CRCLEME

Cooperative Research Centre for
Landscape Environments
and Mineral Exploration

ANNUAL REPORT 2002–2003

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

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.

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Cover photography: Ian Robertson

Contents

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Highlights

- Salinity mitigation programs moved into top gear as eight new projects under the NAP SWQ program were commenced.
- Order-of-magnitude cost savings are possible for effective airborne electromagnetic (AEM) salinity mapping surveys.
- The scholarship program creates a vibrant Graduate School, with 51 postgraduate student projects underway, and 27 Honours projects completed to date.
- New analytical techniques using Sensitive High Resolution Ion Microprobe (SHRIMP) and Thermal Ionisation Mass Spectrometry (TIMS) can date regolith materials such as opaline silica, silcrete and iron oxides.
- Specific regolith mineral phases are potential sampling media for concealed mineralisation.
- Electromagnetic surveying finds covered manganese deposits at Woodie Woodie, Western Australia.
- Acid sulfate soils and saline discharges are potential sampling media for concealed mineralisation.
- Regolith and landform information in upland areas improve our understanding of present and future salt outbreaks.
- Publication of a LEME monograph *Calcrete: Characteristics, Distribution and Use in Mineral Exploration* will aid mineral explorers.
- Website publication of 23 site studies on regolith expression of Australian ore deposits, and nine studies of landscape evolution.
- The *Eastern Australian Regolith Conference*, sponsored by CRC LEME and the Minerals Council of Australia attracted 75 participants to Canberra.
- CRC LEME presented the *Minerals Exploration Seminar* in Perth, attracting 95 delegates.
- No lost time injuries or dangerous incidents were recorded during the reporting period.

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

Research efforts within CRC LEME are directed along nine strategic research themes:

- Understanding regolith processes
- Models of regolith-landscape evolution
- Acid sulfate soils: regolith processes and implications
- Regional mineral exploration studies
- Making geochemistry more effective
- Geophysical mapping and modelling in regolith terrains
- Salinity systems in regolith and groundwater
- Regolith geoscience and urban Australia
- Environmental geochemistry and the regolith

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

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

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

Executive Summary

Dr Ross Fardon, Chairman

Photograph by Ian Robertson

Chairman's Report

CRC LEME is under full sail again. We have recovered from the loss of important people, participating organisations and funding. That was then. We have the researchers and the long-term leaders, we have the important goals, objectives, and the strategy. But we have to aim higher.

We in CRC LEME have two reasons for being:

- to help mineral explorers find major new mines through regolith cover across major provinces of Australia, and
- to help solve the salinisation problems plaguing about a seventh of Australia by mapping and explaining the distribution and controls of salt in the regolith.

The mineral industry has lost comittment to exploration during a period of mergers and acquisitions, and corporate cost cutting. This is all well and good until the resources are no longer there. So we scientists have to lead the way back to discovery. But this requires close and rigorous cooperation between scientists and users. The users are the Government Geological Surveys and the industry. We call on users to be more creative in dealing with research, and researchers to be more dedicated to the big strategic breaks that are required. Veterans in exploration know that the regolith has been our toughest technical battle in the last two decades. Who believes we can make strategic changes again? We have a long way to go with the mineralogical, geochemical and geophysical basics of exploration through the regolith. Rigour in research is not just weeding out the useless, it is a wholesale assent to the creative. The best is yet to be.

The tough times require raising the sights. CRC LEME, with its users, must dare to be strategic again on the large scale, not just solving local problems or developing just the current ideas among the researchers. What will we do that will be remembered? We need to more closely mesh the Minerals Advisory Council with the activities of our researchers, rather than meet for just one day a year.

Cooperative Research Centres are resilient organisations. They can be nothing else, with the cooperation of long-term experts, keen new students and young researchers across the land. But the real driver is the importance of what we must do for Australia.

As to salinity and landscape environments - salinity is teaching Australians that the whole living, evolving regolith and its long history are vital. CRC LEME needs to be at the forefront in public awareness, not just in background research, as without our holistic approach, half-baked measures are all about us. From the deserts to rural engineering, to the suburbs and our coastal zones, the landscape and the regolith beneath it are not just "Australia", but the foundation for a sustainable Australia. The conflicts in Queensland between our approaches, unfinished as they were then, and other maps of salinity hazard, were a good thing, pointing to the many half-representations possible before we know the total system.

This is my last report as foundation Chairman of CRC LEME, and it is time for new people. Not just the new CEO Dennis Gee, but also the new Chairman whom I warmly welcome, Mr George Savell. They are the leaders we need, along with the Board and the Minerals and Land Use Advisory Councils. Working with such a group leads to increasing respect for the researchers and teachers. The Board and Executive exist on behalf of them and what they will do for Australia.

Thankyou to all the good people and to the great organisations in CRC LEME 1 and 2. I have had eight years of privilege since supporting Ray Smith's planning for the CRC.

To all of you in CRC LEME 2, working together with the users of research - achieve things that will be remembered.

Chief Executive Officer Report

Dr R Dennis Gee, Chief Executive Officer

The year 2002-2003 saw important initiatives in new salinity projects, a strategic refocus on minerals-related research, new applications of regolith geoscience to environmental benchmarking, and advances in the education and training program. This has happened during a period of dwindling mineral exploration activity, major changes in the management and corporate structure of CRC LEME, and increasing management complexities in the funding of natural resources and salinity research. All this has unfolded against a backdrop of increasing expectations of all stakeholders in the outcomes of LEME research, and a sharpened focus by our core participants on the question of "equity".

The year 2002-2003 saw important initiatives in new salinity projects, a strategic refocus on minerals-related research, new applications of regolith geoscience to environmental benchmarking, and advances in the education and training program.

A simple breakdown of expenditures in 2002-2003 shows $1.9M in salaries, $0.54M on the scholarship program, and $1.91M on research operating costs. External income totalled $0.81M. Following our project review and restructuring we are strategically budgeting for greatly accelerated research expenditures in 2003-2004.

We are still grappling with the aftermath of the withdrawal of Bureau of Rural Science from CRC LEME as reported last year. This has created funding shortfalls, management challenges, and imbalances in the structure of the Centre as prescribed in the Commonwealth Agreement. A major challenge for the Executive was management of the withdrawal of University of Canberra - one of our founding core participants - from the joint venture, as of the end of calendar 2002. This problem was successfully resolved by the assumption of their rights and obligations by another core participant - the Australian National University. This move has had the happy effect of not only maintaining but also enhancing the pool of expertise available for regolith research – especially in the important areas of regolith processes and the environment.

A major achievement was the adoption of the LEME Strategic Plan by the Board, after a long period of review, consultation and reiteration by the Executive. We now have a strategic plan which is a guiding document for all our planning and operations. It sets out our research priorities and how the two main streams of mineral exploration and natural resource science are to be coordinated and integrated. It remains a living and evolving document.

In both the minerals and salinity fields, industry and agency contacts have been actively maintained and further developed. However there is clearly a significant diminution of research funding in the mineral exploration stream, as the mining industry in Australia continues to undergo its so-called "rationalisation and consolidation". This seminal event in Australian economic history has been developing for the last six years, and will continue. The successes of regolith geoscience that derive from minerals-related programs are now spinning off into salinity and land use matters. This has created two quite different groups of stakeholders, each with their own demands. The challenge for the Executive will be to forge the right level of cohesion and balance between these two streams. Cohesion and balance will be retained by remembering the basic mission of CRC LEME – to apply regolith geoscience to the challenges that face Australia in the fields of mineral exploration and natural resource management. I am confident that the vibrancy and relevance of the new discipline of regolith geoscience will bind us all together, and deliver the breakthroughs we seek.

In this reporting year, our inaugural portfolio of salinity research projects took shape. These projects initially took the form of specific site studies under contracts of work funded by, and reporting to, State and catchment agencies under the National Action Plan for Salinity and Water Quality (NAP). This style of project is important because it demonstrates the practicality of regolith geoscience directly to an important group of stakeholders. However, our strategic research into the applications of regolith geoscience in natural resource management, especially in land salinisation, will increase and diversify. For example, in the latter part of the year we developed collaborative projects for groundwater flow models as applied to land salinisation, and evaluation of enhanced airborne electromagnetic techniques in salinity hazard mapping.

However there will remain a strong focus on mineral exploration in the firm belief that there are many more discoveries to be made beneath our extensive regions of transported regolith. Accordingly, the Board directed the Executive to review the portfolio of mineral-related projects, with a view to re-align projects with the Strategic Plan, and to re-examine any managerial problems in coordinating research in an eight-participant unincorporated joint venture. We recognised that our minerals-related projects fall into four categories, reporting and communication projects, generic process projects, regional focus projects, and technology development projects. Although we have a large number of projects, we have achieved the objective of assembling integrated multi-disciplinary and multi-party mega-projects across all the nodes and core participants.

In the mineral exploration sector, we recognise that exploration geochemistry has entered a new phase where it must be integrated with all other exploration tools. The supreme challenge is to make geochemistry work through transported cover. We are some distance from achieving the breakthroughs required by our stakeholders, but we recognise that advances will require knowledge in three areas: three-dimensional architecture of the regolith; understanding chemical, hydrological, mineralogical, physical and biological processes in the regolith; and dynamics of regolith processes determined by dating the age of events.

Our education and training program continues to be a showcase for the Centre. The program has three objectives: to contribute to the research themes of CRC LEME; to deliver specialist training in regolith geoscience to scientist and practicing professionals; and to produce quality graduates trained in regolith geoscience for future national requirements of the country. We are well on our way to achieving our targets of 60 PhD graduates and 60 Honours graduates in the life of CRC LEME. In the latter half of the year we had 20 Honours scholars and 44 PhD scholars distributed across our three core universities - Adelaide, Curtin and ANU. Their research projects are closely integrated with all the core research priorities, and our scholars are clearly making a major contribution to the objectives of CRC LEME.

Another important advance is the development of the LEME website – http://crcleme.org.au. This now contains a wealth of technical information on our scientific strategies, programs and outputs. An essential part of our communication policy is to progressively release information as it becomes available, whilst still preserving our traditional publication outlets.

We look forward with energy and enthusiasm to the ensuing years of CRC LEME, as we address fertile areas for the application of regolith geoscience to the major challenges in mineral exploration and salinity mitigation.

My particular thanks to the Perth management team for their support over the last year.

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 under which the Centre was established, and undertake its research and management. Under that agreement, CSIRO Exploration and Mining was appointed as the Centre Agent and takes responsibility for the bulk of administrative responsibilities. 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 Mineral Resources (NSW DMR)
- Primary Industries and Resources, South Australia (PIRSA)
- The University of Adelaide (UofA)

The Bureau of Rural Sciences was originally a core participant in the Centre, but withdrew from CRC LEME with goodwill on both sides in August 2002, as a result of changes in Commonwealth and State funding arrangements for salinity activities. It is still heavily involved with Centre activities as a collaborating partner. The University of Canberra withdrew as a core participant in January 2003, as a result of internal funding constraints. Its obligations and entitlements have been assumed by the Australian National University, significantly increasing its commitment to the Centre.

Board of Management

The Governing Board is responsible for setting LEME policy and strategy. All core participants are represented on the Governing Board, as are a number of other independent stakeholders. The Board is chaired by Dr Ross Fardon, who is independent of the Core Participants.

At the end of the reporting period the Governing Board membership was:

- Dr Neville Alley, Primary Industries and Resources, South Australia
- Prof Tim Brown, Australian National University
- Ms Janet Dibb-Smith, University of Adelaide
- Dr Ross Fardon, Chair (independent)
- Dr David Garnett, Becquerel Laboratories (independent)
- Dr Dennis Gee, CRC LEME (Chief Executive Officer)
- Mr Kevin Goss, Murray-Darling Basin Commission
- Mr Gary Kong, Board Secretary, CRC LEME (Business Manager)
- Mr Adrian Larking, Association of Mining and Exploration Companies
- Prof Graham Lodwick, Curtin University of Technology
- Prof Neil Phillips, CSIRO Exploration and Mining
- Dr Chris Pigram, Geoscience Australia
- Dr Kevin Tuckwell, Minerals Tertiary Education Council
- Dr Ted Tyne, New South Wales Department of Mineral Resources

A number of changes to the membership of the Governing Board occurred during the reporting period. Prof Mohamed Khadra from University of Canberra, and Dr Peter O'Brien from Bureau of Rural Sciences, stepped down from the Board when their respective organisations withdrew as core participants. Mr John Cramsie, representing the New South Wales Department of Mineral Resources, retired during the year, and was replaced by Dr Ted Tyne. Dr Lindsay Gilligan filled the position in the interim period between John Cramsie's retirement and Ted Tyne's appointment. Prof Paul Rossiter was replaced by Prof Graham Lodwick as the Curtin University of Technology Board Member. Dr Dennis Gee took up the position of Chief Executive Officer in November 2002, relieving Paul Wilkes, who had been acting in that role after Dr Ray Smith, the founding Chief Executive Officer, stepped down.

The Board held special meetings in Adelaide on 2 August, and 6 November by teleconferencing, and plenary meetings on 29 August in Perth, 28 November in Canberra, and 14 March 2003 in Adelaide. The next meeting is scheduled for 5 September 2003 in Perth.

The Safety Sub-Committee has continued its operation through the reporting period, and now comprises Dr Chris Pigram (Chair), Adrian Larking and Dennis Gee. The LEME Field Safety Procedures have been approved by the Board and are currently on the LEME website.

The Audit Sub-Committee comprises Dr Ross Fardon (Chair), Dennis Gee, David Garnett, Gary Kong and Chris Pigram. The committee appointed the auditor for the Centre, and met just prior to the Annual General Meeting in November 2002 to discuss the audit report. They subsequently recommended to the Board that it be accepted.

CRC LEME Board Members, *left to right standing:* Kevin Goss, Chris Pigram, Ted Tyne, Tim Brown, David Garnett, Adrian Larking, Paul Wilkes (Observer), Graham Lodwick, Gary Kong, Kevin Tuckwell. *Seated:* Ross Fardon, Janet Dibb-Smith, Dennis Gee, George Savell (Chair Designate), Neville Alley, Neil Phillips.

Advisory Councils

Two Advisory Councils act as a mechanism for external stakeholders to provide input and strategic guidance to the research programs of CRC LEME.

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 18 June 2003, and then met the following day.

Current members are:

- Mr Paul Agnew, Rio Tinto Exploration Pty Ltd
- Dr Nigel Brand, Anglo American Exploration (Australia) Pty Ltd
- Dr David Garnett, Becquerel Laboratories (Chair)
- Prof Bob Gilkes, University of Western Australia
- Prof Gerry Govett, Consultant (CRC Program Visitor)
- Dr Jon Hronsky, WMC Exploration Division
- Dr Richard Mazzucchelli, Searchtech Pty Ltd
- Mr Nick Sheard, MIM Exploration Pty Ltd
- Dr Bryan Smith, Bryan Smith Geosciences
- Mr Carl Swensson, Consultant (Deputy Chair)
- Dr Paul Taufen, Consultant
- Mr Mike Webb, Anglo American Exploration (Australia) Pty Ltd
- Prof Peter Williams, University of Western Sydney

The **Land Use Advisory Council** provides comment and advice on land use and environmental management issues, from a variety of governmental and semi-governmental user groups, where understanding the regolith is fundamental to issues of natural resource management. It reports to the Board through its Chair, Kevin Goss. The inaugural meeting was held in Canberra on 24 September 2002.

Current members are:

- Dr Ian Acworth, University of New South Wales
- Ms Bobbie Brazil, Condamine Catchment Queensland
- Mr Shawn Butters, Department of Natural Resources and Environment Victoria
- Mr Wayne Cornish, South Australian Farmers Federation
- Prof Peter Cullen, formerly CRC for Freshwater Ecology (retired)
- Dr Richard George, Department of Agriculture Western Australia
- Mr Kevin Goss, Murray-Darling Basin Commission (Chair)
- Prof Gerry Govett, Consultant (CRC Program Visitor)
- Ms Lyn Mason, Australian Local Government Association - National Environment
- Mr Dennis Mutton, formerly PIRSA (retired)
- Mr Bill O'Kane, Goulburn-Broken Catchment Management Authority
- Mr Colin Simpson, Consultant
- Dr Mirko Stauffacher, Salinity Directorate, CSIRO Land and Water
- Mr Simon Veitch, Australian Government Department of Agriculture, Fisheries and Forestry
- Mr Paul Wilkes, CRC LEME Deputy CEO

The CRC LEME CEO Dennis Gee, and Board Chairman Ross Fardon, are *ex-officio* members of both advisory councils.

