broad range of geographical and geological settings across Australia. The contributing authors represent the full range of organisations involved in regolith research in Australia, both within and outside of LEME.

REGIONAL FOCUS PROJECTS

Cobar-Girilambone – *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*

The Cobar-Girilambone project was completed at the end of the reporting year. It developed methods to assist mineral explorers in transported regoliths of the western Lachlan Fold Belt. It elucidated regolith controls on dispersion of target and pathfinder elements, and compiled a geochemical database. Scientific advances in the project were reported at the Cobar-Girilambone Field Workshop which was held in Cobar between the 24 – 27 May. Abstracts of presentations, as well as comprehensive field notes are available on the LEME website. This group of projects addressed Milestone 4.

Regolith landform-mapping. The NSW Geological Survey released four standard series 1:100k scale regolith-landform maps of Byrock, Hermidale, Coolabah and Sussex sheets, around the Cobar mineral field. Peter Buckley constructed the Byrock regolith-landform map, which sets a new standard in digital construction. It lies on the northern end of the Girilambone belt and covers the transition from residual/erosional regimes to largely depositional regimes. It is based on new 60m altitude magnetics, radiometrics, and DTM, augmented by Landsat 7 and field mapping. It is constructed by on-screen digitising which facilitates rapid and systematic production. Polygons are coded using the RTMAP scheme which portrays both the landform and regolith materials.

Regolith landform maps have value in planning geochemical surveys, and assessing the effectiveness of previous geochemical surveys. The regolith-landform map complements solid geology and outcrop maps, and is the starting point for 3D reconstructions.

Girilambone regolith drilling. A program of 247 shallow air-core holes funded by NSW DPI (was Dept Mineral Resources) over the Girilambone Group northeast of Cobar is reported in LEME Open File Reports 148 and 149. Lithological logs, 29-element analyses, PIMA spectrometer data, and selected XRF data are also freely available from the LEME website. Findings include:

- kaolinite crystallinity and water absorption peak are useful determinants of the transported-saprolite interface
- previously unknown mafic rocks, which by association have exploration interest, are identified by geochemical signatures
- occurrences of anomalous gold are noted in calcrete at the saprolite-transported interface, and in saprolite itself
- anomalous Zn is associated with weathered volcanics in several locations beneath transported regolith
- transported material is largely devoid of recognisable gold, base metal and pathfinder elements, as determined by total digest.

Judicious sampling of the interface between transported materials and the saprolite remains the recommended method of geochemical exploration in these areas.

Girilambone palaeochannels. Roslyn Chan and colleagues have developed a method for reconstructing complex superimposed palaeodrainage patterns using aeromagnetic images and GIS-based landform reconstructions, augmented by a program of 247 shallow air-core drillholes. In the Cobar area multiple phases of palaeochannel development are recognised, possibly ranging in age from Mesozoic to the present. Some palaeochannels are charted by maghemite trails displayed on 1.5VD magnetic imagery. Some earlier channels have totally different transport direction to current superimposed drainages, indicating a complex pattern of repeated river capture, associated with rotational tilting related to neo-tectonic activity. Reports, including data are available on the LEME website.

Drilling indicated that palaeochannels were more extensive than indicated by magnetics. This was confirmed by running two test profiles of fast-turnoff TEM profiles which showed a useful contrast between low resistivity palaeochannel sediments, and high resistivity saprolitic basement. Understanding the drainage in such a mineral province assists in review of previous geochemical surveys, planning new surveys, and interpretation of transported or displaced anomalies.

Aeolian geochemical diluents. Susan Tate (Hons student ANU), and Richard Greene looked at the quantity and form of aeolian diluents in soils of the Girilambone belt. Aeolian material is being continuously deposited on the land surface, which will dilute the signals from any underlying mineralisation. The study involved a comparison of soil components from a variety of alluvial / colluvial covered areas, with a control site with shallow soils over a distinctive bedrock. A wide range of techniques, including semi-quantitative XRD, XRF, particle size distribution and grain morphology by SEM have been used to quantify the aeolian component. The study shows that aeolian material constitutes more than 70% of near-surface soils, and is represented by rounded quartz grains in the 70 micron mode. It is possible to enhance a geochemical anomaly by removing the minus 70 micron fraction; partial analysis can also effectively bypass the aeolian fraction.

Lag geochemistry. Ken McQueen and Dougal Munro, an Honours student at ANU, examined the distribution of ore and pathfinder elements in residual and transported lags related to Cu-Au systems in the Cobar Goldfield. In the *in-situ* regolith, goethite is an important host for Zn, Cu, As and to a lesser extent Pb, Bi and Sb. Hematite is the predominant host for Cu. Thus in goethite-dominant near-surface caps there is a strong correlation of As and Zn with Fe, whereas in hematite-dominant phases there is a strong correlation of Cu with Fe. However in the redistributed lags there is a progressive conversion of goethite-hematite phases to hematite-maghemite phases. At the same time there is an increasing correlation of Pb, As, Sb, Bi, Ba, Cr and Th with Fe, as these pathfinder elements increase in the mature lags. Significantly Zn, Cu and Au do not increase in the mature lags. Thus the actual ore elements fail to report, and the normally immobile Pb, once fixed into hematite, can become widely dispersed by mechanical methods. These results indicate that pathfinder elements should be normalised against Fe for their correct interpretation.

Regolith geochemistry. Keith Scott highlighted the contrasting geochemical expressions of different types of base metal deposits in the semi-arid environment of the Lachlan Fold Belt. He demonstrated that the composition of gossan and residual soils is controlled by pH conditions at the time of weathering. The ore at Elura Zn-Pb-Ag deposit (43 km northwest of Cobar) is pyrite-rich, generating acidic conditions during weathering, resulting in depletion of Cd and Zn throughout the profile, whereas As, Ba, Pb and Sb remain highly anomalous in surficial ironstone and soil. There may be local concentrations of Ag, As, Ba, Cu, Hg, Pb, Sb and Sn in the profile. In contrast, at Parkers Hill, in the Mineral Hill field (65km north of Condobolin), the primary Pb-Zn mineralisation has a carbonate association and is pyrite-poor, resulting in much less acid conditions during weathering. In consequence, Cu and Zn (as well as As, Pb and Sb) are retained in surficial ironstones in essentially the same abundances as the primary mineralisation. Silver, As, Cd, Cu, Sb and Zn may be also concentrated at various levels in the weathering profile. Thus, variations in the suite of geochemical indicators present in ironstones and residual soils are likely to reflect differences in the original mineralogy and the degree of acidity produced during weathering of base metals.

Supergene oxide geochemistry. Peter Williams (UNSW) and his students have examined thermodynamic models for the dispersion of Cu and As in the oxide and supergene zones of the Cu-Au (Bi-As) systems at Cobar. They provide an explanation of the commonly observed pattern of relatively broad Cu anomalies encircling linear and more precise Pb and As anomalies over near-surface truncated oxide zones. They looked at two oxide mineral systems, the proximal Cu-Pb arsenides, and the overprinting secondary Cu carbonates. They predict thermodynamically that total dissolved Cu in the ambient groundwaters is two orders of magnitude greater in solutions associated with carbonate supergene events than it is in the arsenate event. In this situation there is enough As to fix all of the Pb, but not enough for all of the Cu which remains sufficiently mobile to eventually report in the hydroxy carbonate/malachite/azurite phases. Consequently in the truncated and exhumed oxide zone, Cu provides the broader footprint which can be sharpened by the Pb anomaly.

Western New South Wales – *Patrice de Caritat, Steve Hill, Dirk Kirste, Richard Barratt, Kingsley Mills, Tim Sharp, Barney Stevens, Kylie Foster, Louisa Ruperto, Guy Fleming*

The Western NSW Regolith project was completed at the end of 2003-04. It aimed to provide information about landforms and geochemistry of transported regolith. The final phase of this project addressed groundwater geochemistry as an exploration tool in thick transported regolith. Summary findings of this aspect are presented in the Program 2 report.

Tibooburra – *Steve Hill*

Regolith mapping and landscape modelling is tracking gold distribution in the enigmatic Tibooburra goldfield in western New South Wales. Heavily cemented residual and transported materials drape over Palaeozoic metasediments and intrusives of the Tibooburra and Waratta Inliers. The sediments include marginal marine Mesozoic granule sands and pyritic shale of the Eromanga

Photograph: Patrice de Caritat

Sampling groundwater from a mineral exploration borehole in the southern Barrier Ranges, Curnamona Province

Basin, plus Cainozoic sediments of the Lake Eyre Basin. Gold nuggets up to one centimetre in size are found in the extensive and complex colluvial regolith that fringes the basement inliers. However, no evidence of primary gold has ever been seen in the basement. Recent work has shown that the eluvial and alluvial gold particles are spatially associated with the base of the Mesozoic sediments. The basal beds are intensely indurated with silica, calcium carbonate and iron, and contain cements of opal, anatase, dolomite, barite, and gypsum. These chemical cements contain clearly anomalous gold (up to 60ppb), in a form yet to be determined. Degradation and redistribution of gold-bearing "silcretes" creates large diffuse and spurious anomalies. But when the original distribution of silcrete is reconstructed from the regolith map, and the gold in silcrete is normalised against iron, then vectors emerge that indicate primary dispersion patterns. The real primary source of the gold is still uncertain – but it could come from the Mesozoic sediments or the basement. The Tibooburra Inlier 1:25k regolith-landform map has been released and can be obtained via the LEME website. This project addresses Milestone 8.

Curnamona Craton and White Dam – *Steve Hill, Pat James, John Joseph, Graham Heinson, Karin Barovich, Aaron Brown and Ian Lau*

These projects have examined the regolith-landform framework for the Olary and Mingary region of the central Curnamona Craton in SA, and the detailed regolith geology of the White Dam mineralisation within this region. Ian Lau (PhD student AU) has successfully used remote sensing tools, including hyperspectral data, to map and characterise regolith units. Paul Wittwer (Hons student AU) with Karin Barovich and Steve Hill, have shown that calcrete chemistry reflects polymetallic mineralisation beneath shallow (<5 m) transported cover, and noted other sites of previously unknown mineralisation. The use of calcrete geochemistry, combined with regolith-landform maps is confirmed as a valuable tool in regional exploration.

At White Dam, research first involved detailed (>1:25 k scale) regolith-landform mapping, then proceeded with a new approach for mapping surface dispersion vectors using vegetation litter dams. This approach provides an accurate and sensitive representation of surface dispersion vectors, and enabled Aaron Brown to rank surface geochemical anomalies and trace many of them back to their source area. On the biogeochemical side, bladder saltbush is proving a promising media for reflecting Cu-Au mineralisation buried by 5 m of transported cover around White Dam.

These projects are also revisiting the vexed question of biogeochemical sampling for metals. Karen Hulme a PhD student at AU is focussing on river red gums (*E camaldulensis*) which present an ideal sampling medium because of their widespread occurrence in the transported regolith and their extensive tap roots. Orientation sites have been set up in the Curnamona Craton, on the basis of proximity to various styles of mineralisation. This work complements biogeochemical research in mulga trees in the Yilgarn Craton, and results of significance to mineral exploration are noted in the Program 2 report. Achievements are set against Milestone 4.

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

This project commenced in 2003-04, as part of our strategy to expand regolith science into new terrains. It aims to establish a regolith-landform framework for the entire Northern Territory to guide mineral explorers and range-land managers. The project will reconstruct the Mesozoic and Cainozoic landscape history of a large part of continental Australia. A documentation traverse along the Stuart Highway from south of Alice Springs to the Darwin coastal plain across the Northern Territory, was completed during September and October 2003. Such a large-scale regolith calibration traverse has not previously been undertaken in Australia. Imagery derived from radiometric, Landsat TM, magnetic, elevation and Aster data was used during the traverse to identify regolith characteristics and sampling sites. Achievements will be set against Milestone 8.

Early results suggest that particular regolith materials and landscapes have complex relationships, and that some materials are more widely distributed in some areas than has been previously recorded. An early result from a dating sample gives an age of at least 780ka. Laboratory work following the 2003 traverse involves XRF and XRD analysis of 58 regolith control samples. Thin and polished sections are also being prepared.

A regolith workshop was held in Darwin for the NTGS in January 2004.

Photograph: Ian Robertson

Mike Craig taking an oriented palaeomagnetic specimen in the Georgina Basin

South Australian Regolith – *Melvyn Lintern*

The final report on the South Australian Regolith Project has been released (LEME Open File Report 156: *The South Australian regolith project final report – summary and synthesis*). This project addressed the distinctive SA regolith which is characterised by calcareous and siliceous cements, in contrast to the predominantly ferruginous cements of the Yilgarn Craton. The study summarises the regolith profiles and 3D distribution of gold at various sites in the central Gawler Craton which have different thicknesses of transported cover. The typical profile at these sites consists of saprolite capped by silcrete, overlain by transported materials of fluvial, colluvial and aeolian origin. Calcrete has intergrown with these upper materials and generally occurs within the top 5m. The most important calcrete unit is that developed at the top of the silcrete, which forms a permeability barrier. Major conclusions are:

- anomalous gold in calcrete registers well with underlying gold mineralisation where calcrete is formed immediately above silcrete saprolite
- where thickness of transported regolith is greater than 5m, basement gold signatures are totally suppressed in near-surface calcrete
- highly anomalous concentrations of gold (hundreds of ppb) may occur in silcrete and calcrete at the interface between saprolite and transported materials
- in erosional and depositional regimes, gold may be dispersed laterally in both degraded silcrete and younger calcrete, thus providing false anomalies.

This project initiated a new mega-project designed to understand where and why calcrete geochemistry does or does not work. Possible mechanisms for gold concentration in calcrete include evapotranspiration, chemical precipitation, residual concentration, transformation by soil biota, root uptake and microbial deposition.

Central Gawler Gold Landscapes – *John Keeling, Mal Sheard, Mel Lintern, Baohong Hou, Alan Mauger*

This three-year project commenced in June 2003. It develops new strategies for gold exploration in the regoliths of the Central Gawler Gold Province. Its scope was defined in planning meetings with collaborators in PIRSA and GA. The scope includes the compilation of a data catalogue describing all data on the Central Gawler Gold Province, digital and non digital. This was released in March 2004 in response to stakeholder request. It can be accessed via the LEME website. Achievements are set against Milestone 4.

The project has shown that chlorite-sericite alteration associated with gold mineralisation at Tunkillia Prospect can be mapped through transported cover by integrating aeromagnetic (AM) and airborne electromagnetic (AEM) data. The AM data is used to define zones of magnetite destruction in regional structures, and AEM data is used to locate chlorite-sericite alteration within these zones. Chlorite-sericite alteration in this region of deep weathering creates contrasts in electrical properties of altered and unaltered rocks.

In the pursuit of making geochemistry work through transported regolith John Keeling has found evidence of upward capillary movement of copper-bearing solutions into transported clays 5 – 15 m thick, above the Poona (Moonta SA) Cu–Au deposit. Atacamite nodules were developed in transported kaolin/illite/smectite clays and in thin seams of alunite-halloysite clay. This happens where there is direct contact between transported clay and underlying weathered porphyry. The alunite-halloysite is interpreted to form by acid-sulfate weathering of the transported clay.

In September 2003 LEME staff assisted PIRSA with organising the Gawler Craton 2003 State of Play excursion. A detailed Field Guide (*PIRSA unpublished report 2003/17*) includes contributions from LEME staff: Baohong Hou, John Keeling, Mel Lintern, Alan Mauger, Ian Robertson and Malcolm Sheard. The regolith aspects of field trip were led by Malcolm Sheard and John Keeling. The excursion was attended by representatives from Helix Resources, Adelaide Resources, Range River Gold, WMC Ltd, Avoca Resources, Orogenic Exploration, and Dominion Mining.

Lake Harris Greenstone Belt – *Mal Sheard, Ian Robertson*

This project was completed in 2003-04 with the production of a final report and 3D GIS model. Findings of this project are reported in the previous Annual Report.

GENERIC PROCESSES

Geochronology and Quantitative Models of Landscape Evolution – *Brad Pillans, Andrew Christy, Patrick de Deckker, David Ellis, John Dunlap*

Geological evidence indicated that much of the Australian continent has experienced extensive subaerial weathering over long periods. From a mineral exploration viewpoint, it is important to know if weathering processes, and hence anomaly formation, is an expression of continuous or episodic weathering. The LEME geochronology project involves both the development of quantitative weathering models and new technologies.

The basic geochronological framework of the Australian regolith is provided by palaeomagnetic dating. This is done by plotting the pole of the chemical remnant magnetism (CRM) of secondary mineral phases on the trace of palaeomagnetic poles of known age – commonly known as the Australian apparent polar wander path. Most useful is the phase change from goethite – which has no CRM – to hematite which does. Brad Pillans records palaeomagnetic determinations from some 30 sites (mostly mine sites) throughout Australia, with a focus on the Yilgarn Craton. This compilation is now on the LEME website. There are events around 10 Ma and 50-60 Ma, with some evidence of Mesozoic or even earlier weathering. The two episodes of hematite formation in the Tertiary occurred under differing bioclimatic regimes.

This spread of palaeomagnetic ages is revealed at Lancefield gold pit (WA), where initial work in a new Program 2 project suggests several palaeo-geochemical Au-As-Cu-Zn systems in the regolith. Some early results are noted in the Program 2 report. Achievements will be set against Milestone 11.

During the year, Brad Pillans completed measurements on a suite of samples from Dead Bullock Soak, The Granites and Tanami gold mines in the Northern Territory. Palaeomagnetic ages, from the deeply weathered Proterozoic bedrock exposed in the open pit

Neville Alley admires the landscape at Trinity Well, northern Flinders Ranges, site of the world's only known Cretaceous glacial deposits, where Brad Pillans and Jim Dunlap have undertaken K/Ar dating of Mn oxides in the sub-Cretaceous weathering profile

mines, extend back to the Late Carboniferous, making them some of the most ancient weathering profiles yet dated in Australia

More precise isotopic techniques are being developed in LEME, notwithstanding the problems of finding suitable minerals, and the uncertainties regarding closed systems. Bob Pidgeon (CUT) is developing the (U+Th)/^{4}He method on lateritic duricrust from the Darling Range, and has produced a date around 10 Ma, that is compatible with the youngest age of lateritic duricrust in the Yilgarn, recorded by palaeomagnetism. Other developments are U-Pb and U-series of goethite by Alex Nemchin (CUT), and SHRIMP dating of opal by Susan Symons (PhD student, CUT).

A highlight of the year was the trial application of U/Pb dating by Laser Ablation ICPMS to anatase in silcrete from the Broken Hill area, by ANU PhD student Martin Smith. Initial results were sufficiently encouraging to make further measurements to prove the method. Given the widespread occurrence of silcrete in the Australian landscape, and the lack of knowledge concerning their ages, Martin's pioneering work may pave the way for a major breakthrough in regolith dating in Australia. Martin and co-supervisor, Jim Dunlap, are also testing the application of the (U-Th)/He dating method to hematite.

Miocene leaf fossils in silcrete, Stuart Creek, southern Lake Eyre Basin, where Brad Pillans has collected anatase-rich silcrete samples for U-Pb dating at ANU

History of Aridity – *John Magee, John Chappell*

This new project researches the history of aridity in Australia, in terms of regolith processes at the continental scale. It will provide the framework for many other LEME projects. Australia became progressively drier while it drifted northwards in the Cenozoic, and its regolith and landforms should record major geological events like the separation of Australia from Antarctica, the onset of strong easterly currents in the Southern Ocean (Eocene), global cooling and development of an Antarctic ice sheet (Oligocene) perhaps with reduction of atmospheric CO_2, uplift of the Himalayas (Mio-Pliocene) which enhanced Asia-Austral monsoons, and closure of the Panama isthmus (Pliocene) which enhanced deep ocean circulation and northern hemisphere cooling.

The complexity of our climatic history and its effects is illustrated by the occurrence of thick alluvial fan remnants in arid-zone ranges; non-catenary slopes mantled by multiple buried soils in the eastern highlands; variations of soil production rate and salinisation; slopes of unweathered bedrock adjacent to deep-weathered duricrusted crests; continental dune-fields of different age; past perennial lakes where only dry lakes or playas exist today, and extensive but now-inactive colluvial aprons. This project will provide a framework for interpreting thick gravels, duricrusts, silcretes, and regolith-choked palaeochannels.

In addition to physical processes that contribute to regolith and landscape evolution, saline groundwater plays a complex role, particularly at and near playas. Episodes when playas approached halite saturation were characterised by deflation of sediments and salts, which dispersed across the continent, probably suppressed vegetation, promoted dune activity, and added salts to the landscape.

This new project will interact widely within the "discovery science" of LEME, and will be of international significance. It will use the full range of dating and analytic techniques available to the team, plus the use of cosmogenic isotopes to establish quantitative models of soils production and soil loss.

In its initial year the project studied dunefield chronology in the Strzelecki, Tirari and Southern Simpson Deserts in northern South Australia and the Northern Simpson Desert in southern Northern Territory. The project incorporates the PhD research of Kathryn Fitzsimmons and other work involving John Magee, John Chappell, Ed Rhodes and Derek Fabel which aims to combine OSL dating and novel cosmic isotope dating of deep dune profiles. This involves drill rig sampling. The two modules overlap

Photograph: Ian Robertson

geographically in the Strzelecki Desert, ensuring that results from the novel cosmic dating exercise and the drilling will be accessible to Kathryn Fitzsimmons.

In May 2004 John Chappell and Ed Rhodes used the ANU RSES drill rig to sample dunes on New Crown Station in the Northern Simpson Desert (NT). It was then used by John Magee in the Lake Frome and Moomba areas of the Strzelecki Desert (SA). Suitable large dunes, thought likely to contain multiple stratigraphic horizons, were selected where it was possible to locate the drill rig high on the dune. OSL and cosmic isotope dating samples at regular intervals (1-1.5m) down the dune profile were obtained in 20cm stainless steel push tubes within solid auger casing. Two dunes at New Crown, one at Lake Frome and two at Moomba area were successfully sampled using this technique, meeting the targets for the field work. The samples are now being processed in the laboratory, but no results are yet available.

Kathryn Fitzsimmons in the Strzelecki, Tirari and Southern Simpson dunefields of the Lake Eyre Basin is examining different regional dunefield patterns as revealed in satellite imagery and how they relate to dune landscape history. She visited specific target sites in mid 2004, based on satellite image mapping, and obtained samples for OSL dating, sedimentological, petrological and mineralogical analyses.

TECHNOLOGY DEVELOPMENT PROJECTS

Electrical and Electromagnetic Regolith Studies – *Graham Heinson, John Joseph, Anton Kepic, Jayson Myers, Stewart Greenhalgh, Paul Wilkes*

These are mostly student projects with LEME staff as co-researchers. Details are provided in the Chapter on Application and Commercialisation. The projects include:

- Margarita Norvill (PhD CUT) has developed a new signal processing technique for harmonic noise removal in electrical and EM geophysical data, and for spherics removal with arrays of sensors.
- Anousha Hashemi (PhD CUT) is developing innovative EM techniques for exploration for high-grade manganese ore under cover in the East Pilbara of WA.
- Philip Heath (PhD AU) is developing 3D automated inversions of potential field tensor data.
- Hashim Carey (MSc AU) used the "applied potential" electrical technique to avoid near miss or "*Mise a la Masse*" situations of drill holes in zones of mineralisation. He removed the electrode effect from the observed electrical potential data.
- Tania Dhu, (PhD AU) is using electrical and EM data to characterise regolith land forms and near surface features. Data is being used from river-borne nanoTEM from the Murray River, nanoTEM from Tunkillia, EM38 from Hermann's Gap, and GEM300 from Tibooburra.

Directions for 2004-2005

Regional focus projects will continue to be the principal vehicle for delivery of research outcomes to minerals explorers through collaboration with Program Two, and to natural resource managers through collaboration with Programs 3 and 4. In the case of mineral explorers these projects will improve their success rate, and reduce the risks attached to those elements of their exploration strategy that depend on understanding regolith processes. The ultimate goal of these projects will be the development of terrain-specific exploration methodologies. In the case of natural resource managers, regional focus projects will concentrate on enhancing management outcomes by reducing risk attached to those elements of their management strategy that depend on understanding of regolith processes.

Program 2: Mineral Exploration in Areas of Cover

Program Leader: Dr Ravi Anand

Highlights

- Microbes have been shown to play an important part in mobility of gold. DNA staining on gold flakes shows the presence of biofilms.
- There is evidence of remobilised gold and pathfinder elements in secondary minerals formed in transported overburden by hydromorphic and vegetation mechanisms.
- Bacterial leach experiments allow identification of possible areas of buried mineralisation that were not apparent through other chemical extractions. However, the success is inconsistent
- HyLogger has acquired spectra and imagery of some 35000m drill core in South Australia.
- Fifty case histories on Regolith Expression of Australian Ore Systems were released via the LEME website during the reporting period.

Overview

Program 2 aims to provide new and improved tools for mineral exploration in areas of cover. This is being achieved by understanding the processes that move metal ions and complexes through transported cover, so as to make exploration geochemistry more predictive and less empirical. The projects involve multi-core parties and are multi-disciplinary, working in collaboration with the exploration and mining industry. There are three broad categories of projects, generic processes, regional focus, and technology development

GENERIC MECHANISMS FOR GEOCHEMICAL ANOMALIES

Metal mobility and microbes – *Bear McPhail, Sue Welch, Andy Kirsty, Joel Brugger, Ken McQueen, David Ellis, Brad Opdyke, David Gray, Frank Reith, Alistair Usher*

This suite of projects reflects a greater research interest in the role of biota in mineral transformation processes in the regolith. Achievements are set against Milestones 7, 9 and 10.

Frank Reith (PhD student ANU) is looking at the role of heterotrophic bacteria in the dissolution, transport and stabilisation of gold in three gold sites around Australia – Tomakin in temperate southeast NSW, Peak Hill in semiarid central NSW, and Palmer River in tropical north Queensland. He has completed microcosm experiments using field fresh, sterilised and gold-spiked samples, showing conclusively that gold is mobilised by microbial activity. Microcosm experiments monitor changes in regolith, water geochemistry and changes in microbial ecology. Although it is yet to be demonstrated unequivocally, we can observe changes in microbial ecology that correlate with gold mobilisation and trapping. Frank is now working with Steve Rogers in CSIRO (Adelaide) Waite Laboratories, where DNA and RNA from gold flakes from both Tomakin and Palmer River have been successfully isolated. DNA staining on gold flakes shows the presence of biofilms.

Alistair Usher (PhD student ANU) has successfully measured UltraViolet-Visible (UV-Vis) absorbance spectra of Au(III) complexes in LiCl and NaCl solutions, over a wide range of chloride concentration and temperatures between 25 and 90°C. The results show the presence of several unidentified gold chloride complexes at low (much less than seawater) chloride concentrations. Quantitative interpretation of complexes and calculation of thermodynamic properties has begun. The results will allow us to predict how gold can be transported in fresh and hypersaline waters under oxidised (close to atmospheric oxygen), acidic conditions.

Sue Welch is looking at rates and phases of mineral dissolution reactions using soil, groundwater micro-organisms and microbial ligands, and comparing these with inorganic abiotic reactions. Laboratory experiments show that in granite samples, there is a ten-fold increase in release of major ions like Fe and Al in organic solutions, compared to inorganic controls. Trace elements Ga, Ti, Li and REE show preferential mobilisation by organic acids.

Geochemical modelling, a collaborative project with pmd* CRC, is focussed on developing a web-based database of reliable thermodynamic properties and associated modelling software. We are now starting the critical assessment of thermodynamic properties in the database. We have chosen gold minerals and aqueous species, of interest to both LEME and pmd* CRC in the dispersion and formation of gold anomalies in the regolith, and the formation of hydrothermal gold deposits.

Mineral and biological hosts for gold and base metals – *Ravi Anand, Rob Hough, Mel Lintern, Cajetan Phang, Ray Smith, Charles Butt, Steve Rogers, Bear McPhail, Ken McQueen, Karen Hulme, Ryan Noble*

We continue to study mineral phases and associations that act as hosts for trace levels of metals in regolith. Achievements in this suite of projects are set against Milestones 7 and 8. The new range of modern analytical instruments enables us to better understand the formation of geochemical anomalies in regolith. Micro-mineral mapping combined with *in-situ* geochemical analyses at the micron scale, points to new techniques of anomaly detection. We have shown that significant anomalous gold in hardpans and clastic ferricrete some 20 metres above the primary/supergene gold

deposit in the Enterprise Pit (Mt Gibson gold project), occurs within a variety of hosts, including kaolinite spherules, hematite overprints of hematite clasts, hematite cutans, and calcite matrix. All of this is consistent with late stage hydromorphic dispersion of gold in transported regolith.

Example of micro mineral mapping by LA-ICPMS. This technique is a powerful *in-situ* method of identifying the sites of Au and other element distribution in regolith minerals.

Evidence of remobilised gold and pathfinder elements is most instructive at the Lancefield goldmine, where the oxidised ore body is overlain by sediments comprising 10-20 m of mottled Permian fluvio-glacial sediments, 3-8 m of mottled Tertiary palaeochannel clays, and 2 metres of hardpanised colluvium. There is evidence from palaeomagnetic dating of multiple oxidising (weathering) events pre-Permian, post-Permian, post-palaeochannels and post-hardpan. An early As-Cu-Au hydromorphic system seems to have been adsorbed on goethite/hematite mottles in Permian, and a later Cu-Zn(-Au) system adsorbed onto goethite in mottles in the palaeochannels clays.

Ravi Anand with assistance of Prof Pauline Grierson (University of WA) is conducting biogeochemical surveys over base metal (Jaguar) and gold (McGrath, Whirling Dervish) mineralisation in the Yilgarn Craton. Phyllodes, branch wood, bark, litter and roots of several plant species are being analysed. Pits were excavated to collect soil samples and plant roots for microbiological studies. Initial analytical results are very encouraging. This complements the research done on bio-geochemistry of *E camaldulensis,* reported in the Program 1 Report.

Ian Robertson and Ravi Anand (CSIRO) testing the potential of leaves, branches, roots and bark as a sampling medium for locating base metal mineralisation at the Jaguar Deposit, near Leonora, WA

The *Gold in Calcrete* project of Mel Lintern is ongoing. *Bacillus cereus* and other spore-forming soil bacteria, previously noted as being associated with Au deposits in other countries, have been isolated from gold prospects in South Australia and Western Australia.

Ryan Noble (PhD student Curtin University) is investigating the efficacy of bacterial leaching in locating gold mineralisation in the Stawell goldfield of western Victoria. The results of BL experiments have identified possible areas of buried mineralisation that were not apparent through other chemical extractions. However, the success is inconsistent.

Biogeochemistry of calcrete – *Andreas Schimdt-Mumm, David McKirdy, Joel Brugger, Mel Lintern*

Some initial testing of microbial activity was done in carbonate-bearing dune sands on the Barns prospect. The aim was to identify microbially induced enzymatic degeneration of urea, a breakdown product from the decay of amino acids. It was demonstrated that the urease-enzyme induced breakdown of urea does occur in the auriferous calcrete bearing sands on Barns. This is direct indication of microbially mediated calcite precipitation in calcrete.

Mechanisms of metal transfer through transported regolith – *Mehrooz Aspandiar, Ravi Anand, David Gray*

The project aims to summarise potential geochemical dispersion mechanisms through transported regolith overlying known mineralisation. It selects unmined sites which will serve as testing grounds for individual dispersion mechanisms. A review of possible mechanisms for creating anomalies in soils above transported regolith highlights difficulties in facilitating upward movement of ions and complexes from the watertable to surface soils. Perhaps the best avenues of research lies with surrogate soil gasses and biotic transfers.

The outlook for the next six months is to select field sites with known surface responses of buried mineralisation to identify mechanism of mobility. These would become type sites for Stage 2 research, possibly through AMIRA.

The AMIRA project P618 *Isotopic discrimination of partial leach geochemical anomalies in covered terrains* was completed and the results remain confidential to the industry sponsors.

REGIONAL FOCUS PROJECTS

Western New South Wales regolith project – *Patrice de Caritat, Steve Hill, Dirk Kirste, Richard Barratt, Kingsley Mills, Tim Sharp, Barney Stevens, Kylie Foster, Guy Fleming*

In its third and final year, the *Western New South Wales Regolith* project had a focus on the study of the regolith in the Teilta 1:100,000 map sheet. A hydrochemical study found that groundwaters of distinct character occur in the Teilta area. They are compositionally different from the regional Curnamona groundwaters, having higher sodium and bicarbonate contents, are more reducing and warmer. They are typical of Great Artesian Basin (GAB) groundwaters, the concealed southern extent of which coincides with the study area. The GAB groundwaters have been affected by bacterial sulfate reduction (BSR), which decreases the sulfate concentration in groundwaters. This process also results in a heavier sulfur isotopic composition of the remaining sulfate dissolved in groundwater. The combined effect of BSR is thus to make the waters less applicable from a mineral exploration perspective. The lesson is that more selection criteria should be applied to groundwaters affected by BSR, when searching for evidence of interaction with sulfide mineralisation under cover.

The Teilta basement modelling study shows that depth to prospective basement varies from 0 to 250 m. A product of this study is a contour map showing the depth to prospective basement over the Teilta map sheet.

Curnamona Craton and White Dam Projects – *Steve Hill, Pat James, John Joseph, Graham Heinson, Karin Barovich, Aaron Brown, Ian Lau*

This project was initiated in 2002-03 as a Program 1 project, and has now moved to Program 2. It studied the regolith-landform framework for the Olary and Mingary region of the central Curnamona Craton in SA, detailed regolith geology of the White Dam mineralisation. Results on regolith processes and geochemistry for 2003-04 are reported in the Program 1 Report.

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

The aim of this project, jointly sponsored by CRC LEME, CSIRO Exploration and Mining, and Geological Survey of Western Australia, is to produce a geochemical map of the western Yilgarn Craton using lateritic residuum as the principal sample medium. Sampling is on a 9 km triangular grid, mainly along public roads in agricultural areas, nature reserves and National Parks. Samples mainly comprise loose lateritic gravel handpicked from surface, and lateritic duricrust. Results will be published in two stages. Stage 1, to be completed by mid 2005, will cover the south-western quadrant of the Yilgarn Craton. To date, approximately 500 samples out of a proposed total of 1100, have been collected. Data for the southwestern quadrant will be released in 2005 in digital format.

Yilgarn regolith – *Matthais Cornelius, Balbir Singh, Ian Robertson, Amanda Cornelius, Ravi Anand, Tim Munday, David Gray, Mehrooz Aspandiar, Lindsay Collins, Anton Kepic, Sue Welch)*

The objective of this project is to develop more effective techniques applicable to mineral exploration, leading to reduced discovery costs (drilling and surface exploration), through better understanding the processes of gold and base-metal anomaly development in the sedimentary (colluvial-alluvial sequences) terrains of the Yilgarn Craton.

Sampling, field studies and analytical work at Whirling Dervish and McGrath gold deposits have been completed and data are being interpreted. Work in 2004-05 will involve mineralogical, geochemical and soil gas studies.

At the Jaguar volcanic hosted massive sulphide (VHMS) deposit, work has been carried out on colluvium and alluvium. This is aimed at identifying the regional regolith expression of buried VHMS mineralisation. Initial results show a geochemical signature in locally derived ferruginous gravels within the colluvium sequence. Achievements are set by Milestone 12.

Regolith expression of Australian ore systems – *Charles Butt, Ian Roberston, Matthias Cornelius, Keith Scott, Jennie Campbell, Anglo Vartesi, Travis Naughton*

This project is to produce a compilation of the regolith expression of a wide variety of Australian ore systems, leading to a series of conceptual exploration models. A total of 50 case histories have been released on the CRC LEME web site (www.crcleme.org.au/RegExpOre). It is intended to publish in 2004-05 a comprehensive monograph that may eventually include as many as 100 case histories, plus description of predictive models.

TECHNOLOGY DEVELOPMENT PROJECTS

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

Portable ASD spectro-radiometer producing automatic mineralogical analysis from rapidly read VSWIR spectra

This project aims to develop practical automatic logging and interpretation tools for regolith materials obtained as core, drill chips, or analytical pulps. It develops spectral logging technologies which measure reflected radiation in the visible, near and shortwave infrared spectrum, and converts this data into mineral species. In the past year we have developed a suite of case study materials for different geological and regolith settings. Information gathered now forms the basis for developing a regolith materials-

based spectral library for use in software programs developed within CSIRO for interpretation of spectra, ie The Spectral Geologist and The Spectral Assistant (TSG/TSA). It also will allow automated procedures for classifying regolith materials using spectrally derived mineralogical and petrochemical information.

This has now become a collaborative project with CSIRO Divisions of Exploration and Mining and Mathematical and Information Sciences. They were the originators of the HyLogging system of spectral logging technologies and the TSG spectral processing software, as applied to drill core. Progress is set against Milestone 14.

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

Alexandria Pingelly (Honours student AU) completed studies of the relationship of Hymap signatures to regolith materials over zinc mineralisation at Reliance and Beltana deposits in the northern Flinders Ranges. Complementary PIMA measurements of image-located surface sites provided a higher level of confidence in the reflectance spectra derived from the HyMap data.

The CSIRO HyLogging system was used over a four month period to acquire spectral data and imagery of some 35,000 m of drill core. It focussed on acquiring data from drill cores and chips from prospects including Weednanna, Barns, Tunkillia, Tarcoola and Lake Harris Greenstone in the Central Gawler Gold Province. Preliminary results from Barns show interesting new correlations between mineral assemblages and gold mineralisation. In addition White Dam, Garford Palaeochannel, several uranium exploration holes and drill holes from Poona copper deposit in the Moonta/Wallaroo district were scanned.

Directions for 2004-2005

All projects will continue next year. Generic process projects will be the core of Program 2, and we anticipate significant progress in metal dispersion processes, which will benefit the exploration industry. The ultimate aim is to make geochemistry work through transported overburden. We will also use Synchrotron radiation techniques to characterise adsorption of elements on specific minerals. These will be the first *in-situ* experiments to specify true situation of metals in weathering products above a mineral deposit, and crucially, identify whether they were incorporated as the weathering phases grew, or were hydromorphically dispersed later. We also expect to determine in what form metals were transported – as ions, complexes or colloids. These fundamental issues will enable a bottom-up approach in elucidating how metal anomalies form in the regolith. We continue to collaborate with mineral industry geoscientists and seek financial support where possible. Providing suitable study sites can be found, we expect to commence Stage 2 of *Mechanisms of Metal Transfer through Transported Regolith*.

Research on hydrogeochemistry of gold and base metals will expand. Hydrogeochemistry as an exploration tool can have a major role for Ni-sulfide deposits around the world in regions of cover. This is a fertile field for future research which LEME will pick up. The immediate focus will be the productive Leonora-Wiluna belt. We will be seeking external funding for this project. LEME will also join a consortium researching soil gas above mineral deposits.

Photograph: Ian Robertson

Program 3: Environmental Applications of Regolith Geoscience

Program Leader: Dr Steve Rogers

Highlights

- Pilot geochemical surveys of the Riverina district demonstrate the value of baseline geochemical maps to identify exploration pathfinders for gold and copper.
- Airborne electromagnetic and electrokinetic seismic systems have promise in mapping regolith architecture.
- New LEME and WA Government research initiatives will assess geochemical risks associated with salinity mitigation drainage schemes in the WA wheatbelt.

Overview

Program 3 provided the initial regolith support for dryland salinity research in Program 4, but also had a developmental focus on environmental geochemistry and environmental hazards. Consequentially its original milestones were broad and, as explained earlier in the Annual Report, new program milestones have been devised. A new business plan, drawn up by Steve Rogers, further develops the environmental and biological regolith research activities in this Program, and gives less support for Program 4, moving geophysical applications to salinity-related projects to Program 4 from 1 July 2004.

MDBC pilot baseline geochemical surveys – *Patrice de Caritat, Ian lambert, Alice O'Connor*

Geochemical baselines provide information on the natural concentration of chemical elements and compounds in regolith. Natural concentrations vary regionally, due to geological, biological and other processes. It is important to know the natural concentration and distribution of elements so that:

- baselines can be established to measure future changes, and
- Localised anomalies or contaminations can be identified and understood.

This knowledge will assist in environmental management and mineral exploration. Regional geochemical surveys targeting 'normal' (background) sampling sites, as opposed to mineralised or polluted sites, are needed to generate baseline geochemical datasets. These fundamental data layers are needed to develop environmentally appropriate and responsible land-use policies, and are also useful in promoting the mineral potential of certain regions.

The focus of this project is to carry out a pilot project in the Riverina bio-region in southern New South Wales and northern Victoria, to test methodologies for regional geochemical surveys in Australia. Overbank sediments were chosen as the preferred sampling media, from which a near-surface sample (TOP: O horizon, from 0-10 cm below the humus layer) and a bottom sample (BOT: B-C horizon, ~10 cm interval between approximately 70-90 cm below the humus layer) were collected. Sample sites were selected to be near outlets or spill points of large catchments, so that overbank sediments would represent well-mixed, fine-grained composite samples of all rock, regolith and soil types present in the catchment. River Red Gum (*Eucalyptus camaldulensis*) leaves were also collected at a number of locations.

Sample characteristics were documented, along with bulk parameters (texture, moist and dry colour, field pH) in the field. In the laboratory, samples were analysed for moisture content, EC 1:5, pH 1:5; some were also subjected to laser particle size analysis. Bulk (<180 µm) composition was determined by X-Ray Fluorescence (XRF), Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Instrumental Neutron Activation Analysis (INAA). Samples were also analysed by sequential digestion and prepared for heavy mineral separation. All together 62 elements were determined. Maps are presented showing spatial and statistical distributions in TOP and BOT samples, and TOP/BOT ratios. These results demonstrate the application of geochemical maps to identification of exploration pathfinders for Au or Cu-Au mineralisation. These results will be the basis for further interpretative work, and the springboard for a geochemical atlas of the Riverina.

Work carried out in this project meets the requirements of Program 3 revised milestone 5.

Regolith Background to Environmental Geochemistry – *Patrice de Caritat, Colin Pain*

This year we hosted an international short course on *Medical Geology, Health and Environment*, on behalf of the International Working Group on Medical Geology, a part of the International Union of Geological Sciences Commission on Geological Sciences for Environmental Planning (COGEO-ENVIRONMENT). This took place in Canberra in December 2003, with presenters coming from United States and Sweden.

Last year we also reported the invitation by COGEO-ENVIRONMENT for LEME to host an International Geoindicators Workshop. Geoindicators are measures (magnitude, frequencies, rates, trends) of geological phenomena occurring at or near the Earth surface, whose observed changes may be significant in documenting environmental change over a periods of 1 up to 100 years. Most indicators are associated with regolith processes and are relevant to the measurement of progress in combating dryland salinity, and other land management issues. The primary sponsor of the Workshop, Geoindicators Initiative (GEOIN), is a non-profit international endeavour to encourage the application of

Photo by Patrice de Caritat

Fieldtrip of the Geoindicators workshop investigating impacts of the January 2003 bushfires on regolith and environmental systems of the ACT region

Don Hunter (LEME PhD student) and Andrew Boyd (Rio Tinto Consultant) watch HOISTEM system overfly a calibration loop on the ground, Paraburdoo, WA, part of the AMIRA project P407

geoscience to environmental issues through monitoring and assessing rapid geological change. The workshop was held in Canberra in late November 2003, with presenters coming from Canada, Lithuania and Great Britain.

Work carried out in this project meets the requirements of Program 3 revised Milestone 5.

WA geochemical surveys – *Charles Butt, Ron Watkins*

This initiative was a scoping study to develop a full proposal for the application of regional geochemical surveys in areas of medium- to broad-acre agriculture, in the areas of agricultural production, environmental management and mineral exploration.

Although multi-application regional geochemical surveys are regarded as essential components of public geoscience applied to resource management in many parts of the world, such surveys have not been conducted in Australia. Moreover they have rarely, if ever, been conducted in areas of broad-acre agriculture. This project aimed to test the benefits of such surveys.

Following the pilot geochemical data from the Western Australia wheatbelt, a full project was proposed to the Grain Research Development Council in November 2003.

Airborne EM – *Jayson Meyers*

Last year we reported on the application of new airborne electromagnetic (AEM) systems for regolith mapping and environmental applications. This included sponsorship and support of *AMIRA Geological-Constrained Automatic and Interactive Interpretation of EM data* (P407B) Project, which is developing innovative software for processing AEM data to produce three-dimensional conductivity depth interval (CDI) models. Developments on the calibration of HoistEM data were carried out at CUT, and results were accepted for publication at the ASEG annual meeting in Sydney in August 2004. EM inversion software being developed in P407b was modified to accommodate LEME projects in South Australia, principally Riverland, whereby data from the new Resolve FDHEM system of Fugro Airbornes could be inverted to CDIs. Further refinements in the mathematics for inversion and noise reduction, code and programming were carried out to accommodate old data sets and generate better CDIs. Beta-test trials were run on historical CRC-AMET owned SALTMAP and TEMPEST TDAEM data, and Cawse Geophex FDHEM data. Preliminary results are very encouraging. The better noise removal and CDI processing is leading to more reliable and better calibrated CDIs, without having to collect ground verification data and carry out long-running noise-removal algorithms.

Continued research into HoistEM inversion and exploration targeting was carried out on Woodie Woodie data sets. A new manganese ore discovery was made adjacent to the Radio Hill pit by drilling a HoistEM target. Preliminary resource estimates show this blind discovery to be of large tonnage. Calibration experiments incorporating ground data from drill holes has lead to a dramatic improvement in noise reduction and more reliable CDIs. An extended abstract has been accepted for publication by the ASEG.

TEMPEST TDAEM data is still being processed in Adelaide as part of the LEME Gawler Craton project. EM Flow training was given to students using the AMIRA project software.

Work within this project meets revised Milestone 6 in Program 4. Management of this project will be transferred to Program 4 from July 1 2004.

Direct seismic-electric layer detection – *Anton Kepic, Paul Wilkes*

Last year we reported on the development of electrokinetic seismic (EKS) for regolith mapping. New high-resolution seismic and electrical methods can operate at frequencies that allow direct detection of boundaries in regolith. Such direct detection methods involve a controlled source that passes acoustic (seismic) or electrical energy into the subsurface, which then bounce off, or travel along layers in the regolith, and is finally detected as a response at the surface. Little is known about the capabilities of these methods in mapping regolith features, which may be strongly contrasting and sometimes subtle. We are working with ANSTO on seismoelectric and borehole methods as part of this project.

Field tests of the seismoelectric method conducted at Nannup in southwest Western Australia have been successful. A new technique of gathering data was trialled at three different borehole locations. The method correctly detected sand-clay interfaces from depths of 5 –120 metres. Normally, only 50% of soundings are successful in producing any interpretable data, so this is a great improvement. New records for depth of detection were also achieved. We are able to see between 3 to 10 times deeper than other researchers in the field.

Curtin University LEME students Margarita Norvill and Mohammad Rosid worked in the Nanup field trials, and produced conference abstracts based upon their work. These will be presented in August 2004 at the ASEG meeting in Sydney, and in October 2004 at the SEG meeting in Denver, USA.

Work within this project meets revised Milestone 6 in Program 4. Management of this project will be transferred to Program 4 from July 1 2004

Regolith mapping standards – *Colin Pain*

Currently there is no nationally agreed standard for mapping regolith. We continue to develop those standards, and present them to both the geological and natural resources communities. We have been discussing standards with stakeholders and interested parties, primarily Chief Government Geologists, and the Working Group on Land Resource Assessment. A draft national standard has been completed and distributed to interested parties, for comment. Management of this project will be transferred to Program 4 from July 1 2004.

PROGRAM 3 BUSINESS PLAN

Given the previous support nature of Program 3, and the re-scoping of Program 3 milestones, there was a requirement to re-define scientific deliverables and outcomes of this Program, whilst still retaining the original objectives. Figure 1 summarises potential business opportunities and NRM issues that LEME has the scientific capacity to address. It is based on a detailed assessment of the potential market for regolith knowledge. State and Australian NRM agencies, state agriculture departments, and commercial environmental consults are identified as potential clients for LEME environmental regolith geoscience research.

Program 3 addresses the following strategic research themes; Theme 3 Acid sulfate soils – Regolith processes and implications, Theme 8 Regional Geoscience and Urban Australia, Theme 9 Environmental Geochemistry and the Regolith.

Based on these three themes a set of research priorities is identified, using criteria such as research capacity, existing areas of research, relationships with clients, ability to deliver scientific outputs over short time periods (12-18 months), and external client requirements.

Program 3 priority research focus areas and their associated milestones

1. Inland and floodplain acid sulfate soil and sulfidic environment geochemistry and mineralogy.

   New Milestone: Establish the distribution, conditions of formation, and management options of inland acid-sulfate soils, and alkaline soils – Jun 2007.

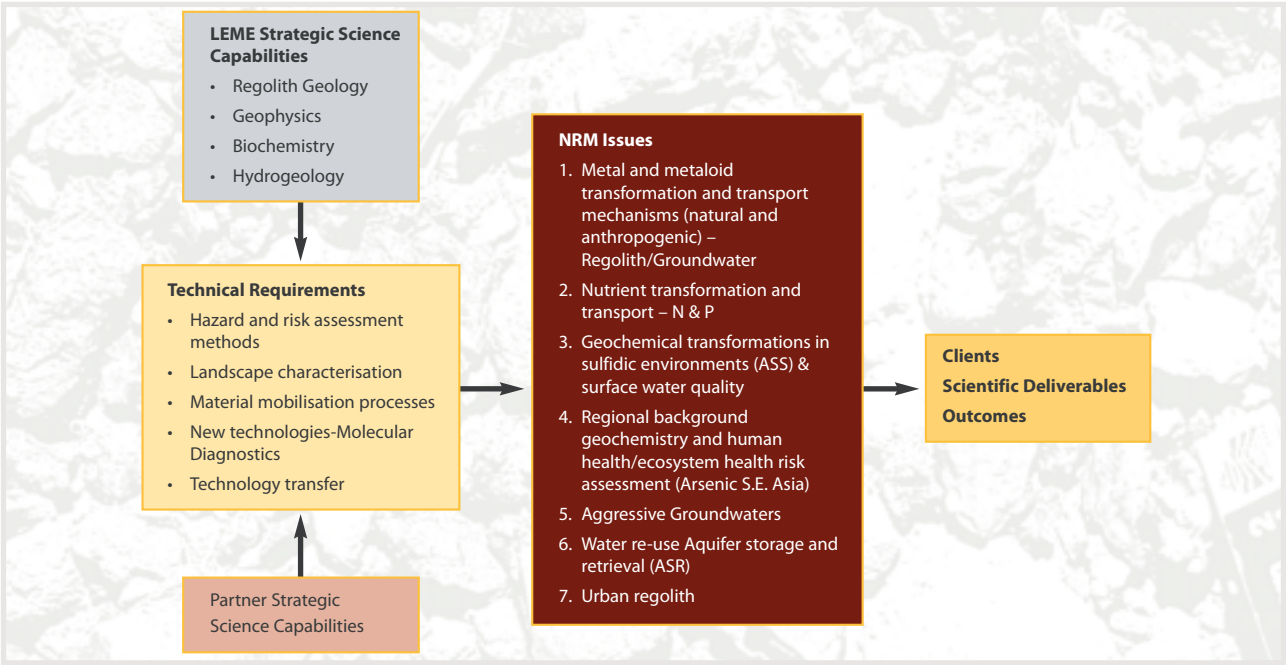
2. Trace element transport and transformation in the regolith, with strategic focus on developing geochemical risk assessment and understanding biological (both faunal and microbial) processes across all four LEME core research Programs.

   New Milestone: Develop methodologies for geochemical risk management of soils and groundwater at the catchment scale – by Jun 2005.

3. Regional and national biogeochemical surveys.

   New Milestone: Complete regional baseline geochemistry studies in three diverse regions – Riverina, Gawler and WA Grainbelt – by Dec 2006.

Figure 1 – Business model for Program 3 – 'Prediction, Risk Assessment & Management'



Photograph: Ian Robertson

Directions 04-05

The main focus will be on developing new projects addressing the three revised research priorities for Program 3.

A new two-year project *WA Wheat belt Drainage Acidic Groundwater – Geochemical Risk Assessment and Evaluation of Management Options* will commence in July 2004, jointly funded by LEME and the WA Department of Environment (WA DoE). The project is a multi-agency consortium involving LEME, WA DoE, WA Dept of Agriculture, CSIRO Healthy Country Flagship and community groups such as the Western Australia Channel Management Group.

This project aims to address issues like acid drainage and trace element transport, occurring as a result of salinity mitigation engineering drainage schemes in the WA wheatbelt. These include:

- Understanding processes of acidic groundwater in pre-disturbed regolith, and beneath the cleared landscape.
- Forecasting impacts of engineering drainage on transport and transformation of trace elements in undrained and drained environments (geochemical risk assessment).
- Assessing feasible management options (opportunities and constraints).
- Demonstrating and evaluating management options such as productive recovery of minerals, and salt and trace elements in drainage waters at relevant scales.

Three new CRC-funded inland acid sulfate soil projects will commence in the new financial year:

- *Impacts of water level drawdowns on the geochemistry of saline River Murray Wetlands*
- *Investigating the role of microbial processes in cycling of Fe, S and metals in acid sulfate soil sites*
- *Inland acid sulfate soils: distribution and regolith processes.*

All three projects plus two new LEME sponsored PhD projects at ANU will focus on a single site identified as having acid sulfate issues in the River Murray floodplain. Discussions between LEME and the South Australian Department of Water Land and Biodiversity Conservation (WLABC) to select a suitable site are ongoing.

Regional geochemistry survey work will continue to be seed-funded by LEME, with additional surveys being conducted in the Gawler Craton and Western Australia wheatbelt

Program 3 staff will be involved in organising the *International Conference on Biogeochemistry of Trace Elements* in Adelaide in April 2005. LEME is a sponsor of this meeting.

Program 4: Salinity Mapping and Hazard Assessment

Program Leader: Dr Ken Lawrie

Highlights

- New constrained inversion techniques integrating AEM, geology and borehole data deliver spectacular results at Riverland.
- Methodologies are developed for integrating geophysics, regolith-landscape analysis, borehole data and sedimentology to produce 3D models essential for salinity mitigation.
- AEM is an essential, cost-effective tool in identifying salt stores above and below the watertable.
- Isotopes and mass balance calculations indicate salt has accumulated over hundreds of thousands of years from marine sources.
- NRM projects kick off in Western Australia.
- Gravity and TEM precisely defined axes of palaeochannels that are considerably offset from their surface expressions.

Overview

Research in 2003-04 focussed on providing reports, datasets and decision-support tools to underpin salinity management in a variety of landscapes and land-use zones. Most projects involve integrated geoscience that combines regolith, landscapes, geology, airborne and ground geophysics, hydrogeology and hydrogeochemistry, at sub-catchment scales.

We have finalised externally-funded NAPSWQ projects in South Australia and in the Lower Balonne catchment (Qld). Client assessments of our outputs are positive, attracting invitations to participate in further projects in other catchments. Several Centre-funded pilot projects were completed, with additional external funding received for some of these including *Groundwater Flow Systems* project. A new collaborative project (*Catchment to Coasts*), on monitoring and evaluating catchment health, funded by the NLWR Audit 2 was started.

Highlights include the spectacular results of *Constrained Inversion of Helicopter EM*, in tandem with Riverland and Tintinara Projects in South Australia. Outputs have contributed to salinity credits through our contributions to recharge modelling. Additional future benefits are anticipated through changes to irrigation zonation and reduced salt inputs to the main aquifer. The related project – *Loxton Salt Interception Scheme* (SIS), has assisted with the design and construction of new SIS bores that intercept salt in the aquifer before it reaches the Murray River. Benefits continue to flow from the in-river conductivity mapping, as shown by monitoring impacts of new SIS bores located using our knowledge. In the *Angas Bremer Hills Project* (SA), integration of regolith-landscape studies and airborne geophysics has contributed to salinity hazard assessment and catchment management plans.

In the *Lower Balonne* project (Qld), integration of AEM, regolith, landscape, hydrogeological and hydrogeochemical information give new insights into salinity and groundwater processes, and the recognition of a groundwater resource at depth. We demonstrated ways of reducing, by an order of magnitude, the acquisition costs of AEM data for salinity mapping.

The *Groundwater Flow Systems* project developed a multi-disciplinary method for producing *Hydrogeomorphic Response Unit* (HRU) maps. These are a sub-catchment scale version of Groundwater Flow System (GFS) maps, and will be used to underpin salinity interventions in upland landscapes. Our recently completed projects are recognised by research peers and land managers as making major contributions to better salinity and groundwater management practices.

The LEME Board has endorsed research into the application of regolith geoscience in integrated water management. Specifically, a joint research program is being discussed with CRCs Catchment Hydrology and Freshwater Ecology.

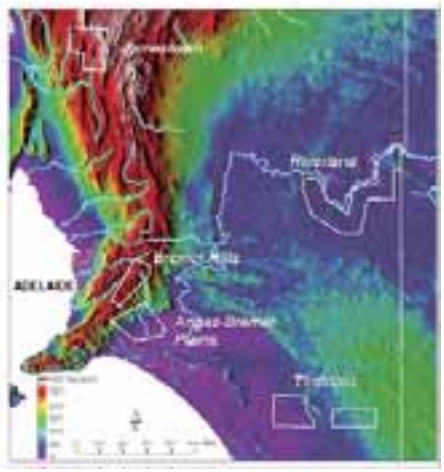
Over 40 staff contributed to the program during the year, and 12 students engaged in related research. A sedimentologist, two regolith geoscientists and specialist geophysicists were contracted to assist with projects.

A two-day salinity forum was held in July 03 to review achievements, plans for future work and opportunities for collaboration. Findings were delivered to the LEME Land Use Advisory Council meeting in Canberra 7 – 8 August, and the CRC Program 2nd year review. This helped to shape the portfolio of projects for 2004-05 and beyond.

SOUTH AUSTRALIAN NAPSWQ PROJECTS

Projects were completed in five geographic areas: Riverland, Tintinara, Angas Bremer Hills, Angas Bremer Plains, and Jamestown (Figure 1). This achieved Milestones 1, 2, 3 and 4. These projects were the first occasion in Australia where geophysical data were specifically acquired as part of a natural resource management strategy. LEME worked in collaboration with SA Government Department for Land, Water and Biodiversity Conservation, CSIRO Land and Water and the Bureau of Rural Sciences. It was important to ensure that geophysical products were

properly incorporated into existing management strategies. The SA-SMMSP was not simply about "salinity hazard assessment" nor about "salt mapping", rather it concerned the nature and distribution of regolith materials that prescribe water and salinity management practices. New technologies ensured geophysical products could be readily used in targeted salinity and water management options.



Several lessons were learned from the South Australian studies:

- Airborne electromagnetics (AEM) is essential in salinity management, but needs well defined targets and applications for the derived products.
- While focus on a specific target is important, the design of the survey should consider other targets that may be useful in salinity management. We are prepared for the unexpected benefit, but this should not be the driver of the survey.
- AEM is not limited to mapping of salt, but can map regolith materials.
- The success of the constrained inversion of AEM data was facilitated by a wealth of existing hydrogeological information – the more data, the more accurate the product.
- The assertion that where a large pool of land-management data exists at an appropriate scale, airborne geophysics is unlikely to add value, is incorrect. On the contrary, AEM should always be examined, *but only* where the means exists to translate derived information into something of value.
- The value of airborne geophysical (particularly AEM) data increases with the value of the asset. In lower value areas landscape and regolith considerations must be given to geophysical inputs in order to minimise costs.
- Similarly, in areas with limited hydrogeological information, there may be more investment in ground programs to get full value from AEM datasets.
- In project planning, it is important that all data generated contributes to *implementing* salinity management plans, which are invariably economic only when protecting significant assets, such as the River Murray.
- Derived products only have value if they contribute to the *planning* of economic activities.

Constrained inversion of DIGHEM helicopter EM data

This project was concerned with the calibration and inversion of *Helicopter Frequency Domain Electromagnetic* (HEM) data to derive products useful in areas of groundwater recharge in the Riverland area of the lower Murray. Specifically, the intent was to map the near-surface fine textured unit known as *Blanchetown Clay.* This is an aquitard which reduces recharge to the lower aquifer. The Blanchetown Clay is characterised by elevated conductivities relative to the overlying and underlying sedimentary units. The project aimed to interpret the variations in observed conductivity defined in the HEM data, and to map the distribution and thickness of the clay. Outputs from this project will lead to improved regional planning tools including:

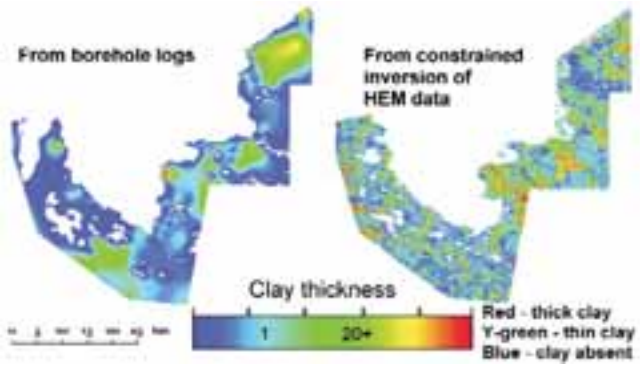
- Improved recharge maps for underlying groundwater systems up to 100 years into the future, using the Blanchetown Clay map and recent developments in soil hydrology.
- A floodplain attenuation model that simulates the impact on salt loads to the River Murray, and impact of irrigation development on the floodplain.
- Improvements to models commonly used in land-use and salt assessments (SIMPACT (irrigation planning model) and Border-to-Lock 3 MODFLOW (recharge and floodplain attenuation model).

Riverland

In this project, the intention was not to use airborne geophysics to define salt stores and salinity management strategies, but for defining biophysical features of landscape and regolith that can be used in designing better strategies. The objective was to map the distribution and thickness of the conductive, near-surface Blanchetown Clay which inhibits drainage and natural recharge. Increase in aquifer recharge in Riverland as a consequence of land clearing is one of the factors in predicting rates of increase in Murray River salinity. Working with SA-based partners we chose to use high-resolution helicopter EM data to map these materials.

Even for *data rich* areas, the constrained inversion of the HEM data was essential for accurately mapping the clay layer. Without spatial constraints on depth to groundwater, groundwater salinity, and petrophysical (electrical) responses of the principal sedimentary units, we would not have been successful in generated a useful product. Principal outcomes are:

- Development of new sedimentological models for the Blanchetown Clay and underlying Loxton-Parilla Sand.
- Successful staged use of airborne and ground geophysics for salinity management.
- Development of a new constrained inversion technique to map clay distribution.
- Geophysical interpretations contribute to salinity management plans and recharge reduction schemes. Clay thickness maps allow new estimates of aquifer recharge for dryland agriculture for present and future years (2023, 2053 and 2103). New hydrogeological models (MODFLOW and SIMPACT) are developed by CSIRO, DWLBC and SA DEH, using these data. These provide spatial information to achieve the greatest impact on river salinity through revegetation.
- Salinity inputs to the Murray River can be reduced.