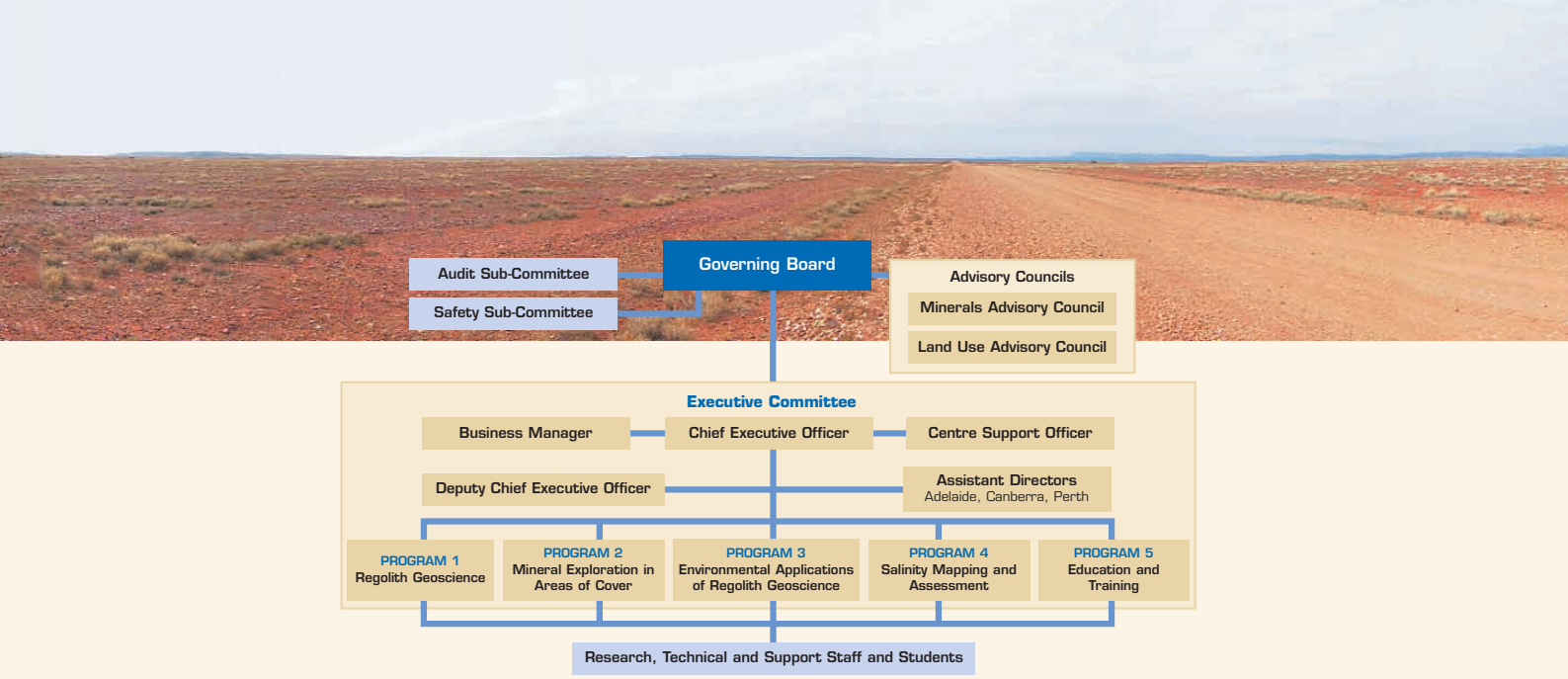
Executive Committee

At the end of the reporting period the membership of the CRC LEME Executive was:

- Dr Dennis Gee, Chair (CEO)
- Mr Paul Wilkes (Deputy CEO)
- Assoc Prof Lindsay Collins (Assistant Director, Perth)
- Mr John Keeling (Assistant Director, Adelaide)
- Assoc Prof Ken McQueen (Assistant Director, Canberra)
- Mr Gary Kong (Business Manager)
- Dr Ravi Anand (Program 1 Leader)
- Mr Keith Scott (Acting Program 2 Leader)
- Dr Colin Pain (Program 3 Leader)
- Dr Ken Lawrie (Program 4 Leader)
- Assoc Prof Pat James (Education and Training Program Leader)
- Dr Bear McPhail (*ad hoc* Member)
- Mrs Susan Game (Executive Secretary)

During the reporting period, a number of changes occurred within the Executive Committee. Dr Dennis Gee took up the position of Chief Executive Officer in November 2002, relieving Paul Wilkes, who had been acting in that role since the resignation of Dr Ray Smith, the founding Chief Executive Officer. Paul Wilkes was subsequently appointed Deputy CEO. Prof Norm Uren retired in July 2002, and was replaced by Prof Lindsay Collins as Assistant Director, Perth. Prof Nigel Radford resigned to return to the exploration industry in September 2002, and Keith Scott has been acting Program 2 Leader for the remainder of the period.

The Executive Committee met nine times during the year via teleconference, and in person as opportunities arose. Project reviews were conducted throughout February 2003 in each of the nodes (Perth, Adelaide and Canberra), involving in each case the CEO, Program Leaders, Executive members and senior researchers in the node. Program Leaders then met with Board members on 14 March for a Strategic Review session. An Education and Training review was held in Adelaide in May 2003, involving the CEO, Deputy CEO, Business Manager, Education and Training committee, and other senior educationalists in Adelaide. Two executive meetings were also held in June 2003 via teleconference to discuss the 2003-2004 budget and research portfolio.



Centre Culture

CRC 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, CRC LEME acts as a cohesive entity in the best interests of the joint venture, whilst still recognising the needs for equitable returns for individual participants in the joint venture.

CRC Visitor

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 CRC LEME and the CRC Committee. Prof Govett made visits to various LEME locations and attended a number of meetings during the year. These included:

- Centre headquarters in Perth in August 2002, for discussions with the Chairman, Executives and other staff.
- The Land Use Advisory Council in Canberra in September 2002.
- The CRC Association Annual Conference in Canberra in May 2003.
- Meetings with LEME participants in Adelaide and Perth in June 2003.
- Centre headquarters in Perth in June 2003, for discussions with Executives, and to attend the LEME Minerals Exploration Seminar, and the Minerals Advisory Council meeting.
- Board meetings in Perth, Canberra, and Adelaide throughout the year.

Prof Govett submitted a written report to the CRC Program Committee following his June visit, noting *inter alia* his perception of "renewed confidence and enthusiasm following a period of uncertainty after the withdrawal of the BRS and the resignation of the previous CEO".

Strategic Planning

The strategic plan for CRC LEME was reviewed and re-cast by the new CEO, Dennis Gee, in November 2002, in consultation with the Advisory Councils and the Board. During the last six months of the reporting period, the strategic plan has been subjected to continuous refinement, although it has been adopted by the Board as a working document. It is proving effective in focusing research on strategic priorities.

Research Programs

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

These programs are closely interrelated, and combine to contribute to our strategic research priorities:

- Improve our understanding of regolith processes and landscape evolution
- Make exploration geochemistry work through cover
- Develop techniques to interpret regolith architecture
- Use regolith knowledge to enhance prospectivity in geological regions
- Develop methods to map and predict salinity with outcomes linked to mitigation and remediation

Centre Communications

Centre policy is to consult and communicate with stakeholders at the technical level, and to promote the worth of CRC LEME through deliverables. The Centre is continuing to establish effective methods for communicating its results and achievements to the industry, research and the broader community. A Communications Officer has not been appointed, but a coalition of LEME staff has been promoting LEME activities via printed and electronic means, as well as through their involvement in conferences, workshops and seminars. A technical publications policy is in development, and initiatives are underway to further the use of electronic delivery of information and data to Centre stakeholders, under the concept of continuous disclosure.

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 that could create potentially dangerous situations. As a result, field safety is one of our principal concerns, 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 CRC 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 employers. CRC 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.

The Board Safety Sub-Committee recommended that draft policies and procedures for LEME staff working in the field be prepared. A comprehensive manual, *Policy and Procedures on Field Safety* was subsequently prepared by one of the Core Participants – Geoscience Australia – in consultation with the Occupational Health and Safety representatives from the other Core Participants. This manual draws together best-practice material from companies in the exploration industry, providing essential reference material for all 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 host agency. They have been endorsed by the Board, drawn to the attention of all staff by way of the LEME intranet, and have now been implemented.

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.
- All persons must follow the environmental 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.

Communication and reporting procedures for researchers in the field have also been improved, thanks to the efforts of Dr Ian Robertson, Mel Lintern and Steve Fraser from CSIRO Exploration and Mining. They were the recipients of the inaugural CSIRO Occupational Health and Safety Achievement Award, announced in December 2002. Their *Field Safety Initiative* has standardised field safety authorisation, communication and emergency procedures across CSIRO Exploration and Mining, and aspects of these procedures are now being adopted by several other CSIRO Divisions, CRC LEME and several of its Core Participants.

The initiative has been so successful, it is currently a finalist in the Safety Rehabilitation and Compensation Commission (SRCC) Safety Awards for 2003.

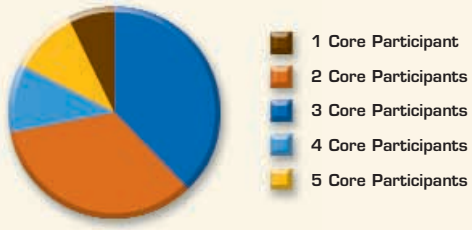
Presentation of inaugural CSIRO OHS Award to the Field Safety Initiative Team. *L to R:* Geoff Garrett, Steve Fraser, Mel Lintern. Ian Robertson, another award winner, was not present at the award

Cooperative Linkages

CRC LEME has established productive cooperative links both between the diverse Centre Participants, and with the users of its research in industry, the scientific research community, government authorities and community stakeholders.

Internal Linkages

Research themes pursued within CRC LEME have been more closely focused to align with the revised strategic plan. Multi-party and multi-disciplinary projects have been intentionally cultivated, to better ensure that regolith knowledge can be effectively directed towards the needs of our diverse stakeholders in both mineral exploration and natural resource management. The Centre makes optimum use of the wealth of expertise available through the core participants to assemble the most appropriate multi-disciplinary team for each project. Of the 29 projects funded by the Centre, 27 had participation from more than one core participant.

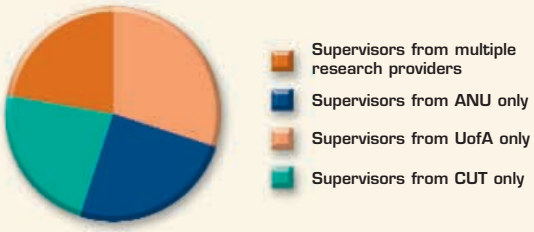


Cooperation in Centre-Funded Projects

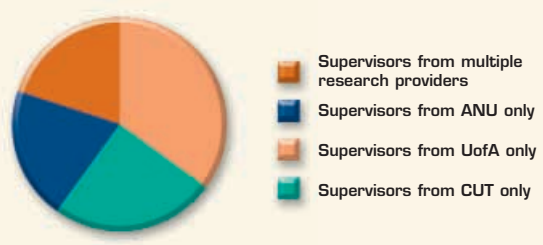
Educational Linkages

Effort is made to integrate the scope of Honours and postgraduate research projects into research programs. LEME students make significant contributions to our overall research effort. They benefit through opportunities for professional development and networking with a range of LEME staff, as well as exposure to industry and government organisations, and potential future employers.

Cooperation is fostered by maximising opportunities for co-supervision of students by staff from LEME Core Participants and industry participants, in addition to the required University staff supervision.



Cooperation in Honours Student Supervision



Cooperation in PhD Student Supervision

A number of student projects are run with the support of government and industry partners, including CALM, Department of Agriculture Western Australia, Barrick Gold Corporation, AngloGold Australia, Stawell Gold Mines and others. Details of these linkages are provided in the Research Utilisation and Applications, and Education and Training sections of this report.

The Education and Training program is committed to operate in concert with the Minerals Council of Australia for the provision of regolith training across the country, and has made submissions for ongoing participation and extensions to the program over the next two years.

Linkages with Industry and other End Users

Research projects and educational activities involving external organisations as clients or collaborators were undertaken during the reporting period. The list of companies on page 10 provided cash or in-kind funding for research and educational activities during the reporting period.

The two user Advisory Councils provide a mechanism for external stakeholders to have input to the research themes and strategic directions of the Centre. These Councils represent the principal Centre stakeholders in mineral exploration, and natural resource management. Significant effort has been made to further develop networks with individual stakeholders, both at the individual and organisational levels, to promote research cooperation, technology transfer and feedback, outside of the structured mechanism of the Advisory Councils. In particular, effort has gone into developing networks with catchment management authorities (CMAs) and natural resource management (NRM) agencies in a number of states.

Presentations and meetings with reference to environmental work have been held with NRM agencies in New South Wales, South Australia, Queensland, Victoria and Western Australia, and with the Murray-Darling Basin Commission. Some of these have been followed by project proposals. Meetings have also been held with CSIRO to discuss LEME involvement with CSIRO Healthy

Country projects in Queensland and Western Australia. LEME staff have participated in a workshop with the Rural Industries Research and Development Corporation (RIRDC) designed to promote regolith work in agroforestry. We have submitted a number of proposals to RIRDC and are awaiting funding for some of these projects. During 2002-2003 we have also worked with the Department of Conservation and Land Management (CALM) in Western Australia on two projects - Lake Bryde recovery catchment and Marshall Plantation, south of Collie. Collaborative work is in progress between ANSTO and CRC LEME to develop and apply electrokinetic seismic methods to hydraulic conductivity investigations.

Linkages with users of Centre research are also maintained through staff participation in conferences and industry workshops. Details of these activities are provided in the Education and Training, and Communication and Public Relations sections of this report.

International Linkages

Prolonged deep weathering over the last 50 to 300 million years on a predominantly stable continent has created a uniquely Australian regolith. The primary focus of CRC 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.

Kachen Neosuparp from Chulalongkorn University in Thailand was a visitor to CRC LEME in 2003, working with Dr Jayson Meyers at CUT as part of his PhD on geophysical prospecting and mineral potential of the Loei district in Thailand. This involved a comparison of tropical regolith of Thailand with Australian regolith.

Dr Alejandra Duc-Rodin from the Geological Survey of Canada was a visitor in 2002, and worked predominantly with Geoscience Australia in Canberra, including some input into the Girilambone project (Cobar-Bourke) in Program 2. Roslyn Chan from Geoscience Australia will shortly leave for Canada on a reciprocal visit.

Dr Sue Welch, previously from the University of Wisconsin, has joined us as a CRC-funded lecturer at ANU.

Assoc Prof Cliff Stanley from Acadia University, Canada is a co-supervisor to one of our PhD students, as he is a recognised expert in the application of new techniques in ratio analysis of whole rock geochemistry and the recognition of alteration systems in the regolith. He was a visitor to the Centre on 9 December 2002.

Dr Colin Pain and Dr Graham Taylor were invited to present at the Hong Kong branch of the Geological Society, London, in March 2003. Their presentation led to a request from consulting and Hong Kong Geological Survey geologists for further information on regolith mapping and characterisation. This group will now become part of the Regolith Mapping Discussion Group to be instituted next financial year.

Assoc Prof Pat James attended the Learning and Teaching Support Network – Geography, Earth and Environmental Science Residential Conference in the UK in June 2003. He presented a poster outlining the *Management of the Learning environment of an Australian training program in the Earth and Environmental Sciences – CRC LEME*. He also presented a talk highlighting the links between teaching and research at University of Adelaide Geology and Geophysics.

CRC LEME is also strengthening its international linkages through the activities of its postgraduate students, some of whom originate from Iran, Sri Lanka, Papua New Guinea, Indonesia and Switzerland.

Collaboration with other CRCs

Two joint student projects (joint funding and supervision) have been undertaken with the CRC for Plant-based Management of Dryland Salinity, working on drainage schemes in eastern South Australia. A joint working group on regolith mapping has also been set up with the CRC for Plant-based Management of Dryland Salinity, and this will become part of the Regolith Mapping Discussion Group to be instituted next financial year.

The Centre has run joint workshops, and is currently discussing joint projects with CRC for Catchment Hydrology. The Centre is also planning work with the new CRC for Spatial Information, with the possibility of forming a joint Advisory Council.

We are also seeking to develop major integrated multi-disciplinary cluster projects in locations where the CRC for Predictive Mineral Discovery (pmd*CRC) is also carrying out projects. There is potential to develop new joint projects related to modelling the mobility and transport of metals in groundwater systems. Currently, scientists at CSIRO Exploration and Mining and pmd*CRC are developing models that couple groundwater flow and geochemistry, which are potentially useful in the development of new mineral exploration strategies. Our staff are interested in collaborating to develop robust predictive models that incorporate the knowledge and expertise available in both CRCs.

A new joint research initiative by Dr Bear McPhail and Dr Evgeniy Bastrakov, funded and staffed by both CRC LEME and pmd*CRC, will develop a web-based database of thermodynamic properties and ancillary software for use in geochemical and reactive transport modelling. This project is listed in Program 2, but the initiatives of this project will be relevant to all five LEME programs.

CRC LEME also contributes to the active Minerals and Energy Sector within the Cooperative Research Centre Association, and Dennis Gee has participated in meetings with fellow CEOs. The Sector CEOs are considering strategic alignments to collaborate in long-term strategic research projects, and in the shorter term are investigating possible collaborations in education and training, communication, and creating a "CRC Minerals Forum".

Companies that provided cash or in-kind funding for research and educational activities during the reporting period.

Abelle Ltd
AngloGold Australia Ltd
APAI Farm Map Consulting Pty Ltd
Apex Minerals NL
Australian Water Environments
Barrick Gold Corporation
BHP Billiton Ltd
Consolidated Minerals Ltd
Dominion Mining Ltd
Gold Fields Australasia Pty Ltd
Helix Resources Ltd
Independence Gold NL
Lightning Ridge Miners Association
Metals Quest Australia Ltd
MIM Holdings Ltd
Mineral Mapping Agency of Japan
Minotaur Resources Ltd
Newmont Australia Ltd
Oroya Mining Ltd
Pasminco Ltd
Peak Gold Mines Pty Ltd
Perilya Ltd
Pilbara Manganese Pty Ltd
Pima Mining NL
Range River Gold NL
Sons of Gwalia Ltd
South Australian Water Corporation
Stawell Gold Mines Pty Ltd
Straits Resources Ltd
Striker Resources NL
Tasman Resources NL
Teck Cominco Ltd (Cam Allen)
Tensor Geophysical Services Australia Pty Ltd
Tesla 10 Pty Ltd (now Fugro Airborne Surveys)
Triako Resources Ltd
WMC Resources Ltd
URS Corporation
Zonge Engineering and Research Organisation Inc

Research Programs

Paul Wilkes, Deputy Chief Executive Officer

Photograph by Steve Hill

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

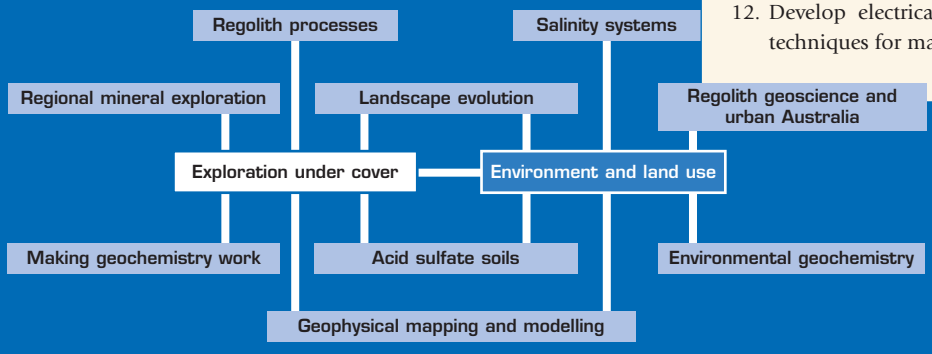
Although structured in this way to facilitate management and reporting, these research programs are closely interrelated by regolith geoscience, and all contribute to our strategic research priorities designed to:

- Improve our understanding of regolith processes and landscape evolution
- Make exploration geochemistry work through cover
- Develop techniques to interpret regolith architecture
- Use regolith knowledge to enhance prospectivity in geological regions
- Develop methods to map and predict salinity with outcomes linked to mitigation and remediation

Multi-party and multi-disciplinary projects have been consciously cultivated as the research programs develop, so the intellectual capital generated is effectively directed towards the needs of our diverse stakeholders in both mineral exploration and natural resource management.

Program Milestones

Progress is reported against the outputs and milestones derived from those in the Commonwealth Agreement, as follows:



Program 1 Milestones

1. *Regolith geology of the Yilgarn* – published.
2. *Regolith-landscape models with case histories – Australia* – compiling.
3. *Manual on three-dimensional mapping of the regolith* – compiling.
4. *Manual on calcrete* – published.
5. Develop multi-disciplinary research teams involving staff from several Core Participants and/or Supporting Participants and Associates by end of Year 2.
6. Develop regolith-landscape models for key mineral areas such as western New South Wales, Gawler Craton, Curnamona and Cobar Provinces.
7. Initiate and deliver results on dynamics, distribution and diagenesis of transported regolith in selected regions by Year 2.
8. Determine the chemical, mechanical and biological processes leading to the formation of geochemical anomalies in regolith.
9. Date secondary minerals, regolith and landsurfaces in selected areas.
10. Produce control training sets for the interpretation of mineralogy from the spectral signatures of regolith materials.
11. Produce mineral maps.
12. Develop electrical and electromagnetic geophysical techniques for mapping regolith in three dimensions.

Program 2 Milestones

1. Compile and release case histories and exploration models of *Regolith expression of Australian ore deposits.*
2. Deliver first results from integrated regolith projects in the Gawler and Cobar regions during Year 2.
3. Complete initial studies in integrating three-dimensional geochemical and airborne electromagnetic modelling in Year 2.
4. Complete the first phase of the *Base Metals Exploration Project* by Year 2.
5. Complete multi-client projects in isotope geochemistry in selective extraction analysis.
6. Assess use of acid sulfate soils and saline discharges in exploration.
7. Develop major interdisciplinary projects involving staff from several Core Participants in the principal exploration regions (Curnamona, Gawler, Lachlan and Yilgarn).
8. Expand integrated exploration research into key regions elsewhere (Northern Territory, northern Western Australia, Queensland).

Program 3 Milestones

1. Discuss with potential collaborators such as GA Division of Minerals and Geohazards and the CRCs for Catchment Hydrology and Plant-based Management of Dryland Salinity, to plan collaborative research projects.
2. Identify and pursue research problems critical to the success of the dryland salinity work being undertaken in Program 4.
3. Identify and pursue environmental risks requiring regolith geoscience input, in collaboration with GA Division of Minerals and Geohazards.
4. Identify and assess geochemical datasets that can be used for baseline environmental geochemistry of selected regions.
5. Develop the use of conventional and new remotely-sensed data for a variety of uses in areas where regolith geoscience is being applied to environmental problems.

Program 4 Milestones

Milestones for the new projects in Program 4 were not developed in the initial Commonwealth Agreement, which simply referred to "intergovernmental agreements with State agencies". Program 4 will provide key information and services to facilitate the implementation of the National Action Plan for Salinity and Water Quality (NAP SWQ). As such, CRC LEME will conduct two types of projects – commercial projects (either totally or partially external funded contracts of work), and strategic research as centre-funded collaborative projects.

Commercial projects have their own defined milestones as recorded in the respective State-Commonwealth 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 following is a distillation of the major milestones in terms of strategic intent and deliverables.

1. Develop a management structure and the technical capability to generate and undertake State-based salinity projects, and to provide for technological transfer to clients, by December 2003.
2. Develop new constrained inversion methodologies for modelling wide-band frequency domain helicopter EM data by December 2003.
3. Develop and report on the application of geophysically-based methodologies for designing optimal recharge strategies, and developing hydrological models in lowland (for example irrigation) areas by December 2003.
4. 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; to be completed by December 2003.
5. 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.
6. Develop theoretical and practical models with the involvement of CSIRO Land and Water, for predicting salt mobilisation and water quality in various regolith environments; release information annually from July 2003 to July 2005.

Photograph by Ian Robertson

Program Leader Dr Ravi Anand

Program 1: Regolith Geoscience

Highlights

- Purchase of a portable ASD FieldSpec Pro Spectroradiometer from a Western Australian Government grant. Spectral datasets will objectively aid geochemical, geological, geophysical and geotechnical interpretation of regolith materials.
- Publication of a LEME monograph *Calcrete: Characteristics, Distribution and Use in Mineral Exploration*. This is a benchmark study on calcretes for use by regolith geologists and mineral explorers.
- Development of analytical techniques using Sensitive High Resolution Ion Microprobe (SHRIMP) and Thermal Ionisation Mass Spectrometry (TIMS) to date opaline silica. These new applications may provide the first precise and accurate dates for silcrete, opal and iron oxide formation.
- Palaeomagnetic dating of regolith at the ANSTO Lucas Heights facility in Sydney demonstrated that faults encountered during the excavation for the new nuclear reactor had not moved in the last five million years.
- Publication of the Yilgarn regolith map.
- Identification of new mineral phases as potential sampling media for concealed mineralisation.
- A total of 44 case studies on regolith-landform evolution have been edited, with 23 posted on the LEME website. The case studies are drawn from a broad range of geographical and geological settings, and reflect the current state of regional regolith research in Australia.

Overview

This program aims to understand the fundamental controls on the formation and distribution of our unique Australian regolith and the multitude of complex processes that shaped the regolith. As such, it forms the scientific foundation for the mineral exploration and environmental programs.

Our research activities are conducted within a number of projects, under the theme *understanding regolith processes and landscape evolution*. The theme contributes to a process-driven understanding of the evolution of the regolith and mechanisms of formation of geochemical anomalies. It was developed in response to industry needs identified through extensive consultation. A number of multi-disciplinary projects at a range of scales are in progress in several exploration regions of Australia, including Gawler Craton, Curnamona Province, Yilgarn Craton and western New South Wales. A comprehensive review of our research activities in early 2003, focusing on delivering outcomes that meet industry needs, resulted in the development of a suite of new multi-disciplinary and multi-party regionally-based projects for the coming years.

Thematic Volume: Regolith-landscape Evolution – Dr Ravi Anand, Dr Peter de Broekert, Travis Naughton and Angelo Vartesi.

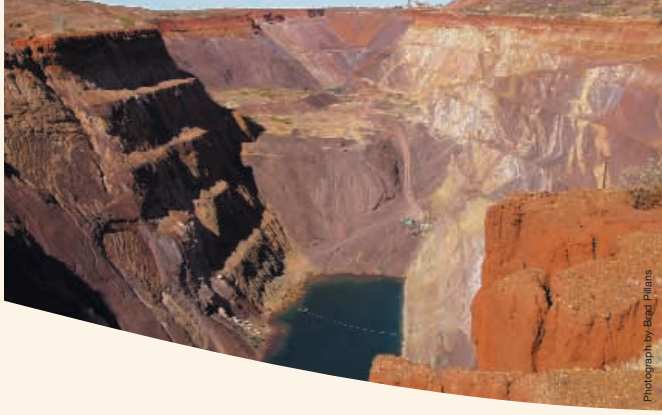
Editing and production of the monograph of regolith–landform evolution case studies is approaching completion. Forty four of the 53 case studies committed to by various industry and government agency authors have been edited, and 23 posted as early releases on the LEME website.

The case studies describe and interpret aspects of regolith and landform development in a broad range of geographical and geological settings, ranging from Quaternary coastal dune formation at King Island, through Tertiary volcanism in western Victoria, to late Palaeozoic glacial deposition in Western Australia. The contributing authors represent the full range of organisations involved in regolith research in Australia. Apart from providing detailed site-specific information, the monograph also reflects the current state of play of regolith research in Australia. It will be invaluable to all scientists involved in this rapidly developing field. Achievements in this work are set against Milestone 2 of Program 1.

Thematic Volume: Three-dimensional Regolith Mapping – Dr Colin Pain and others.

The *Three-dimensional Regolith Mapping* volume is in progress, with the following chapters received by the editor:

- A Geological Systems Approach
- The Role of Geomorphology, Climate and Vegetation
- The Role of Weathering History
- Data Sources
- Regolith Mapping Methods
- Case Histories
- Regional Three-dimensional Regolith Models
- Depth to Bedrock Mapping



During the latter part of the year a new output has been conceived from the three-dimensional volume. As there is no national standard for mapping regolith, the new output will develop standards, and present them to both the geological and natural resources professional communities. A discussion paper has been prepared, and can be obtained from the LEME website. Achievements in this project are set against Milestone 3.

Geochronology and Quantitative Models of Landscape Evolution – Dr Brad Pillans, Dr Alexander Nemchin, Dr Derek Fabel, Dr John Magee, Dr Nigel Spooner, Prof John Chappell, Dr Andrew Christy, Dr Patrick de Deckker, Prof David Ellis, Dr Mehrooz Aspandiar and Assoc Prof Lindsay Collins.

A highlight of the year was the successful application of palaeomagnetic dating techniques to regolith at the ANSTO Lucas Heights facility in Sydney. This demonstrated that faults discovered during the excavation for the new nuclear reactor had not moved for at least 5 million years. This was sufficient to satisfy the International Atomic Energy Agency that the faults were "non-capable" and that it was geotechnically safe to proceed with construction.

ANSTO excavation at Lucas Heights - south wall

Palaeomagnetic methods used in the Lucas Heights study have been increasingly applied by Brad Pillans and PhD student Martin Smith in their regolith studies. They are providing a chronological framework for ferruginous regolith throughout Australia. This has shown that deep oxidation of ferruginous saprolite has been markedly episodic over the past 200 million years of Australian geological history. We are also investigating a new application of (Uranium-Thorium)/Helium methods to the dating of iron oxides.

A workshop held in Canberra in November 2002, brought together the LEME Geochronology and Quantitative Modelling team, as well as other invited participants. Presentations were made by staff and students, and a report of the meeting is in preparation.

Exciting new applications of regolith dating techniques are being developed, which may provide the first precise and accurate numerical ages for regolith phases such as silcrete, opal and iron oxides. Analytical techniques using Sensitive High Resolution Ion Microprobe (SHRIMP) and Thermal Ionisation Mass Spectrometry (TIMS) have already been developed to date opaline silica. Results of this work were reported at the International Goldschimdt Conference in Denver. Achievements in this project are set against Milestones 6 and 9.

South Australia Sediments – John Keeling, Alistair Crooks, Adrian Fabris, George Gouthas, Dr Baohong Hou, Paul Rogers and Malcolm Sheard.

In South Australia, work continued on the nature, architecture and distribution of sedimentary cover in areas of mineral potential in the central Gawler Craton and Curnamona regions. Results of earlier work on the stratigraphy and sedimentology of palaeo-valleyfill in the Gawler Craton were published in two papers in the *Australian Journal of Earth Science*. Current investigations aim to use available datasets to predict and identify areas of channel fill and to model their role in the concentration of heavy minerals, placer and chemical gold, and uranium. Drill hole data in the Harris Greenstone Belt were used to construct a three-dimensional model showing the distribution and thickness of sediments in the Kingoonya palaeochannel that overlie Archaean greenstones prospective for nickel and gold. The model also delineates basement faults that were active during sedimentation in the palaeochannel.

In the Curnamona Province, work was completed on northern Murray Basin sediments near the southern margin of the Olary Block. Past depositional environments were reconstructed and the potential for heavy mineral sands was reviewed. Regolith mapping at 1:25 000 scale for the Mingary 1:100 000 sheet continued in concert with detailed mapping of sparse outcrops of older Proterozoic basement rocks in which equivalents of the famous Broken Hill Group have been recognised. The mapping project will be accelerated next year and extended to include the Kalabity district. Studies on geochemical sampling media and thickness of transported cover will develop sampling strategies appropriate to the nature and thickness of regolith cover. Drilling data were used to model the thickness of cover sediments in the Callabonna sub-basin. A regional interpretation of palaeodrainage in the basin was completed using company exploration data. This first-pass model of sediment thickness and architecture has highlighted deficiencies in the current data and the need for additional datasets, including airborne EM, to effectively map the cover units. Achievements in this project are set against Milestones 6 and 7.

Photograph by Brad Pillans

Regolith Patterns on the Yilgarn Craton – Mike Craig, Max Churchward (collaborator) and Dr Ravi Anand.

This recently completed regolith map draws from previously published material from CSIRO, Geoscience Australia, Geological Survey of Western Australia and Department of Agriculture Western Australia. Source maps are either specific for soils and landforms, or are geological maps. This new regolith map covers much of the Yilgarn Craton, an area of intense interest to mineral explorers.

This new map provides a much-needed overview of regolith units across very large areas and will be a useful supplement to published larger scale regolith maps. Achievements in this project are set against Milestones 1 and 6.

Objective Logging of Regolith – Dr Ravi Anand, Cajetan Phang, Dr Ian Robertson, Dr Ian Tapley, Dr Charles Butt, Dr Merhooz Aspandiar, John Keeling and Dr Alan Mauger.

The *Objective Logging Regolith Project* is a new research initiative to provide technologies to support the Australian mineral exploration industry in optimising information gained from exploration drilling. It aims to develop practical automated interpretation tools for logging regolith material such as core, drill chips, or pulps. The main problems encountered by explorers working in intensely weathered terrain are discriminating bedrock from its weathered counterpart, distinguishing transported from *in situ* regolith, and identifying hydrothermal alteration in weathering material. These tasks are particularly difficult for geologists of all levels of experience, who evaluate prospects by logging drill chips. Manual logging is slow, subjective, expensive and imprecise. Important features, such as the unconformity below transported regolith, may also be overlooked.

There is an urgent need to develop procedures to log regolith materials more rapidly and precisely, using properties that may not be evident through visual inspection. The most effective route is likely to involve automated instrumental determination of mineralogy and petrophysical properties. The intent is to provide the exploration geologist, mining engineer, geomorphologist and environmental scientist with a meaningful, objective analysis of regolith materials to aid geochemical, geological, geophysical and geotechnical interpretation. The goal is not to replace experience, but to complement and refine this knowledge through rapid analysis and presentation of mineralogical (spectral) and multi-parameter (magnetic susceptibility, density) petrophysical measurements of the regolith.