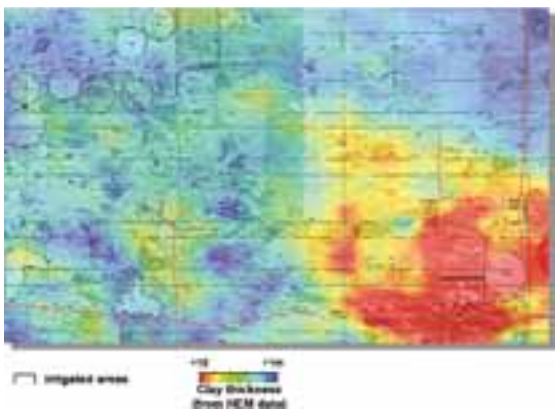
Tintinara

In the Tintinara area in southeast South Australia, where groundwater sustains irrigation and dryland agriculture, airborne geophysics can provide biophysical data relevant to the management of irrigation and groundwater recharge. The lifetime of the groundwater resource is limited by leaching of soil salt that accumulated prior to land clearing for agriculture. For some areas, groundwater may become saline and unusable for irrigation within 10 – 20 years. The presence of a near-surface clay unit can control the rate of deterioration by slowing recharge.

We mapped the clay-rich back-barrier lagoon-facies clays that developed as the Pliocene sea retreated from the Murray Basin. Geophysical forward modeling suggested that frequency-domain HEM could detect conductivity variations associated with this clay. A survey using the constrained inversion technique on RESOLVE® HEM data demonstrated that this unit could be accurately mapped. The clay imaging was confirmed with shallow drilling. We have now generated a clay thickness map for use in unsaturated recharge and groundwater salinisation modeling. Significant outcomes of this project include:

- The derived clay-thickness map was used for estimating rates of drainage through the unsaturated zone and for predicting groundwater recharge and salinisation of a deep aquifer. Salinisation probably commenced 10-20 years after irrigation rather than the 5-10 years suggested previously. This information is being used to plan irrigation development and reduce aquifer salinisation.
- Salt flux maps have been used to model long-term impacts of land clearing and irrigation development on groundwater resources by DWLBC.

Clay thickness and consequence for longevity of water resource

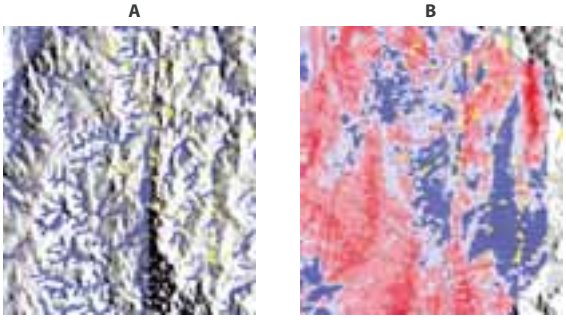


Angas Bremer Hills

Weathering history dating back to middle Mesozoic, combined with recent faulting, tectonic uplift and erosion has led to complex upland landscapes in the Angas Bremer Hills. Weathered landforms are juxtaposed with youthful landforms with little regolith. This produces complex relationships between landscapes and salinity. This project assessed gamma radiometric data, digital elevation models and regolith landscape studies for salinity hazard assessments in upland landscapes. The main findings of this project are:

- Gamma-ray data separates highly weathered landforms from areas of thin soil and fresh bedrock, with significant implication for the delineation salinity systems.
- Gamma-ray data and digital elevation data, when combined with ground data, gives valuable insights into the distribution of regolith materials and salt stores (Figure 1).
- The main control of salt in the landscape is rainfall. The development of regolith might determine the capacity to store salts, but rainfall largely determines the relative abundance of salts in the profile. Profiles in the high rainfall zone (western side of the hills) store considerably less salt than those on the drier eastern side.
- Highest salt fluxes are in Western Flat Creek in Mt Barker catchment, which have the highest annual rainfall in the area. Gamma-ray imagery indicates much of this catchment is deeply weathered. This suggests that high salt exports are associated with deeply weathered landscapes in high rainfall areas. Conversely, fresh water runoff is associated with less weathered catchments in areas of high rainfall. Salinity hazard maps have been produced taking into consideration regolith-salinity-rainfall relationships (Figure 2).
- 3D models (Figure 3) show relationships between regolith characteristics, salinity stores, stream discharges, and hydrogeomorphic processes. Conceptual models can predict the hydrogeological behaviour of different parts of the catchment. This information will constrain groundwater flow models and define spatially explicit hydrogeomorphic units (HGUs) over the whole region. The HGUs would classify the region into sub-catchments with similar salinity patterns and hydro-geomorphic processes, which will assist catchment managers with revegetation strategies.

Figure 1. A – Flag index LOW, drainage lines and mapped salt scalds over hillshaded DEM. Example taken form the northern part of the study area. B – K – residual image highlighting weathered landscapes in blue and less weathered in red.



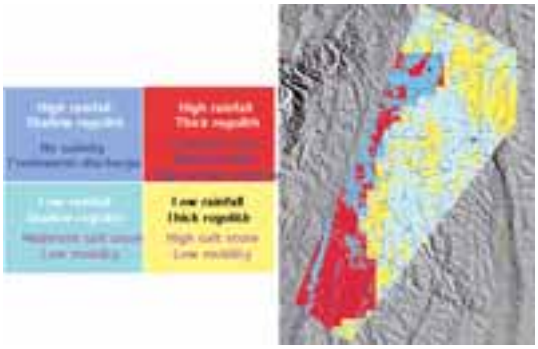


Figure 2 – Combined regolith and rainfall associations utilised to produce salinity hazard maps for the Angas-Bremer Hills project

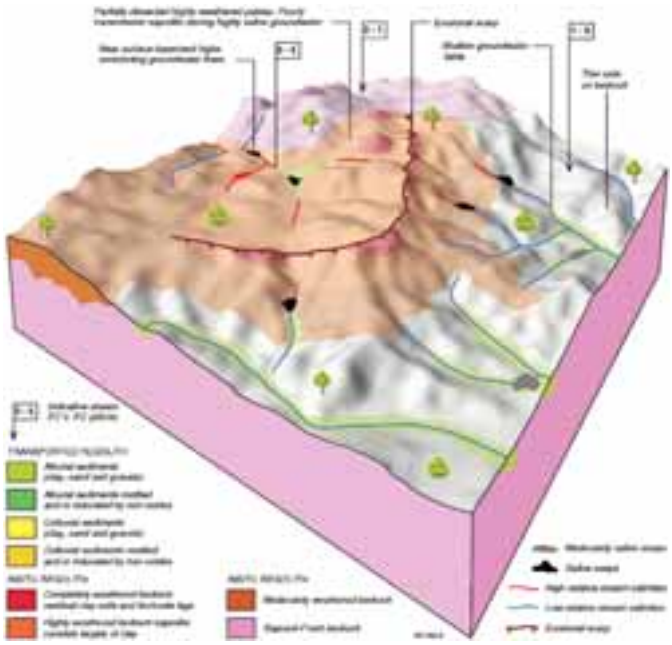
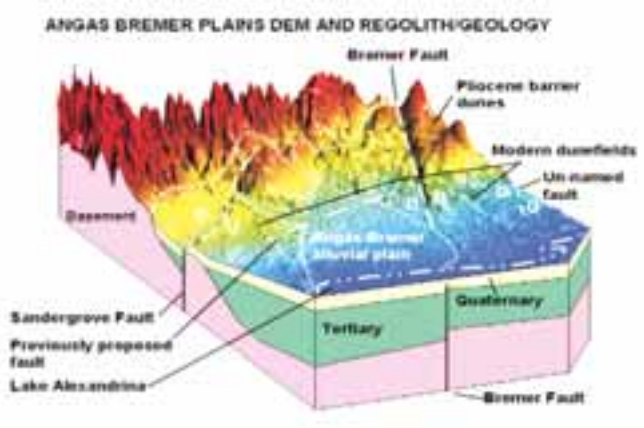


Figure 3. 3D – hydrogeomorphic model based on the integration of information on regolith, hydrological processes, salt stores, rainfall, stream EC and landforms

Angas Bremer Plains

This project aimed to provide a new regolith-landform framework for hydrological modelling, using available drill data, new airborne geophysics (DEM, magnetics, radiometrics and AEM), augmented by new drilling and field observations. Principal findings were:

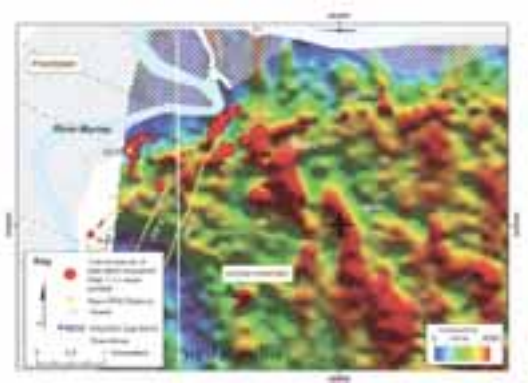
- Integrated datasets provide an excellent framework for understanding salinity and groundwater.
- However, palaeochannels of the Angas and Bremer Rivers were not discernible on magnetic images due to lack of magnetic detritus.
- DEMs are accurate to within 2-3 m, and should give elevations for non-surveyed water bores, allowing regional trends in watertable elevation and flow paths to be determined.
- DEM and AEM data do not support the presence of a fault previously thought to have controlled the recharge pathway of the Tertiary aquifer. Three new faults have been interpreted from AEM, DEM and drill data. These offset the aquifers by up to 80 m, and create a previously unknown local groundwater basin.
- Although AEM conductivity increases with salinity of the Tertiary aquifer, the relationship does not allow accurate prediction of good quality groundwater.
- Radiometrics combined with DEM show unrivalled detail of soil type, and should be able to be used to construct detailed soil maps.



Jamestown

Wide valleys and rolling hills of eastern Jamestown belie a complicated regolith related to meandering palaeochannels and intercalated colluvial deposits. This project aimed to combine AEM, magnetic and radiometric data along with ground information, to delimit the nature, extent and origin of regolith materials. This information will help constrain hydrogeological models for the study area undertaken by research partners. The main findings are:

- Integrated geophysics and regolith-landscape analysis, and derived three dimensional models, improve the understanding of regolith thickness, subsurface drainage, salt stores and mobilisation pathways (both conduits and barriers).
- Surface salinisation within the valleys occurs where salt stores are higher, and regolith becomes thinner; this is where basement barriers or valley constrictions impede groundwater flow.
- Dryland salinity in valley constrictions occurs in Bundaleer and Caltowie valleys, but not Belalie valley, despite having the highest salt store. This is because Belalie system has thicker transported cover with numerous buried transmissive inter-connected networks. This efficient sub-surface drainage prevents build up of shallow watertables and salts in the upper soil layer.
- Baseline biophysical information on salt stores and pathways helps build robust and predictive hydrological models to assist land managers. Outputs can underpin revegetation strategies through delineation of target areas with high near-surface moisture.



Loxton Salt Interception Scheme

Salt interception schemes (SIS) being developed at Loxton and Bookpurnong on the Murray River, employ bore fields in the Loxton Sands aquifer. Their purpose is to remove saline groundwater that rises in mounds beneath irrigated areas. This project has contributed to achieving Milestone 6.

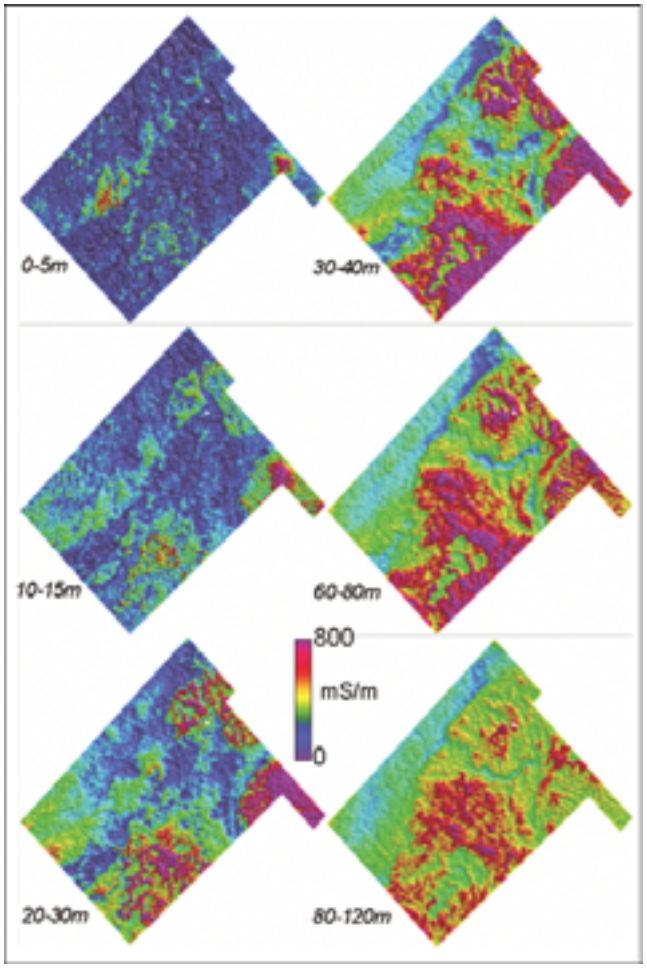
At Bookpurnong a new sedimentological model that defines lateral and vertical facies in the main aquifers is based on borehole geology, ground and airborne geophysics, and sedimentological analysis of Loxton Sands and underlying Bookpurnong Sands. This is a precursor to a predictive groundwater hydraulic model of the principal aquifer system. Narrow zones of high transmissivity, characterized by reduced electrical conductivity at the watertable are the target for ground TEM geophysical traverses. These are elements of a basin-wide beach-barrier strandline sequence that developed in the Pliocene. Constrained inversions from HEM data have helped to better define the hydrogeological interpretation of the Loxton Sands SIS.

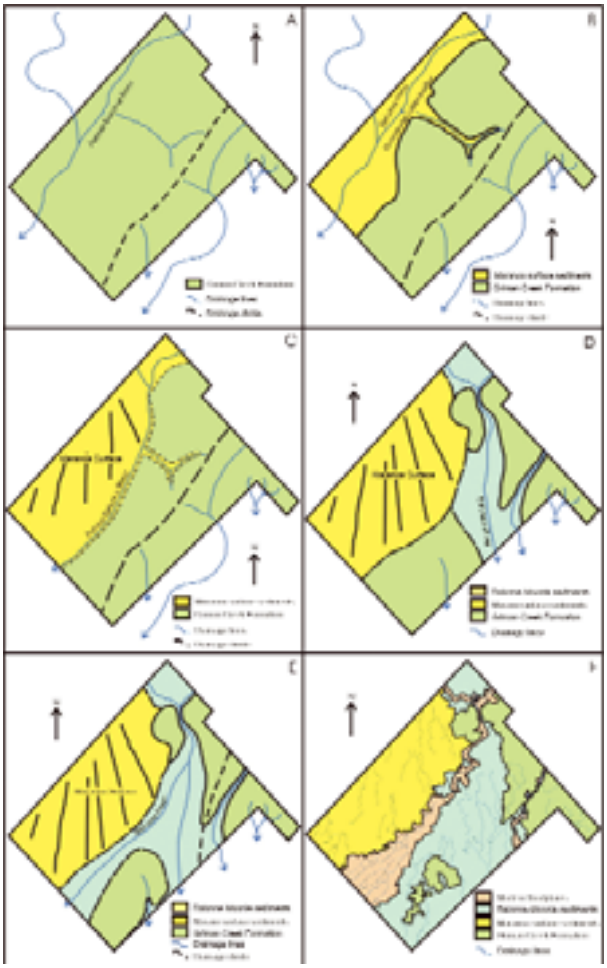
Lower Balonne (Queensland)

This demonstration project was undertaken in conjunction with QDNRM, BRS, local catchment managers and cotton irrigators. It was funded under NAPSWQ. It evaluated the use of airborne geophysics (principally gamma radiometrics and time-domain AEM), for mapping surficial floodplain deposits and groundwater systems. The project is novel in its application of AEM technology to large inland fluvial floodplains. The AEM survey is the largest in Australia for investigating salinity issues. The area is an important cotton irrigation district, with debate over land cropping practices, water allocation and salinity risks. Highlights include:

- New method for constrained inversions of time-domain AEM data in areas of conductive basement.
- New model of landscape evolution developed from integrating geophysics and biophysical datasets. It has complex regolith architecture, a fault-controlled palaeo-valley at depth that hosts a fresh water aquifer, and saline aquifers near the surface.
- The 3D regolith model, when integrated with hydrogeochemical data, allows surface-groundwater interactions and groundwater movements to be modelled. The integrated approach reveals disconnected aquifers in nested groundwater flow systems concealed beneath the low relief landscape. Groundwater flow paths are different in each of three major landscape zones.

Images of conductivity for various depth slices produced from the constrained inversion of the AEM data





- Integrated datasets map near-surface groundwater tables, and detect water gain and loss points in the Lower Balonne system.

The project achieved Milestone 4. The main outcomes of the project include:

- Airborne geophysics, particularly AEM, significantly improves the understanding of salinity risk and water security, in areas that are data poor. Such datasets must be integrated with biophysical data (including bedrock geology and regolith data), and hydrogeological and hydrogeochemical data, in order to provide the best information on rates of movement of groundwaters and salt.
- Integrated geoscience datasets provide a better understanding of the distribution of soil and regolith properties, salt stores and groundwater quality. This knowledge highlights areas in danger of salinisation if current practices are maintained.
- New land and groundwater management zones are identified which enable modification of land practices that should lead to reduction in salinity risks. The knowledge should also lead to more efficient water management.
- The project contributes to a new dynamic water balance.

Groundwater Flow Systems (and Hydrogeomorphic Units)

Maps of *Groundwater Flow Systems* (GFS) are an important tool to manage dryland salinity in Australia. These new generation maps rely on hydrogeomorphic units that have common geomorphological and hydrogeological characteristics. Present GFS maps, at national and catchment scales, rely on published soil maps, surface landforms (from regolith landform maps and digital elevation models), and surface geology maps. GFS maps provide a useful starting basis for large-scale NRM planning. Achievements are set against Milestone 7.

GFS constructions are limited by available data, and are conceptual rather than spatially explicit. Present GFS maps have limited value at sub-catchment scales due a lack of data at this scale, lack of three-dimensional data, and poor understanding in most landscapes of the spatial extent of salinisation. This severely restricts the functionality of GFS maps for salinity mapping at sub-catchment scales where targeted interventions are required.

This project was initially Centre-funded, but in March 2004 received co-funding from MDBC to demonstrate 'proof of concept' in upland landscapes. This project demonstrates how to add value to traditional GFS frameworks for use at sub-catchment scales. Insights gained can also add value to catchment-scale and regional maps.

In upland landscapes, predictions of regolith thickness and salt stores that rely primarily on present day morphology from digital terrains models do not give reliable estimates, especially in southeast Australia. Little of the known variability in regolith complexity and thickness is predicted from terrain-index approaches. Rather, an integrated geoscience approach to GFS maps can give much better predictions of regolith thickness and salt stores.

The holistic approach incorporates landscape evolution with knowledge of sub-surface data such as the nature and thickness of weathering, the nature and thickness of Cainozoic sediments that fill depositional basins, and bedrock geology. Modern airborne magnetics and gamma radiometrics define boundaries and key geological characteristics primarily within the bedrock. In this approach, the landscape is partitioned into *hydrogeomorphic response units* (HRUs), based on the 3D framework of catchments and hydraulic conductivities that predict rates of groundwater movement. The approach is tested in both data-poor and data-rich catchments to identify local controls on salt stores, and groundwater recharge and discharge points. Ultimately this information should optimise management strategies for sub-catchment interventions. HRU constructions will be used within the CRC Catchment Hydrology '2C' Project, which aims to predict salt movements in catchments.

In depositional landscapes, or in upland valleys where erosional landscapes may be buried by sedimentation, the geomorphic processes will differ markedly from those associated with now-buried landscapes. The nature of sedimentary fill defines the response time of groundwater flow within a GFS. This project demonstrates a methodology for incorporating information from existing borehole information, landscape evolution, bedrock composition, and weathering and erosion processes. The ability to map these properties in the sub-surface should aid predictive models of groundwater and salt mobility.

Aquifer Parameters

Australia urgently needs practical procedures for the 3D characterisation of aquifer systems in regolith materials. This is necessary to be predictive in our management practices for land susceptible to dryland salinity. Physical characterisation of regolith-landscape systems in terms of hydraulic properties will provide a better understanding of how and where salt is stored in the regolith, and mechanisms of mobilisation. This information will help define hydrogeological models to drive particular land management situations.

This project combines conventional geophysical methods, nuclear technology, and regolith features. Data from boreholes, ground and air surveys are combined in key project areas to determine spatial variability of the regolith, its hydraulic behaviour, the manner in which groundwater moves through regolith, and how it may interact with stored salt.

LEME has collaborated with ANSTO in testing the wider application of electro-kinetic sounding (EKS). This is a hybrid geophysical technique that uses a seismic source (P wave) to induce differential movement of dissolved ions in pore-water against surrounding mineral grains. It is the only geophysical technique that directly measures aquifer permeability. Along with AEM, magnetics and radiometric data, we have trialled this technique to better define groundwater flow systems and salt stores in landscapes in the Riverland-Loxton area.

Achievements are set against Milestone 6. The main finding is:

- Comparisons of conventional ground electrical and nuclear-based geophysical technologies have found significant divergence in aquifer permeability between EKS, nanoTEM and borehole data. A new EKS tool is currently being developed collaboratively with ANSTO.

Lower Burdekin

The lower Burdekin Delta in north Queensland is the oldest irrigation area in Australia. Water practices involve widespread groundwater pumping and irrigation, and artificial recharge of aquifers in the coastal zone. Management is hindered by lack of a 3D understanding of aquifers, aquitards, and groundwater dynamics. Water management is complicated by saltwater intrusion, which in places extends 11km inland. This project is a component of large multi-disciplinary projects within CSIRO flagship project – *Water for a Healthy Country.*

Geophysical logging on selected boreholes within the area focussed on nested piezometers within the saltwater intrusion. Conductivity (electromagnetic induction) and natural gamma logging were used. A standing water level reading was collected at the time of measurement. A desk-top analysis of borehole records, new wire line logging data, and two new boreholes give new insights into the delta. Results from the first phase include:

- Borehole geophysical logging successfully maps variations in water quality, and successfully delineates the saltwater intrusion in the coastal zone.
- Despite abundant borehole data there remain gaps in knowledge of the sedimentology of the Burdekin Delta. Although it is widely regarded as a classic wave-tide dominated delta, our analysis suggests the Holocene 'delta' is a fan. This has implications for aquifer continuity and integrated water management. Using all available information (gamma logging, facies correlation, known scaling) it has been possible to designate architectural units within sequence units.

NLWR Audit – Catchment To Coast

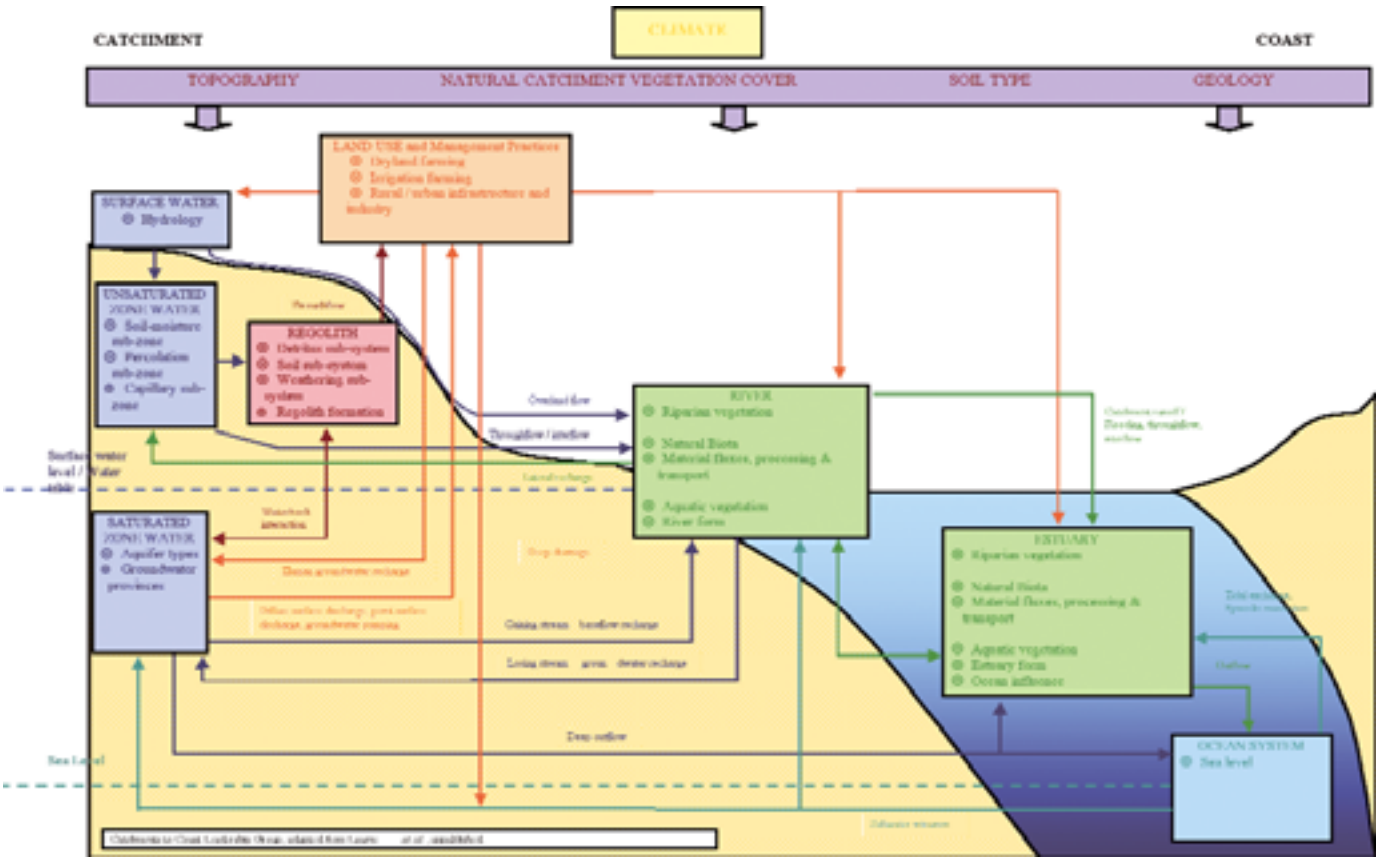
The NLWR Audit 2 is scheduled to deliver a national report on the health of catchments by end 2007. Audit 1 in 2000-2002 hardly mentioned hydrogeology and regolith geoscience. Involvement in Audit 2 is an opportunity to inject regolith geoscience into surface and sub-surface catchment assessments, and to integrate regolith science into the NRM agenda.

This is a collaborative project between CRCs of LEME, Catchment Hydrology, Freshwater Hydrology, Coastal Zone Estuary and Waterway Management, plus CSIRO Flagship project – *Water for a Healthy Country*. Phase 1 involved a scoping study, which was completed in May 2004, and submitted to the NLWRA Advisory Council. The scoping study outlined plans to establish the *Catchment to Coast* project, which will assess biophysical aspects of catchment conditions over the next three years. It is intended that the main study will link to another project that assesses the economic and social condition of catchments.

The *Catchments to Coasts* project will be a holistic integration of surface water, groundwater and land surfaces. It will demonstrate how each of these biophysical components can be combined with social and economic aspects to provide a 'triple bottom line' assessment of catchment condition. The holistic and national approach clearly makes this project unique.

Catchments to Coasts project will demonstrate biophysical conditions and trends in a number of key catchments, in alignment with the *Social and Economic* project of Audit 2.

An illustration of bio-physical conceptual models that will identify key catchment processes at a range of scales




Inland sulphidic soils at Ramco Lagoon, SA (R. Fitzpatrick and S. Lamontagne)

Achievements will be measured against Milestone 9. In summary it will:

- Integrate the social, economic and biophysical components of catchment conditions
- Integrate catchment, river and estuary assessments.
- Develop methodologies to collect and interpret new data.

Upper Burdekin-Fitzroy Basins

This collaborative project between LEME, GA and QDNRM aimed to assemble regolith and other geoscience spatial data in GIS form, to assess its use in natural resource management. The demonstration area is the upper Burdekin and Fitzroy catchments in Queensland.

Aeromagnetics, radiometrics, DEM, drillhole data, ground geophysics, and geological mapping were compiled in GIS, using physiographic regions as a framework. The report and GIS datasets will be available in September 2004. A bibliographic database in PROCITE has been prepared.

Published geological mapping is at 1:100,000 scale, and updates are in progress. Geophysical data is compiled to produce high resolution regional stitches. Integration of mineral exploration data at scales of less than 1:100k is in progress, as well as interpretation of recently acquired aeromagnetic and radiometric data in the Drummond and Central Bowen Basins. Re-interpretation of borehole data is planned. A preliminary depth-to-bedrock map was produced for the Central Bowen Basin using borehole data.

The project has assembled a vast amount of data that otherwise would not have been considered in NRM planning. The data will be available to the Burdekin Dry Tropics Group and the Fitzroy Basin Association. Recommendations for future acquisition, modelling, visualisation and interpretation of geospatial data for NRM purposes are presented in the report.

Salinity Mobilisation

1) Sources and mobilisation of salt

Research in the sources and mobilisation of salt from uplands is a neglected area, compared with lowland and regional systems. For example, the effects of advanced weathering and evapo-concentration on salt loads in upland areas are problematic. The generation of solutes is spatially variable and complicated by atmospheric fallout, *in-situ* weathering of carbonate, silicate and sulfidic minerals, and diffusion from ancient pore fluids. Furthermore, mobilisation pathways through the subsurface are not well understood. We need to unravel the complex links between climate, geology, geomorphology, mineral weathering and hydrogeology. A rigorous methodology to quantify solute sources and mobilisation pathways using regolith datasets is the subject of peer reviewed reports and papers from the Adelaide Hills. The main findings to date are:

- SA NAP projects in uplands landscapes demonstrate how integration of geophysical and regolith information with hydrogeological modelling can be used to predict salinity at a sub-catchment scale (eg Angas Bremer Hills and Jamestown projects).
- Evidence from Br/Cl ratios and stable isotopes of water show that solutes are not from relict connate seawater, or dissolution of evaporite or rock minerals. Sulfide mineral oxidation and rock weathering contribute little salt on a basin-wide scale.

2) Cycling of salt and associated elements in floodplains and acid sulfate soil system:

This study looked for environmentally significant sulfidic materials in the lower River Murray floodplains. Soils and sediments can contain accumulations of pyrite (FeS_2) and monosulfides (FeS), especially in environments of elevated SO_4^{2-}, high availability of labile carbon, and anoxic conditions which favour sulfate reduction. Wetlands of the lower River Murray floodplains may be at risk because current conditions of river regulation and salinisation could promote sulfate reduction. This is an important management question, especially because recently proposed salinity remediation initiatives could expose sulfidic material to the atmosphere.

Eight wetlands in the Riverland of South Australia and one near Buronga in New South Wales were selected as a representative range from freshwater wetlands with near natural wetting and drying cycles, to hypersaline evaporation basins. The main findings are:

- Sulfidic materials are widespread, conditions for their formation are ubiquitous, and there is sufficient sulfate, iron and carbon available. A limiting factor may be availability of labile carbon, because significant accumulation seems to occur only when flooded conditions are maintained for periods of years. Seasonal drying may also enhance oxidisation of sulfides.
- Acidification does not appear to be a major risk because wetlands with high sulfide content also have acid neutralising capacities – that is high carbonate concentrations in sediments. However, two wetlands are at risk of acidification and Bottle Bend Lagoon was severely acidified (pH < 3) during a recent draw down event. Noxious smells were prevalent during recent drying in some Riverland disposal basins (Loveday, Berri and Ramco).
- Overall, the findings have significant implications for management of floodplain salinity, and recommendations have been made for future studies.

3) Influence of aquifer properties on mobilisation of salt:

In alluvial systems and adjacent bedrock fracture systems, the structure of aquifers and aquitards controls mobilisation of salt. Geophysical methods can help unravel subsurface shapes of aquitards, aquifers, subsurface salt repositories. Hydrogeochemical methods can elucidate groundwater pathways and salt sources. With regional end-of-valley targets now in place, there is a need to quantify the volumes and fluxes of salt mobilised into streams. This project is an evaluation of a groundwater model using geochemistry and isotopes in the Lower Balonne in southern Queensland. The main findings were:

- Lower Balonne groundwaters are of marginal to brackish quality with seawater characteristics. Cl/Br ratios are the same as seawater indicating a marine aerosol deposition via rainfall. Evapo-transpiration is responsible for concentration of the ions prior to recharge.

- Recharge rates range from 0.1 mm/yr in Griman Creek Formation, to 0.25- 0.5 mm/yr for the other brackish aquifers. However, recharge is 4-5 mm/yr for the fresh groundwater aquifers.
- Radiocarbon ages for the lower alluvial aquifer are older (5,000-25,000 years) than the upper alluvial aquifer (2,500 years) suggesting that vertical leakage is very slow.

Cost Effective Airborne Geophysics

Some NRM managers consider AEM methods prohibitively expensive for salinity and groundwater mapping compared to other geophysical techniques. However, this study shows that cost reductions of an order of magnitude are possible if critical landscape elements that control salinity and groundwater are taken into account. Savings can be made if the spatial and geo-electrical characteristics of the elements permit wider line spacings during acquisition.

Re-processing of existing AEM datasets at incrementally wider line spacings suggests that 1km line spacing is adequate to map most landscape and salinity elements in depositional landscapes. This has been done for datasets from GILMORE, Lower Balonne and Honeysuckle Creek TEMPEST AEM. Even 2km-line spaced data provides information on sub-catchment scale salt stores. This may be adequate for broad scale planning and national audit purposes. This means that much larger areas can be flown for the same cost. For example, based on $85 per line kilometre:

- 1 km line-spacing is less than $0.7/ha for acquisition
- 2 km line-spacing is less than $0.4/ha for acquisition

This effectively makes time domain AEM data as affordable as airborne magnetics. It achieves Milestone 2.

Salt and Metal Mobility in NSW

This project was established to determine the mobility of salts and trace metals in regolith materials in the Bland catchment of central NSW, in the eastern Murray-Darling Basin. The objective was to understand the physical, chemical and biological processes that control salt and trace metal accumulation and mobility in regolith. The study area has regolith types and salinity characteristics of lowland areas in the Murray-Darling Basin. There is also significant Cu-Au mineralisation. Regolith characteristics are well documented by previous LEME research related to the GILMORE project. *Salt and Metal Mobility* project will involve geochemistry of regolith and groundwater, plus landscape analysis, to produce a four-dimensional model of groundwater flow and salt mobility.

Achievements are set against Milestone 7. The main findings to date are:

- Groundwater and pore waters in the Bland Basin show a wide range in salinity, often approaching that of seawater. Hydrogeochemical patterns can be used to establish the origin and mobility of the salts that have potential for salinity hazards. Chemical and isotopic compositions indicate a sluggish groundwater flow system dominated by evapo-transpiration and water-rock interaction (WRI).
- The principal cause of high salinity is evapo-transpiration; whereas ion exchange, weathering and dissolution of labile minerals control solute composition.
- Isotopes and mass balance calculations suggest salt has accumulated over hundreds of thousands of years.
- ^{36}Cl isotopes indicate that groundwater has a maximum age in clay-rich aquitards and displays younger ages in aquifers.
- The low flux of saline waters from the large-volume aquitards to the small-volume aquifers suggests that salt stores are relatively immobile.

Hostile Regoliths

The precursor project called *Regolith and Trees*, initially in cooperation with RIRDC, did not receive anticipated external funding from the National Heritage Fund. After discussions with CSIRO Plant Industries, NSW DIPNR, and CRC PBMDS, the project was re-scoped as *Hostile Regoliths*. Activities now focus on characterising regolith materials in sub-catchments associated with the *Groundwater Flow Systems* project at Cowra. Ground geophysics and drilling were done in sub-catchments where perennial plants were contemplated. Scientific outcomes will be used within a larger seven-year project into plant-based salinity management in central-western NSW. Research with CRC PBMDS will characterise regolith impediments to growth of perennial plants.

NRM Projects in Western Australia

Palaeochannels for salinity mitigation. This project was funded under the Engineering Initiative within the WA Department of Environment. The objective was to demonstrate the use of geophysical methods to define the location and geometry of palaeochannels. This is the prime starting point in siting production bores aimed at lowering saline watertables in agricultural land. Gravity and transient EM (TEM) are used in two test areas – North Tammin (160 km east of Perth) and Dumbleyung (230 km southeast of Perth). At the Tammin site gravity and TEM defined a palaeochannel whose axis was surprisingly 1 km away from the surface expression. This knowledge will greatly assist in optimising dewatering bores. Work is still in progress at Dumbeyung.

Rural Towns – Liquid Assets. Urban salinity has economic impacts on at least 38 rural towns in WA. With increasing water restrictions, economic and social development is constrained by water supplies. This project involving 16 priority towns will show how locally sourced saline groundwater may be converted into a useful resource. LEME is helping to define the regolith and palaeochannels within and around townsites. Geophysical methods define depth to bedrock, identify faults and provide a framework for hydrology. The project is managed by WA Department of Agriculture. Partners include CSIRO Land and Water, Curtin University, KBR Engineering, Local Government, Regional Catchment Councils, UWA and the WA Chemistry Centre. This project commenced in the reporting period and runs for at least 18 months.

Salinity Communication

This project specifically aims to convince stakeholders of the necessity for regolith geoscience as part of an integrated approach to salinity management. It aims to inform farmers, landcare groups, catchment management boards, state NRM agencies,

research scientists, engineers and policy makers at high levels of government. Despite our impressive advances, stakeholders and end-users are still largely unaware of the benefits of regolith geoscience. The challenge is in communicating our multi-disciplinary science to a very diverse audience.

In the reporting period, activities included:

- Participation in conferences and regional workshops. These included keynote or invited addresses at the 17th AGC, 9th PUR$L Conference, Australian Academy of Technological Sciences and Engineering Water Symposium, CRC Association Conference, SEG conference in the United States. Staff participated in the MDBC Hydrogeology Conference, LEME regolith symposia, and several other conferences.
- Each of the completed NAPSWQ projects involves transfer of knowledge and technology. During the year workshops were held to report progress to interested groups. The SA Dryland Salinity Committee held a Salinity Forum in June 2004 to communicate findings of the SA NAPSWQ projects, and similar forums are planned for Queensland projects.
- The Program 4 Team made important contributions to the Australian Academy of Sciences Review of Salinity Mapping, and also made a submission to the House of Representatives Review of Salinity Mapping and the National Action Plan for Salinity and Water Quality.
- We co-funded and wrote material for the Academy of Science NOVA website. In its early months this was the most popular site in the NOVA series. It is the primary investigation tool for high school students.
- The team finalised a GIS for salinity, based on GILMORE data. This seven-CD dataset is intended as a workshop and university teaching resource, and was in final edit at the end of 2003-04.

Outlook for 2004-2005

We are confident that benefits of recently completed NAPSWQ projects will be realised in 2004-05. Visits to key catchment management boards are planned to discuss new opportunities. A number of new externally funded and co-funded projects have been identified. It is intended to generate projects that are linked to research in salinity and groundwater management.

A contract has been signed with the Murray-Darling Basin Commission for a 3-year period to provide inputs to:

- catchment management planning
- floodplain salinisation processes and mapping
- validation of in-stream salinity (conductivity) mapping, and
- salt interception scheme design.

New research proposals have been developed under the auspices of NAPSWQ, the CSIRO Flagship Program – *Water for a Healthy Country*, as well as further initiatives in the grainbelt of Western Australia. Focus will remain on catchment planning and salinity intervention strategies.

It is hoped that the full *Catchment to Coast* project will eventuate. Regolith science has much to offer this important national project, which seeks to demonstrate how biophysical assessments can combine with social and economic assessments to provide an integrated triple bottom line indication of catchment condition.

A number of new Centre-funded projects will commence 2004-05. These will have LEME seed funding, augmented by co-funding from other NRM agencies. Summaries of all projects, including new projects are on the LEME website.

Photograph: Ian Robertson

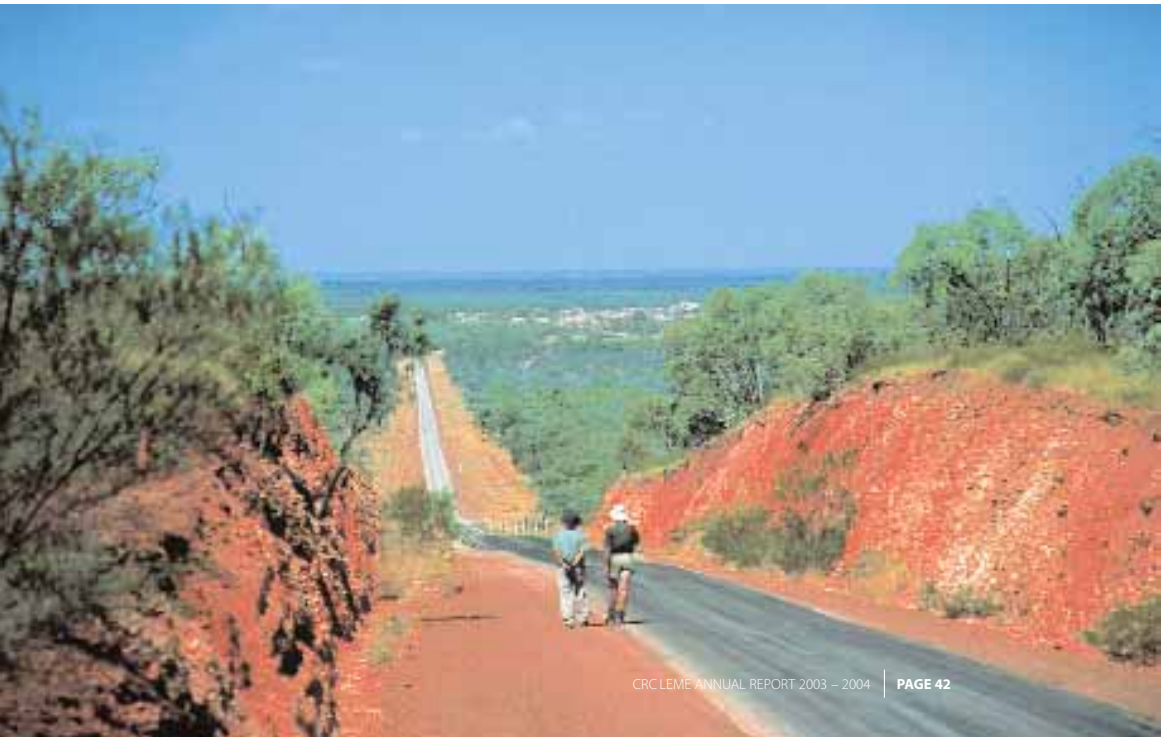


Photo at right: MTEC Shortcourse Regolith Geology and Goechemistry – group at Waratah Fault, Mornington Peninsular

Photo in centre: John Field (left) – ANU and Steve Hill – AU teaching 3rd Year Student regolith-landform mapping techniques at Broken Hill

LEME student shows the way at Tibooburra Tors, NSW

Photographs: Ian Roach

6. Education and Training

Education and Training Program Leader: Dr Steve Hill (Adelaide University)

Highlights:

- Current student enrolments (8 Honours graduates and graduands, 47 PhD in progress) will ensure we meet performance indicators, as set out in the Strategic Plan.
- Regolith Symposia held for CRC LEME scientists and students as well as external participants in Adelaide, Canberra and Perth during November 2003. Symposia Proceedings volume published in printed and internet formats.
- Shortcourses for students and industry professionals conducted as part of the Minerals Tertiary Education Council (MTEC) participation.
- Development and delivery of undergraduate and post-graduate short courses.

Strategic Objectives

Education and training are vital to create the expertise to sustain strategic goals in the longer term. One of our strategic objectives is to be recognised as an Australia-wide, world-class provider of quality graduates and researchers to satisfy the growing demand for specialist regolith geoscientists and environmental scientists in Australia.

Strategies to achieve this include:

- 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 industry, government and institutional professionals.
- In cooperation with industry and other agencies, contribute regolith content to university courses.

Program Leader

This year saw a change in Program Leader for the Education & Training Program. Dr Steve Hill was appointed at end of April 2004. He took over from Associate Prof Pat James who moved to the University of South Australia to head the School of Natural & Built Environments. Dr Ian Roach continues as the Deputy E&T Program Leader and MTEC Lecturer. Associate Prof Pat James and former E&T Program Leader Prof Graham Taylor are recognised and acknowledged for providing a strong foundation for Education and Training in CRC LEME.

Education & Training Committee

The E&T Program leader seeks assistance and recommendations from the E&T Committee, which includes: Steve Hill (Leader), Ian Roach (Deputy and MTEC Lecturer), Mehrooz Aspandiar (CUT), Richard Greene (ANU), and Maureen Blake (administrative assistant). The committee includes representation from each of the university core participants, as well as the Minerals Tertiary Education Council (MTEC) of the Minerals Council of Australia. It is planned to enlist a further representative on this committee from Adelaide University in the near future. This committee has met through phone conference and email discussion throughout the year, to award scholarships, coordinate the CRC LEME Regolith Symposia, implement student policy, oversee undergraduate and postgraduate teaching and coordinate courses.

Post-graduate Students

Our post-graduate students play an important role in strengthening research outputs both in the short-term timeframe of the CRC but also strategically into the future. Besides financial support from LEME, most of these students have also secured competitive scholarships at each of the core participant universities. Their research is integrated into many projects within our core research programs.

The PhD student numbers are now closely approaching our KPI target of 60 completed students within the lifetime of the CRC, where we now have 8 graduated or graduand students and 47 ongoing students. It is likely we will exceed the KPI target within the life of the LEME. We also have a smaller contingent of Masters students (7 graduates and graduands, and 3 continuing students).

Honours Students

Honours students are the bridge between undergraduate study and post-graduate research. The strength of these programs at the participating universities reflects the emerging vitality of the research culture for students that may potentially move towards a research career or industry employment. With 58 Honours graduates and graduands so far within the LEME and a further 10

ongoing students we anticipate exceeding our KPI target for graduated Honours students within the life of LEME. Honours students are also linked to projects within the core research programs.

Summer Scholarships

These scholarships offer an opportunity to introduce emerging scholars into CRC LEME activities. Students in this program work within a research project over the summer non-teaching period. In 2003-04 ten Summer Student Scholarships were granted at ANU, AU and CUT. These involved regolith geophysics, regolith geochemistry, groundwater modelling and regolith processes. As well as making direct contributions to LEME research projects, on completion, summer students submit a brief report outlining their experience and research findings during this period. Many summer students have since continued their association with LEME as Honours students.

Undergraduate Students and Teaching

All three participating universities offer undergraduate regolith training within their teaching programs. These courses are supported and taught by LEME staff. At ANU, staff members John Field, Richard Greene, Dirk Kirste, Bear McPhail, Ian Roach, and Sue Welsh teach in regolith related courses including the third year course *Regolith & Hydrology*. At CUT Mehrooz Aspandiar convenes the third year course *Regolith Exploration* which is also taught by Mehrooz and staff from CUT and CSIRO. Peter Collins and Mehrooz teach regolith, landscapes and regolith-mapping in a second year *Remote Sensing* course at CUT. At AU, undergraduate regolith teaching is part of the third year unit Environmental Geology III. This includes specialised regolith teaching from David Chittleborough, Steve Rogers, Steve Hill and Andreas Schmidt-Mumm. Other undergraduate courses also contain some regolith teaching and related science as taught by Karin Barovich, David Chittleborough, David McKirdy, Pat James, Graham Heinson, Nick Direen, Stewart Greenhalgh, John Joseph, Andreas Schmidt-Mumm.

Dr Ian Roach, ANU, Deputy E&T Program Leader and MTEC Course Leader

MTEC Shortcourses

The Minerals Council of Australia is a core participant in CRC LEME, and provides incentive funding to develop and deliver relevant industry-linked short courses for students and industry geoscientists through the Minerals Tertiary Education Council (MTEC), as well as the salary of the MTEC Lecturer, Ian Roach.

MTEC Courses conducted during 2003-2004 include:

- *Regolith Geology and Geochemistry Masters Course*, 4-15 August 2003, Fowlers Gap, NSW.
- *Regolith Geology and Geochemistry (RGG)*, 23-27 February 2004, Wilsons Promontory, Victoria.
- *Regolith Mapping and Field Techniques (RMF)*, 15-19 March 2004, Fowlers Gap, NSW.
- *Introduction to Hydrogeochemistry (HGC)*, 29 March – 2 April 2004, University of Melbourne.
- *Advanced Remote Sensing (RSM)*, 13-16 April 2004, CSIRO Waite Institute, Adelaide SA.
- *Environmental Mineralogy (EMN)*, 21-25 June 2004, ANU, Canberra.

Participants in Honours courses came from many Australian universities, as well as our participating universities. The MTEC network draws from other universities including La Trobe, Macquarie and Wollongong. The Masters course attracted participants from the minerals industry (Noranda), government research organisations (NTGS, GSV, CSIRO) and MTEC network universities. Participant numbers were relatively healthy: Masters course 11; RGG 15; RMF 15; HGC 13; RSM 14; and, EMN 18. Teaching staff came from all three participating universities plus Geoscience Australia and CSIRO. The Education & Training program continues to develop course materials and methods to better reach and serve industry through innovative teaching practises, on-line and electronic learning packages and on-site course delivery.

Table 6.1 – Short Courses 2003-2004

Shortcourse Title	Presenter(s)	Format	Venue	Date	No. of Participants
Regolith Geology and Mineral Exploration Masters Course	Leanne Hill, Steve Hill, Bear McPhail, Ken McQueen, Keith Scott, Ian Roach, Ian Robertson	11 day Masters course	Fowlers Gap NSW	4-15 August 2003	10
Regolith Geology and Geochemistry	Mehrooz Aspandiar, Steve Hill, Ian Roach	5 day Honours course	Wilsons Promontory, VIC	23-27 Feb 2004	15
Regolith Mapping and Field Techniques	Steve Hill, Ian Roach, Karen Hulme	5 day Honours course	Fowlers Gap NSW	15-19 March 2004	16
Introduction to Hydro-geochemistry	Dirk Kirste, Patrice de Caritat	5 day Honours course	University of Melbourne	29 March – 2 April 2004	12
Advanced Remote Sensing for Mineral Exploration and Natural Resource Management	Alan Mauger and Megan Lewis	4 day Honours course	Waite Campus, Adelaide University	13-16 April 2004	14
Environmental Mineralogy	Tony Eggleton and Ulrike Troitzsch	5 day Honours course	Australian National University	21-25 June 2004	20

Regolith Symposia

In November 2003 an ambitious project led by Ian Roach was the successful running of the three Regolith Symposia. This involved low-cost symposia in Adelaide (13-14 November), Canberra (19-21 November), and Perth (27-28 November). The objectives were to bring together LEME and other regolith scientists and students at the three nodal universities, and to provide opportunities for people to travel to the different nodes to showcase their latest science to research and industry groups. This was particularly beneficial in providing outlets for current student research, and integrating research into the core research programs.

In total 106 papers were presented at the symposia by LEME staff, students and scientists from other Australian research institutions. These presentations record a snapshot of the gamut of Australian regolith research. Proceedings have been released on the CRC LEME website, as are published in the LEME monograph *Advances in Regolith* of 444 pages.

It is planned to hold the next symposia again in the three nodes in November 2004 using a similar format to the one successfully employed in 2003.

Student Highlights

- PhD thesis completions and post-doctoral destinations: Leanne Hill (PhD thesis submitted ANU January 2004) has since joined the graduate program of Department of Environment and Heritage (DEH). Andrew McPherson (PhD submitted ANU December 2003) is now a regolith geoscientist with Geoscience Australia.
- 2003 Regolith Symposia Student Awards. These were judged by a committee at all three symposia, and are based on excellence in oral and visual presentations. Awards consisted of book prizes including *Regolith Geology and Geomorphology* by LEME Honorary Fellows Prof Graham Taylor and Prof Tony Eggleton, the *LEME Regolith Glossary*, and the LEME monograph by Chen and others *Calcrete: characteristics, distribution and use in mineral exploration*. The three Taylor & Eggleton awards for best overall oral and written presentation went to Aaron Brown (AU), Louisa Roberts (ANU), Mark Paine (CUT). The Regolith Glossary awards for best oral presentation went to Alexandra Pengelly (AU), Susan Tate (ANU), Jenna Leonard (ANU), and Anousha Hashemi (CUT). The editor's choice awards for best written work went to Karen Hulme (AU), Kerrie Tomkins (Macquarie University), and Kirsty Beckett (CUT).
- Aija Mee (AU, PhD student) was winner of the *Best Poster Award* at the joint national meeting of the Australian Organic Geochemistry Conference and International Humic Substances Society, February, 2004.

Table 6.2 – Honours Students 2003-2004

Student	Project	Program	Supervisor(s)	Funding	Year	University
Honours Degree – completed during 2003-2004						
David Baker	Ground penetrating radar, DC resistivity and visualisation techniques to map 3D physical properties of regolith	2	Graham Heinson	PIRSA	2002	AU
Kristy Bewert	Regolith landform aspects and environmental management around the Cadia Mining Area, Central NSW	2	Bear McPhail Ken McQueen	LEME	2003	ANU
Christopher Buxton	A lithological and geochemical investigation of the regolith at the Hercules Prospect, Southern Cross, WA	2	Mehrooz Aspandiar	LEME/ Outside funding	2003	CUT
Allan Cadd	Regional geophysical study of crustal architecture near Challenger, for understanding Archaean Au mineral systems and regolith development, northwest Gawler Craton	2	Nick Direen	LEME	2003	AU
Nigel Cantwell	High resolution geophysical methods for Au exploration under regolith cover – Songvang Prospect, Agnew, WA	2	Jayson Meyers	LEME	2003	CUT
Brendan Corscadden	Geophysical characterisation of the Thunderbox orebody and overlying regolith to assist future gold exploration in the Eastern Goldfield, Western Australia	1	Paul Wilkes	LEME	2003	CUT
Daniel Glanville	The regolith and landscape evolution of the Byrock area, NSW	2	Ian Roach Ken McQueen	LEME	2003	ANU
Robert Grzegorzek	Detailed 3D mapping and evolution of the Eldee Creek Fan, Broken Hill	2	Steve Hill Martin Williams	WNSW Project	2003	AU
Peter Haddrill	Surface and groundwater flow system development in central west NSW: implication for dryland salinity hazard mitigation	3	Dr Benger Leah Moore	Nil LEME	2002	UC
Kathleen Harvey	Groundwater flow systems on Ordovician sediments	3	Leah Moore, Steve Hill	LEME	2002	UC
Amy Lockheed	Finding blind orebodies : geochemical exploration for large nickel-copper PGE sulphides on the Western Gawler Craton	2	Karin Barovich	LEME	2003	AU

Table 6.2 – Honours Students 2003-2004 (cont'd)

Student	Project	Program	Supervisor(s)	Funding	Year	University
Honours Degree – completed during 2003-2004 (cont'd)						
Sam McDermott	Developing a regolith landform mapping approach for environmental applications in the Lower Onkaparinga River, SA	3	Steve Hill Pat James	LEME	2003	AU
Alexandria Pengelly	Continuous mapping of zinc-oxides under cover in the Beltana Region	1	Pat James Steve Hill	Mineral Mapping Project	2003	AU
Louisa Roberts	Spatial prediction of soil properties using high-resolution gamma-ray spectrometry and EM-31/38 data, Boorowa NSW	3	John Field	LEME	2003	ANU
Claire Robertson	Tree growth survival and regolith in salt affected areas at Blackwood/Bridgetown area, SW Western Australia	1	Ravi Anand SPaul Wilkes	LEME	2003	CUT
Edward Summerhayes	Mobility of zinc in the regolith: Hemimorphite solubility	2	Bear McPhail	LEME	2003	ANU
Susan Tate	Characterisation of regolith materials in the Girilambone region, northwestern Lachlan Fold Belt, NSW	2	Richard Greene	LEME	2003	ANU
Jodi Webb	The role of shrink swell clay soils on surface stone formations	1	John Magee Richard Greene	LEME	2003	ANU
Honours Degree – commenced or continuing/graduand						
Nicole Anderson *	Tectonic controls on 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 *	Geochemical dispersion and under-cover expression of gold mineralisation at 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 pyrite in ASS.		Susan Welch Sarah Beavis	LEME	2004	ANU
Jennifer Leonard *	Vegetative uptake of gold and pathfinder elements by native dry schlerophyll forest		John Field	LEME	2004	ANU
Vjekoslav Matic * §	Integrating geophysics for regolith landform characterisation in Fitzroy Basin, Qld, and application to natural resource management	4	Prame Chopra	LEME	2003	ANU
Dougal Munro §	Regolith controls on geochemical dispersion in the CSA area, Cobar NSW	2	Ken McQueen	CSA Project funding	2003	ANU
Kate Pfeiffer *	Predictive petrophysics in regolith-covered Au-hosting Proterozoic terranes with specific reference to Callie-DBS-Granites area, Tanami gold province	2	Nick Direen	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 calcrete in the Murray Basin	1	David Chittleborough	LEME	2004	AU
Michael Whitford *	Electrical and seismic properties of 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	UA
Thomas Woolrych *	Regolith controls on geochemical dispersion in the Cobar goldfield NSW	2	Ken McQueen Ian Roach	LEME	2004	ANU

* Denotes LEME Scholar
§ Denotes thesis submitted, awaiting assessment

Table 6.3 Postgraduate Students 2003-2004

Student	Project	Program	Supervisor(s)	Funding	Year	University
Master of Science (MSc) Graduated						
Hashim Carey	Quantitative analysis of mise-a-la-masse responses through innovative methods	2	Graham Heinson	LEME/ Newmont	2002-2003	AU
Troy Cook	Evaluation of two gross pollutant traps in minimizing geochemical contaminants from entering two stormwater catchments of contrasting styles	3	Ron Watkins	LEME	2002-2003	CUT
Michael Holzapfel	Dryland salinity hazard mitigation along the Booberoi – Quandialla transect, central west NSW	3	Leah Moore / Xiangyang Chen	NSW DLWC	1999-2004	ANU

Table 6.3 – Postgraduate Students 2003-2004 (cont'd)

Student	Project	Program	Supervisor(s)	Funding	Year	University
Master of Science (MSc) Graduated (cont'd)						
Bobak Willis Jones	A scoping study of urban geochemistry and mapping in the Perth metropolitan area for pollution risk assessment and land use management	3	Ron Watkins	LEME	2002-2003	CUT
Master of Science (MSc) commenced or continuing						
Ralf Kriege *	Determination of interfaces within regolith structure of Whirling Dervish (Yilgarn) using near-surface geophysical and petrographic methods	2	Anton Kepic	LEME	2004	CUT
Master of Philosophy (M Phil) commenced and continuing						
Matthew Lenahan *	Accumulation and mobility of salt in the regolith: Gilmore study area, NSW	4	Bear McPhail Dirk Kirste	LEME	2003	ANU
Luke Wallace *	Hydrogeochemistry of salts in regolith environments	3	Bear McPhail	LEME	2004	ANU
Doctor of Philosophy (PhD) – Graduated						
Nil	(five student have submitted their theses during the period)					
Doctor of Philosophy (PhD) – commenced/continuing/graduand						
Simon Abbott *	Application of geophysical techniques in identifying the role of palaeochannels in the hydrology and management of dryland salinity in WA	4	Anton Kepic Keith Smettem	APA + LEME Top-up	2004	CUT
Andrew Baker *	Isotopic and geochemical studies of soil-regolith-rock interactions with groundwater, stream waters and basemetal mineralisation: implications for mineral exploration and the environment	1	Rob Fitzpatrick Ron Watkins	APA + LEME Top-up	2002	AU
Glen Bann *	Dryland salinity, biodiversity and geodiversity: Using bio and geo-indicators to determine the effects of dryland salinity on terrestrial biodiversity in eastern Australia, with applications for NRM	4	Colin Pain	LEME	2003	ANU
Kirsty Beckett *	A multi-disciplinary approach to modelling catchment hydrogeology	3&4	Jayson Meyers	CUPS + LEME Top-up	2002	CUT
Aaron Brown *	Improved reconstruction of primary rock compositional from major, trace and rare earth element composition, using numerical modelling procedures	1	Andreas Schmidt-Mumm Patrick James Martin Williams	LEME	2002	AU
Paul Carlile *	Four-dimensional modelling of salt distribution and movement within the Little River catchment, NSW	3	Tony Jakeman Brian Lees	LEME	2004-	ANU
Troy Cook *	Geochemical investigation into the acid generating potential of wetland sediments of the Gnangara and Jandakot Mounds : Implications for long-term water quality	3	Ron Watkins	APA + LEME Top-up	2004	CUT
Steven Cotter *	The nature, origin and geochemistry of chert breccias at Mt Isa	1	Graham Taylor Ravi Anand, Leah Moore	APA + LEME Top-up	1998	UC
Mike Craig	Regional regolith and landscape evolution in the Eastern Goldfields, Yilgarn Craton, Western Australia	1&2	Ken McQueen Graham Taylor, Colin Pain	GA	1998	UC
Robert Dart *	Origin and distribution of calcrete in southern Australia	2	Karin Barovich David Chittleborough Megan Lewis	LEME/AU	2004	AU
Tania Dhu *	Electrical and EM studies of regolith and sub-regolith structure	1	Graham Heinson Stewart Greenhalgh Patrick James	LEME/AU	200	AU
Katie Dowell *	Low temperature silicification in regolith using black opal as a primary example	1	John Mavrogenes	APA + LEME Top-up	2003	ANU
John Drewry *	Catchment contaminant cycle	tba	Tony Jakeman	ANU + LEME Top-up	2004	ANU
Michael Durkey	Effect of drains on soil properties in SE SA	4	David Chittleborough Steve Hill	AU/DWLBC	2003	AU
Kathryn Fitzsimmons *	Interaction between transverse and longitudinal dunes associated with playas of the Eyre Basin: a chronology of landscape evolution	1	John Magee	APA + LEME Top-up	2003	ANU
Luke Foster *	Landscapes, geochemistry, and GIS at Marlborough Qld	2	Tony Eggleton, Colin Pain	LEME	1997	ANU
Mark Fritz *	Baseline geochemistry of South Australian saline and acid sulfate soils	1	Rob Fitzpatrick	LEME/AU	2003	AU
Lachlan Gibbins *	Measuring hydraulic conductivity with streaming potentials	1	Graham Heinson	LEME/AU	2004	AU
Chris Gunton *	Element dispersion and mobility in the regolith	2	Bear McPhail	APA + LEME Top-up	2002	ANU
Anousha Hashemi *	Innovative geophysical and geochemical exploration for high-grade manganese ore under cover in the East Pilbara of WA	2	Jayson Meyers	LEME	2003	CUT