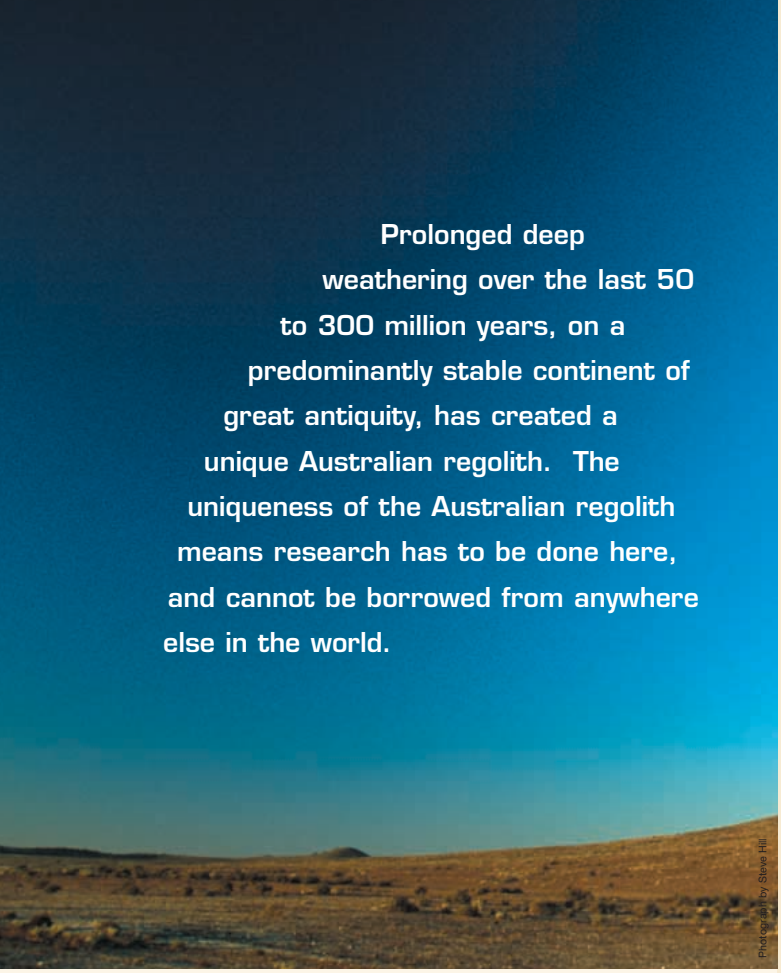
Over the last five years, CSIRO Exploration and Mining, as well as mining companies and industry consultants, have demonstrated that significant mineralogical information can be derived from the spectral reflectance of rock and regolith. The most frequently used instrument for this work has been the PIMA-II field-portable spectrometer. However, PIMA-II has a limited spectral range (1300-2500 nm) and cannot detect some of the most prevalent mineral phases in regolith. In contrast, the ASD FieldSpec Pro Spectroradiometer has a wider spectral range (350-2500 nm) and identifies minerals including clays and iron oxides, from cores, chips and pulps. The instrument is portable and suitable for both laboratory and field use. It collects spectra and digitally characterises materials in seconds. Interpretation of the large digital datasets produced is supplemented by control datasets that provide constraints to the interpretation of spectral data.

This project has industry collaboration in its first year and covers a range of regolith environments in South Australia, New South Wales, and the Yilgarn Craton of Western Australia. The project will draw on the skills of the CSIRO Mineral Mapping Group to develop processing and interpretation procedures for different regolith materials and settings. Software engineering will be required. One of the main outcomes will be the production of three-dimensional mineral maps, and importantly, the discrimination of transported from *in situ* regolith.

Achievements in this project are set against Milestone 10.

Mineral Spectra Mapping South Australia – Dr Alan Mauger, John Keeling, Vicki Stamoulis, Dr Graham Heinson, Assoc Prof Pat James and Prof Martin Williams.

We are also using spatial distribution spectra of minerals to study geomorphic and regolith processes and surface mineral distribution. Honours and PhD students from the University of Adelaide are involved in the project. Sean Mahoney (Honours student) completed a regolith study of the Tarcoola Region, Gawler Craton Province, using Hyperion hyperspectral satellite data, and published this work at the *11th Australasian Remote Sensing and Photogrammetry Conference* in Brisbane in 2002. It was awarded the best poster prize. Achievements in this project are set against Milestone 11.



Electrical and Electromagnetic Regolith Studies – Dr Graham Heinson, Dr Anton Kepic, Assoc Prof Jayson Meyers, Prof Stewart Greenhalgh and Paul Wilkes.

New ground-based electrical and electromagnetic techniques are under development to define regolith architecture and bedrock features beneath cover. During the reporting period, a team of six Honours and six postgraduate students have been involved in instrument developments, field studies, data processing and modelling. These projects are linked to industry objectives, and collaboration has been established with Barrack Gold Corporation, Newmont Australia, MIM Exploration and Zonge Engineering and Research Organisation. Agencies such as Primary Industry and Resources South Australia, Geoscience Australia and CSIRO Exploration and Mining are also involved.

The project team presented results at the *16th Australian Geological Convention* (AGC), the *16th Australian Society of Exploration Geophysicists* (ASEG) and the *Third International Symposium on Three-dimensional Electromagnetics Workshop*. Research papers are in press in a number of international journals. At the ASEG meeting Brian Barrett, a recently completed Masters student, was awarded Best Student Paper. He constructed a floating towed electromagnetic mapping platform, which was used to determine salinity beneath the Murray River bed. It has been extensively used by South Australian Water Corporation to investigate the efficiency of salt-interception pumping schemes along reaches of the Murray River.

With five postgraduate students in this program, research will continue to develop efficient tools and methods for land management agencies. New methods are currently being tested in South Australia and Western Australia. Achievements in this project are set against Milestone 12.

Mechanism of Formation of Geochemical Anomalies in Regolith

Strategic research aims to determine how geochemical anomalies form, which will in turn assist in the understanding of when, how and where particular regolith materials are useful indicators for mineral exploration.

Mineral Hosts for Gold and Trace Elements in Regolith – Dr Ravi Anand, Dr Rob Hough, Cajetan Phang, Dr Ray Smith, Melvyn Lintern, Dr Bear McPhail and Dr Ken McQueen.

We continue to study mineral phases and mineral associations that act as hosts for trace levels of metals in regolith materials. Reports dealing with the Boddington and Mt Percy gold deposits, and the Golden Grove lead-zinc deposit are now completed. This project presents new data about the occurrence and abundance of selected trace elements in a variety of regolith minerals, and has real potential to improve exploration procedures in regolith-dominated terrains. There is direct industry support for this project.

Work has also concentrated on the microanalysis of gold ores from the Mt Gibson and Lawlers deposits, and Golden Grove base metal deposit, where we have mineralogical and geochemical knowledge from previous regolith studies. Following further fieldwork (Mt Gibson) and detailed sampling, we have targeted key samples that display element anomalies in their bulk geochemistry. Scanning electron microscopy (SEM), electron microprobe and microRaman spectroscopy have been used to characterise the *in situ* mineralogy and geochemistry of these samples at the thin-section scale.

The *Gold in Calcrete* project is ongoing, and a literature review was completed and published. Fieldwork was undertaken at the ET Gold Prospect in the Gawler Craton, where size-sieving analyses over an anomaly in transported overburden indicate that the fine size fraction (<75 microns) has the highest gold concentration but represents the smallest part by weight of the sample. Microanalyses indicate zones both rich and poor in gold within the calcrete, which is unusual and not yet understood.

Over the coming year we will conduct Laser Ablation Inductively-Coupled Plasma Mass Spectrometry (ICPMS) analyses on samples from regional project areas, to further refine our understanding of which regolith minerals act as sinks for elements such as gold. Scanning and transmission electron microscopy (SEM and TEM) will be used to determine the siting of gold grains in calcrete at the micron scale. This work will improve our understanding of the processes involved in anomaly formation in both residual and transported regolith, to further guide mineral exploration in areas of cover. Achievements in this project are set against Milestone 8.

Interactions of Microorganisms with Gold in Regolith Materials – Frank Reith (PhD student).

The chemical mobility of gold in the regolith allows its dispersion and re-concentration in and around mineralised zones. Understanding how gold is mobilised and trapped in the regolith is vital for developing successful gold exploration strategies. In this study, analytical and experimental methods are used to understand the relationship between gold and microorganisms in the regolith. The field studies are based at Tomakin Park and Peak Hill gold mines in central New South Wales, and the Palmer River region in northern Queensland. The sites were chosen to provide comparison between temperate and tropical environments.

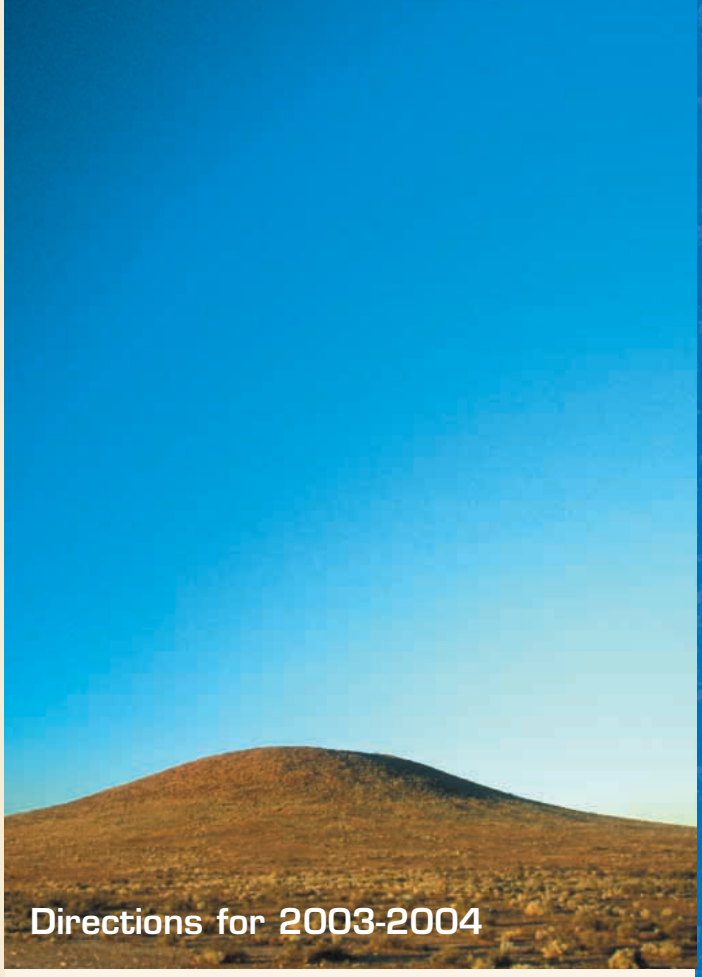
Gold has long been known to be highly mobile in Western Australian soils and regolith, probably because of their saline groundwaters. Gold has also shown to be mobile at the Tomakin Park and Peak Hill sites in New South Wales, in less saline environments. Selective sequential leaching experiments on soil and regolith samples from these mines indicate significant mobility of gold in the weathered host rock, and soils overlying these deposits.

The mechanisms for the dissolution of gold in non-saline weathering environments have not yet been identified. It has long been proposed that natural microflora can affect solubilisation, mobility and precipitation of gold. Gold encrusted microfossils have been detected on gold flakes panned from soils and stream sediments from Palmer River and Tomakin Park. This indicates the presence of gold-precipitating microorganisms, previously described as *Pedomicrobium spp*. In addition, results from Tomakin Park indicate a strong correlation between *Bacillus cereus* and gold. *Bacillus cereus* is a common soil bacterium, and has been shown to act as a bio-indicator for gold in soils. The results of microcosm experiments with soil and regolith hosts indicate the ability of natural microflora to mobilise gold. In experiments conducted with live microflora, dissolved gold concentrations of up to 3 ppm were measured after 30 days, whereas in sterile control experiments little or no dissolved gold was detected after 90 days. Similar experiments are currently being conducted with samples from Palmer River.

In addition to studying the relationship between microorganisms and gold, preliminary studies of gold in natural vegetation are also underway. Plants in the Peak Hill area show elevated levels of gold in their leaves. These results are promising and microbiological studies in which *Bacillus cereus* has been identified point to a possible pre-screening method to supplement conventional geochemical methods of gold exploration.

Further research will explore gold mobility in laboratory column experiments with percolating solutions. Plant community structure analyses based on carbon utilisation patterns are also planned, to assess the differences between the soil microflora, with and without gold.

Achievements in this project are set against Milestone 8.

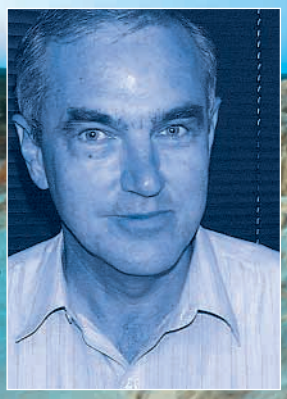


Directions for 2003-2004

- Commence multi-disciplinary project on gold and base metal anomaly formation in areas of transported cover (colluvial-alluvial sequences) with moderate salinity in the northern Yilgarn Craton.
- Commence multi-disciplinary project on expression of gold and base metal mineralisation in hypersaline environments of the southern Yilgarn Craton.
- Commence project on regolith-landscape evolution of the entire Northern Territory.
- Commence project on establishing the history of aridity in Australia and the expression of this history in regolith features and processes.
- Commence investigations into the role of biological processes on mineral weathering and element mobility in regolith.
- Commence investigations into the mobility of gold, lead and arsenic in saline and hypersaline environments.
- Produce monographs on regolith-landscape evolution across Australia and three-dimensional regolith mapping.
- Continue research on developing automated interpretation of regolith materials.
- Continue research into mineral hosts for gold and trace elements in regolith.
- Continue research into providing numerical ages for regolith materials and to develop kinematic models of landscape evolution.
- Continue research into testing and developing geophysical techniques for mapping regolith in three dimensions.

Program 2:

Mineral Exploration in Areas of Cover



Acting Program Leader Keith Scott

Photograph by Steve Hill

Highlights

- Application of electromagnetic surveying to find blind manganese deposits at Woodie Woodie, Western Australia.
- Establishing acid sulfate soils as a potential sampling medium for concealed mineralisation.
- Evaluating the merits of various sampling media in exploration in areas of shallow cover in the Gawler Craton, South Australia and Girilambone Belt, New South Wales.
- Using weathering processes to define best sampling techniques at Nifty, Western Australia and Mineral Hill, New South Wales.
- Release of regolith expression of Australian ore systems as case histories via the web.

Overview

In October 2002, after making a substantial input into the strategic direction of CRC LEME, Program 2 Leader Prof Nigel Radford resigned to return to industry. Since that time, Keith Scott has been Acting Program 2 Leader.

The aim of Program 2 is to provide new and improved tools for mineral exploration in areas of cover. This is achieved by better understanding the processes that modify primary geological, geochemical and geophysical features in the regolith environment.

Acid Sulfate Soils: Regolith Processes and Implications – Dr Rob Fitzpatrick, Dr Marian Skwarnecki, Dr Richard Merry, Phil Davies, Mark Raven and Andrew Baker.

This project is reported in full under Program 3 as a regolith application to environmental matters. However, the study has revealed a new sampling medium for mineral exploration and therefore is also relevant to Program 2. This completed work achieves Milestone 6 of Program 2.

Regional Mineral Exploration Studies - Gawler Craton – Malcom Sheard, Mel Lintern, Dr David Gray, Dr Ian Robertson, George Gouthas, Jim Painter, Dr Karin Barovitch and Dale Longman.

Work in the Gawler Craton aims to develop techniques for exploring in regions of transported overburden. This requires understanding the relationships between geochemical dispersion patterns, weathering processes and evolutionary stages of regolith and landform development over concealed mineralisation. A number of highly focused regolith studies at known sites of economic mineralisation like Challenger and Edolden Tank have been conducted with the support of Dominion Mining, Helix Resources and Adelaide Resources.

It is important to establish regolith stratigraphy and processes by which landforms are shaped, because geochemical exploration programs are sensitive to variation in regolith materials and depth of transported overburden. Remote sensing methods such as digital elevation, radiometrics, aerial photography, spectrometry and radar give important information on the nature of the landforms and surficial materials. Other ground penetrating methods such as airborne electromagnetics (AEM) give sub-surface information on the presence and depth of palaeochannels.

Distinguishing *in situ* from transported regolith is of critical importance to the sampling strategy because the geochemical responses will give very different signals depending on the depth of cover. The extent of cover may be inferred from regolith landform relationships, augmented by judicious drilling to provide definitive information. The usefulness of kaolinite crystallinity (determined from PIMA spectra) in drill cuttings as an indication of transported-*in situ* boundaries has been

demonstrated. Geochemistry can also be used in some circumstances to discriminate between cover sequences and weathered crystalline basement.

Calcrete is the best near-surface sampling medium for gold in these non-lateritic areas, and should be used as a first-pass geochemical sampling technique. It works best as a guide to mineralisation where transported overburden is absent or less than five metres thick, and where there is saprolite rather than fresh rock. However, experience in the Gawler Craton shows that gold traces may be smeared for considerable distances in calcrete, where local topography and underlying palaeotopography create focused groundwater flow patterns.

For calcrete, isotopic data indicate a marine source for the calcium and a biological origin for the carbon. This is consistent with other studies on calcretes from South Australia and other parts of the world. Sulfur isotopes suggest a marine source although the distribution of discrete accumulations of gypsum in certain portions of the regolith at Challenger Gold Deposit requires more explanation. In the absence of calcrete, other sample media may be used but anomalies are weak and more erratic.

Silcrete has been demonstrated as a viable sample medium for the first time, at the Challenger gold deposit, provided that it has developed *in situ*. Soil generally has an aeolian component so the use of either fine or coarse size fractions is recommended in order to remove sand that is the chief diluent of pathfinder elements.

In regard to multi-element geochemistry it is important to consider the nature of the mineralisation being sought, potential associated pathfinders, the type of regolith material being sampled, and the high cost of multi-element analytical suites. For gold in the western Gawler Craton, multi-element geochemistry was of limited use because mineralisation was not associated with concentrations of pathfinder elements such as arsenic or copper, as is commonly found in the Yilgarn Craton. Furthermore, the paucity of iron-rich regolith materials, such as lateritic duricrust or ferruginous lag, meant that these metal-scavenging materials could not be used systematically in an exploration program.