Table 6.3 – Postgraduate Students 2003-2004 (cont'd)

Student	Project	Program	Supervisor(s)	Funding	Year	University
Doctor of Philosophy (PhD) – commenced/continuing/graduand (cont'd)						
Philip Heath *	3-D automated inversion of potential field tensor 2Stewart Greenhalgh data		LEME/AU Nick Direen	2003	AU	
Jonothan Higgins	Palaeochannels of the Kingoonya System, Gawler Craton, SA	1	Larry Frakes Vic Gostin	-	1998	AU
Leanne Hill * §	Chemical dispersion pathways in a variety of landscapes	1	Tony Eggleton	APA + LEME Top-up	1999-2003	ANU
Karen Hulme *	Biogeochemistry of river red gums (Eucalyptus camaldulensis) in the Curnamona region of SA and NSW	1&2	Steve Hill	LEME/AU	2003	AU
Donald Hunter *	Surface NMR for hydrogeological applications in Australia	2	Anton Kepic	APA + LEME Top-up	2002	CUT
Kamal Khider *	Regional chemical dispersion processes in the regolith of Cobar-Nymagee area, Central West, NSW	2	Ken McQueen Bear McPhail	LEME	2002	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	Pattrick James	LEME/AU	2002	AU
Sam Lee *	Hydrogeology of the Cape Range karst and coastal-plain aquifers, Exmouth, NW Australia	3	Qadeer Rathur Lindsay Collins	APA + LEME Top-up	2002	CUT
Mel Lintern	The role of biological and non-biological factors in the formation of Au anomalies in calcrete	2	Lindsay Collins Mehrooz Aspandiar Ravid Anand		2001	CUT
David Little *	Biogeochemical actions in the inter-rhizosphere	1	John Field	LEME	2003	ANU
Sean Mahoney	Use of multi-temporal imagery for water condition monitoring, environmental and wetland management in southeast SA	4	Megan Lewis Patrick James Dr Bertram Ostendorf	AU/DWLBC	2003	AU
Annamalai Mahizhnan §	Red-brown hardpans on the Yilgarn	1	Ravi Anand	APA	1997	CUT
Sam McDermott *	3D architecture of the Neales Fan palaeochannels	1	Simon Lang	LEME/AU	2004	AU
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 * §	Salt sources and development of the regolith Upper Billabong Creek Catchment, southeast NSW	3	Tony Eggleton	LEME	2000-2003	ANU
Aija Mee *	Lacustrine and soil organic matter as proxies for mid-latitude Holocene environmental change in southeast Australia.	1	David McKirdy	APA + LEME Top-up	2003	AU
David Mitchell	Increasing spatial resolution of soil maps using geophysics and GIS	4	Megan Lewis Bertram Ostendorf	AU/PBMDS	2003	AU
Ryan Noble *	Dispersal mechanisms of arsenic and antimony in regolith and surface deposits in the vicinity of buried gold ore bodies, northwest Victoria	2	Ron Watkins	APA + LEME Top-up	2003	CUT
Margarita Norvill *	Use of distributed sensor arrays in electromagnetic imaging	2	Anton Kepic	APA + LEME Top-up	2002	CUT
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	2001	CUT
Anna Petts *	Regolith and landscape evolution of the Bulloo-Bancannia Basin (Tibooburra-Koonenberry Belt) western NSW	2	Steve Hill	LEME/AU	200	AU
Mark Reilly *	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
Frank Reith *	Interactions of microbes and gold in regolith in moderate, arid and tropical climates	1	Bradley Opdyke Bear McPhail	IPRS + LEME Top-up	2002	ANU
Mohammad Rosid	Groundwater investigations using the seismo-electric method	3	Anton Kepic	-	2001	CUT
Greg Shirtliff *	Weathering of wasterock at Ranger Uranium Mine, NT, Australia.	1	Tony Eggleton David Jones Patrice deCaritat	ERA + LEME Top-up	1999	ANU
Suzanne Simmons *	U-Th-Pb systematics of opaline silica: implications for the dating of surface processes	1	Alexander Nemchin	LEME	2002	CUT
Martin Smith *	Landscape evolution of western NSW : a framework for comparison of regolith dating methods	1	Brad Pillans	ANU + LEME Top-up	2002	ANU
Michael Smith *	Source and geochemical evolution of salts in the regolith in the Barwon region, NSW	4	Bear McPhail Dirk Kirste	ANU + LEME Top-up	2003	ANU
Greg Street	Interpretation of geophysics for catchment management	3	Norm Uren Jayson Meyers	APAI Farm Map Consulting Pty Ltd Tesla 10 Pty Ltd	2000	CUT

Table 6.3 – Postgraduate Students 2003-2004 (cont'd)

Student	Project	Program	Supervisor(s)	Funding	Year	University
Doctor of Philosophy (PhD) – commenced/continuing/graduand (cont'd)						
Mark Thomas *	Combining remote sensing and terrain analysis with topo-sequence models in dry saline areas (Jamestown and Mt Lofty Ranges) for up-scaling root zone constraints	3	Graham Heinson Rob Fitzpatrick Megan Lewis	LEME/DWLBC/ PIRSA	2002	AU
Michael Turner *	3-Dimensional pore scale characterisation of permeability and porosity of regolith materials	4	Bear McPhail	APA + LEME Top-up	2002	ANU
Alistair Usher *	Gold mobility and geochemistry in hypersaline brines	2	Bear McPhail	APA + LEME Top-up	2003	ANU
Victor Waclawik *	Regolith geology and landscape evolution of Umbum Creek, west Lake Eyre, South Australia..	1	Simon Lang Steve Hill Patrick James	LEME/AU	2003	AU
Michael Whitbread §	Using lithogeochemistry to map cryptic alteration: Elura and Century case studies	2	Ken McQueen Leah Moore	PASMINCO + LEME Top-up	1999	UC
Paul Wilkes	Geophysics in the search for diamonds	2	Jayson Meyers	Nil	2000	CUT
Vanessa Wong *	The effects of salinity and sodicity on soil carbon turnover	3	Richard Greene Graham Farquhar	ANU + CRC Greenhouse + LEME Top-up	2004	ANU
Martin Worthy	Major water quality degrading events in the Cotter catchment – characteristics and management	3	Robert Wasson Mike Hutchinson	ACTEW + LEME Operating	2004	ANU
Pierre-Allain Wulser *	Mobility of uranium and rare earth in the Mt Painter – Lake Frome regions, SA : geochemical and temporal controls	2	Joel Brugger John Foden	IPRS + LEME Top-up	2003	AU

* denotes LEME Scholar

§ denotes thesis submitted, awaiting assessment

Table 6.4 – Summer Scholarship Students – 2003

Student	Project	Supervisor(s)	Year	Institution
Jessie Davey	Ground penetrating radar for shallow subsurface investigations	Dr John Joseph	2003	AU
Louise Kropinski	Spectral scanning of drill core and cuttings in the Barnes Gold prospect on northern Eyre Peninsula	Mr John Keeling	2003	AU
Christine Lawley	Investigation the natural occurrence of dehydrated schoepite, to provide evidence for achieving official mineral status	Dr John Foden	2003	AU
Catherine Loye	Predictive petrophysics in regolith-covered Au hosting shear zone systems with specific reference to the Yarlbrinda shear zone, Central Gawler Gold Province	Dr Nick Direen	2003	AU
Stefania Madonna	Gold and trace metal geochemistry in calcrete-bearing regolith	Dr Andreas Schmidt-Mumm	2003	AU
Angelina McRae	Creating derivative maps using geochemical information systems for the Hermidale region	Dr Patrice de Caritat	2003	ANU
Benjamath Pewkliang	Biomineralisation and opalisation	Dr Joel Brugger	2003	AU
Nathan Reid	Regolith studies – sample preparation	Dr Steve Hill	2003	AU
David Schaefer	Evaluation of groundwater modelling software	Dr Qadeer Rathur	2003	CUT
Trudy Wellby	3D modelling and inversion study of the Yarlbrinda Shear Zone, Central Gawler Au Province	Dr Nick Direen	2003	AU

Photograph: Ian Robertson

7. Collaboration

Over three years CRC LEME has established excellent 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.

Internal Linkages

Multi-party and multi-disciplinary projects are an integral part of LEME planning. This ensures that regolith knowledge is directed towards the needs of diverse stakeholders in both mineral exploration and natural resource management. The Centre optimises the wealth of expertise available through the core participants to assemble the most effective multi-disciplinary team for each project. Of the 42 projects funded by the Centre, 33 had participation from more than one core participant.

Educational Linkages

Honours and postgraduate research projects are integrated into our research projects and LEME staff supervise students. Thus LEME students make significant contributions to the overall research effort. In return, they benefit through opportunities for professional development and networking with LEME staff from all core participants, and by introductions to industry, government organisations and other potential employers.

Student projects are run with the support of government and industry partners, including CALM, Department of Agriculture Western Australia, NSW Department of Infrastructure Planning and Natural Resources, Newmont Australia, Sons of Gwalia, ANSTO and others. Details 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 across the country.

Linkages with Industry and other End Users

A range of research projects and educational activities involving external organisations as clients or collaborators were undertaken during the reporting period. A table detailing this collaboration is shown under the Commercial, Technology Transfer and Utilisation Section.

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 and strategic direction. In this way, individual and organisational networks with stakeholders are continuously expanded, to promote research cooperation, technology transfer and feedback outside of the structured mechanism of the Advisory Councils.

Program 3 and 4 personnel in particular have continued their liaison with NRM agencies. A significant number of contracts have come to fruition during the period with work continuing into 2004-2005.

Of particular note is collaboration with the Murray Darling Basin Commission, with a pilot project in 2003 evolving into a large MBDC-LEME Partnership Project on salinity and groundwater management over the period 2004-2007

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 social networking at such events. Details of these activities are provided in Public Presentations, Public Relations and Communication. A significant number of LEME personnel participated in 43 public conference/seminars within Australia during the reporting period and conducted nine seminars/symposia.

International Linkages

Prolonged deep weathering over the last 10 to 250 million years on a predominantly stable continent has created a uniquely Australian regolith. The primary focus of LEME is to apply regolith geoscience to problems facing Australia, so this uniqueness means that regolith research has to be carried out here, and cannot be borrowed from elsewhere in the world. This is reflected in the Centre Strategic Plan.

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 may provide keys for developing our own models of regolith evolution. Consequently we encourage our international linkages.

Since 1999 LEME and the Geological Survey of Canada have been exchanging visits and information on research of mutual interest. For example, the glacial terrains in Canada provide some constraints on the mechanisms of metal mobility in relation to gold in calcrete, diamond exploration, and chemical extraction methods in the Australian regolith. This time it was the turn of Roslyn Chan, GA who visited the Geological Survey of Canada and the United States Geological Survey during July-September 2003. Roslyn gave a number of talks and worked with scientists from both organisations.

Baohong Hou was invited to China between 18 May and 17 July 2004 as guest of a consortium of universities (further detail in Public Presentations, Public Relations and Communication). An outcome of this visit is the commencement of collaborative studies on electro-geochemical prospecting techniques for exploration through cover to commence late 2004 in South Australia using Chinese equipment and expertise.

LEME staff participated in nine major International Conference, held both in Australia and overseas, including the 21st International Geochemical Exploration Symposium, Dublin, and the XVI International Union of Quaternary (INQUA) Congress, Reno, USA. Details are shown in Chapter 11 – Public Presentations.

Photographs: Ian Robertson

Collaboration with other CRCs

Two student projects have been undertaken jointly with CRC for Plant-based Management of Dryland Salinity *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 methodology for element transport in regolith and ore-forming environments.

LEME is looking forward to expanding research collaboration with PBMDS CRC, once its new CEO Kevin Goss commences on 1 July 2004. Kevin was formerly Chair of the LEME Land Use Advisory Council.

LEME was contracted for the *Catchments to Coasts Scoping Study Plan* by the National Land and Water Resources Audit 2, alongside CRC for Freshwater Ecology, CRC for Catchment Hydrology, CRC for Coastal Zone, Estuary and Waterway Management, and CSIRO – Water for a Healthy Council Flagship Project. LEME is bidding to participate in Stage 2 of this major national project. The aim of the project is to develop methods for assessing the biophysical aspects of catchment condition and trends across Australia.

Dennis Gee joined with other CRC Chief Executive Officers from the Minerals Sector to present in the *Innovation Stocktake and Telescope* session, Minerals Week 2004, 31 May to 4 June, Canberra. This was staged by the Minerals Council of Australia. Excellent publicity has been generated from these talks which highlighted achievements by the seven CRCs involved – pmd* CRC, LEME, CRC Mining, AJ Parker Centre for Hydrometallurgy, Coal in Sustainable Development, Sustainable Resources Processing and Greenhouse Gas Technologies.

CRC LEME participates in the Minerals and Energy Sector activities within the Cooperative Research Centre Association. Sector CEOs are considering strategic alignments to collaborate in long-term strategic research projects, and in the shorter term are planning joint efforts in education and training, communication, plus the creation of a *CRC Minerals Forum*.

Dennis Gee presented a paper on *Valuing LEME Research*, at a session on *Valuing Public Good CRCs*, at the CRC Association Annual Conference in June 2004.

8. Management and Operating

Business Manager, Mr Gary Kong CPA

The values held by LEME staff, and guiding our activities, are:

- Excellence and scientific integrity
- Long-term commitment
- Professionalism
- Fairness

These are underpinned by commitments to safety, staff development and national benefit.

CRC LEME has world-class expertise in regolith geoscience, and the supporting disciplines such as mineralogy, geochemistry, hydrogeochemistry, sedimentology, geophysics and geochronology. In this third year of funding, CRC LEME had a total complement of 145 staff, of whom 135 were professional geoscientists. This distilled down to 70 FTE scientists, made up of 45.4 in-kind and 24.6 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 following tables.

Table 8.1 – 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
Australian National University										
Banks J	R	10				10	10			
Beavis S	R	20				20	20			
Chappell J	R	50	50				50			
Chopra D	R	20	20				20			
Cristy A	R	10	10				10			
Croke B	R	20				20	20			
DeDeckker P	R	20	10	10			20			
Dunlap J	R	25	25				25			
Eggins S	R	20				20	20			
Ellis D	R	15	15				15			
Fabel D	R	25	25				25			
Field J	R	40			10	30	40			
Gingele F	R	100				100	100			
Greene R	R	30	15	10	5		30			
Jakeman T	R	20	20				20			
Lees B	R	40				40	40			
Magee J	R	25	25				25			
Mavrogenes J	R	20				20	20			
McPhail D	R	100	60	15	25		100			
Opdyke B	R	20	20				20			
Pillans B	R	50	45	5			50			
Rhodes E	R	25	25				25			
Wasson R	R	10				10	10			
White I	R	20				20	20			
		735	365	40	40	290	735	0	0	0
Geoscience Australia										
Apps H	R	100				100	100			
Chan R	R	100		100			100			
Craig M	R	100	100				100			
Csaky D	R	33				33	33			
Czamota K	R	33				33	33			
Gibson D	R	100				100	100			
Kilgour P	R	100			35	65	100			
Lawrie K	R	100				100	100			
Pain C	R	100			35	65	100			
Wilford J	R	100				100	100			
Worral L	R	33	33				33			
		899	133	100	70	596	899	0	0	0
Curtin University										
Aspandiar M	R	50	30				30	20		
Collins L	R	60	20				20	40		
Collins PLF	R	30	20	10			30			
Fagan R	R	20	15	5			20			
Kepic A	R	50	30	5	15		50			

Table 8.1 – 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
Curtin University (cont'd)										
Meyers J	R	50	10	15	25		50			
Rather A	R	70	35	35			70			
Watkins R	R	70	10	5	55		70			
Watling J	R	20		5	5		10	10		
		420	170	80	100	0	350	70	0	0
Adelaide University										
Barovich K	R	70		70			70			
Brugger J	R	10	5	5			10			
Chittleborough D	R	10		10			10			
Direen N	R	70	20	50			70			
Foden J	R	30		25		5	30			
Greenhalgh S	R	25	5	10	10		25			
Heinson G	R	55	30	10	10		50	5		
James P	R	70	15	10			25	45		
Lang S	R	15	5	5	5		15			
McKirdy D	R	25		25			25			
Schmidt-Mumm A	R	45		40			40	5		
Williams M	R	10	5	5			10			
		435	85	265	25	5	380	55	0	0
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	45	35			80			
Mauger A	R	80	75				75	5		
Painter J	R	30	20	10			30			
Rogers P	R	100		100			100			
Sheard M	R	100		100			100			
Stamoulis V	R	50	45				45	5		
		750	185	555	0	0	740	10	0	0
NSW Dept of Mineral Resources										
Barratt R	R	40		40			40			
Buckley P	R	50		50			50			
Fleming G	R	30		30			30			
Hicks M	R	100		100			100			
Mills K	R	20		20			20			
Sharp T	R	20		20			20			
Stevens B	R	10		10			10			
		270	0	270	0	0	270	0	0	0
CSIRO										
Andrew A	R	10		10			10			
Butt C	R	70	40	15	15		70			
Carr G	R	5		5			5			
Gray D	R	90	80	5			85	5		
Robertson I	R	80	65	15			80			
Scott K	R	40	10	30			40			
Smith R	R	100	100				100			
Fitzpatrick R	R	5			5		5			
Walker G	R	5			5		5			
Anand R	R	100	90		10		100			
Cornelius M	R	100	70	30			100			
Gatehouse S	R	10		10			10			
Hough R	R	50	50				50			
Munday T	R	100	45			55	100			
Pirlo M	R	50	50				50			
Cox J	R	15			15		15			
Davies P	R	10			10		10			
Dighton J	T	10			10		10			
Gildfedder M	R	40			40		40			
Herczeg A	R	20			20		20			
Hicks W	R	20			20		20			
Lamontagne S	R	25			25		25			
Lefournour M	R	10			10		10			
Rogers S	R	65			65		65			
Stauffacher M	R	5			5		5			
		1035	**600**	**120**	**255**	**55**	**1030**	**5**	**0**	**0**
TOTAL RESEARCH STAFF: IN-KIND CONTRIBUTIONS		**4544**	**1538**	**1430**	**490**	**946**	**4404**	**140**	**0**	**0**

KEY: 100 = 1 person year

Table 8.2 – 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	20	20	20	35	95	5		
McQueen K	ANU	R	75	30	35		10	75			
Pillans B	ANU	R	50	50				50			
Roach I	ANU	R	100					0	100		
Welch S	ANU	R	100	100				100			
de Caritat P	GA	R	100	5	40	40	10	95	5		
Foster K	GA	R	100		100			100			
Ruperto L	GA	R	25			25		25			
Aspandiar M	CUT	R	50	45				45	5		
Wilkes P	CUT	R	100	10	20	20	50	100			
Hill S	AU	R	100		70	10		80	20		
Joseph J	AU	R	100	35	45	20		100			
Cornelius A	CSIRO	R	100	90	10			100			
Lintern M	CSIRO	R	100	50	50			100			
Phang C	CSIRO	R	100	100				100			
Scott K	CSIRO	R	20		20			20			
Singh B	CSIRO	R	100	100				100			
Cox J	CSIRO	R	5				5	5			
Cresswell R	CSIRO	R	40				40	40			
Davies P	CSIRO	R	10				10	10			
Dighton J	CSIRO	R	25				25	25			
Herczeg A	CSIRO	R	5				5	5			
Hicks W	CSIRO	R	20				20	20			
Lamontagne M	CSIRO	R	25				25	25			
Lefournour M	CSIRO	R	35				35	35			
Rogers S	CSIRO	R	5				5	5			
			1590	635	410	135	275	1455	135	0	0
Industry or Externally Funded											
Tan K P	ANU	R	100				100	100			
Cahill K	GA	R	25				25	25			
Clarke J	GA	R	100				60	60	40		
Coram J	GA	R	60				60	60			
Fitzpatrick A	GA	R	100				100	100			
Gray M	GA	R	25				25	25			
Halas L	GA	R	25				25	25			
Lane R	GA	R	20				20	20			
Please P	GA	R	60				60	60			
Reilly N	GA	R	25				25	25			
Reisz A	GA	R	50				50	50			
Roberts L	GA	R	100				100	100			
Tate S	GA	R	25				25	25			
Gray D	CSIRO	R	10		10			10			
Korsch M	CSIRO	R	15		15			15			
Robertson I	CSIRO	R	20	20				20			
Tapley I	CSIRO	R	5		5			5			
Bryce A	CSIRO	R	15		15			15			
Denton G	CSIRO	R	55		55			55			
Gardner B	CSIRO	R	15		15			15			
Law A	CSIRO	R	15		15			15			
			865	**20**	**130**	**0**	**675**	**825**	**40**	**0**	**0**
TOTAL RESEARCH STAFF: CRC GRANT AND EXTERNAL FUNDS			**2455**	**655**	**540**	**135**	**950**	**2280**	**175**	**0**	**0**

Table 8.3 – 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	45.44	15.38	14.3	4.9	9.46	44.04	1.4	0.0	0
CRC grant funded	15.9	6.35	4.1	1.35	2.75	14.55	1.35	0.0	0
Industry funded	8.65	0.2	1.3	0.0	6.75	8.25	0.4	0.0	0
Total funded by CRC LEME	24.55	6.55	5.4	1.35	9.5	22.8	1.75	0.0	0
Grand total	69.99	21.93	19.7	6.25	18.96	66.84	3.15	0.0	0
Proportion of total professional staff resources in each activity (100%)	100	31	28	9	27	95	5	0	0

8.4 – Administration and Technical Staff

Name	Position	Main Activity	Total % of Time
In-kind Contributions			
			0
CRC Grant Funded			
Australian National University			
Edwards D	Research Support Officer	T	5
Shelley J	Education Support Officer	A	50
			55
Geoscience Australia			
Walsh M	Program Support Officer	A	50
			50
Adelaide University			
Blake M	Program Support Officer	A	50
			50
CSIRO			
Campbell J	Administration Support Officer	A	60
Game S	PA to CEO/Centre Support Officer	A	100
Harris C	Program Support Officer	A	50
Kong G	Business Manager	A	100
Gee D	Chief Executive Officer	A	100
Mills J	Financial Accountant	A	80
			490
			645
Industry or Externally Funded			
Geoscience Australia			
Walsh M	Program Support Officer	A	50
			50
TOTAL ADMINISTRATION AND TECHNICAL STAFF:			695

KEY: 100 = 1 person year

New Equipment and Computing

Specialised (Micromine, Surfer and Rockware) computing software was purchased during the period, using infrastructure funding provided by the WA State Government.

Safety

CRC LEME aims to instil an awareness of safety in the office, laboratory and field environment, so as to achieve a Lost Time Frequency Rate of zero. In the course of carrying out research activities, staff and students frequently operate in remote and difficult environments. As a result, field safety is one of our principal focuses, especially for students who need to learn how to work safely in remote areas and under challenging conditions. The Board has a duty of care in this respect but, since LEME is an unincorporated joint venture that does not directly employ people, the primary duty of care in respect of all occupational health and safety matters rests with the core participants, who are the designated legal employers. LEME follows fully 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 comprehensive manual, *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 an essential reference for all Centre participants. 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 respective host agency. They have been endorsed by the Board, drawn to the attention of all staff and students by way of the LEME intranet, and have now been implemented.

Some essential components of the LEME policy include:

- Documentation of journey plans, including proposed itinerary, overnight locations, methods of daily reporting, and hazard assessment before undertaking fieldwork in remote or outback areas.
- First-aid training is mandatory for staff involved in fieldwork in remote areas.
- Basic off-road driver training from an accredited provider for all drivers of 4WD vehicles.
- Encouragement of all students to complete Senior First-Aid Certificates, courses in 4WD vehicle handling and remote-area radio communication.
- Staff working on mine sites must undertake training and receive the necessary certification – in most case MARHSTA.
- All persons must follow the policies of the Core Participants, in regard to environmental awareness and field practices.

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.

9. Specified Personnel

Specified personnel, contributed by the Core Participants as required by the Commonwealth Agreement, are shown below. During the year Steve Rogers, Lisa Worrall and Steve Hill became Program Leaders, after Keith Scott and Colin Pain and Pat James stepped aside. Bear McPhail and Colin Pain became new Key Researchers. Ray Smith ceased being a Key Researcher on his retirement. These changes in specified Personnel have been approved by the CRC Secretariat.

At the end of the reporting period, LEME specified personnel contributed by Core Participants were:

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% (from 23.4.2004)*

Assoc Prof Pat James, Program Leader, AU 70% (to 24.2.2004)

Dr Ken Lawrie, Program Leader, GA, 100%

Dr D.C. (Bear) McPhail, Key Researcher, ANU, 100% (from 11.2.2004)

Dr Colin Pain, Program Leader, GA, 100% (to 31.12.2003)

Dr Colin Pain, Key Researcher, GA, 100% (from 10.2.2004)

Dr Steve Rogers, Program Leader, CSIRO, 65% (from 5.2.2004)

Mr Keith Scott, Acting Program Leader, CSIRO, 40% (to 31.12.2003)

Dr Raymond Smith, Key Researcher, CSIRO, 100% (to 27.2.2004

Mr Paul Wilkes, Deputy CEO, CUT, 100%*

Ms Lisa Worrall, Program Leader, GA, 100% (from 10.2.2004)

*Paid from the CRC Grant

Photograph: Ian Robertson

Photograph: Ian Robertson

10. Publications and Patents

Publications by LEME staff and students, pertaining to LEME research and supported by LEME, published and in press during the reporting period are listed below.

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

JOURNAL PAPERS

Anand, R.R. 2003. Importance of regolith for gold exploration in the Yandal gold province, Yilgarn Craton, Western Australia. In: Ely, K.S. and Phillips, G.N. (Eds) *Yandal Gold Province: Geoscience and Exploration Success*. CSIRO Exploration & Mining, Melbourne. pp27-52.

Anand, R.R. and Butt, C.R.M. 2003. Distribution and evolution of 'laterites' and lateritic weathering profiles, Darling Range, Western Australia. *Australian Geomechanics*, 38, Institute of Engineers Australia/Australian Geomechanics Society. pp41-58.

de Caritat, P., Kirste, D., Carr, G., and McCulloch, M. In Press. Sulfur, strontium and lead isotopes in groundwater: deciphering basement signatures through sedimentary cover. *Applied Geochemistry, AIG5 volume*. Elsevier, Amsterdam.

Dhu, T. and Heinson, G.S. 2003. Environmental monitoring using electrical resistivity tomography. *Exploration Geophysics, 35*. Australian Society of Exploration Geophysics. pp33-40.

Gilkes, R.J., Lee, S. and Singh, B. 2003 The imprinting of aridity upon a lateritic landscape; an illustration from southwestern Australia. *Comptes Rendus – Academie des sciences.* Geoscience, 335. pp1207-1218.

Gray, D.J. 2003. Naturally occurring Cr6+ in shallow groundwaters of the Yilgarn Craton, Western Australia. *Geochemistry: Exploration, Environment, Analysis*, Vol 3, Issue 4. Geological Society of London and Association of Applied Geochemists. pp359-368.

Heath, P., Heinson, G.S. and Greenhalgh, S.A. 2003. Inversion of potential field tensor data. *Exploration Geophysics, 34*. Australian Society of Exploration Geophysics. pp57-62.

Hill, S.M., Eggleton, R.A. and Taylor, G. 2003. Neotectonic disruption of silicified palaeovalley systems in an intraplate, cratonic landscape: regolith and landscape evolution of the Mulculca range-front, Broken Hill Domain, New South Wales. In: Cockbain, A.E. (Ed) *Australian Journal of Earth Sciences, 50*. Geological Society of Australia. pp691-707.

Hou, B., Frakes, L.A., Alley, N.F. and Heithersay, P. 2003. Evolution of beach placer shorelines and heavy-mineral deposition in the eastern Eucla Basin, South Australia. In: Cockbain, A.E. (Ed) *Australian Journal of Earth Sciences.* Volume 50, Issue 6, December 2003. Geological Society of Australia. pp995-965.

Hou, B., Frakes, L.A., Alley, N.F., Gammon, P., and Clarke, J.D.A. 2003. Facies and sequence stratigraphy of Eocene valley fills in Eocene palaeovalleys, the eastern Eucla Basin, South Australia. In: Crook, K.A.W., Miall, A.D. and Sellwood, B.W. (Eds) *Sedimentary Geology.* Volume 163. Elsevier, Amsterdam. pp111-130.

Kepic, A. and Campbell, T. 2003. Geophysical monitoring of tree root zones. In: Denham, D. (Ed) *Preview.* Australian Society of Exploration Geophysicists. Issue No. 105, pp29-34.

Lawrie, K., Gray, M., Fitzpatrick, A., Wilkes, P. and Lane, E. 2004. Reducing the acquisition costs of airborne electromagnetic surveys for salinity and groundwater mapping. In: Denham, D. (Ed) *Preview*. Australian Society of Exploration Geophysicists, Issue 106. pp31-38

Noble, R.R.P., Ammons, J.T. and Vassenev, I.I. 2004. A comparison of U.S. and modern Russian taxonomic systems of six Russian soils. In: Wilson, M. (Ed) *Soil Survey Horizons 45(2)*. Soil Science Society of America, Madison. pp39-51.

Norvill, M. 2003. International geophysical societies. In: Denham, D. (Ed) *Preview*. Australian Society of Exploration Geophysicists. Issue No. 105, pp14-20.

Pillans, B. 2003. Subdividing the Pleistocene using the Matuyama-Brunhes boundary (MBB): an Australasian perspective. In: Rose, J. (Ed) *Quaternary Science Reviews, vol 22*. Pergamon, New York, USA. pp1569-1577.

Robertson, C. 2004. Relationships of regolith and tree survival in a eucalyptus Blue Gum plantation. In: Denham, D. (Ed) *Preview*. Australian Society of Exploration Geophysicists. Issue No. 110, pp24-26.

Scott, K.M. In press. Rutile geochemistry as a guide to porphyry Cu-Au mineralisation, Northparkes, New South Wales, Australia. *Geochemistry: Exploration, Environment, Analysis.* Geological Society of London and Association of Applied Geochemists

Tonui, E. and de Caritat, P. 2003. Composition, diagenesis and weathering of sediments and basement of the Callabonna Sub-basin, Central Australia: Implications for landscape evolution. In: Milliken, K.L. and North, C.P. (Eds). *Journal of Sedimentary Research. Vol 73.* Dept of Geological Sciences, University of Colorado. pp1036-1050.

BOOKS OR CHAPTERS

Clarke, J.D.A. and Pain, C.F. 2004. From Urah to Mars: regolith-landform mapping and its application. In: Cockwell, C.D. (Ed), *Martian Expedition Planning.* American Astronautical Society Science and Technology Series, 107. pp131-159.