To understand the regolith geology of the poorly-exposed Harris Greenstone Belt in the central Gawler Craton (which has potential for nickel and gold mineralisation) detailed geochemistry, X-ray diffraction (XRD) and petrology have been undertaken on three specifically drilled regolith cores. Initial results were released to industry at the *Gawler Craton 2002: State of Play Conference* in Adelaide in November 2002. The final report and associated map and rock atlas will also be released. Achievements in this theme are set against Milestones 2, 3 and 7.

Regional Mineral Exploration Studies – Western New South Wales Region

– Dr Patrice de Caritat, Dr Steve Hill, Richard Barratt, Kingsley Mills, Barney Stevens, Tim Sharp, Kylie Foster, Karen Hulme and Melissa Quigley.

This project aims to stimulate mineral exploration in western New South Wales through greater understanding of regolith areas dominated by thin to thick sedimentary cover surrounding the Broken Hill region.

Regolith-landform mapping at 1:25 000 and 1:100 000 scales has been undertaken on the edges of the Broken Hill Block. The Pinnacles, Mt Gipps and Tibooburra maps were released in November 2002. The Teilta area is now being studied using a combination of regolith-landform mapping and sampling of groundwater, regolith and plants. The study reveals that residual regolith is more abundant than initially thought and that anomalous copper values may be present in silcrete. Data from this study is being interpreted using a systems approach, leading to an integrated regolith model of landscape evolution and geochemical dispersion. A comparison of Hymap™ spectral data with that derived from regolith landform mapping is also underway.

In areas of deeper cover, regional groundwater sampling has shown that elevated concentrations of base metals were associated with anomalous sulfur (and lead) isotopic signatures. Additional work is now focussing on data gaps and anomaly definition, in order to evaluate the advantages and limitations of applying hydrogeochemistry to mineral exploration. Achievements in this theme are set against Milestone 7.

Regional Mineral Exploration Studies - Girilambone Region

– Dr Ken McQueen, Dr Richard Greene, Keith Scott, Roslyn Chan, Mike Hicks, Peter Buckley, Guy Fleming, Ben Maly, Anthony Senior, Kamal Khider, Joe Shifano, Susan Tate, Hugh Glanville and Paul Wilkes.

This project provides new regolith knowledge and develops methodologies for improved mineral exploration in areas of regolith cover specific to central western New South Wales. This work is in collaboration with the New South Wales Department of Mineral Resources, and involves a multi-disciplinary team of scientists with skills in regolith geology, geomorphology, bedrock geology, geochemistry, geophysics and soil science. The project is focused on the Girilambone Belt between Nyngan, Cobar, Bourke and Nymagee. Stage 2, covering the southern part of the project area, and the drilling and sampling program for Stage 3, in the northern area, were completed in the current reporting year.

Work to date indicates a much more complex landscape history than previously realised, with a highly variable regolith cover. Much of the area is draped with mixed colluvial, alluvial and aeolian materials, creating extensive networks of buried and partly eroded palaeovalleys. These draping sediments cover variably weathered Palaeozoic metasediments and metavolcanics, felsic volcanics and ultramafic intrusives. A three-dimensional picture of the regolith has been developed using surficial regolith-landform mapping and regional geophysical data, augmented by carefully targeted drilling. Physical, mineralogical and geochemical analyses of regolith materials are being integrated to provide a framework to better understand geochemical dispersion and enhance anomaly detection. A number of important regolith-controlled element associations have been established. Different sampling protocols and selective digestion techniques are being tested.

Students involved in this project are studying groundwater geochemistry and behaviour of major and trace elements in unmineralised regolith. The applicability of partial extraction data for exploration in areas of cover, and the importance of aeolian material are being assessed.

New regolith models and geochemical anomalies continue to be discovered. Results to date have been communicated at industry presentations and in two major technical reports. The project is stimulating exploration interest in the Girilambone Belt. Achievements in this theme are set against Milestone 2.

Making Geochemistry More Effective in Areas of Thin Cover – Dr Matthias Cornelius, Keith Scott, Geoff Denton, Dr Anita Andrew, Simon Gatehouse, Michael Korsch, Alistair Law, Dr David Gray, Dr Graham Carr, Barbara Gardner, Andrew Bryce, Michael Whitbread and Ryan Noble.

Studies of the regolith at a number of mineralised sites are assisting in making geochemical sampling more effective. Near the Nifty copper deposit in the Pilbara region, projects funded by Straits Resources have shown that analysing the coarse soil fraction for As, Co, Cu, Pb, S, Sb and Zn provides the best geochemical discrimination for underlying copper mineralisation. However, regionally, where aeolian material occurs, copper and lead were anomalous in both fine and coarse soil fractions, but the finer fraction represented a better sampling medium due to its greater abundance.

In the Mineral Hill Mining Field of central New South Wales, studies funded by Triako Resources revealed that weathering of sphalerite-galena rich (but pyrite-poor) mineralisation at Parkers Hill occurs under less acid conditions than generally encountered during the weathering of massive sulfide deposits in the Lachlan Fold Belt. Consequently, the carbonate-rich part of the oxidate profile (cerussite) is particularly well developed at Parkers Hill.

The AMIRA Project P618 *Isotopic discrimination of partial leach geochemical anomalies in covered terrain*, involving six industry sponsors has continued, with results from studies at Elura, Rosebery and Cannington released to the sponsors.

Ryan Noble has commenced studies to determine the distribution, species and background abundances of arsenic and antimony in the regolith about the Stawell gold mine, Victoria.

Michael Whitbread is writing his PhD thesis, which addresses recognition of hydrothermal alteration in regolith at Elura (western New South Wales) and Century (northwest Queensland) base metal deposits. The implications of this work have been recognised by a number of mining companies and applied on a worldwide basis. Nevertheless, a proposal to AMIRA International to develop a project to map alteration in regolith above and around mafic-hosted gold deposits, specifically in the Yilgarn Craton, did not generate enough financial support to continue.

Achievements in this theme are set against Milestones 4, 5, 7 and 8.

Geophysical Mapping and Modelling in Regolith Terrains – Dr Graham Heinson, Prof Stewart Greenhalgh, Assoc Prof Jayson Meyers, Dr Anton Kepic, Paul Wilkes, Dr Nick Direen, Dr John Joseph, Brian Barrett, Hashim Carey, Don Hunter, Margarita Norvill, Anousha Hashimi, Nigel Cantwell, Brendan Corscadden, Kim Bone, Allan Cadd and Philip Heath.

New ground-based electrical and electromagnetic (EM) techniques, such as multi-receiver electrical and EM systems, nuclear magnetic resonance, audio-magnetotellurics, electrical resistivity tomography, self potentials and tensor resistivity are being developed to map regolith architecture, hydrogeological properties and bedrock beneath cover.

New techniques are being developed for gravity and magnetic inversions, with the goal of automatically processing an entire survey to produce three-dimensional geological images of the potentially mineralised subsurface. The concept is to work with airborne gradient and tensor data, and to take advantage of new developments in instrumentation, for example the FALCON′ airborne gravity gradiometer.

A major success in the application of integrated regolith and geophysical techniques is provided by the Woodie Woodie Manganese Project sponsored by Consolidated Minerals. Over three million tonnes of manganese ore has been discovered beneath regolith cover. The "blind" discoveries were made using innovative helicopter electromagnetic surveying, including novel processing of electromagnetic and gravity data. Two of the newly-discovered deposits are already being mined and the third, the largest ore body discovered in the district, will be mined in late 2003. It would not have been found without this project. Preliminary results of this project were presented at the CRC LEME and Association of Mining and Exploration Companies (AMEC) Minerals Exploration Seminar in June 2003.

Additional work is being accomplished within student projects. These generally relate to work being undertaken in other programs and themes, with many projects sponsored by companies (MIM, Consolidated Minerals, Gold Fields Australasia, Independence Gold). Achievements in this theme are set against Milestones 3 and 8.

Regolith Expression of Australian Ore Systems – Dr Charles Butt, Dr Matthias Cornelius, Keith Scott, Dr Ian Robertson, Jennie Campbell, Angelo Vartesi and Travis Naughton.

The task of compiling a comprehensive database on the expression of bedrock ore systems in the Australian regolith is continuing. More than 100 case histories, documenting the geochemical signatures of a range of ore deposit styles and commodities in different regolith settings and regions, are being included. The case histories will help develop conceptual dispersion and process models for gold, base metals, platinum-group elements and uranium occurrences in different areas of Australia. Recommendations on appropriate exploration procedures are embedded in the models.

Success of the project relies on the availability and preparation of appropriate case histories, many of which are derived from industry sources. Unfortunately, ongoing changes in the exploration industry are preventing or delaying delivery of some contributions. Achievements in this theme are set against Milestone 1.

To expedite release of this information, a decision has been made to present individual case histories as PDF files on the LEME website (http://crcleme.org.au/RegExpOre), as individual contributions become available. It is intended that the complete collection will be published as a monograph.

Directions for 2003-2004

All projects reported above were reviewed during February 2003. With the completion of many of the smaller projects, the opportunity to group projects regionally to allow better integration of the technical resources of Program members has been taken. Thus next year, the broadly-based work in the Gawler Craton will focus on the central Gawler Gold Province. Work in the Broken Hill Region will be broadened to include regolith modelling in the whole Curnamona Region, with a focused multi-disciplinary study of the White Dam gold deposit. Similarly, work in the Girilambone region will be expanded to consider specific regolith problems within mineralised areas of the Lachlan Fold Belt by conducting one-on-one studies with mineral exploration companies.

Program Leader Dr Colin Pain

Program 3:
Environmental Applications of Regolith Geoscience

Highlights

- Regolith and landform information in upland areas has been shown to improve our understanding of present salt outbreaks and to help predict areas at future risk.
- The details of inland acid sulfate soil formation have been elucidated, and shown to include geological, pedological, mineralogical, geochemical and biological processes.
- CRC LEME has been selected to host international workshops and short courses in Medical Geology and Geoindicators.

Overview

In 2002-2003, the four research themes identified within Program 3 were:

- Regolith background to dryland salinity
- Geophysical mapping and modelling
- Regolith background to acid sulfate soils
- Regolith background to environmental geochemistry

Regolith Background to Dryland Salinity –

John Wilford and Dr Colin Pain.

Last year we reported that remotely sensed data, especially radiometrics, and field verification suggested that much of the salt in groundwater has its origins in upland areas. This was based on work in catchments between Cootamundra and Goulburn in central New South Wales.

This year hydrological indices derived from digital terrain analysis were used to predict areas of salinisation. For example, valley floors and sides are extracted using terrain analysis to delineate areas of possible saline discharge (Figure 1). This figure shows salt scalds (yellow) mapped from aerial photographs superimposed on a digital elevation model (DEM) highlighting likely discharge sites (locally low areas) in blue. Although most of the salt scalds correlate with predicted discharge areas, the modelled DEM alone would not be able to predict the salinity outbreaks in the area.

Figure 2 shows salt scalds superimposed over a regolith map. The map highlights shallow, slightly weathered bedrock in red, and deep, highly weathered bedrock in blue. Areas of thick regolith act as a sponge that stores salts. Combining terrain and regolith attributes substantially improves our prediction of salt outbreaks.

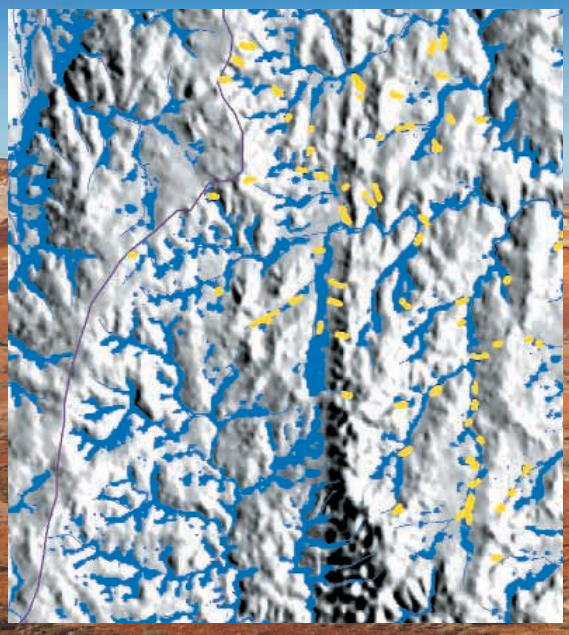
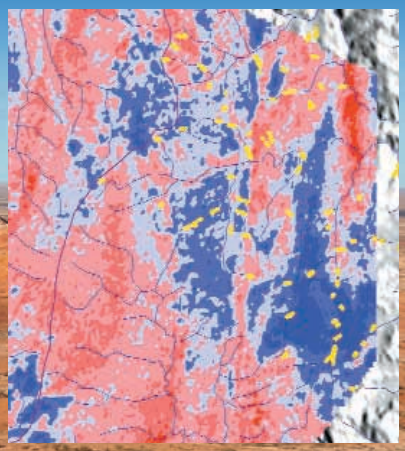


Figure 1 – Salt scalds (yellow) mapped from aerial photographs superimposed over a digital elevation model highlighting likely discharge sites (locally low areas) in blue



Images by John Wilford

Figure 2 – Salt scalds superimposed over a modelled regolith map, shallow slightly weathered bedrock is highlighted in red, and deeper highly weathered bedrock in blue

Photography by Brad Pillans

Relationships between regolith materials and the concentration and mobility of salts were explored through a series of DC resistivity traverses, where salt concentrations show as red on the profiles (Figure 3). A quad-bike geophysical survey, including radiometrics and electromagnetics (EM31/38) was carried out. Holes drilled to depths of 20 m across contrasting regolith materials and along previously surveyed ground DC resistivity transects were used to 'ground truth' the modelled gamma-ray imagery and resistivity surveys. Regolith materials from the drill holes were described, and representative samples analysed for mineralogy, geochemistry, conductivity, moisture, texture, anions and cations.

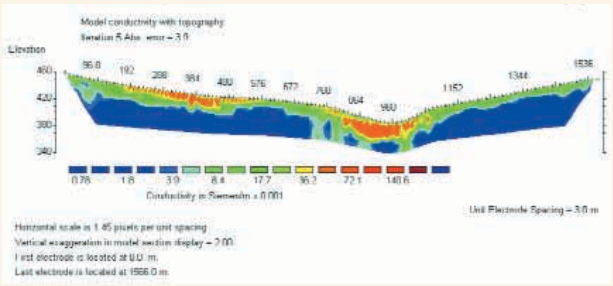


Figure 3 – DC resistivity survey

Initial results show good correlation between regolith depth based on geophysical predictions, and depth found by drilling. At a local scale there is considerable variability in the depth of the weathering front, which probably reflects differences in bedrock mineralogy and structure. For this reason, structural lineaments were digitised and incorporated into a GIS of the area. Thematic regolith maps were generated for future field activities.

Although digital terrain analysis is useful in predicting present day hydrological and geomorphic processes, in many cases it is a poor surrogate for describing palaeo-landscape processes. Understanding both present day and palaeo-landscape processes can be critical in predicting salt stores and mobilisation pathways. Knowledge of how the landscape has evolved and the characteristics of the regolith, combined with digital terrain analysis, enhances our capability to predict areas of present day and future salinity.

The New South Wales Department of Infrastructure, Planning and Natural Resources has become an important partner in the project by sharing data, providing local knowledge for validating results, customising products and potential cost sharing.

There are still some tasks to be completed before this project concludes. These include interpretation of the drill-hole materials for mineralogy, geochemistry, textural analysis and determination of salt load. In addition, bore water samples will be collected over parts of the catchment to better understand the origin of salts and the dynamics of the groundwater system.

Work carried out within this research theme meets the requirements of Milestones 1 and 2. With the realignment of the Centre strategic directions, this theme and its projects will be transferred to Program 4.

Geophysical Mapping and Modelling – Assoc Prof Jayson Meyers, Dr Anton Kepic and Paul Wilkes.

Work has been carried out on the application of geophysical techniques, including new airborne electromagnetic (AEM), and electrokinetic seismic (EKS) systems, for regolith mapping and environmental applications. This includes sponsorship, monitoring, and support of AMIRA project P407b, which is developing innovative software for processing AEM data to produce three-dimensional conductivity depth interval (CDI) information. We are also working with the Australian Nuclear Science and Technology Organisation (ANSTO) on development of EKS for regolith work. Data integration and visualisation for interpretation is an important facet of this work.

Applications include:

- Locating palaeochannels for groundwater studies
- Studying dispersion of metals in the regolith
- Determining *in situ* physical properties, possibly even porosity and permeability
- Cavity detection in mines, below roads, and karstified rock
- Studying sedimentation and weathering
- Mapping depth to buried features

Student work during the reporting period includes:

- Geophysical methods for defining the base and character of palaeochannels
- Using the spectra of radiometric data for soil mapping and hydrogeology
- Delineating a perched aquifer system south of Perth, sponsored by the Western Australian Water Corporation

A report summarising a number of geophysical techniques was published during the year. Work carried out within this research theme meets the requirements of Milestone 5.

Regolith Background to Acid Sulfate Soils – Dr Rob Fitzpatrick, Dr Marian Skwarnecki, Phil Davies, Dr Richard Merry, Dr Jim Cox and Andrew Baker.

Last year we reported activity under this theme mainly in the area of coastal acid sulfate soils (ASS). This year the focus moved to inland areas. Inland ASS and sediments containing sulfidic materials (pyrite), sulfuric horizons (pH < 4; oxyhydroxysulfates) and monosulfidic black ooze (monosulfides) are currently developing in a wide range of landscapes across Australia, generally in association with areas undergoing salinisation.

Oxidation of sulfidic materials and monosulfidic black ooze following the lowering of water tables or soil disturbance is contributing to degraded saline seepages and poor stream water quality. Our objectives this year were to conduct:

- a detailed orientation study in a small catchment (14 km^2) near Mt Torrens in the Mt Lofty Ranges with known ASS overlying mineralised zones to determine detailed biogeochemical mechanisms,
- a regional (1000 km^2) study of seepages containing ASS in the Mount Lofty Ranges, and

- a reconnaissance study of 17 saline seepages, which may contain inland ASS, across Australia (funded by National Dryland Salinity Program 2).

The regional study determined that the geochemistry and mineralogy of ASS commonly have anomalous levels of indicator elements such as As, Bi, Cd, Cu, Pb, Tl and Zn, for which iron oxides have a high sorptive capacity. In other words, ASS may be indicating the presence of hidden mineral deposits on the one hand, or high levels of environmentally toxic elements on the other.

Conceptual or mechanistic models have been developed to explain the formation of inland ASS in saline seepages (Figure 4). These models illustrate the pedological, geological, biogeochemical, mineralogical and hydrological processes involved. Saline groundwaters enriched in sulfate (with elements such as lead and zinc coming from the mineralised zone) seep up through soils and concentrate by evaporation to form various iron-rich minerals. The combination of rising sulfate-rich groundwaters, anaerobic conditions associated with saturated soils, and organic carbon in soils yield pyrite-enriched or metal sulfide materials through anaerobic bacterial reduction of sulfate. When these sulfidic materials are eroded and exposed to air, pyrite is oxidised producing sulfuric acid, which dissolves soil minerals and leads to the precipitation of other minerals.

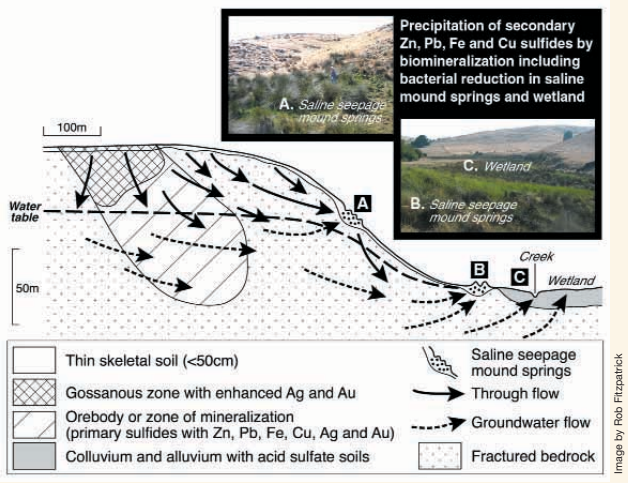


Image by Rob Fitzpatrick

Figure 4 – A model illustrating the pedological, geological, biogeochemical, mineralogical and hydrological processes involved in inland ASS

These poorly crystalline nanoparticulate minerals are abundant in inland ASS environments and may cause less permeable iron-rich layers to form in discharge areas because they can irreversibly clog soil pores. These minerals may also leak (dissolve or move as colloids) into drains, streams and floodwaters, killing vegetation and aquatic life due to the effects of deoxygenated acidic waters rich in metals.

Information from these studies has been used to better understand some of the complex processes operating in these soils, and to explain the mechanisms that lead to degraded soils, erosion and poor water quality. For example, we have found that metals (Cu, Cd, Pb and Zn) are adsorbed by these nanoparticulate minerals via biomineralisation processes (Figure 5). This is of fundamental importance to understand how toxic heavy metals are being transported in these soils. Finally, this basic information has been used to underpin development of methodologies for characterising, predicting and managing the extent and severity of inland ASS.

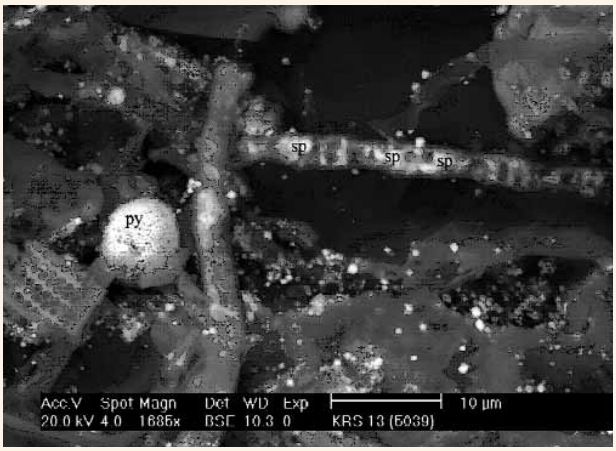


Image by Rob Fitzpatrick

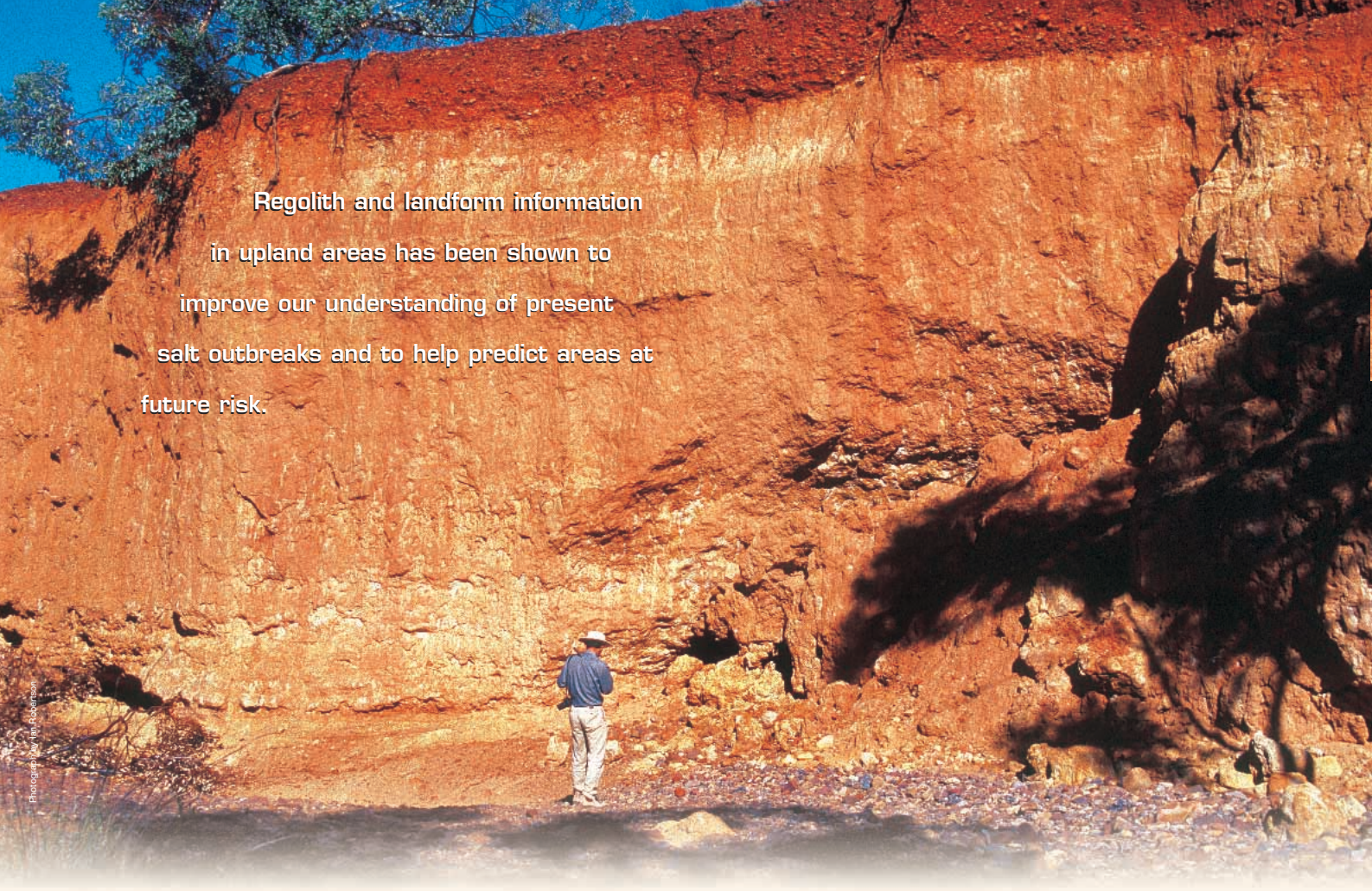
Figure 5 – Sphalerite (sp) in plant rootlets associated with pyrite (py) framboids in inland ASS

Work within this research theme meets the requirements of Milestones 3 and 4 of Program 3, and Milestone 6 of Program 2.

Regolith Background to Environmental Geochemistry – Dr Patrice de Caritat and Dr Colin Pain.

Last year we reported on the application of regolith geochemistry to the growing discipline of geohealth. We have continued to monitor this area, and have been invited by 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), to host an international short course on Medical Geology, Health and the Environment. This will take place in Canberra in December 2003, with presenters travelling from the United States and Sweden.

COGEO-ENVIRONMENT have also invited us to host an International Geoindicators Workshop. Geoindicators are measures (magnitude, frequencies, rates, trends) of geological processes and phenomena, occurring at or near the surface of the Earth and subject to changes that are significant for understanding environmental change over periods of up to 100 years. Most of these indicators are associated with the regolith, and are highly relevant to measuring progress in combating dryland salinity, for example. The primary sponsor of the workshop, the Geoindicators Initiative (GEOIN), is a non-profit international endeavour to encourage the application of geoscience to environmental concerns through monitoring and assessing rapid geological change. The workshop will be held in Canberra in late November 2003, with presenters coming from Canada, Lithuania and Great Britain. In addition to these international connections, we have also continued our connection with the University of Canberra Geohealth Consortium.



On a broader front, several projects were developed on the assessment of regional regolith geochemistry. Australia is one of the last countries in the world to carry out this kind of survey. However, recent low-density geochemical surveys in China suggest that wide-spaced geochemical sampling can provide good knowledge of broad geochemical patterns across a nation. Geoscience Australia has proposed a baseline geochemical study of the Murray-Darling Basin (MDB) in collaboration with CRC LEME, and will provide in-kind support. This baseline study will provide:

- a reference point from which we can monitor future environmental change, and
- valuable insights into mineral potential, natural resource management and land use, human, animal and plant health issues, and agricultural productivity.

The proposed initial pilot surveys will be undertaken in the Riverina and St George regions of the MDB at sampling densities of 1/300 to 1/1000 km^2. These surveys will ascertain suitable sampling methodologies for the remainder of the MDB, with particular reference to spatial distribution of sampling sites, elements analysed, geology, regolith and other sampling and analytical parameters. A similar project has been designed for the Yilgarn Craton of Western Australia, which supports active gold mining and wheat cropping on salinating land.

Work in this area to date has therefore focused on gathering support for new project initiatives, and planning for the coming year. Work within this research theme meets the requirements of Milestones 3 and 4.

Directions for 2003-2004

Projects on regolith background to dryland salinity will be transferred to Program 4 in order to consolidate all dryland salinity work.

Geophysical mapping and modelling will continue. There are a number of exciting new developments, and some of these will be followed up with ANSTO.

In the area of regolith background to acid sulfate soils, we will conduct a regional study of inland ASS in Western Australia, including detailed studies of 20 sites where ASS has recently been identified in highly degraded landscapes. We will also conduct regional and catchment studies on inland ASS in Victoria, New South Wales and Tasmania.

The regolith background to environmental geochemistry will continue to be an important part of Program 3. Next year will see pilot studies of regional baseline geochemical surveys, and the lessons learned will guide work in later years.

CRC LEME will collaborate with GA and the Queensland Department of Natural Resources and Mines in a study in the Upper Burdekin-Fitzroy Catchments, which will interpret available geoscience data from a natural resource management perspective.

Program Leader Dr Ken Lawrie

Program 4:
Salinity Mapping and Hazard Assessment

Overview

This year was a period of rapid development for Program 4, with externally-funded projects ramping up and significant recruitment to enhance our technical capability. Ten projects, largely externally-funded, were initiated.

Nine projects in South Australia and Queensland are funded wholly or in part under the National Action Plan for Salinity and Water Quality (NAP SWQ). These are priority action projects to evaluate the use of airborne geophysics as part of a broader geoscientific and hydrogeological approach to groundwater mapping and salinity management. The projects are multi-agency and multi-disciplinary, with Australian and State government agencies working in collaboration with local catchment management groups. Project outcomes and recommendations will be important in determining the level of uptake of airborne geophysics in other catchments in Australia. Preliminary results look positive as the projects are delivering outcomes that meet user expectations.

Assessing the design and acquisition costs of airborne geophysical surveys for salinity and groundwater mapping is of considerable importance. Early results suggest that order-of-magnitude savings are possible for airborne electromagnetic (AEM) surveys in some landscapes, making some AEM technologies broadly cost-competitive with other airborne geophysical techniques such as gamma radiometrics and magnetics.

Project Structure

The inaugural projects in Program 4 are all commercial, and relate to five specific sites in South Australia – Riverland, Tintinara, Angas-Bremer Hills, Angas-Bremer Plains, and Jamestown. They were developed under a collaborative agreement between the Commonwealth agency, BRS and CRC LEME, to facilitate salinity mapping under the bilateral agreement between the Commonwealth and the State of South Australia, funded by, and reporting to the National Action Plan for Salinity and Water Quality (NAP). A management project and a technology development project (constrained inversion of helicopter AEM) were also established relating to these five project areas, making a total of seven inaugural projects.

In addition an eighth commercial project was developed in 2002-2003 under the NAP program, between CRC LEME and Queensland Department of Natural Resources and Mines (QDNRM).

It should be noted that the delegation of NAP SWQ funds to Catchment Management Authorities (CMAs) and Boards across Australia has added a level of complexity to initiating NAP SWQ projects, with project development now requiring direct negotiation with the CMAs as well as both State and Federal NRM agencies.

A considerable amount of generative work on new Centre-funded projects was carried out, including the commencement of one project on *Salt Mobilisation and Water Quality* with CSIRO Land and Water.

Outputs and milestones for these projects are detailed in the schedules associated with the State – Commonwealth NAP agreement. A distillation of these, plus newly developed milestones for Program 4 are listed earlier in this section of the Annual Report.

Team Development

In the first quarter of the financial year, Program 4 activities centred on the development and assessment of salinity mapping methodologies and technologies by a relatively small core team of scientists based in the Canberra node. With the departure of the Bureau of Rural Sciences from the CRC, skills gaps in hydrogeology and hydrogeochemistry were filled through the re-focusing of staff from CSIRO Land and Water Division on a new project *Salinity Processes and Dynamics*, and through employing additional staff.

There was also a significant addition to the Program team as major projects were developed in South Australia and Queensland. The need to engage contract staff for Program 4 activities is a reflection of the multi-disciplinary nature of many NRM projects, and also an indication of key gaps in the skills base within LEME Core Participants, and particularly in NRM agencies.

During the year CRC LEME employed an AEM geophysicist and contracted three other geophysicists for specific short-term activities. We also engaged two hydrogeologists and a regolith geoscientist/sedimentologist. Staff from the University of Adelaide also assisted in the sedimentological aspects of the Queensland project. Staff numbers were also boosted through the addition of a number of graduate geologists from Geoscience Australia rotating through Program 4. Progress in Team Development is set against Milestone 1.

Salinity Mapping Methodologies and Technologies – Dr Ken Lawrie, Kirsty Beckett, Andrew Fitzpatrick, Matthew Gray, Paul Wilkes and others.

Achievements in salinity mapping methodology development have been submitted as a draft report to the Australian Government Department of Agriculture, Fisheries and Forestry (AFFA). This was largely based around the GILMORE Project datasets in New South Wales. The project demonstrates the value of incorporating airborne geophysics and regolith geoscience in salinity mapping in a variety of landscapes.

Sections of the report have been submitted for journal publication, and extracts submitted to the *National Review of Salinity Mapping Methods and Technologies in the Australian Context*, due to report in late calendar 2003. This review should provide guidelines on the appropriateness of various salinity mapping techniques in different landscapes and for a range of scales. Such information will greatly assist catchment management authorities to decide upon required biophysical datasets and strategies, and is likely to have a bearing on future business opportunities for CRC LEME.

The LEME submission to this review, which includes many post-GILMORE insights, highlights the value–adding that an integrated geoscience approach (regolith geoscience, geophysics, hydrogeology and hydrogeochemistry) brings to understanding the process and dynamics of mapping salinity and groundwater systems. Recommendations are also made for further development of Groundwater Flow Systems and Catchment Characterisation Frameworks for salinity and groundwater mapping and assessment. In particular, the need to incorporate information on sub-surface regolith, salt store and geological structure is highlighted, as is the desire to develop geospatially explicit frameworks at sub-catchment scales to support on-ground salinity and groundwater management actions.