Joyce, E.B., Webb, J., Dahlhaus, P.G., Grimes, K.G., Hill, S.M., et al. 2003. Geomorphology: the evolution of Victorian landscapes. In: Birch, W.D. (Ed) *Geology of Victoria.* Geological Society of Australia Special Publication 23. pp533-561.

In: Anand, R.R. and de Broekert, P. (Eds) ***Regolith-Landscape Evolution Across Australia: a compilation of regolith-landscape case histories and landscape evolution models.*** CRC LEME Monograph, http://crcleme.org.au/RegLandEvol/

Anand, R.R. 2003. Jarrahdale district, Western Australia

Anand, R.R. 2003. Lawlers district, Western Australia

Anand, R.R., King, J.D., Robertson, I.D.M. 2003. Mt Magnet district, Western Australia

Anand, R.R., Wildman, J.E., Varga, Z.S., Phang, C. 2003. Bronzewing district, Western Australia

Aspandiar, M.F., Taylor, G. and Eggleton, R.A. 2003. Chartres Towers Region, Queensland

Butt, C.R.M. 2003. Mt Percy gold deposit area, Western Australia.

de Broekert, P. 2003. Lady Bountiful Extended gold deposit, Western Australia

Chen, X.Y. 2003. Wagga Wagga 1:100 000 map sheet, New South Wales

Fitzpatrick, R.W. and Skwarnecki, M.S. 2003. Mt.Torrens, Eastern Mount Lofty Ranges, South Australia

Fitzpatrick R.W. 2003. Gatum, Dundas Tableland, Victoria

Hill, S.M. 2003. Wilson's Promontory, Victoria

Hill, S.M., Hill, L.J. and Chamberlain, T. 2003. Tibooburra Inlier, NSW

Hill, S.M. et al. 2003. Southern Barrier Ranges – Northern Murray Basin, New South Wales

Hou, B., Frakes, L.A. and Alley, N.F. 2003. Palaeochannel evolution, northwestern Gawler Craton, South Australia

Johnson, C.B. and McQueen, K.G. 2003. Gold-bearing palaeochannel sediments and Gidji, Western Australia

Killick, M.F., Churchward, H.M., Anand, R.R. 2003. Hamersley Iron Province, Western Australia

Lintern, M.J. 2003. Challenger gold deposit area, South Australia

Lintern, M.J. 2004. Bounty Gold Deposit, Forrestania Greenstone Belt, Western Australia

Paine, M.D. and Foo, M.F.P. 2003. Gourdis and Empire gold deposits, Western Australia

Paine, M.D. and Phang, C. 2003. Dundas Tableland, Victoria

Phang, C., Munday, T.J., Wildman, J.E. 2003. Tringadee area, Queensland

Pillans, B. 2004. Geochronology of the Australian regolith

Robertson, I.D.M. and Churchward, H.M. 2003. Telegraph, Lancefield and Beasley Creek gold deposits, Western Australia

Robertson, I.D.M., Phang, C. and Munday, T.M. 2003. Harmony-Peak Hill gold deposit Western Australia

Scott, K.M. and Lintern, M.J. 2003. Panglo gold deposit, Western Australia

Taylor, G. and Roach, I.C. 2003. Monaro Region, New South Wales

Wilford, J.R. 2004. Selwyn District, Queensland

In: Butt, C.R.M., Robertson, I.D.M., Cornelius, M. and Scott, K.M. (Eds) ***Regolith Expression of Australian Ore Systems: a compilation of geochemical case histories and conceptual models.*** CRC LEME Monograph, http://crcleme.org.au/RegExpOre/

Butt, C.R.M 2003. Mystery Zone Gold Deposit, Mt Parcy, Kalgoorlie, Western Australia

Butt, C.R.M. and Brand, N.W. 2003. Mt. Keith nickel sulphide deposit, Western Australia

Butt, C.R.M. and Sergeev, N.B. 2003. Dalgaranga base metal prospect, Mt. Magnet district, Western Australia

Cornelius, M. 2003. Yarawindah Brook PGE-Ni-Cu deposit, New Norcia, Western Australia

Cornelius, M. and Smith, R.E. 2004. Freddie Well Zn-Cu deposit, Murchison district, Western Australia

Lintern, M.J. 2004. Birthday gold prospect, Gawler Craton, South Australia

Lintern, M.J. 2004. Steinway Gold Deposits, Kalgoorlie, Western Australia

Lintern, M.J. 2004. Zuleika Sands Gold Deposit, Ora Banda, Western Australia

McQueen, K.G., Scott, K.M. and Leah, P.A. 2004. New Cobar Cu-Au deposit, Cobar Goldfield, New South Wales

Phang, C. 2004. Tringadee zinc anomaly, NW Queensland

Robertson, I.D.M., King, J.D., Anand, R.R. and Butt, C.R.M. 2004. Quasar gold deposit, Mt. Magnet, Western Australia

Scott, K.M. and van Riel, B. 2004. Goornong South gold deposit, Central Victoria

Smith, R.E. 2003. Gossan Hill Cu-Zn-Au deposit, Golden Grove, Western Australia

Swarnecki, M.S. 2004. Oonagalabi Base Metal Prospect, Harts Range, Northern Territory

CONFERENCE PAPERS PUBLISHED IN REFEREED PROCEEDINGS

Black, J., Spiccia, L. and McPhail, D.C. Towards an understanding of copper (I) speciation and reactivity in the copper-ammonia-thiosulfate lixiviant system. In: Young, C.A. et al (Eds) *Hydrometallurgy 2003* – Fifth International Conference in Honour of Prof Ian Ritchie. Volume 1: Leaching and Solution Purification. The Minerals, Metals and Materials Society. pp183-194.

Brown, T., Fischmann, A., Spiccia, L. and McPhail, D.C. 2003. Alternative copper (II) catalysts for gold leaching: Use of multidentate ligants to control thiosulfate oxidation. . In: Young, C.A. et al (Eds) *Hydrometallurgy 2003* – Fifth International Conference in Honour of Prof Ian Ritchie. Volume 1: Leaching and Solution Purification. The Minerals, Metals and Materials Society. pp213-226.

Broxholme, K. Heinson, G.S., Busuttil, S. and Lilley, F.E.M. 2003. Two dimensional magnetotelluric modelling of three dimensional structures. In: Macnae, J. and Liu, G. (Eds). *Proceedings of the 3DEM-3 Symposium*, Adelaide, SA, February 2003. Australian Society of Exploration Geophysicists. CD

Croke, B.F.W., Carlisle, P. and Jakeman, A.J 2003. Identifying evapotranspiration relationships for input into rainfall-runoff models using the SWIM model. In: Post, D.A. (Ed) *MODSIM 2003 International Congress on Modelling and Simulation-2*. Modelling and Simulation Society of Australia and New Zealand. pp879-884.

Noble, R.R.P., Oldmeadow, D.W.G.T., Watkins, R.T. and Ammons, J.T. 2004. Geochemical characterisation of spoil material to assess suitability for use as a cover in tailings rehabilitation. In: Barnhisel, R.I. (Ed). Proceedings of a joint conference of *American Society of Mining and Reclamation (ASMR), 21st Annual National Conference and 25th West Virginia Surface Mine Drainage Task Force Symposium.* Morgantown, West Virginia. 18-22 April 2004. ASMR, Lexington, USA. pp1362-1375 and CD.

In: Roach, I.C. (Ed) ***ADVANCES IN REGOLITH, Proceedings of the CRC LEME Regional Regolith Symposia 2003***, at Adelaide University, Australian National University (Canberra) and Curtin University of Technology (Perth). November 2003. CRC LEME. 446pp.

Baker, A.K.M. and Fitzpatrick, R.W. Lead Isotopes for constructing geochemical dispersion models in sulfidic wetlands. pp2-7.

Beckett, K.A. Airborne geophysics applied to groundwater modelling. pp8-10.

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Brown, A.D. and Hill, S.M. Litter dams: a new method of mapping surface dispersion vectors at the White Dam Prospect, Curnamona Craton, SA. pp24-28.

Cadd, A.G., Direen, N.G, and Lyons P. Geophysical investigations of crustal architecture around the Challenger Au Mine, NW Gawler Craton, SA: a basic step towards understanding Au dispersion pathways. pp34-37.

Cantwell, N. High resolution geophysical methods for gold exploration under regolith cover, Songvang Prospect, Agnew, WA. pp43-44.

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de Caritat, P. and Reimann, C. Baseline geochemistry of surficial regolith, Broken Hill Region, Australia. pp53-54.

de Caritat, P., Kirste, D., Carr, G. and McCulloch, M. Vectoring towards mineralisation under cover using groundwater geochemistry: an example from the Curnamona Province. pp49-52.

Chappell, J. New determination of the long-term production and migration of soil, our largest mineral deposit. pp66-69.

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Csaky, D. and Please, P. Salinity hazard mapping methodologies: the past, present and future. pp82-83.

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Dowell, K.M., Mavrogenes, J., McPhail, D.C. and Chappell, J. Fantastic Australian Opals. pp100-103.

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Fitzsimmons, K.E. Longitudinal and transverse dunes of the Lake Eyre Basin. pp126-130.

Foster, J. and Chittleborough, D. Soil development on dolomites of the Cambrian Normanville Group at Delamere, South Australia. pp131-132.

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Lau, I.C., Cudahy, T.J., Heinson, G., Mauger, A.J. and James, P.R. Practical applications of hyperspectral remote sensing in regolith research. pp249-253.

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McQueen, K.G. and Munro, D.C. Weathering-controlled fractionation of ore and pathfinder elements at Cobar, NSW. pp296-300.

Nemchin, A. U and Th decay chains: application to regolith chronology. pp304-305.

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Pengelly, A. and James, P.R. Regolith mapping and interpretation of airborne hyperspectral data for zinc silicate/oxide mineralisation near Beltana in the northern Flinders Ranges of South Australia. pp319-320.

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Rhodes, E., Chappell, J. and Spooner, N. Age and mobility of arid regolith: assessment by luminescence dating methods. pp342-344.

Roach, I.C. Three years of MTEC. pp345-351.

Roberts, L.M., Wilford, J.R., Field, J.B. and Greene, R.S.B. High-resolution ground based gamma-ray spectrometry and electromagnetics to assess regolith properties, Boorowa, NSW. pp352.357.

Robertson, C. Relationships of regolith and tree survival in a eucalyptus blue gum plantation. pp358-359.

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Smith, M.L., Eggins, S. and Pillans, B. U-Pb dating of anatase in silcrete pp388-390

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Thomas, M., Fitzpatrick, R.W. and Heinson, G.S. Mapping complex soil-landscape patterns using radiometric K%: a dry saline land farming area case study near Jamestown, SA. pp411-416.

Turner, M., Sakellariou, A., Arns, C., Sok, R., Limaye, A., Senden, T. and Knacktedt, M. Towards modelling regolith permeability with high resolution X-ray tomography. pp421-425.

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CONFERENCE PAPERS AND ABSTRACTS

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Anand, R.R., Hough, R. Phang, C., Norman, M. and Le Gleuher, M. Regolith mineral hosts for gold and other base metals. pp25-28

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Pillans, B. Regolith geochronology and mineral exploration. pp16-18.

Rogers, S. Role of biota in mineral transformations and transport. pp39-41.

Worrall, L. The formation of geochemical anomalies in the Eastern Goldfields: the role of an Eocene acid weathering event. p21.

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Brown, A., Hill, S.M. and James, P.J. 2003. Detailed regolith mapping as a tool for refining the interpretation of geochemical results at White Dam, Curnamona Craton, SA. In: Peljo, M. (Compiler), *Broken Hill Exploration Initiative: Abstracts from the July 2003 Conference.* Geoscience Australia Record 2003/13. pp3-5.

Brugger, J., Etschmann, B., Liu, W. and Foran, G. 2004. Structure of transition metal chloro-complexes in hypersaline solutions. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p58.

Carr, G.C., Denton, G.J., et al. 2003. Pb isotope discrimination of geochemical anomalies using terrain-specific models – the Proterozoic of Northern Australia. Program and Abstracts, *21st International Geochemical Exploration Symposium*, Dublin, Ireland, 29 August – 3 September 2003. Association of Exploration Geochemists. pp47-48.

Chan, R. and Tonui, E. 2003. Regolith-landform processes at Northparkes Cu-Au Mine, NSW, Australia. Abstracts – *XVI INQUA Congress: Shaping the Earth – a Quaternary perspective.* The Desert Research Institute, Reno, Nevada, USA. 20-23 July 2003. p81.

Chan, R. 2003. Regolith geochemistry, mineralogy, regolith mapping, geomorphology. Abstracts – *XVI INQUA Congress: Shaping the Earth – a Quaternary perspective.* The Desert Research Institute, Reno, Nevada, USA. 20-23 July 2003. p82

Clarke, J. Lawrie, K., Riecz, A., Fitzpatrick, A. and Macphail, M. 2004. Architecture of a rapidly evolving Neogene fluvial system, St George region, southern Queensland: implications for salinity management. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p9.

Clarke, J. and Pain, C.F. 2004. Application of regolith-landform mapping to a Mars analog environment in Utah. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p9.

Coram, J.E. and Beverly, C. 2003. Mobilisation of salts in Australian landscapes – understanding water balance and salt movement. *Proceedings of the 9th PUR$L (Productive Use and Rehabilitation of Saline Land) Conference*, Yapoon, Qld. 30 September to 30 October 2003. National Dryland Salinity Program. CD

Coram, J., Herczeg, A.L. and Dighton, J.B. 2004. Salt sources and groundwater recharge processes in the St George region of SW Queensland. *Proceedings – 9th Murray-Darling Basin Groundwater Workshop*, Bendigo, Vic. 17-19 February 2004. Department of Primary Industries, Victoria. 6pp

Cudahy, T., Okada, K. and Hewson, R. 2004. Targeting porphyry-skarn-epithermal alteration at Yerington, Nevada, using airborne hyperspectral mineral mapping data. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p64.

Cudahy, T., Langford, L., Hausknecht, P. and Hewson, R. 2004. New generation maps of regolith mineralogy and regolith stratigraphy from new generation remote sensing data. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p11.

Davey, A., Joseph, J. and Heinson, G. 2004. Electromagnetic profiling of palaeochannels in the Girilambone Region, NSW. In: McQueen, K.G. and Scott, K. M. (Eds) *Exploration Field Workshop Cobar Region 2004: Proceedings.* CRC LEME. pp28-30.

de Caritat, P., Jaireth, S., Lambert, I., Lech, M., Pyke, J. and Wyborn, L. 2004. Low density geochemical survey of Australia: scope, strategy and potential benefits. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p12.

de Caritat, P., and Kirste, D. 2004 Using groundwater geochemistry as a tool for mineral exploration under cover: example from the Curnamona Province, Australia. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p59.

Dowell, K. and Mavrogenes, J. 2003. Mystery of Lightning Ridge's black opal. *National Opal Symposium Abstracts.* Quilpie, Qld. 22-25 September 2003. Qld Boulder Opal Association. 10pp.

Duk-Rodkin, A., Chan, R.A. and McQueen, K.G. 2004. Drainage evolution of the Cobar Region. In: McQueen, K.G. and Scott, K. M. (Eds) *Exploration Field Workshop Cobar Region 2004: Proceedings.* CRC LEME. pp37-42.

Duk-Rodkin, A., Chan, R.A. and McQueen, K. 2003. Late Cretaceous to late Pleistocene drainage evolution of Cobar upland, NSW, Australia. Abstracts – *XVI INQUA Congress: Shaping the Earth – A Quaternary Perspective.* The Desert Research Institute, Reno, Nevada, USA. 20-23 July 2003. p81

Dowell, K. and Mavrogenes, J. 2004. Black opal. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p68.

Fitzpatrick, A., Lane, R. and Brodie, R. 2004. The importance of utilising 'a priori' information in the modelling of airborne electromagnetic data for salinity and natural resource management: a case study – the Lower Balonne Airborne Geophysics Project. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p14.

George, R., Lawrie, K.C. and Woodgate, P. 2003. Convince me all your bloody data and maps are going to help me manage salinity any better: A review of remote sensing methodology for salinity mapping. Proceedings of the *9th PUR$L (Productive Use and Rehabilitation of Saline Land) Conference*, Yapoon, Qld. 30 September to 30 October 2003. National Dryland Salinity Program. CD

Gibson, D. 2004. A new regolith/geology/landform framework for natural resource management in the Angas-Bremer Plains area, SA. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p15.

Gray, D.J. 2003. Hydrogeochemistry in the search for mineral deposits. Program and Abstracts, *21st International Geochemical Exploration Symposium*, Dublin, Ireland, 29 August – 3 September 2003. Association of Exploration Geochemists. pp48-49.

Hill, S.M. 2003. Exploration without hitting rock bottom: a brief guide to recent developments in exploration in regolith-dominated terrains of the Curnamona Craton and adjoining areas. In: Peljo M. (Compiler). *Broken Hill Exploration Initiative: Abstracts from the July 2003 conference.* Geoscience Australia Record 2003/13. pp73-76.

Hill, S.M. and Roach, I.C. 2003. Regolith geoscience education and training within the western NSW teaching laboratory. In: Peljo, M. (Compiler), *Broken Hill Exploration Initiative: Abstracts from the July 2003 Conference*. Geoscience Australia Record 2003/13. pp79-80.

Hill, S.M., Hill, L.J. and Chamberlain, T. 2003. Towards a regolith and landscape evolution framework for mineral exploration programs near the Tibooburra Goldfields, NW, NSW. In: Peljo, M. (Compiler), *Broken Hill Exploration Initiative: Abstracts from the July 2003 Conference*. Geoscience Australia Record 2003/13. pp77-78.

Hill, S.M., Thomas, M., Earl, K.L. and Foster, K.A. 2003. Regolith expressions of mineralisation within the Flying Doctor Prospect, Northern Leases, Broken Hill, New South Wales. In: Peljo, M. (Compiler), *Broken Hill Exploration Initiative: Abstracts from the July 2003 Conference.* Geoscience Australia Record 2003/13. pp81-82.

Hicks, M.G. and Gleming, G. 2004. Girilambone-Cobar project: a collaborative venture between NSW DMR and CRC LEME. In: McQueen, K.G. and Scott, K. M. (Eds) *Exploration Field Workshop Cobar Region 2004: Proceedings.* CRC LEME. pp43-45.

Hou, B. and Mauger, A. 2004. Remotely sensed imagery aids palaeochannel-landform identification and exploration. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004,. Geological Society of Australia. p20.

Hou, B., Alley, N. and Frakes, L. 2004. What does the ancient analogue imply for the Murray Mouth tomorrow? Comparison between the Wilkinson and Murray estuaries, SA. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004,. Geological Society of Australia. p20.

Hou, B., Alley, N. and Gray, D. 2004. 3D palaeochannel modelling as an aid to exploration in palaeodrainage terrains – Harris Greenstone Belt, Gawler Craton, SA. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p21.

Hou, B., Alley, N., Frakes, L. and Heithersay, P. 2004. Tertiary beach placer potential of the eastern Eucla Basin: old province – new ideas. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p234.

Hou, B., Alley, N, Frakes, L., Cowley, W. and Stoian, L. 2004. Eocene stratigraphy and stepwide evolution of the eastern Eucla Basion, South Australia. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p234

Hough, R., Phang, C., Norma, M. and Anand, R.R. 2004. A search for mineral hosts for gold at the Enterprise pit, Mount Gibson gold deposit. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia p88.

Hunter, D. and Kepic, A. 2003. Depth of SNMR signal contributions in conductive Australian regolith terrains. Proceedings of the *2nd International Workshop on Magnetic Resonance Sounding*. BRGM and IRIS Instruments, Orleans, France. November 2003. pp45-48.

Hulme, K., and Hill, S.M. 2003. River red gum biogeochemistry: towards an innovative new tool for mineral exploration programs in the Curnamona Craton and adjacent regions. In: Peljo, M. (Compiler), *Broken Hill Exploration Initiative: Abstracts from the July 2003 Conference.* Geoscience Australia Record 2003/1383-84.

Lamontagne, S., Hicks, W., Fitzpatrick, R. and Rogers, S. 2004. Sulfidic materials: an emerging environmental issue for the management of salinity in the River Murray floodplain. Proceedings – *9th Murray-Darling Basin Groundwater Workshop*, Bendigo, Vic. 17-19 February 2004. Department of Primary Industries, Victoria. 6pp

Lamontagne, S., Hicks, W., Fitzpatrick, E. and Rogers, S. 2003. Sulfidic materials: an emerging issue for the management of saline wetlands. In: Abstracts – *Conference of the Ecological Society of Australia*, Armidale, NSW, 8-10 December 2003. University of New England. p99.

Lawrie, K.C. 2004. Regolith geoscience – a key to addressing the National Research Priority: environmentally sustainable Australia. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p25.

Lawrie, K.C., and Mernagh T. 2003. Hydrothermal zircon: a resistate mineral with potential use as an indicator/pathfinder in exploration. *21st International Geochemical Exploration Symposium*, Dublin, Ireland, 29 August – 3 September 2003. Program and Abstracts, Association of Exploration Geochemists. p43.

Lawrie, K.C., Fitzpatrick, A. and Coram, J. 2003. Mapping groundwater flow systems, aquifers and salinity – preliminary results from the Lower Balonne airborne geophysics evaluation project. In: Silburn (Ed). *Where is the water and salt going and what is it doing?* Northern Murray Darling Basin Water Balance/Deep Drainage Group Workshop, Narrabri, NSW, 19-20 November 2003. Murray Darling Basin Commission.

Lawrie, K.C., Please, P. and Coram, J. 2003. Groundwater quality (salinity) and distribution in Australia. In: *Water the Australian Dilemma*. Proceedings of the Annual Symposium of the Academy of Technological Sciences and Engineering. 17-18 November 2003, Melbourne. Vic ATSE.

Lawrie, K.C., Please, P., Coram, J., Pain, C., Grundy M., and Walker, G. 2003. An integrated geoscience approach to re-assessing regional groundwater flow systems for salinity and mitigation in the Murray-Darling Basin. Proceedings of *the 9th PUR$L (Productive Use and Rehabilitation of Saline Land) Conference,* Yapoon, Qld. 30 September to 30 October 2003. National Dryland Salinity Program. CD

Lawrie, K. C., Please, P., Fitzpatrick, A., Grey, M. and Pain, C. 2003. An integrated geoscience approach to groundwater management and salinity mitigation at catchment and sub-catchment scales. Proceedings of the *Catchment Management Conference,* Sydney, NSW, 26-28 November 2003. Australian Water Association. CD.

Lawrie, K.C., Wilford, J., Gibson, D., de Caritat P. and Kirste, D. 2003. Groundwater flow systems: a framework for interpreting geochemical anomalies in complex regolith landscapes. Program and Abstracts, *21st International Geochemical Exploration Symposium*, Dublin, Ireland, 29 August – 3 September 2003 Association of Exploration Geochemists. pp49-50.

Lech, M., Raymond, O., Wyborne, L., de Caritat, P. and Lambert, I. 2004. Why we want baseline geochemical data and can we get it from available whole-rock analyses? *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p26.

Lennard, J. and Field, J. 2004. Effects of trees on regolith and landscapes. Abstracts – *11th Australian and New Zealand Geomorphology Group Conference*, Mt Buffalo, Victoria, 15-20 February 2004. ANZGG. p46.

Lintern, M.J. 2003. Biogeochemistry – new data from South Australia. Program and Abstracts, *21st International Geochemical Exploration Symposium*, Dublin, Ireland, 29 August – 3 September 2003. Association of Exploration Geochemists. pp52.

Little, D., Field, J. and Banks, J. 2004. Inter-relationships between soil and regolith patterns and nutrient processes at a subalpine inverted treeline. *Abstracts – 11th Australian and New Zealand Geomorphology Group Conference*, Mt Buffalo, Victoria, 15-20 February 2004. ANZGG. p48.

Liu, W., Brugger, J., Etschmann, B. and Spiccia L. 2004. UV spectrophotometric and X-ray absorption experiments on ferric chloride complexes in brines. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p93.

Lau, I.C., Mauger, A.J., Heinson, G. and James, P.R. 2003. Remote spectral mapping of regolith in the Olary Domain. In: Peljo, M. (Compiler), *Broken Hill Exploration Initiative: Abstracts from the July 2003 Conference.* Geoscience Australia Record 2003/13.

McQueen, K.G. 2003. Mineral hosts for pathfinder elements in the Cobar Goldfield, NSW, Australia. Program and Abstracts, *21st International Geochemical Exploration Symposium*, Dublin, Ireland, 29 August – 3 September 2003. Association of Exploration Geochemists. pp71

McQueen, K.G. 2003. Evidence of a granite-related source for the Braidwood-Araluen-Majors Creek goldfields, NSW, Australia. In: Blevin, P., Jones, M. and Chappell, B. (Eds). *Magmas to Mineralisation: The Ishihara Symposium.* Geoscience Australia Record 2003/14. pp97-100.

McQueen, K.G. and Scott, K.M. (Editors). 2004. *Exploration Field Workshop Cobar Region 2004 Proceedings,* 24-26 May 2004, Cobar, NSW. CRC LEME. 109pp.

McQueen, K.G. 2004. The nature, origin and exploration significance of the regolith, Girilambone-Cobar Region. In: McQueen, K.G. and Scott, K. M. (Eds) *Exploration Field Workshop Cobar Region 2004: Proceedings.* CRC LEME. pp51-56.

McQueen, K.G. and Munro D.C. 2004. Factoring in weathering-controlled chemical fractionation in surface sampling media. In: McQueen, K.G. and Scott, K. M. (Eds) *Exploration Field Workshop Cobar Region 2004: Proceedings.* CRC LEME. pp57-61.

Mee, A.C., McKirdy, D.M., Krull, E.S. and Williams, M.A.J. 2004. Lacustrine organic matter as a proxy for mid-latitude Holocene environmental change in southeastern Australia – a work in progress. In: McIntyre, C. (Ed) Program and Abstracts – *Combined national conference of the Australian Organic Geochemists and the International Humic Substances Society.* CSIRO Petroleum, North Ryde. pp89-90.

Mitchell, D., Lewis, M., Ostendorf, B. and Chittleborough D. 2004. Mapping surface and subsurface soil properties using geophysical remote sensing and regolith information. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p33.

Munday, T.J. 2003. Mapping deeper salinity in intermediate and regional groundwater flow systems. *Public forum on salinity mapping methods in the Australian Context,* Australian Academy of Science Canberra, ACT, 17 October 2003. http:www.science.org.au/proceedings/salinity/index.htm.

Munday, T., Hill, T., Hopkins, B., Green, A., Brodie, R., Tan, K.P. and Barnett, S. 2004. 'Peeling back the cover' – some observations on the sedimentary framework of the Riverland region, South Australia, as defined by airborne electromagnetic data, with particular reference to the Loxton-Parilla Sands and Blanchetown Clay. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p33.

Pain, C.F. 2003. Mapping salinity in the near-surface and upland landscapes. Proceedings of the Australian Academy of Science – *Public forum on salinity mapping methods in the Australian Context,* Canberra, ACT, 17 October 2003. Australian Academy of Science. http://www.science.org.au/proceedings/salinity/pain.htm.

Pain, C., Wilford, J. and Lawrie, K.C. 2003. Geomorphology and salt: what can landforms tell us about salinity prediction in upland areas? Proceedings of the *9th PUR$L (Productive Use and Rehabilitation of Saline Land) Conference*, Yapoon, Qld. 30 September to 30 October 2003. National Dryland Salinity Program. CD

Pain, C.F., Wilford, J.R. and Lawrie, K. 2003. The role of geomorphology in assessing salt and water movement in upland landscapes. Proceedings of the *Integrated Catchment Management Conference*, Theme 1, Paper 1. Sydney, NSW. 26-28 November 2003. Australian Water Association. CD.

Pain, C.F., Clarke, J. and Thomas, M. 2004. Geomorphic processes, landforms and regolith on Mars. Abstracts – *11th Australian and New Zealand Geomorphology Group Conference*, Mt Buffalo, Victoria, 15-20 February 2004. ANZGG. p55.

Paine, M., Anand, R.R. and Morand, V. 2004. Nature and origin of fossiliferous ferruginous duricrusts on the Dundas Tableland, southwestern Victoria. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p35.

Pillans, B. 2004. Dating long term landscape evolution in Australia: highlights from the CRC LEME geochronology project. Abstract – *11th Australian & New Zealand Geomorphology Group Conference*, Mt Buffalo, Victoria, 15-20 February 2004. ANZGG. p56.

Reith, F. and McPhail, D.C. 2004. Evidence for geomicrobiologically mediated gold cycle in soil and regolith in eastern Australia. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p115.

Robertson, I.D.M. 2003. Dispersion into Mesozoic cover from the Eloise Cu-Au-Ag deposit, Queensland, Australia. *21st International Geochemical Exploration Symposium*, Dublin, Ireland, 29 August – 3 September 2003. Program and Abstracts, Association of Exploration Geochemists. pp72

Rosid, M. and Kepic. A. 2003. Using the seismoelectric method for hydrogeological investigations. Proceedings of the *Symposium on the Application of Geophysics to Engineering and Environmental Problems: Geophysical Solutions for Today's Challenges*. Environmental and Engineering Geophysical Society, Colorado Springs, USA. 22-26 February 2004. pp1480-1489.

Scott, K.M. 2003. Rutile geochemistry as a guide to mineralisation at the North Parkes porphyry copper deposit, New South Wales, Australia. Program and Abstracts, *21st International Geochemical Exploration Symposium*, Dublin, Ireland, 29 August – 3 September 2003. Association of Exploration Geochemists. pp44.

Scott, K.M. and Le Gleuher M. 2004. Geochemical dispersion in the regolith, Girilambone Belt Region. In: McQueen, K.G. and Scott, K. M. (Eds) *Exploration Field Workshop Cobar Region 2004: Proceedings*. CRC LEME. pp74-77.

Smitt, C., Herczeg, A., Davies, P. and Cox, J. 2004. Identifying sources of salt and its mobilisation processes in the eastern Mt. Lofty Ranges, South Australia. Proceedings – *9th Murray-Darling Basin Groundwater Workshop*, Bendigo, Vic. 17-19 February 2004. Department of Primary Industries, Victoria. 6pp

Tan, K.P., Munday, T., Leaney, F., Barnett, S, Green, A. and Brodie, R. 2004. Some observations on the sedimentary framework of the Ngarkar region, South Australia, as defined by airborne electromagnetic data, with implications for informing groundwater recharge models. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p43.

Tate, S.E., Greene, R.S.B., Scott, K.M. and McQueen, K.G. 2004. The aeolian input to the Girilambone regolith – implications for exploration. In: McQueen, K.G. and Scott, K. M. (Eds) E*xploration Field Workshop Cobar Region 2004: Proceedings*. CRC LEME. pp94-100.

Thomas, M. and Clarke J.D.A. 2004. Application of regolith landform mapping at the Mars Desert Research Station in Utah. Abstracts – *11th Australian and New Zealand Geomorphology Group Conference*, Mt Buffalo, Victoria, 15-20 February 2004. ANZGG. p68.

Whitbread, M.A. 2004. Using Lithogeochemistry to explore in regolith dominated terrains: avoiding closure, background and weathering effects. In: McQueen, K.G. and Scott, K. M. (Eds) *Exploration Field Workshop Cobar Region 2004: Proceedings*. CRC LEME. pp105-108.

Wilford, J. 2004. Delineating salt stores and near-surface saline water flow in contrasting regolith-landform environments from South Australia. *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p45.