The submission includes early results from the new project, called *Cost-effective airborne geophysics and landscape analysis for salinity mapping*. This study shows that an integrated geoscience approach that considers present landforms and buried landscapes can assist with designing cost-effective surveys for salinity mapping and broader NRM applications. This project has shown that in three depositional landscapes within the Murray-Darling Basin, a line spacing of one kilometre could have successfully mapped most sub-catchment scale landscape elements important for understanding salinity in the sub-surface. Even wider line spacings could be achieved in one survey area. In general, this suggests that for a fixed number of line-kilometres, significant savings in survey acquisition costs might be achieved in comparable landscapes.

We are continuing to develop salinity mapping methodologies, and assess new technologies. A new joint project with QDNRM will add value to Queensland's Salinity Hazard Mapping Methodology. Outputs will be incorporated into both the new Rural Industries Research and Development Corporation (RIRDC) and Burdekin Projects. This project demonstrates the benefits of applying new software developed as part of AMIRA project 407b (Program 3) to obtain significant increases in data resolution. Progress on this aspect is measured against Milestone 5.

South Australian Projects – Dr Tim Munday, Dave Gibson, John Wilford, Heike Apps, Andrew Fitzpatrick, Dr Kok Piang Tan and Mr Ross Brodie.

Projects in South Australia were undertaken in Riverland, Tintinara, Jamestown, Angas-Bremer Hills and Angas-Bremer Plains. Research in these sites is being conducted in collaboration with CSIRO Land and Water, PIRSA, and Bureau of Rural Sciences (BRS). All the projects involve close community consultation.

In the Mallee Highlands Zone (*Riverland* and *Tintinara* projects), there has been an increase in salinity of groundwater resources as a consequence of dryland agriculture and higher rates of recharge. Where present, near-surface clay layers appear to reduce the adverse affects of irrigation recharge due to the leaching of salt accumulated in the soil zone. Irrigation schemes planned to coincide with the distribution of these clay layers, rather than more permeable sand, will preserve the quality of the existing groundwater resource. Management of this issue should be aided by a better understanding of the distribution of the clay layers. These are relatively conductive and therefore represent a target for airborne EM systems.

In the *Riverland Project*, our role is to calibrate and invert helicopter frequency domain electromagnetic (HEM) data in order to determine rates of groundwater recharge in this test area in the lower Murray. A secondary objective is to define the variability in conductivity of the deeper aquifer, in order to constrain groundwater solute models designed to predict water quality within the aquifer. The *Tintinara Project* has similar objectives, and the HEM data and derived products help to determine rates of groundwater recharge (Mallee Highlands Zone) and variations in groundwater quality (Coastal Plain Zone). In the Coastal Plain Zone, where water tables are near the surface, the aim is to better understand the variability in groundwater conductivity in terms of salinity, variations in soil type and topography. These factors are

important in developing plans for preserving biodiversity in the region.

In the *Angas-Bremer Hills Project*, scientists are using gamma-ray spectrometry and DEMs to delineate regolith materials and predict geomorphic and hydrologic processes in an upland landscape. The complementary *Angas-Bremer Plains Project* area contains some important irrigation schemes and aquatic habitats that are at risk from rising groundwater and secondary salinity. Groundwater systems are believed to be influenced by varied regolith and sedimentary systems. This complexity requires land management strategies founded on an understanding of the origin, nature, character and distribution of regolith materials in three dimensions. The main objective of the project is therefore to provide a regolith framework to better understand the hydrology of the area. Similarly, the objectives of the *Jamestown Project* are to develop a better understanding of the three-dimensional basis of the landscape, and the distribution of salt stores and groundwaters.

In the South Australian projects CRC LEME has made contributions that appear to be changing the ways in which airborne geophysics and regolith geoscience are used by land managers. Some outcomes are:

- In Riverland, a map of clay thickness, derived from a HEM survey and validated by ground studies and drilling, shows that the distribution of fine-textured clay units is more complex than the simple maps produced from widely spaced drilling (Figure 1). It has also been found that the clay layers are not all the Blanchetown Clay as previously thought, but comprises a range of fine-textured materials of different age and origin. The new HEM conductivity maps of clay distribution and thickness are helping to determine the consequence of saline groundwater recharge in areas of cleared land, the implications for irrigation zonation, and the relationship to salinity discharge into the Murray River. Such maps should also be of benefit in locating future sites for salt disposal basins.
- HEM surveys have also been used to map a series of features in the underlying aquifer, the Loxton-Parilla sedimentary system. Facies variations within the aquifer are attributed to alternating strandline sand ridges and intervening clay accumulations (Figure 2). Mapping these features within the aquifer has consequences for the location of production bores for salt interception schemes, and aquifer management more generally.
- At Tintinara a clay thickness map is helping to determine where to site irrigation to ensure longevity of the groundwater resource.
- At Angas-Bremer Hills, gamma radiometrics validated by regolith mapping and ground electromagnetics and drilling is helping to provide a picture of salt stores and links between regolith landscapes and stream salinity. This project contributes to the larger picture of salinity trends and salt balance in Mt Lofty Ranges.
- At Jamestown, airborne magnetics and AEM identified a complex palaeo-valley system, which is providing insights into the geological features of salt stores in valley-fill sediments. This provides a biophysical basis for developing an improved hydrogeological and salinity management model in the area.
- Work at Angas-Bremer Plains has given an improved understanding of the soils-landscape framework that is providing better constraints on hydrogeological concepts and models.

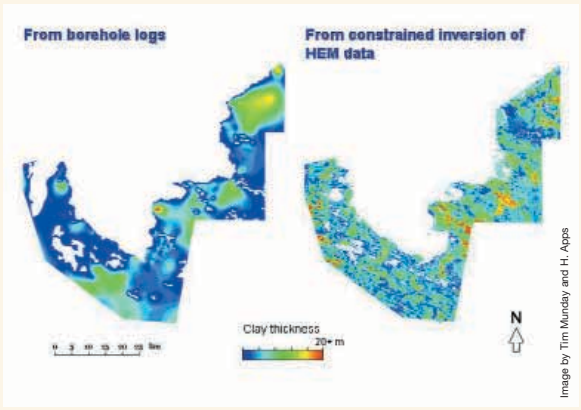


Figure 1 – Comparison of estimates of thickness of Blanchetown Clay from drilling and HEM

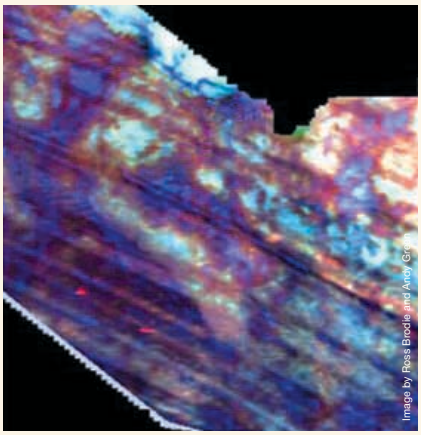


Figure 2 – Riverland Project HEM image of the Parilla Sands, alternating dark and light bands equate with strand line deposits

Overall, the South Australian projects are meeting or exceeding user expectations. More general lessons that have been learned include:

- there are significant benefits of testing outcomes by forward modelling using geophysical and related data in a staged process to select the best technology prior to committing significant funds for airborne geophysical surveys,
- it is critical to have well defined objectives and targets, and
- a multidisciplinary approach is important.

In South Australia another highlight was the completion of Brian Barrett's Masters thesis *Developments of River Based Geophysical Methods for Saline Hydrogeological Studies.* In conjunction with local industry and NRM agencies, this project developed a novel method for mapping resistivity of river bed sediments, leading to the identification of salinity hot spots in the bed of the River Murray. This has since led to the design of an additional salt interception scheme bore, and to the commissioning of further river EM surveys.

Progress on this research is measured against Milestones 2,3 and 4.

Queensland – Dr Ken Lawrie, Dr Jonathan Clarke, Andrew Fitzpatrick, Amy Kernich, Ben Maly and Dr Colin Pain.

The NAP SWQ-funded project in the Lower Balonne Catchment in southeast Queensland is in collaboration with the Queensland Department of Natural Resources and Mines and BRS. The study evaluates the use of airborne gamma radiometrics and time-domain AEM, for mapping surficial floodplain deposits and groundwater systems. This is a novel application of AEM technology to the study of large inland fluvial floodplains, in an area where the distribution of salts is unknown, and where the hydrogeology is thought to be dominated by regional groundwater flow systems.

In the Lower Balonne Project, the highlights are:

- Ground validation showed significant problems with original AEM products, which had poor correlation with borehole conductivities. This appears to be due to a problem with a survey geometry correction factor, and also due to the presence of a variably conductive rather than resistive basement.
- The AEM data was re-processed in a number of steps, leading to a rise in confidence level from 20% to approximately 80%. It is now recognised that highly conductive features in areas of conductive basement lie at greater depths than previously thought, while other conductive anomalies are now mapped at higher levels in areas of less conductive basement. A comparison of the original product with imagery based on geometry corrections and constrained inversions is shown (Figure 3).
- Surface mapping based on the combined use of aerial photographs, LANDSAT TM, gamma radiometrics, and AEM has identified several geomorphic units that had not previously been recognised. This surface map is an important new data layer that will assist in land-use planning, and in development of surface and near-surface hydrogeological models.
- Integrated palynology and regolith sedimentology using drillcores demonstrate an unusually thick Quaternary sedimentary sequence in a fault-bounded trough. This sequence probably reflects deposition in an active fault basin (Dirrinbandi Trough). AEM images also show a complex three-dimensional architecture and groundwater flow system not readily apparent from surface datasets.

This aspect of research is measured against Milestones 4 and 5.

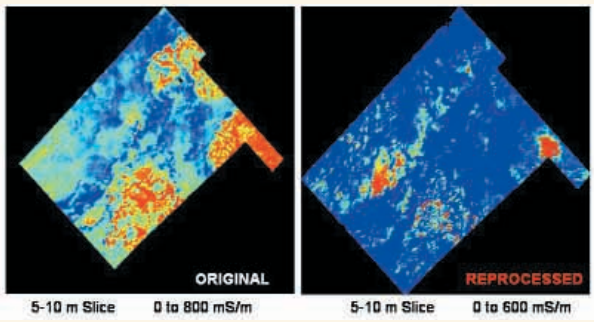


Figure 3 – Lower Balonne Tempest AEM survey. Images show contrasting processing to produce Conductivity Depth Slices, original data produced without access to ground data (left), and with ground data to assist calibration (right)

Salt Mobilisation and Water Quality – Dr Andrew Herczeg, Dr Jim Cox, Phil Davies, John Dighton, Dr John Foden, Dr Rob Fitzpatrick, Warren Hicks, Dr Dirk Kirste, Dr Sebastien Lamontagne, Megan Lefournour, Kerryn McEwan, Dr Richard Merry, Mark Raven, Dr Steve Rogers, Dr Mirko Stauffacher, Dr Glen Walker and John Wilford.

This ambitious three-year project is the primary vehicle for bringing the expertise of CSIRO Land and Water into other projects in Program 4. It seeks to develop the capability to predict and manage dissolved salt loading mechanisms and stream loads in a variety of regolith and geographic settings within the Murray-Darling Basin. Work commenced in 2003 producing the following highlights and achievements.

- Geophysical mapping of NAP project areas completed with promising results for locating regolith salt stores and aquifer properties - especially for the Bremer Hills and Jamestown sites.
- From collection of data from several floodplain sites, sulfur stores and microbial processes have been shown to be highly variable. This has implications for floodplain rehabilitation strategies which in turn affects the efficacy of salinity amelioration in the River Murray.
- Development of modelling and geochemical approaches for estimating time scales for salt and water mobilisation. This gives confidence in being able to predict the extent and time scale of salinisation under various scenarios.
- Completion of reconnaissance sample collection of River Murray floodplain sites and liaison with State agencies for collaborative support.
- Successful method development for analysis of $^{34}S/^{32}S$ on dissolved and mineral sulfates.

Progress of this project is measured against Milestone 6.

Outlook for 2003-2004

One focus is to complete the reporting of various NAP SWQ-funded projects by January 2004. These projects will be subjected to peer review by relevant agencies prior to publication, and the reviews are likely to enhance the opportunity for securing similar projects in the immediate future.

Several new CRC-funded pilot projects will commence in the new financial year. The projects include *Groundwater Flow Systems, Cost-Effective Airborne Geophysics and Landscape Analysis, Aquifer Parameterisation, Regolith, Salinity and Trees, Lower Burdekin Aquifer and Salinity Mapping, Upper Burdekin/Fitzroy Geoscience Datasets for Salinity Mapping and Broader Natural Resource Management Application,* and *Salt and Metal Mobility in the Murray-Darling Basin.* Some of these projects have already attracted external funding. Significant progress on Salinity Processes and Dynamics is also anticipated.

The team has been invited to present at a number of important conferences and workshops in the coming financial year.

Many of the salinity projects in Program 4 are delivering outcomes that are likely to benefit the mineral exploration industry. The knowledge being developed is important for understanding metals dispersion within the regolith, while AEM surveys in South Australia have benefits by mapping fossil shorelines which often trap heavy mineral sands that have economic content of titanium minerals.

Education and Training

Education and Training Coordinator
Assoc Prof Pat James

Deputy Education and Training Coordinator
Dr Ian Roach

Scholarship Program

During the 2002 and 2003 academic years CRC LEME dramatically increased its funded postgraduate and Honours cohort by more than 100% and can now realistically claim to be operating a Graduate School given the size, breadth and quality of its education and training program. At the end of calendar 2002, 24 LEME Honours students graduated from the core participant Universities, with nine first class and 15 second class degrees. Many of these students were soon employed in relevant industries or took up postgraduate opportunities within and outside CRC LEME.

A national and international media advertising campaign in October 2002 sought applicants for 30 Geoscience Scholarships at a total value of more than $600K. The campaign yielded more than 60 applicants for PhD, Honours and Undergraduate Summer Scholarships, however, for a variety of fortunate reasons, almost 50 students eventually joined CRC LEME to undertake research projects in 2003, significantly exceeding initial targets. After the 2003 summer vacation period 21 new PhD, one Masters and 15 Honours students accepted offers of LEME scholarships, the majority of which were part scholarships, supplemented by other agencies.

Three students each at ANU and Curtin University received APA or University scholarships and were therefore awarded supplementary and operating funds by CRC LEME. At University of Adelaide the newly appointed Vice Chancellor oversaw a University-wide program to increase postgraduate numbers by offering a large number of University half scholarships for students with opportunities to gain matching funding. From this initiative, together with International and APA success, Adelaide was able to successfully offer 12 PhD scholarships to students to work within CRC LEME. At the same time, a collaborative research program jointly developed between the new University of Adelaide School of Earth and Environmental Sciences, the South Australian Department of Water, Land and Biodiversity Conservation, CRC for Plant-based Management of Dryland Salinity and CRC LEME supported three of these new PhD students to start research on a project to monitor and assess the problems of salinity, water quality and drainage solutions in the southeast of South Australia.

The consolidation of eastern Australian education programs to the ANU also led to a further advertisement for scholarships and up to six new PhD and Honours scholarships have recently been offered there.

The Summer Scholarship program within CRC LEME was reinstated in 2002-2003 and eight scholarships were offered. At University of Adelaide six Summer Scholars undertook collaborative research and joined LEME research teams in fields as diverse as geophysical modelling of fluid flow in porous media, geochemistry of weathered volcanics and GIS integration and visualisation of mine waste data. Although two students were offered Summer Scholarships at ANU only one took up the stipend and worked with Dr John Field on the symbiotic relationship of soils and plants.

With 48 PhD, five Masters and 20 Honours students currently enrolled at six Australian universities, the scholarship program of CRC LEME makes up the largest single research group of the entire Centre. Students are fairly evenly distributed amongst the three Core Participant universities, with 20-25 students in each. The group spans the full spectrum of LEME activities, contributing fundamental science to all of the programs. About 60% of the students currently study under Programs 1 and 2, with the remaining 40% in the environmental areas of Programs 3 and 4. The Centre is well on target to meet its commitment to graduate 60 PhD students during its lifetime.

CRC LEME already offers world-class, relevant regolith education to the minerals exploration industry (see MTEC overleaf) and is now developing courses and workshops to satisfy demand within the areas of land management, environmental assessment and dryland salinity. Commencing in 2004, these will help to satisfy a growing demand for environment-based knowledge which can be supplied from LEME research.

The vision for Education and Training to be a world-class education and training provider is becoming a reality. Many research students attracted to the Centre over the last year have been of such quality that they successfully gained Australian Postgraduate Award (APA) or industry scholarships before they applied for LEME scholarships. These students have all been offered LEME top-up scholarships, consisting of additional stipend and operating funds, as a reward for their excellence. This external scholarship success has brought into the Centre more than $350K in external scholarship funds in the reporting period as well as significant operating and in-kind support from collaborating agencies and companies. We will continue to offer these stipends in the new financial year, as an incentive to attract excellent students. Undergraduate students are also benefiting, with Core Participant universities now offering undergraduate training in a structured program leading to Honours and postgraduate regolith studies.

The Education and Training Program is supported by an active committee that is responsible for awarding scholarships, running regolith symposia and teaching and coordinating courses. The committee consists of Assoc Prof Pat James, Dr Mehrooz Aspandiar, Dr Steve Hill, Dr Richard Greene, Dr Ian Roach and Maureen Blake. The commitment of the committee members is gratefully acknowledged, particularly the contributions of Steve Hill, who stepped down as Deputy Education and Training Coordinator in June 2003 but remains as a committee member.