Wulser, P., Lahaye, Y. and Brugger, J. 2004. Mineralogy and zircon geochemistry of uranium sedimentary-hosted Beverley deposit (Lake Frome Embayment, Curnamona Province, South Australia). *Dynamic Earth: Past, Present and Future Abstracts 73*. 17th Australian Geological Convention, Hobart, Tasmania, 8-13 February 2004. Geological Society of Australia. p138.

ARTICLES AND NEWSLETTERS

Brown, A. and Hill, S.M. 2003. White Dam – detailed regolith landform mapping as a tool for refining the interpretation of surface geochemical results. MESA Journal, Vol 31. Primary Industries and Resources. pp6-8.

Game, S.J. (Ed). 2003. LEME News No. 23. June/July 2003 CRC LEME Newsletter. 24pp.

Gee, R.D. (Ed). 2004. CRC LEME Minerals Brief – Regolith Science in Mineral Exploration. CRC LEME, February 2004. Circulated electronically and on web site – http://crcleme.org.au. 6pp.

Gee, R.D. (Ed). 2004. CRC LEME Minerals Brief – Regolith Science in Mineral Exploration No. 2. CRC LEME, June 2004. Circulated electronically and on web site. http://crcleme.org.au. 7pp

Gee, R.D. 2004. Science in a new age. Australian Mining Monthly, February 2004. p12

Gee, R.D. 2004. Smart science to explore regolith. Australian Mining Monthly, April 2004. p12.

Gee. R.D. 2004. Micro-mineral mapping to the fore. Australian Mining Monthly, June 2004. p12.

Gee, R.D. 2004. Rich rewards in and under the regolith. Prospect. June-August 2004. p23

Hill, S.M. 2003. Regolith mapping and landscape evolution models in gold exploration. MINFO Quarterly, 79., NSW Dept Primary Industries (Dept Mineral Resources) pp34-35.

Hou, B. and Alley, N.F. 2003. A model for gold and uranium dispersion and concentration in residual and transported regolith along palaeodrainage systems. A case study from the central Gawler Craton, SA. MESA Journal, Vol 30. Primary Industries and Resources SA, Minerals. pp49-53.

Keeling. J.L., Mauger, A.M. and Huntington, J.F. 2004. Spectral core logger update – preliminary results from the Barns gold prospect. MESA Journal, Volume 33. Primary Industries and Resources SA, Minerals. pp32-36.

McQueen, K.G. 2003. Improving team teaching in the earth sciences through an action learning approach. Planet, Issue 10. pp24-29.

Reith, F., 2003. Relevance of Microorganisms for the Formation of and the Exploration for Gold Deposits in the Australian Regolith. AusIMM Bulletin, November/December 2003. pp60-62

Reith, F. 2004. Microbial Gold Prospectors. Australasian Science. July 2004. University of Southern Queensland Magazine. pp23-25.

CRC LEME OPEN FILE REPORTS

de Caritat, P. and Kirste, D. 2004. Teilta regolith project: groundwater geochemistry. CRC LEME Open File Report 158. 27ppand CD

Lintern, M.J. The South Australian regolith project – final report – summary and synthesis. CRC LEME Open File Report 156. 122ppand CD.

Lintern, M.J. 2004. Preliminary regolith studies at Earea Dam Gold Prospect, Gawler Craton, South Australia. CRC LEME Open File Report 153. 63ppand CD.

Ruperto, L. 2004. Teilta regolith project: basement modelling. CRC LEME Open File Report 157. 11ppand CD

Sheard, M.J and Robertson. I.D.M. In Press. Regolith characterisation and geochemistry as an aid to mineral exploration in the Harris Greenstone Belt, Central Gawler Craton, South Australia. CRC LEME Open File Report 155

TECHNICAL REPORTS and SUBMISSIONS

Lawrie, K.C., Wilkes, PO., Lane, R., Coram, J. Pain, C. Fitzpatrick, A., Gray, M., Wilford, J., Beckett, K. and Munday, T. 2003. Submission from CRC LEME to the National Review of Salinity Mapping Methodologies in the Australian Context. 30pp.

Lawrie, K.C., Wilkes, P. and Gee, D, 2003. Submission from CRC LEME to the House of Representatives Standing Committee on Science and Innovation – Inquiry into coordination of the science to combat the nation's salinity problem. Salinity. 7pp.

Smitt, C., Cox, J., McEwan, K., Davies, P., Herczeg, A. and Walker, G. 2003. Salt Transport in the Bremer Hills, SA – FLOWTUBE Modelling. Second Report for the NAP South Australian Salt mapping and Management. CSIRO Land and Water Technical Report 06/03.

Smitt, C., Cox, J. and Davies, P. 2003. Salt Transport in the Bremer Hills, SA: Interpretation of Spatial Datasets for Salt Distribution. Third Report for the NAP South Australian Salt Mapping and Management. CSIRO Land and Water Technical Report 40/03.

Smitt, C., Cox, J. and Davies, P. 2003. Salt Transport in the Bremer Hills, SA. Interpretation of Spatial Datasets for Salt Distribution. Fourth report for NAP South Australian Salt Mapping and Management. CSIRO Land and Water Technical Report 49/03.

MAPS AND GIS PRODUCTS

Buckley, P.M. 2004. Byrock regolith-landform map. (1:100 000). CRC LEME Canberra/Perth

Maley, B.E.R. 2004. Hermidale regolith-landforms. Revised first edition. (1:100 000) CRC LEME Canberra/Perth.

Maley, B.E.R., Chan, R.A. and Senior, A. 2004. Sussex regolith-landforms. First Edition (1:100 000). CRC LEME Canberra/Perth.

Maley, B.E.R., Chan, R.A. and Senior, A. 2004. Coolabah regolith-landforms. First Edition. (1:100 000) CRC LEME Canberra/Perth.

Chamberlain, T. and Hill, S.M. 2004. Tibooburra Inlier 1:25 000 regolith landform map. CRC LEME Perth.

FIELD GUIDE NOTES

Brown, A., Hill, S.M. and James, P.J. 2003. Detailed regolith mapping as a tool for refining the interpretation of geochemical results at White Dam, Curnamona Craton, SA. In: Connor, C. and Crooks (Compilers) *Geology of the Olary Domain, Curnamona Province, South Australia 2003*. Part 2. Field guide and excursion notes. Unpaginated.

Barratt, R.M. and Hill, S.M. 2003. BHEI 2003 Mineral deposits Excursion Guide, Broken Hill. *Geological Survey of NSW Report GS 2003/223*. 83pp.

Hou, B. and Sheard, M.J. 2003. Kingoonya Palaeochannel system. In: Fairclough, M.C. and Schwarz M.P. (Eds). *Gawler Craton 2003: State of Play, the Excursion*. Gawler, SA, 8-16 September 2003. PIRSA Mineral Resources Group Report Book 2003/17. Primary Industries and Resources SA-CRC LEME. Unpaginated.

McQueen, K.G. 2004. Exploration Field Workshop Cobar Region 2004. *Field Guide and Locality Descriptions. Exploration Field Workshop Cobar Region 2004*, Cobar, NSW, 24-27 May 2004. CRC LEME. 32pp.

SHORTCOURSE AND WORKSHOP NOTES

Aspandiar, M., Hill, S. and Roach. I. Regolith geology and geochemistry. *Honours shortcourse*. CRC LEME and Minerals Education Tertiary Education Council's National Geoscience Teaching Network, Wilson's Promontory, Victoria. 23-27 February 2004. CRC LEME Report 200

Barnes, S., Butt, C.M., Gray, D., Peters, B., Huntington and J. Beresford, S. 2004. Workshop notes. Exploring for komatiites hosted nickel sulphide deposits. Kalgoorlie, WA. 11-15 May 2004. CSIRO Exploration and Mining. 115pp.

Eggleton, R.A. and Troitzsch, U. Environmental Mineralogy (EMN). *Honours shortcourse*. CRC LEME and Minerals Education Tertiary Education Council's National Geoscience Teaching Network. Australian National University, 21-25 June 2004. CRC LEME Report 208.

Hill, S., Roach, I. and Hulme, K. Regolith mapping and field techniques. *Honours Shortcourse*. CRC LEME and Minerals Education Tertiary Education Council's National Geoscience Teaching Network. Fowlers Gap, NSW, 15 – 19 March 2004. CRC LEME Report 201.

Hill, L., Hill, S., McPhail, B., McQueen, K. Scott, K., Roach, I. and Robertson I. Regolith geology and mineral Exploration Masters Shortcourse (2 volumes). *Masters Course* CRC LEME and Minerals Education Tertiary Education Council's National Geoscience Teaching Network. Fowlers Gap, NSW, 4-15 August 2003. CRC LEME. Report 194.

Kirste, D. and de Caritat P. Introduction to hydrogeochemistry. *Honours Shortcourse*, CRC LEME and Minerals Education Tertiary Education Council's National Geoscience Teaching Network. University of Melbourne, 29 March – 2 April 2004. CRC LEME Report 203.

Mauger, A.J., Lewis, M. Advanced remote sensing for mineral exploration and natural resource management. *Honours and postgraduate shortcourse*. CRC LEME and Minerals Education Tertiary Education Council's National Geoscience Teaching Network. University of Adelaide, 13-16 April 2004. CRC LEME Report 205.

SPONSORED PROJECT REPORTS AND MAPS UNDER CONFIDENTIALITY AGREEMENTS

Clark, J.D.A. and Reisz, A. 2004. Fluvial architecture of the subsurface of the Darranbandi palaeovalley and St George region, Lower Balonne River, Queensland. Prepared for SA SMMSP. *CRC LEME Restricted report No. 204R*. 41pp.

Gibson, D., 2003. An interpretation of landscape, geology and regolith in the Angas Bremer Plains area, South Australia. Prepared for SA SMMSP. *CRC LEME restricted report 189R*. 95pp.

Gray, David J. and Lintern, Melvyn J., 2004. Challenger gold deposit – Further research and integration with other investigations. Prepared for Dominion Mining Limited. *CRC LEME Restricted Report 197R* . 33pp.

Greene, A. and Munday T.J. 2003. Forward modeling of airborne electromagnetic data for the Riverland, South Australia. Prepared for SA SMMSP. *CRC LEME Restricted Report 181R*. 27pp.

Green A. and Munday, T.J., 2003. Forward modelling of airborne electromagnetic data for the Riverland, South Australia. Prepared for SA SMMSP. *CRC LEME Restricted Report 181R*, 14pp

Le Gleuher, M. 2003. Mineral hosts for gold and trace elements in the regolith, Boddington and Mt Percy gold deposits, Western Australia. Prepared for Newmont Australia. *CRC LEME Restricted Report 196R*. 89pp.

Le Gleuher, M. 2003. Trace element-mineral associations in the regolith, Scuddles Massive Cu-Zn sulphide deposit, Western Australia. Prepared for Newmont Australia. *CRC LEME Restricted Report 195R*. 68pp.

Scott, K.M. 2003. Mineral Hill regolith research 2: Mineralogy and geochemistry at Parkers Hill and Pearse. Prepared for Triako Resources Limited. *CRC LEME Restricted Report 198R*. 20pp.

Photograph: Ian Robertson

11. Public Presentations, Public Relations and Communication

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. However, we recognise that as salinity and environmental programs grow and deliver, there will be a need to promote to the 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.
- The 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.
- Publication of scientific communications in national and international scientific journals.
- Staging conferences, seminars and workshops under the LEME banner, for example Mineral Exploration Seminar, and Regolith Symposia held annually in Canberra, Adelaide and Perth.
- LEME researchers presenting their findings at national and international events.
- Distribution of the electronic newsletter *Minerals Brief* to over 500 recipients.
- Sponsoring multi-disciplinary multi-agency scientific and technical events.
- Technical articles in special interest journals and industry magazines.

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, but increasingly available in digital form. In general, 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, style and guidelines for technical publications have been developed. Guidelines 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.

Website

The website http://crcleme.org.au and the associated intranet have been greatly expanded in content. It now contains over 500 PDF files of technical papers, and is the main medium for conveying LEME activities and research to staff and stakeholders. It contains program and project descriptions, research and technical papers, abstracts for all Open File Reports, monographs/case histories. 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 Education Section advertises MTEC courses, scholarships and proposed student projects and also provides a forum for LEME students to report their progress and keep in touch with student research in other universities.

The website also contains personnel directories (staff, students, Board, Advisory Councils), the LEME Strategic Plan, news and events, upcoming conferences, as well as links to all Core Participant websites. Because its content was expanded dramatically through the year, the website is now going through a major reconstruction.

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 project schedules.

Publications

The main publication outlets are the standard-series 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 170 Open File Reports, dating back to LEME 1. On expiry of the confidentially period, Restricted Reports are re-badged and converted into the OFR Series. Five new Reports published during the reporting period are listed in the Publications section of this report and there are five in the pipeline to be published during October.

LEME produces a variety of monographs which include books, thematic volumes, conference proceedings or extended abstracts. Six new monographs were produced in the year.

Conferences, Seminars and Meetings

In November 2003, 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-fertilisation 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 in the LEME monograph series. These are available in hard copy, PDF or CD.

In association with the Sydney Mining and Exploration Discussion Group (SMEDG), LEME staged a field exploration workshop in Cobar in May 2004, convened by Prof Ken McQueen. This enabled the research results of the three-year Girilambone Project, now entering its final stages, to be conveyed to mineral explorers. There were 11 LEME presenters at this event.

The annual LEME Minerals Exploration Seminar was held in Perth in June 2004, co-sponsored by the major industry group – the Association of Mining and Exploration Companies (AMEC). Over 120 people attended. This successful series conveys timely and relevant research results to the mineral explorers.

In June 2004, CRC LEME joined with the five other CRCs in the Minerals and Energy Sector to present selections of outstanding work in the Innovation Day of *Minerals Week* – a forum staged by the peak industry body Minerals Council of Australia (MCA). Dr Patrice de Caritat presented on exploration for deeply buried basemetal deposits using isotopic signatures of groundwater. Frank Reith presented his finding on the role of bacteria in the dissolution and precipitation of gold in the regolith.

At the CRC Association Annual Conference in Adelaide in June 2004, Program Leader Ken Lawrie gave a presentation in the Achievers Section on the *Application of new regolith technologies to salinity remediation*. Also CEO Dennis Gee gave a presentation on *Evaluating the benefits of LEME research in mineral exploration and natural resource management*.

CRC LEME was a section sponsor of the 17th Australian Geological Convention held in Hobart in February 2004. A total of 26 papers were presented under the banner of CRC LEME, including a keynote speech by Program Leader Ken Lawrie, on *Regolith Geoscience – a key to addressing the National Research Priority: environmentally sustainable Australia*.

At the July 2003 Broken Hill Exploration Initiative Conference, LEME researchers contributed nine papers. This was attended by 150 delegates half of whom were from the mineral exploration industry. Regolith-landform maps, early results of geobotanical exploration methods, groundwater hydrogeochemistry and case histories of regolith expression of mineralisation were unveiled.

Visitors

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

Media Releases

Six significant media releases were made on a range of topics, including public benefits of research on pin-pointing saline discharges to the Murray River, substantial cost reductions in salinity mapping due to new geophysical technologies, history of aridity in Australia, and microbial processes in gold mobility. These releases have mostly been facilitated by the services of Julian Cribb, through the contractual arrangements with the CRC Association, and the CRC Minerals and Energy Sector.

Table 11.1 – Conferences, Seminars and Meetings – attended by LEME personnel

Event	Location	Date	LEME Participants	LEME Additional Involvement
International Union of Geodesy and Geophysics (IUGG)	Sapporo, Japan	1-8 Jul 2003	John Joseph **– presenter**	
Broken Hill Exploration Initiative 2003 Conference	Curnamona, NSW	7-9 Jul 2003	Steve Hill – **Keynote speaker**, Dirk Kirste, Ian Lau, Kylie Foster – **presenters** plus posters, Dennis Gee, Aaron Brown, John Keeling, Ian Lau, Keith Scott – attendees	LEME sponsor
Canadian Geological Survey Seminars (2)	Calgary, Canada	9 Jul 2004 and 18 Jul 2004	Roslyn Chan – **invited speaker (2)**	
Australian Platinum	Perth, WA	14-15 Jul 2003	Dennis Gee – **opening address**. LEME attendees	
XVI International Union for Quaternary (INQUA) Congress	Reno, USA	23-30 July 2003	Roslyn Chan – attendee	
ANU-LEME Seminar Series	Canberra, ACT	7 Aug 2003	John Chappell – **presenter**	
AIG Conference – Vectors to Hydrothermal Mineralisation	Perth, WA	22 Aug 2003	Jayson Meyers – **presenter**	
Soilmaster Field Day	Parkes, NSW	29 Aug 2003	Richard Greene – **Keynote speaker**	
21st International Geochemical Exploration Symposium	Dublin, Ireland	29 Aug – 3 Sept 2003	Ken Lawrie, David Gray **(Keynotes)**, Ian Robertson, Keith Scott, Mel Lintern, Ken McQueen – **presenters**, Pat James, Bear McPhail, Charles Butt, Ray Smith, Patrice de Caritat – attendees	
US Geological Survey Seminar	San Francisco, USA	2 Sep 2003	Roslyn Chan – **invited speaker**	
6th International Symposium on Environmental Geochemistry	Edinburgh, Scotland	8-11 Sep 2003	Charles Butt – attendee	
Advanced Spaceborne Thermal Emission and Reflection Radiometer – ASTER Mini Conference and Workshop	PIRSA, Adelaide, SA	18-10 Sep 2003	Vicki Stamoulis and Alan Mauger – **organisers and session convenors**, John Keeling, Pat James – attendees	
National Opal Symposium	Quilpie, Qld	22-25 Sep 2003	Katie Dowell – **presenter**, poster and Opal booth	
Pur$l Conference "Salinity under the Sun"	Yapoon, Qld	30 Sep – 2 Oct 2003	Ken Lawie, Jane Coram – **presenters**, Colin Pain, Patty Please, David Mitchell – attendees	
Aust Academy of Science Meeting on Mapping Dryland Salinity	Canberra, ACT	17 Oct 2003	Colin Pain – **presenter**, Ken Lawrie – attendee	
Information from Geospatial Data for Natural Resource Management Shortcourse	Perth, WA	12-14 Nov 2003	Greg Street and Kirsty Beckett – **course facilitators**	
Australian Academy of Technological Sciences and Engineering (ATSE) Water Symposium	Melbourne, Vic	17-19 Nov 2003	Ken Lawrie – **Invited speaker**	
2nd International Workshop on the Magnetic Resonance Sounding method applied to groundwater investigations	Orleans, France	19-21 Nov 2003	Don Hunter – **presenter**	
New Generation Gold Conference	Perth, WA	24-25 Nov 2003	Matthias Cornelius and Ravi Anand – attendees	LEME booth and advertising
International Geoindicators Workshop	Canberra, ACT	24-26 Nov 2004	Colin Pain (host), Steve Rogers and other LEME attendees	LEME joint sponsor
Integrated Catchment Management (ICaM) 2003 Conference	Sydney, NSW	26-27 Nov 2003	Colin Pain – **presenter**, other LEME attendees	
World Diamond Conference	Perth, WA	1-2 Dec 2003	Dennis Gee and other LEME – attendees	
7th Annual Environmental Research Conference	Marysville, Vic	1-4 Dec 2003	Bear McPhail – **Keynote speaker**	
Medical Geology – Health and the Environment – Shortcourse	Canberra, ACT	1-4 Dec 2003	Colin Pain (host), Charles Butt, Patrice de Caritat, Megan Lech – attendees	LEME joint sponsor and host
Exploration NSW Geoscience Information Release	Parliament House, Sydney, NSW	3 Dec 2003	Ken McQueen, Keith Scott – attendees	LEME Map display
Geoscience Australia, Minerals Exploration Seminar	Perth, WA	4 Dec 2003	Dennis Gee and other LEME – attendees	
Ecological Society of Australia Conference	Armidale, NSW	8-10 Dec 2003	Simon Lamontagne – **presenter**, Warren Hicks, Rob Fitzpatrick, Steve Rogers – attendees	
Fluid mineral modelling and ore deposits. Controversies in Geodynamics and Ore Genesis.	Monash University, Vic	5-6 Feb 2004	David Gray and Charles Butt – attendees	
17th Australian Geological Convention: Dynamic earth, past present and future	Hobart, Tas	8-13 Feb 2004	Ken Lawrie – **Keynote speaker**, 23 LEME presentations, 5 posters and other LEME attendees** details shown under Publications	LEME Silver Sponsor / Booth
Iron & Sulphur Bacteria workshop	Perth, WA	11-14 Feb 2004	Dennis Gee and other LEME attendees	
9th Murray Darling Basin Groundwater Workshop	Bendigo, Vic	17-19 Feb 2004	Tim Munday (2), Andrew Fitzpatrick – **presenters**, Dave Gibson, John Wilford, Ken Lawrie – attendees	
11th Australia and New Zealand Geomorphology Group Conference	Mt Buffalo, Vic	15-20 Feb 2004	Derek Fabel – **organiser**, Brad Pillans, John Chappell, Derek Fabel, John Field, Kathryn Fitzsimmons, Colin Pain – **presenters**, Roslyn Chan Glen Bann, David Little – attendees	

Table 11.1 – Conferences, Seminars and Meetings – attended by LEME personnel (cont'd)

Event	Location	Date	LEME Participants	LEME Additional Involvement
Northern Territory Regolith Workshop – GABFEST	Darwin, NT	18-21 Feb 2004	Mike Craig, Ravi Anand and David Gray – **presenters**	
Symposium for the Application of Geophysics to Environmental and Engineering Problems (SAGEEP)	Colorado Springs, USA	22-26 Feb 2004	Tim Munday – **presenter**	
ANU-LEME Seminar Series	Canberra, ACT	23 Feb 2004	Chris Gunton – **presenter**	
Geological Survey WA Seminar	Perth, WA	23 Feb 2004	Dennis Gee and other LEME attendees	
Use of geophysics for groundwater detection Seminar. Dept of Water, Land and Biodiversity Conservation SA	Adelaide, SA	12 Mar 2004	Graham Heinson – **presenter**	
ANU-LEME Seminar Series	Canberra, ACT	22 March 2004	Kathryn Fitzsimmons – **presenter**	
Australian Geoscience Exploration Seminar (AGES) 2004	Alice Springs, NT	23-24 Mar 2004	Dennis Gee, Ravi Anand, Graham Heinson – attendees	
Central Gawler Gold Meeting	Adelaide, SA	31 Mar to 1 Apr 2004	Baohong Hou – **presenter**, Keith Scott and others LEME attendees	
ANU-LEME Seminar Series	Canberra, ACT	5 Apr 2004	Marion Kehoe – **presenter**	
1st European Geosciences Union Assembly	Nice, France	25-30 Apr 2004	Nick Direen – **presenter**	
ANU-LEME Seminar Series	Canberra, ACT	19 Apr 2004	Anne Riesz – **presenter**	
CSIRO Public Seminar on Salinity	Urrbrae, SA	22 Apr 2004	Chris Smitt, J Wilford – **presenters**, Andrew Herczeg, Jim Cox, Heike Apps – attendees	
Mr Lofty Ranges Integrated NRM Group and Bremer Barker Catchment Group	Mt Barker Catchment Centre, SA	23 Apr 2004	Chris Smitt, John Wilford – **presenters**, Andrew Herczeg, Jim Cox, Heike Apps – attendees	
ANU-LEME Seminar Series	Canberra, ACT	27 Apr 2004	Peter Bamford, Thomas Woolrych – **presenters**	
Australian Network for Plant Conservation training Program: Ecological restoration for mountain environments	Jindabyne, NSW	28-30 Apr 2004	Richard Greene – **invited speaker**	
Quaternary Isotope Workshop	Lower Hutt, New Zealand	4-7 May 2004	Katie Dowell – **presenter**	
MCA Minerals Week, Innovation Day	Canberra, ACT	1 Jun 2004	Dennis Gee, Patrice de Caritat and Frank Reith – **presenters**	
CRC Association Conference	Adelaide, SA	8-10 Jun 2004	Ken Lawrie – invited speaker, Dennis Gee – **presenter**, George Savell, Steve Hill – attendees	LEME booth
Intrepid 3D WEG – Geological Modelling and Inversion Software Applied to the Geology of Broken Hill	Adelaide, SA	16 Jun 04	Nick Direen – **facilitator**, Graham Heinson, John Joseph, Lachalan Gibbins, Phil Heath – attendees	
Goldschmidt Geochemistry Conference	Copenhagen, Denmark	5-11 Jun 2004	Dirk Kirste – **presenter**	
Tools for Salinity Management: enhancing the community's capacity to manage salinity	Adelaide, SA	21 Jun 2004	Tim Munday – **presenter**, other LEME attendees	

Table 11.2 – Conferences, Seminars and Meetings – conducted by LEME personnel

Event	Location	Date	LEME Participants	No of attendees
Computer Aided Exploration Techniques Seminar	University of WA	10 Jul 2003	Amanda Cornelius, Tim Munday and David Gray – **presenters**	6
CRC LEME Salinity Forum	Adelaide University	21-22 July 2003	Ken Lawrie, Colin Pain – **presenters**	41
Gawler Craton – State of Play. Excursion: Introduction to industry on geology and regolith	In the field: Southern and Central Gawler Craton, SA	8-16 Sep 2003	Malcolm Sheard – **excursion leader.** PIRSA-LEME hosted event	26
CRC LEME Regional Regolith Symposia 2003: Advances in Regolith	Adelaide (Central) Canberra (Eastern) Perth (Western)	13-14 Nov 2003 19-21 Nov 2003 27-28 Nov 2003	Ian Roach – **convenor** 106 LEME presentations and posters** details shown under Publications	300
Exploration Field Workshop Cobar Region 2004	Cobar, NSW	23-26 May 2004	Ken McQueen – **convenor**, Ravi Anand, Roslyn Chan, Dennis Gee, Richard Greene, John Joseph, Ken McQueen, Ian Roach, Keith Scott, Susan Tate, Lisa Worrall (11) LEME presenters, Thomas Woolrych, Peter Bamford, Jenna Lennard – attendee	65
LEME- AMEC Minerals Exploration Seminar	Perth, WA	2 June 2004	Dennis Gee – **convenor**, 19 LEME presenters ** details shown under Publications	120

Table 11.3 – Visits from the Centre

Name and Core Party	Host Organisation and Location	Host Staff	Project Activity	Date (from / to)
Roslyn Chan, GA	Canadian Geological Survey, Calgary and Normal Wells, Canada	Dr Alejandra Duk-Rodkin	Applications of palaeotopographic mapping to mineral exploration and geophysics to regolith studies	Jul – Aug 2003
Ian Lau, AU	LEME/CSIRO Exploration and Mining, Mineral Mapping Technologies Group, Perth	Dr Ravi Anand	ASD Fieldspec usage and Hyperspectral imagery processing	4-8 Aug 2003
Roslyn Chan, GA	US Geological Survey, Menlo Park, San Francisco, USA	Dr Keith Howard	Applications of geophysics to regolith studies, including geohazards	2 Sept 2003
Baohong Hou PIRSA	Kunming University of Sciences and Technology, China	Prof Han Rensheng	Lectures, attending course, Exchange Program	19-25 May 2004
Baohong Hou PIRSA	Jilin University, China	Profs Jin Wei and Liu Zhaojun	Lectures, Exchange Program	26-31 May 2004
Baohong Hou PIRSA	Hefei University of Technology, China	Prof Zhou Taofa	Lectures, Exchange Program	1-4 Jun 2004
Baohong Hou PIRSA	China University of Geosciences	Profs Yao Shushen and Lu Xinbiao	Lectures, Exchange Program	5-8 Jun 2004
Baohong Hou PIRSA	Guilin University of Technology, China	Prof Luo Xianrong	Lecture, attending course, Exchange Program	9-15 Jun 2004

Table 11.4 – Visitors to the Centre

Visitor	Organisation	LEME Host	Location	Date (from / to)
Dr M Raghimi	Gorgan University, Iran	Mehrooz Aspandiar and Arthur Rathur	CUT, Dept Exploration Geology	Jul 2003-Feb 2004
Drs Jill Banfield and Liz Green	University of California, Berkeley	Susan Welch	ANU, Canberra	Jul 2003
Professor John Hepworth (Retired)	Strong interest in silcrete, ex UK overseas Geological Surveys	Dennis Gee	CSIRO Perth	8 Mar 2004
Professor Eugen Stumpfl	Institution of Geosciences, University of Loeben, Austria	Dennis Gee	CSIRO Perth	25 Mar 2004
Messrs Chris Oates, Nick Franey, John Barr	Anglo American PLC, London	Dennis Gee, John Keeling, Ken McQueen	CSIRO in Perth, AU and PIRSA in Adelaide and GA and ANU in Canberra (3 visits)	19, 20 and 21 May 2004
Dr Brian Murphy	DIPNR	Richard Greene	Canberra	9 Jun 2004
Dr David Eldridge	DIPNR	Richard Greene	Sydney	24 Jun 2004

Table 11.5 – Media Reports and Releases

Subject	CRC LEME Contributor	Publication	Date
New exploration techniques for Broken Hill	Patrice de Caritat	The Communiqué (Dept Industry Tourism, Resources Newsletter)	Aug 2003
What's in the dirt?	Patrice de Caritat	GA Media Release	Sep 2003
LEME EM Salinity mapping of the River Murray using a towed transmitter	Brian Barrett and Graham Heinson	ABC 891 (Adelaide) Dr Victor Gostin-AU segment	25 Sept 2003
Hydrogeochemistry used to vector towards mineralisation under cover	Patrice de Caritat	GA Minerals Alert	Sep 2003
Hydrogeochemistry used to vector towards mineralisation under cover	Patrice de Caritat	Australian Mining: Mineralisation under cover issue	Oct 2003
Australia is an arid continent	John Magee-John Chappell	Media release	Nov 2003
LEME Cooperative Research Centre makes breakthrough in salinity mapping	Ken Lawrie-Dennis Gee	Media release	Nov 2003
What on earth is regolith? and Learning about salinity	Ken Lawrie	Canberra Times – NEI Education Supplement – Natural Hazards	Nov 2003
The secret of nuggets	Frank Reith-Dennis Gee	Media release	Jan 2004
Gawler Craton exploration	Graham Heinson and Karin Barovich	ABC 891 News segment	20 Jan 2004
Opals and Katie Dowell	Katie Dowell	Cootamundra Herald	11 Feb 2004
What biogenic minerals tell us	Susan Welch	Science (USA)	11 Mar 2004
UW scientists find microbes in flooded mine	Susan Welch	Wisconsin State Journal	11 Mar 2004
Microbe strategy could inspire new materials	Susan Welch	Scientific American .com	12 Mar 2004
Education and training in landscapes and minerals	Pat James-Steve Hill	Campus Review (Adelaide University)	Mar 2004
Ambitious regolith project ahead for NTGS	Mike Craig	Mining News	31 Mar 2004
Ambitious regolith project ahead for NTGS	Mike Craig	www.miningnets.net/ storyview.asp	31 Mar 2004
Girilambone project and Exploration Field Workshop, Cobar	Ken McQueen	Cobar Weekly	May 2004
Answer to a salty dilemma	Dennis Gee	Daily Telegraph	Jun 2004
Up to the environmental challenge	George Savell, P Wilkes	Farm Weekly, WA	Jun 2004
New technology salt of the earth	Ken Lawrie	Bendigo Advertiser	Jun 2004

12. Grants and Awards

Awards and Appointments

LEME staff activities have been recognised at a number of national and international forums during the reporting period.

Dr Nick Direen received the prestigious Stillwell Medal from the Geological Society of Australia, for the best research paper in the *Australian Journal of Earth Sciences.* This made it two in a row for LEME, because Ravi Anand and Mark Paine received the same award in the previous year.

Dr Baohong Hou has been appointed Adjunct Professor at University of Jilin China. Dr Ken Lawrie and the LEME Program 4 Team received recognition from Geoscience Australia for Achieving Results in Science Award for their excellent work in salinity management technologies.

Three founding icons – Dr Ross Fardon, Prof Tony Eggleton and Prof Graham Taylor – were awarded Honorary Fellow of LEME for outstanding contributions to the development and promotion of regolith science.

Another LEME doyen, our CRC Visitor Prof Gerry Govett, received international recognition from his peers with the award of Honorary Membership from the International Association of Exploration Geochemists, at their international conference in Dublin.

And on the subject of icons, Dr Raymond E Smith, after nearly 40 years of service to geoscience, has retired. He was foundation Executive Director/CEO of both the Cooperative Research Centre for Landscape Evolution and Mineral Exploration (LEME 1) and its successor LEME 2, over the period 1995 to 2002. This year he received the Centenary Medal for services to Australian society in geology, and on retirement, was created Emeritus Research Fellow in CSIRO.

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 Charles Butt and Ray Smith to research and development related to the mineral industry. The inaugural award will be made at the Society of Economic Geologists Conference, which meets in Perth in September 2004.

Student Success

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

Grants

LEME staff 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.

Student Prizes

CRC LEME Regolith Symposia, Canberra, Adelaide and Perth , November 2003

Best Overall Oral and Written Presentation: Louisa Roberts ANU, Aaron Brown AU, Mark Paine CUT

Best Oral Presentation: Susan Tate and Jennifer Leonard ANU, Alexandra Pengelly AU, Anousha Hashemi, CUT

Editors choice award for Best Written Work: Karen Hulme, AU, Kirsty Beckett, CUT

Honourable Mention, Canberra: Katie Dowell ANU, Michael Turner ANU, Chris Gunton ANU, Leanne Hill ANU, Kathryn Fitzsimmons ANU, Amy Lockheed AU, David Little ANU

Honourable Mention, Adelaide: Ian Lau AU, Tania Dhu AU, Brett Thomas Au, Michael Smith ANU, Andrew McPherson ANU

Honourable Mention, Perth: Hashim Carey AU, Suzanne Simons AU, Katie Dowell ANU, Margarita Norville CUT, Don Hunter CUT, Adam Davey AU

Other

Aija Mee AU: Best Student Poster – National Conference of the Australian Organic Geochemists and International Humic Substances Society, Feb 2004

Claire Robertson, CUT – Best Mineral/Environmental Paper – AESG Student Night (WA Branch), Oct 2003

Photograph: Ian Robertson

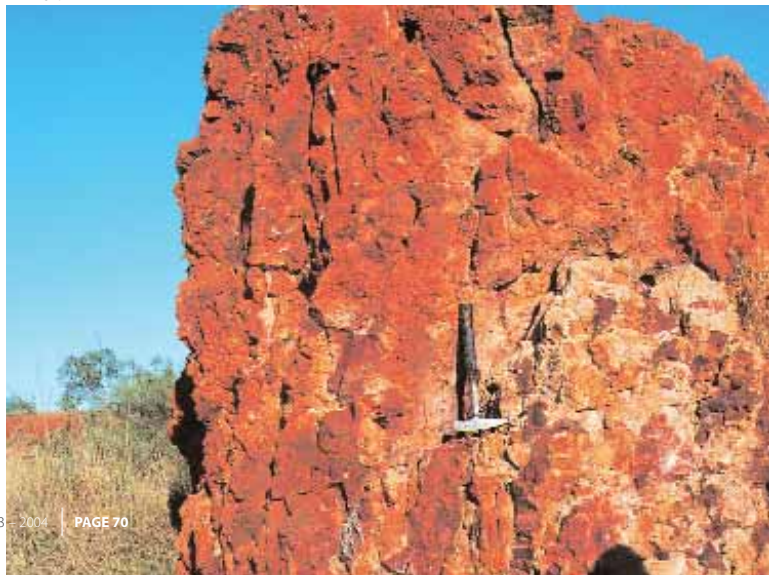


Table 12.1 – Awards and Appointments

Awardee	Awardee's organisation	What	For	By	When
Ray Smith	CSIRO Exploration and Mining	Centenary Medal	Services to Australian society in Geology	Governor General and Prime Minister	July 2003
Ian Robertson and Mel Lintern	CSIRO Exploration and Mining	Workplace safety innovative solutions award	Field Safety initiatives	Safety, Rehabilitation and Compensation Commission	July 2003
Gerry Govett	CRC LEME Visitor	AEG Honorary Membership	Distinguished contribution to exploration geochemistry	Association of Exploration Geochemists	Aug 2003
Jim Cox	CSIRO Land and Water	Fellowship	Research collaboration	Organisation for Economic Cooperation & Development, UK	Aug-Sep 2003
Tony Eggleton	Emeritus Fellow, ANU	Honorary Fellow of LEME	Outstanding contributions to the development and promotion of regolith science	CRC LEME	Nov 2003
Ross Fardon	Past Chair CRC LEME Board	Honorary Fellow of LEME	Outstanding contributions to the developmentand promotion of regolith science	CRC LEME	Nov 2003
Graham Taylor	Senior Lecturer, University of Canberra	Honorary Fellow of LEME	Outstanding contributions to the development and promotion of regolith science	CRC LEME	Nov 2003
Graham Heinson	AU	Appointment	Associate Dean of the Faculty of Sciences	AU	Nov 03 to Nov 04
Ken Lawrie and Program 4 team at GA	GA	Award	Achieving Results in Science	GA Chief Executive	Dec 2003
Andrew Herczeg	CSIRO Land and Water	Associate Editor	Science writing-editing	CSIRO Hydrology Journal	Jan 2004
Ray Smith	CSIRO Exploration and Mining	Emeritus Research Fellow	Outstanding contribution to CSIRO, science and the Australian industry	CSIRO Chief	Feb 2004
Keith Scott	CSIRO	Visiting Fellow	Collaborative Research	ANU. School of Earth and Marine Sciences	Mar 04 to Mar 06
Nick Direen	AU	Stillwell Medal	Best Paper, Australian Journal of Earth Sciences 2003	Geological Society of Australia	May 04
Graham Heinson	AU	Promotion	To Senior Lecturer	AU	Dec 03
Simon Abbott	CUT	Appointment	Associate PhD student	CRC for Plant based management of Dryland Salinity	Jan 04 for 3 years
Kirsty Becket	CUT	Appointment	Associate PhD student	CRC for Plant based management of Dryland Salinity	Jan 04 for 3 years
Baohong Hou	PIRSA	Appointment	Adjunct Professor	University of Jilin, China	June 2004

Table 12.3 – Grants to CRC LEME Personnel

Recipient and core party	Title of Project for which grant awarded	Source of **Grant	Period of Grant	
Katie Dowell, ANU	17th Australian Geological Convention – Full Conference Funding.	Geological Survey Australia	8-13 Feb 04	$300
Glen Bann, ANU	17th Australian Geological Convention – Fees	Geological Survey Australia	8-13 Feb 2004	$250
Glen Bann, ANU	17th Australian Geological Convention – Attendance and paper	Learned Australasian Volcanology Assoc	8-13 Feb 2004	$200
Andrew Herczeg	ARC funding	Salinity Processes	Jan 2004 for 3 years	$268,000
Sue Welch	Investigating the role of microbial processes in generating acid sulphate soils	ANU Faculties Research Grant Scheme	Jan to Dec 2004	$10,000
Michael Durkay	Effects of (artificial)drainage on the hydrology and physio-chemistry of soils in the Upper South East of SA – Research support and equipment	Dept of Water, Land and Biodiversity Conservation SA (DWLBC)	July 03 to June 04	$14,000 and $50,000
Sean Mahony	Evaluation and development of use of multitemporal imagery for water condition monitoring, environmental and wetland management in the SE of SA	DWLBC	July 03 to June 04	$14,000

13. Performance Measures

Performance Measures/Indicators (PIs), along with milestones and outputs, provide a numerical measure of performance against the stated objectives of CRC LEME. 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 indicators 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 CRC 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	01-02	02-03	03-04
Number of external research collaborators	47	86	75
Number of sponsors and the annual value of sponsorship	13 $756,540	13 $616,000	14 $1,183,000
Number of overseas researchers visiting LEME sites	4	10	10
Number of overseas visits by LEME staff	19	7	8
Number and value of overseas research projects	1 $27,489	0	0

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.

Strategy for Utilisation and Commercialisation 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.

Quality and Relevance of the Research Program

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

Strategy for Utilisation and Commercialisation of Research Outputs

Performance Indicator	2001-2002	2002-2003	2003-2004
Number of shortcourses and workshop	7	11	6
Number of media reports and releases	8	9	21
Number of items sold (open file reports, manuals, course notes)	120	75	101
Number of articles in industry magazines	3	1	9
Number of reports to sponsors and companies	15	9	13
Number of collaborative projects with industry users and user organisations	49	48	56
Annual external research income	$782,000	$616,000	$1,183,000
Number of scientific outputs per FTE staff	2.44	3.35	4.22
Increase in external revenues from contract research	NA	-21%	+92%

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 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 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
Number of postgraduate students working on LEME research projects	38	51	50
Number of postgraduate awards each year	1	7	13
Number of BSc Honours graduates completing LEME projects	16	11	21
Number of BSc Honours students commenced/continuing LEME projects	37	20	10
Number of external supervisors of research students	20	12	16
Number of student class-hours of instruction in Masters by Coursework degrees related to the regolith	80	80	80
Number of Honours graduates produced over the lifetime of LEME (incl graduands)	16	27	58
Number of PhD graduates produced over the lifetime of LEME (incl graduands)	1	3	8
Number of Masters graduates produced over the lifetime of LEME (incl graduands)	-	3	4

Photograph: Ian Robertson

Collaborative Arrangements

To ensure that 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.
- Support the interchange of personnel among different sites within the Centre.

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 2003-04.

Collaborative Arrangements

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

Resources and Budget

Performance Indicator	2001-2002	2002-2003	2003-2004
Total resources (cash and in-kind excluding CRC Grant)	$17.65M	$16.69M	$19.8M
FTE research staff (excluding students)	73.3	63.1	69.99
FTE technical and other support staff	11.1	6.35	6.95

14. Financial Information

As at 30 June 2004, all Core Participants met or exceeded in-kind contribution targets defined in the Commonwealth Agreement. The total cash income received for collaborative activities from industry and other users in Year 3 is $1.51M. These are significant achievements considering the general downturn in the mineral industry.

The leverage of actual contributed resources to Program funding from the Commonwealth is 6:1, at the end of Year 3.

Actual contributed resources:	
Total Cash from Industry and other users, and from Core Participants:	$6.08M
Total In-Kind resources from participants $13.72M, giving a total of:	$19.8M
CRC Program funds: All figures for Year 3 only	$3.3M

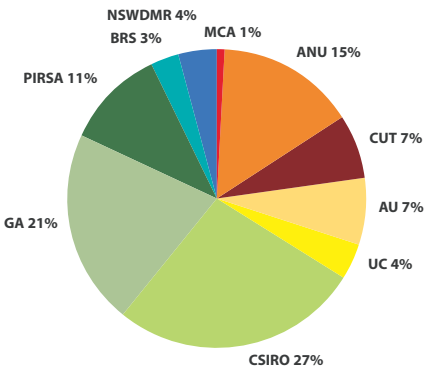
Financial Reports for 2003/2004

The following statements and accounting policy notes represent the known financial status as at 30 June, 2004.

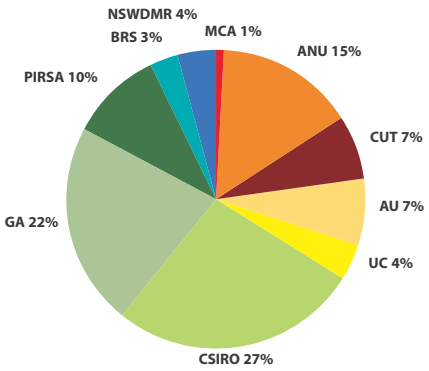
Core Participant equity positions are summarised as follows:

Though CRC LEME did not meet the external income target in its third year of operation, its positive achievements should be acknowledged considering the general downturn in the mineral industry.

Core Participant Actual Cumulative Equity as at 30 June 2004 (Years 1-3)



Core Participant Equity as per Commonwealth Agreement as at 30 June 2004 (Years 1-3)



Total External Income

	Year 1 $'000	Year 2 $'000	Year 3 $'000	Cumulative $'000
Budget	765	1,080	1,658	3,503
Actual	892	811	1,509	3,212
Variance	127	-269	-149	-291

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 Budget.

Expenditure

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

Table 1 – In-Kind Contributions from Partners (Dollars in '000s)

	Expenditure				Cumulative Total to Date						Grand Seven-Year Total			
	YEAR 1 2001/02 Actual	YEAR 2 2002/03 Actual	YEAR 3 2003/04 Actual	YEAR 3 2003/04 Agreement	Actual	Agreement	YEAR 4 2004/05 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
ANU														
SALARIES	474	431	765	752	1,670	1,539	767	809	834	859	4,939	4,808	131	3,127
CAPITAL	-	-	-	-	-	-	-	-	-		-	-	-	-
OTHER	1,126	1,169	2,336	2,308	4,631	4,401	2,383	2,512	1,723	1,687	12,936	12,706	230	8,289
TOTAL	1,600	1,600	3,101	3,060	6,301	5,940	3,150	3,321	2,557	2,545	17,874	17,513	361	11,416
UC														
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														
SALARIES	974	839	814	814	2,627	2,345	879	905	932	960	6,303	6,021	282	5,627
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	1,973	1,928	2,457	2,454	6,358	6,608	2,816	2,536	1,828	1,882	15,420	15,670	(250)	14,812
TOTAL	2,947	2,767	3,271	3,268	8,985	8,953	3,695	3,441	2,760	2,842	21,723	21,691	32	20,439
CURTIN														
SALARIES	329	423	433	433	1,185	1,091	469	483	497	512	3,146	3,052	95	2,694
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	469	646	629	628	1,744	1,560	773	788	670	689	4,664	4,480	184	4,126
TOTAL	798	1,069	1,062	1,061	2,929	2,651	1,242	1,271	1,167	1,201	7,810	7,532	279	6,820
ADELAIDE														
SALARIES	314	403	400	400	1,117	1,066	349	427	522	538	2,953	2,902	51	2,868
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	
OTHER	373	626	753	747	1,752	1,738	712	813	691	710	4,678	4,664	14	4,565
TOTAL	687	1,029	1,153	1,147	2,869	2,804	1,061	1,240	1,213	1,248	7,631	7,566	65	7,433
PIRSA														
SALARIES	506	523	551	551	1,580	1,348	567	584	601	619	3,951	3,719	232	3,161
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	1,984	521	584	584	3,089	2,878	600	617	634	652	5,592	5,381	211	4,651
TOTAL	2,490	1,044	1,135	1,135	4,669	4,226	1,167	1,201	1,235	1,271	9,543	9,100	443	7,812
BRS														
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
NSW DPI														
SALARIES	224	235	223	223	682	671	312	364	373	382	2,113	2,102	11	1,783
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	29	30	63	63	122	120	75	81	83	84	445	443	2	228
TOTAL	253	265	286	286	804	791	387	445	456	466	2,558	2,545	13	2,011
MCA														
SALARIES	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	-	-	35	35	35	35	35	35	35	35	175	175	-	-
TOTAL	-	-	35	35	35	35	35	35	35	35	175	175	-	-
CSIRO														
SALARIES	1,333	1,398	1,169	1,168	3,900	3,509	1,263	1,312	1,237	1,275	8,987	8,596	391	7,670
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	2,559	2,457	2,511	2,490	7,527	7,682	2,603	2,710	1,943	1,999	16,782	16,937	(155)	21,026
TOTAL	3,892	3,855	3,680	3,658	11,427	11,191	3,866	4,022	3,180	3,274	25,769	25,533	236	28,696
SUPPORTING CONTRIBUTIONS														
SALARIES	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL IN-KIND CONTRIBUTIONS														
SALARIES	4,661	4,349	4,355	4,341	13,365	12,119	4,606	4,884	4,996	5,145	32,996	31,750	1,246	30,782
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	9,504	7,718	9,368	9,309	26,590	26,286	9,997	10,092	7,607	7,738	62,024	61,719	305	63,162
GRAND TOTAL (IN-KIND)	**14,165**	**12,067**	**13,723**	**13,650**	**39,955**	**38,405**	**14,603**	**14,976**	**12,603**	**12,882**	**95,019**	**93,469**	**1,551**	**93,944**

Table 2 – Cash Income and Expenditure (Dollars in '000s)

	Actual				Cumulative Total to Date						Grand Total			
	YEAR 1 2001/02 Actual	YEAR 2 2002/03 Actual	YEAR 3 2003/04 Actual	YEAR 3 2003/04 Agreement	Actual	Agreement	YEAR 4 2004/05 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
PARTICIPANTS														
ANU	100	150	200	200	450	450	200	200	100	100	1,050	1,050	-	700
CURTIN	100	100	100	100	300	300	100	100	100	100	700	700	-	700
ADELAIDE	100	100	100	100	300	300	100	100	100	100	700	700	-	700
UC	100	50	-	-	150	150	-	-	-	-	150	150	-	700
CSIRO	150	100	150	150	400	400	200	200	100	100	1,000	1,000	-	750
GEOSCIENCE	100	150	100	100	350	350	100	100	100	100	750	750	-	700
PIRSA	-	-	-	-	-	-	100	100	100	100	400	400	-	-
BRS	810	-	-	-	810	810	-	-	-	-	810	810	-	3,794
NSW DPI	250	250	250	250	750	750	100	100	50	-	1,000	1,000	-	1,400
MCA	100	100	105	100	305	300	80	80	40	-	505	500	5	300
TOTAL CASH FROM PARTICIPANTS	1,810	1,000	1,005	1,000	3,815	3,810	980	980	690	600	7,065	7,060	5	9,744
Supporting Participants	-	300	-	150	300	300	141	10	-	-	451	451	-	450
OTHER CASH														
Non-partic-ipants	-	-	-	600	-	1,500	400	-	-	-	400	1,900	(1,500)	1,900
External Grants	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contract Research	696	599	1,286	600	2,581	1,300	800	900	1,000	1,100	6,381	5,100	1,281	5,100
Commercial-isation	-	-	-	355	-	505	520	640	640	640	2,440	2,945	(505)	2,945
Education	86	17	24	88	127	153	120	120	120	120	607	633	(26)	633
Interest Income	110	195	199	15	504	45	29	15	15	15	578	119	459	105
TOTAL	892	811	1,509	1,658	3,212	3,503	1,869	1,675	1,775	1,875	10,406	10,697	(291)	10,683
CRC GRANT	2,754	3,300	3,300	3,300	9,354	9,354	3,300	3,300	2,700	1,546	20,200	20,200	-	20,200
TOTAL CRC CASH CONTRIB-UTION (T2)	5,456	5,411	5,814	6,108	16,681	16,967	6,290	5,965	5,165	4,021	38,122	38,408	(286)	41,077
Cash carried over from previous year (Note a)	777	2,504	3,566	3,566	-	-	3,081	2,515	1,754	1,978	-	-	-	-
Less Unspent Balance	2,504	3,566	3,492	3,081	-	2,325	2,515	1,754	1,978	756	-	-	-	-
TOTAL CASH EXPENDITURE	3,729	4,349	5,888	6,593	13,966	14,642	6,856	6,726	4,941	5,243	37,732	38,408	(676)	39,084
ALLOCATION OF CASH EXPENDITURE BETWEEN HEADS OF EXPENDITURE														
SALARIES	1,916	1,898	2,541	3,281	6,355	7,363	3,237	3,040	960	932	14,524	15,532	(1,008)	16,540
CAPITAL	-	245	-	-	245	245	206	-	-	-	451	451	-	451
OTHER	1,813	2,206	3,347	3,312	7,366	7,034	3,413	3,686	3,981	4,311	22,757	22,425	332	22,093

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 the CRC (Dollars in '000s)

	Actual				Cumulative Total						Grand Total			
	YEAR 1 2001/02 Actual	YEAR 2 2002/03 Actual	YEAR 3 2003/04 Actual	YEAR 3 2003/04 Agreement	Actual	Agreement	YEAR 4 2004/05 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
GRAND TOTAL (IN-KIND) From Table 1 (T1)	14,165	12,067	13,723	13,650	39,955	38,405	14,603	14,976	12,603	12,882	95,019	93,469	1,551	93,944
GRAND TOTAL (CASH EXPENDITURE) FROM TABLE 2 (T3)	3,729	4,349	5,888	6,593	13,966	14,642	6,856	6,726	4,941	5,243	37,732	38,408	(676)	39,084
TOTAL RESOURCES APPLIED TO ACTIVITIES OF CENTRE (T1 &T3)	17,894	16,416	19,611	20,243	53,921	53,047	21,459	21,702	17,544	18,125	132,751	131,877	875	133,028
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	7,622	19,720	19,482	7,843	7,924	5,956	6,077	47,520	47,282	238	47,322
TOTAL CAPITAL (CASH AND IN-KIND)	-	245	-	-	245	245	206	-	-	-	451	451	-	451
TOTAL OTHER (CASH AND IN-KIND)	11,317	9,924	12,715	12,621	33,956	33,320	13,410	13,778	11,588	12,049	84,781	84,144	637	85,255

Table 4 – Allocation of Resources between Categories and Activities

Program	Resource Usage			
	$ Cash ('000s)	$ In-kind ('000s)	Contributed (In-kind) Staff (FTEs)	CRC Funded Research Staff (FTEs)
Research	3,557	12,512	44.04	22.80
Education	1,320	742	1.40	1.75
External Communications	-	-	-	-
Commercialisation/Technology Transfer	-	-	-	-
Administration	1,010	470	-	-
Total	5,887	13,724	45.44	24.55

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 2003, and for which goods had not been receipted at 30 June 2004.

OTHER NOTES

Costing of contributions

Costing of salaries and on-costs contributed by the Core Participants is as reported to the Centre by each Core Participants. 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
ANU	0.2889
CUT	0.2806
AU	0.2942
UC	0.3426
CSIRO (CSS Superannuation)	0.3185
CSIRO (PSS Superannuation)	0.2205
GA	0.2050
PIRSA	0.2590
BRS	0.2632
NSWDMR	0.3300
MCA	N/A

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

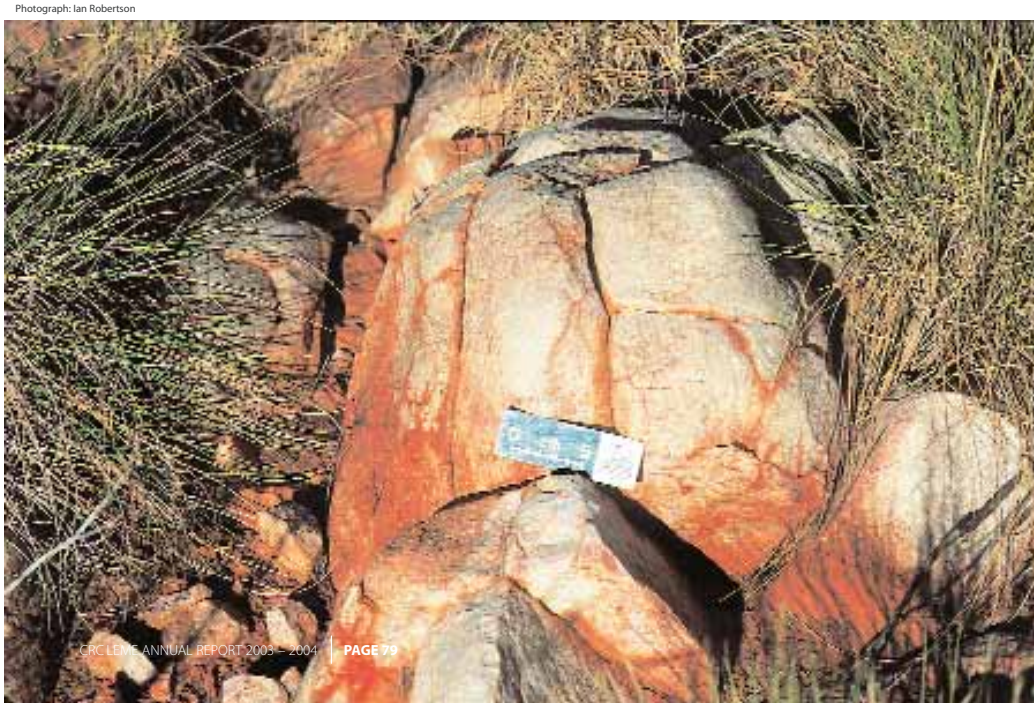
Core Participant	Infrastructure overheads as a multiple of base salary	
	For in-kind staff	For CRC funded staff
ANU	2.3656	2.3656
CUT	1.2800	1.2800
AU	1.5400	1.5400
UC	1.5000	1.5000
CSIRO	1.3400	1.3400
GA	2.1500	2.1500
PIRSA	1.2550	1.2550
BRS	0.9095	0.9095
NSWDMR	0.1700	0.1700
MCA	N/A	N/A

Details of capital expenditure

There were no major items of capital expenditure (individual items exceeding $20K) incurred in the financial year ended 30 June 2004.

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

Photograph: Ian Robertson



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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 2004, section 14), the sources of funding and the application of that funding for the year ended 30 June 2004.

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 contributions and 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 2004. 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.

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.

When this audit report is included in a document containing information in addition to the financial information, our procedures include reading the other information to determine whether it contains any material inconsistencies with the financial information.

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.

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PricewaterhouseCoopers

S.T.Maher

S T Maher
Partner

Perth
8 September 2004

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

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

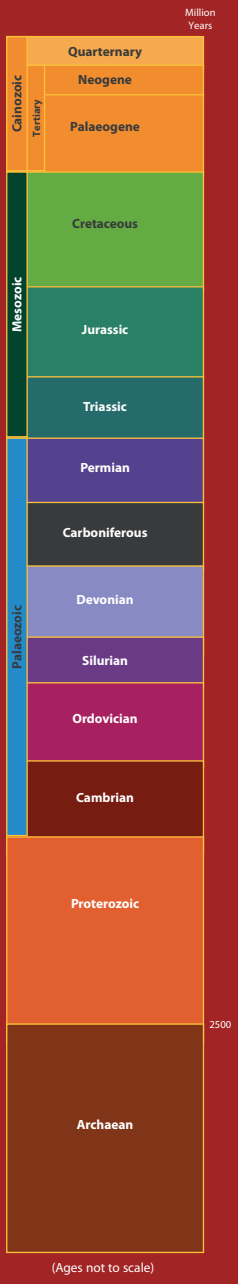
Traverse: a line surveyed across a plot of ground

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
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 Image
CD: Compact Disc
CEM: CSIRO Exploration and Mining
CLW: CSIRO Land and Water
CMA: Catchment Management Authority
COGEO-ENVIRONMENT: International Union of Geological Sciences Commission on Geological Sciences for Environmental Planning
CRC: Cooperative Research Centre
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)
EKS: Electrokinetic Seismic
EM: Electromagnetic
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
IP: Induced Polarisation
IP: Intellectual Property
IPRS: International Postgraduate Research Scholarship
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)
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
PBMDS CRC: Plant-based Management of Dryland Salinity CRC
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: Transmission Electron Microscopy/Microscope
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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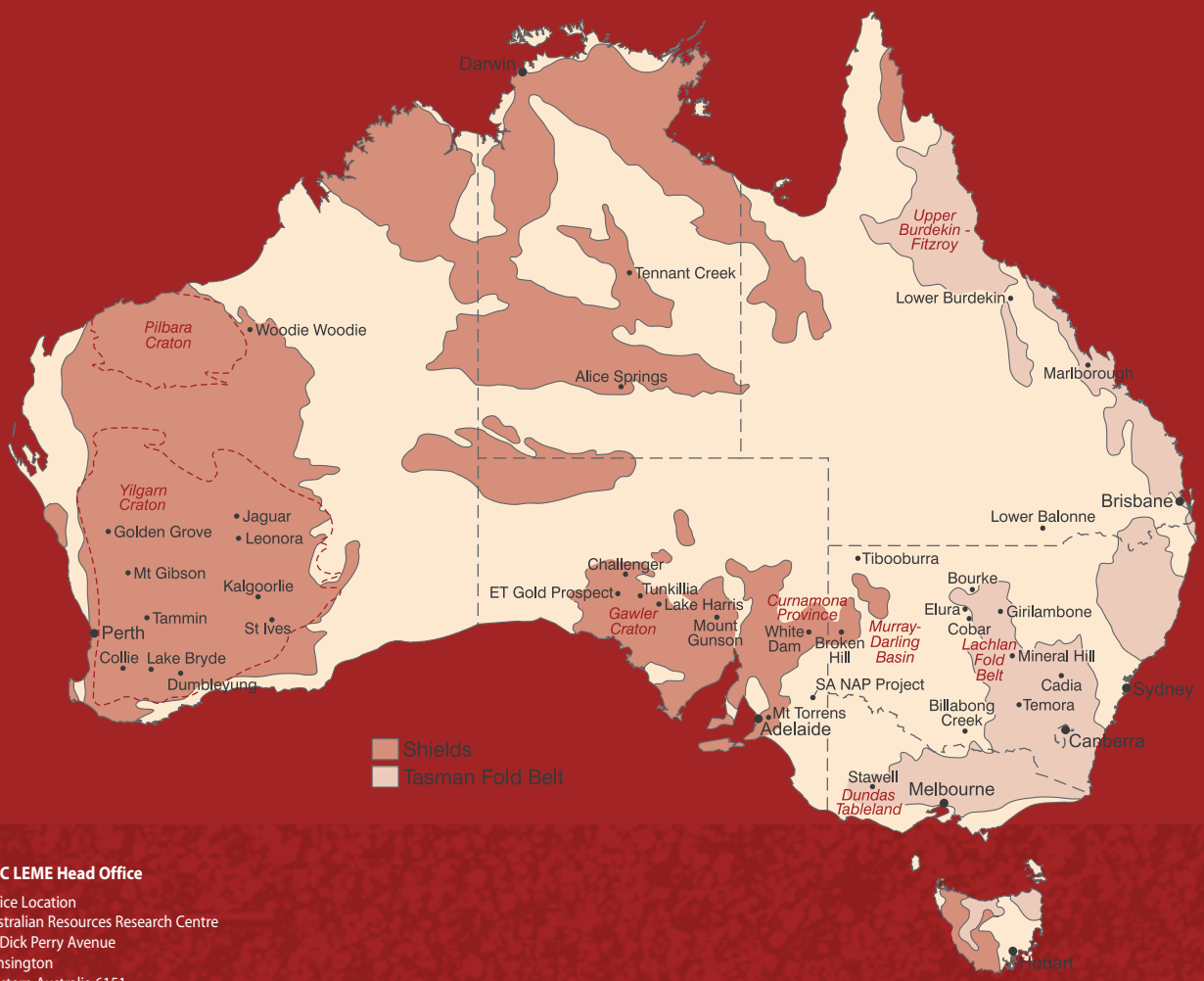
Research Locations



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