Photograph by Ian Robertson

Student Highlights

- Frank Reith (PhD student, ANU Department of Geology) was awarded the Taylor and Eggleton Book Award for overall excellence for his paper on the interactions of gold with microorganisms in regolith, presented at the *Eastern Australian Regolith Conference*, November 2002.
- Leanne Hill (PhD student, ANU Department of Geology) received the Editor's Choice Award for best papers at the *Eastern Australian Regolith Conference*, November 2002.
- Angela Ratchford (Honours student, University of Canberra School of Resource, Environmental and Heritage Sciences) received the Regolith Glossary Award for best presentation at the *Eastern Australian Regolith Conference*, November 2002.
- Mark Paine (PhD student, Curtin University of Technology Department of Applied Geology), together with Dr Ravi Anand, was awarded the prestigious Stillwell Award for best paper of 2002 in the *Australian Journal of Earth Sciences*.
- Sean Mahoney (PhD student, Adelaide University Department of Geology and Geophysics) was awarded the Best Poster Award at the *11th Australian Remote Sensing and Photogrammetry Conference* in Brisbane, September 2002.
- Kate Selway (Honours student, University of Adelaide Department of Geology and Geophysics) won the Newmont Prize for Top Geophysics student at University of Adelaide in 2002.
- Brian Barrett (MSc graduate, University of Adelaide Department of Geology and Geophysics) received an Overseas Student Research Scholarship to study at Leeds University in 2003.
- Philip Heath (PhD student, University of Adelaide Department of Geology and Geophysics) received an AusIMM Bursary in 2002.

Minerals Tertiary Education Council (MTEC)

The Minerals Council of Australia (MCA) is a Core Participant of CRC LEME, and provides funding to develop industry-specific short courses for students and industry geoscientists, under the Minerals Tertiary Education Council (MTEC) Program.

2002-2003 saw our commitment to the MTEC program flourish with the delivery of three Honours-level courses and one Masters-level course to over 70 participants from industry, government and academia. The popularity of these courses continues to grow, with courses in *Introduction to Hydrogeochemistry, Regolith Mapping and Field Techniques,* and *Environmental Mineralogy.* These attracted participants from many eastern Australian universities, Government agencies and industry. The *Regolith Geology and Mineral Exploration* Masters course, held at the University of Canberra over 12-23 August 2002, attracted 13 participants from University of Adelaide, Barrick Gold Corporation, Sons of Gwalia, University of New South Wales, University of Canberra, New South Wales Department of Mineral Resources (NSW DMR), Primary Industries and Resources, South Australia (PIRSA) and the South African Council for Geoscience. The success of these courses highlights the benefits of running relevant, industry-linked regolith geoscience programs, despite the current tough economic outlook we are experiencing in the Australasian minerals industry. MTEC courses are being planned well into the future, with the focus on the transfer of regolith knowledge and skills to the minerals industry.

It is hoped that the MTEC program will be extended beyond 2004 with the introduction of the Minerals Industry Postgraduate Coursework Program (MIPCP). This will offer a series of modular, industry-focused units of two days duration, capable of being delivered on- or off-site on a short turnaround basis. MIPCP units will offer an ideal compromise to industry professionals seeking extension courses or a professional Masters degree, who do not have time to attend five- or ten-day courses. CRC LEME will be participating in MIPCP by offering units in rock weathering, regolith sampling media (including geobotany), regolith geology, regolith mapping and mineral exploration strategies for regolith-dominated terrains.

MTEC Strategic Review

In May 2003, the results of a strategic review of the Tertiary Education initiatives were released. The Eureka Award-winning MTEC initiative was found to be satisfying a demand from the minerals industry for better-trained graduates. We expect MTEC, initially funded for three years, to be given a two-year extension given the positive review. CRC LEME was acknowledged as one of the leading participants in the initiative, offering world-class, relevant courses to industry and academia. This very positive result reflects the dedication of LEME staff and researchers to the MTEC initiative. Centre staff and students whom have taught in MTEC courses, and the Visual Resources Unit at ARRC, are gratefully acknowledged for their support, dedication and professionalism.

Virtual Regolith Worlds

During the reporting period, CRC LEME funded an innovative project investigating the application and influence of new Information and Communication Technologies to its research and teaching under the banner of Virtual Regolith Worlds (VRW). Such learning technologies are currently being widely developed in the education arena to facilitate remote and flexible learning, to increase the value of synchronous and asynchronous communication amongst learners, teachers and researchers, and to take advantage of the spread of digital data capabilities in scientific research and technology transfer.

Within the LEME project, individual sub-projects were supported and developed. These included the purchase and trialing of desktop IP (internet protocol) videoconferencing units within each of the core participant nodes, to aid real-time face-to-face communication between staff, students and researchers in committee meetings, seminars and workshops. Another sub-project involved setting up a web server for Matlab modelling and visualisation software, to allow real-time interaction via the web with sophisticated geochemical and geophysical models.

Finally, two Computer Aided Learning packages were chosen for development, one on the use of *Airborne Radiometrics in Regolith Studies* and one on *Regolith Studies*. These are both ready for evaluation, before being used as an adjunct to teaching in postgraduate and Honours shortcourses in flexible and distance delivery modes.

Regolith Conferences and Symposia

During 21-22 November 2002, CRC LEME hosted the successful *Eastern Australian Regolith Conference* at the University of Canberra. The Conference attracted 75 registrants, of whom 38 were from the Centre and the rest from State or Australian Government agencies, universities and industry. It included a half-day field trip to prominent regolith and landscape features around Canberra. The conference was open to all researchers in regolith or related disciplines but was principally focused on student research and culminated in the publication of *Regolith and Landscapes in Eastern Australia*, a volume of extended abstracts. The University of Adelaide hosted a smaller symposium, dedicated to the work of Honours students.

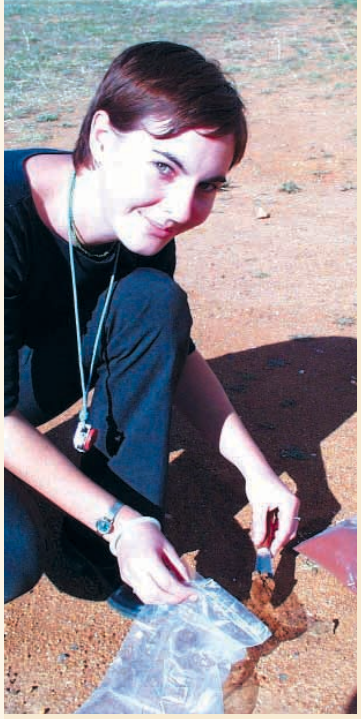
The two meetings were used to test whether CRC LEME could successfully host small, inexpensive conferences quickly and efficiently. As seeds for knowledge transfer and research development, each meeting was highly successful. Based on this success, the Centre will host three symposia in November 2003, at the University of Adelaide, Australian National University and Curtin University of Technology. Each will bring together regolith researchers from the nodes, highlighting research by students, and culminating in the publication of a single volume of extended abstracts.

Acknowledging the University of Canberra

In December 2002 the University of Canberra withdrew from the Centre, regretfully severing an eight year relationship with the Education and Training Program. Prof Graham Taylor instigated and successfully led the Program in CRC LEME 1 before handing over to Assoc Prof Pat James in CRC LEME 2. We gratefully acknowledge the dedication of Graham Taylor and other Centre staff at the University, including Dr Simon Benger, Dr Owen Cartledge, Dr Xiang Yang Chen, Glen Fisher and Bernadette Kovacs.

CRC LEME Legacy

A major objective of any Cooperative Research Centre is to ensure its fundamental knowledge and skills are used by later generations. The Education and Training Program is actively engaged in knowledge transfer by both conventional and electronic means. The program hosts short courses, workshops and meetings, publishes notes and is now involved in the creation of interactive learning products via CD-ROM and the web through the VRW project. Perhaps the greatest legacy the Centre will leave, however, is over 60 PhD and a greater number of Masters and Honours graduates to advance the regolith discipline.



Photograph by Tania Dhu

Above: **Amy Kernich hard at work taking surface regolith samples – ground validation and sample collection.** ***(photo courtesy of Geoscience Australia).***

Above right: **Philip Heath (Adelaide University) surveying with Nanotem at Tunkillia**

Far left: **Andrew Christian (University of Canberra Honours student) taking copious notes during the Regolith Mapping and Field Techniques course held at Silverton, NSW, in 2002**

Student Snapshots

Mark Paine, CRC LEME PhD Student

"Having worked with CRC LEME 1 for four years prior the commencement of my PhD in 2001, I was well aware of the quality of many of the individuals who formed the organisation. These, along with the members of the new CRC, have continued to provide me with support and guidance during the course of my project. I have thoroughly enjoyed this interaction and have found it easy to contact people both within my own organisation and across the other Core Participants. The financial and logistical support offered by the Centre has also been extremely beneficial to the progress of my work".

Amy Kernich, CRC LEME Honours graduate (2002)

"I am now working for Geoscience Australia, in their graduate program. I found that CRC LEME gave me many opportunities for professional development through my Honours year. The scholarship funding covered the project costs for my research and I was able to attend extra courses and presentations. I attended a week long short-course in Canberra on regolith mapping and geochemistry that was highly beneficial to my Honours work. Being associated with CRC LEME also gave me extra opportunities to meet and communicate with professional scientists. Overall, the Centre gave me professional exposure, a greater awareness of the industry, and a view of the career possibilities that existed. This put me in good stead to apply for positions at the completion of my Honours year".

Postgraduate Students Associated with CRC LEME Who Completed, Commenced or Continued their PhD or MSc Studies During the 2002-2003 Reporting Period

Postgraduate Students

Student	Project Title	Program	Supervisor/s	Funding	Year	Institution
Doctor of Philosophy (PhD) Graduated						
Juan-Pablo Bernal	Assessment of U-decay series isotopes as a geochronometer for weathering processes	1	Tony Eggleton	-	1999-2003	ANU
Shawn Laffan	Inferring regolith characteristics using topography and vegetation	4	Brian Lees/Tony Eggleton	APA	1995-2002	ANU
Melissa Spry *	Landscape Evolution at Cobar	1	Ken Queen/Graham Taylor	LEME	1997-2003	UC
Master of Science (MSc) – Graduated						
John Angeloni	Acid sulfate soils in Metropolitan Perth	3	Ron Watkins	-	2002-2003	CUT
Brian Barrett *	Development of river based geophysical methods for saline hydrogeology	3	Graham Heinson/ Karin Hatch	APA/Austwater/ Zonge/ LEME Top-up	2002-2003	UofA
Anousha Hashemi	Constraints on inversion of Tdhem data for near surface conductivity mapping	3	Jeyson Meyers	-	2002	CUT
Graeme Raybone	Mineralisation and regolith evolution in the Mount Bundy region, NT	2	Graham Taylor	-	2001-2003	UC
Doctor of Philosophy (PhD) – commenced and continuing						
Andrew Baker *	Isotopic and geochemical studies of soil-regolith-rock interactions with ground waters, stream waters and base metal mineralisation: implications for mineral exploration and the environment	1	Rob Fitzpatrick/Ron Watkins	APA/ LEME Top-up	2002-	UofA
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 composition from major, trace and rare earth element composition, using numerical modelling procedures	1	Andreas Schmidt-Mumm/ Patrick James/ Martin Williams	LEME	2002-	UofA
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, WA	1&2	Ken McQueen/ Graham Taylor/Colin Pain	GA	1998-	UC
Tania Dhu *	Electrical and EM studies of regolith and sub-regolith structure	1	Graham Heinson/ Stewart Greenhalgh/ Patrick James	LEME/UofA	2003-	UofA
Katie Dowell *	Low temperature silicification in the regolith using black opal as a primary example	1	John Mavrogenes	APA/ LEME Top-up	2003-	ANU
Michael Durkey	Effect of drains on soil properties in SE SA	4	David Chittleborough/ Steve Hill	UofA/DWLBC	2003-	UofA
Kathryn Fitzsimmons *	The interaction between transverse and longitudinal dunes associated with the playas of the Eyre Basin: a chronology and 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 SA saline and acid sulfate soils	1	Rob Fitzpatrick	LEME/UofA	2003-	UofA
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
Hazel Hayward *	The origin, distribution and palaeoclimatic significance of calcretes on the central Gawler Craton and in the southern Murray Basin	1&2	David McKirdy/Karin Barovich	LEME/UofA	2003-	UofA
Philip Heath *	3D automated inversion of potential field tensor data	2	Stewart Greenhalgh/ Nick Direen	LEME/UofA	2003-	UofA
Jonothan Higgins	Palaeochannels of the Kingoonya System, Gawler Craton, SA	1	Larry Frakes/Vic Gostin	-	1998-	UofA
Leanne Hill *	Chemical dispersion pathways in a variety of landscapes	1	Tony Eggleton/ Patrice deCaritat/John Field	APA/ LEME Top-up	1999-	

Postgraduate Students Associated with CRC LEME Who Completed, Commenced or Continued their PhD or MSc Studies During the 2002-2003 Reporting Period (cont'd)

Student	Project Title	Program	Supervisor/s	Funding	Year	Institution
Karen Hulme *	Biogeochemistry of river red gums (*Eucalyptus camaldulensis*) in the Curnamona region of SA and NSW	1&2	Steve Hill	LEME/UofA	2003-	UofA
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, SA)	1	Patrick James	LEME/UofA	2002-	UofA
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 *	Investigate, quantify and model biological factors in regolith formation in humid temperate landscapes in SE Australia	1	John Field	LEME	2003-	ANU
Sean Mahoney	Evaluation and development of use of multi-temporal imagery for water condition monitoring, environmental and wetland management in the SE of SA	4	Megan Lewis/ Patrick James/ Bertram Ostendorf	UofA/DWLBC	2003-	UofA
Wendy McLean *§	Groundwater quality, recharge and sustainability in the lower Namoi Valley	3	Jerzy Jankowski/ Patrice deCaritat	APA/CottonGrowers/ DLWC/LEME Top-up	1999-	UNSW
Andrew McPherson *	Salt sources and storage Billabong Creek SE NSW	3	Tony Eggleton/Richard Greene	LEME	2000-	ANU
Aija Mee *	Lacustrine and soil organic matter as proxies for mid-latitude Holocene environmental change in SE Australia	1	David McKirdy	APA/ LEME Top-up	2003-	UofA
David Mitchell	Increasing spatial resolution of soil maps using geophysics and GIS	4	Megan Lewis/ Bertram Ostendorf	UofA/PBMDS	2003-	UofA
Ryan Noble *	Dispersal mechanisms of As and Sb in regolith and surface deposits in the vicinity of buried Au ore bodies, NW Victoria: implications for Au prospectivity and environmental management	2	Ron Watkins	APA/ LEME Top-up	2003-	CUT
Margarita Norvill *	The 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, W Vic, with implications for salinity management and heavy mineral exploration	1	Mehrooz Aspandiar	CUPS/ LEME Top-up	2001-	CUT
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/UofA	2003-	UofA
Frank Reith *	Interactions of microbes and Au in regolith in moderate, arid and tropical climates	1	Bradley Opdyke/ Bear McPhail	PRS/ 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 W NSW: a framework for comparison of regolith dating methods	1	Brad Pillans	ANU/ LEME Top-up	2002-	ANU
Greg Street	Interpretation of geophysics for catchment management	3	Norm Uren/Jayson Meyers	APAI Farm Map Consulting/Tesla 10	2000-	CUT
Mark Thomas *	Combining remote sensing and terrain analysis with conceptual toposequence models in two dry saline land affected areas (Jamestown and Mt Lofty Ranges) for up-scaling root zone constraints	3	Graham Heinson/ Rob Fitzpatrick/Megan Lewis	LEME/ DWLBC/ PIRSA	2002-	UofA
Michael Turner *	3D pore scale characterisation of the permeability and porosity of regolith materials	4	Bear McPhail	APA/ LEME Top-up	2002-	ANU

Postgraduate Students Associated with CRC LEME Who Completed, Commenced or Continued their PhD or MSc Studies During the 2002-2003 Reporting Period (cont'd)

Student	Project Title	Program	Supervisor/s	Funding	Year	Institution
Victor Waclawik *	The regolith geology and landscape evolution of Umbum Creek, West Lake Eyre, SA	1	Simon Lang/ Steve Hill/Patrick James	LEME/UofA	2003-	UofA
Michael Whitbread *	Using lithogeochemistry to map cryptic alteration: Elura and Century case studies	2	Ken McQueen/ Leah Moore	Pasminco/ LEME Top-up	1999-	UC
Pierre-Allain Wulser *	Mobility of U and rare earth in the Mt Painter-Lake Frome-Curnamona Craton Regions, SA: Geochemical and temporal controls	2	Joel Brugger/John Foden	IPRS/ LEME Top-up	2003-	UofA
Master of Science (MSc) – commenced and continuing						
Hashim Carey	Quantitative analysis of Mise-a-la-Masse responses through innovative methods	2	Graham Heinson	Newmont/ LEME	2002-	UofA
Troy Cook *	Evaluation of two gross pollutant traps in minimising geochemical contaminants from entering two stormwater catchments of contrasting styles	3	Ron Watkins	LEME Suppl.	2002-	CUT
Michael Holzapfel	Dryland salinity hazard mitigation along the Booberoi – Quandialla transect, central west NSW	3	Leah Moore/Xiangyang Chen	NSW DLWC	1999-	UC
Vicki Stamoulis	Using hyperspectral and multiple data sets for mineral mapping in basement areas of SA	1	Patrick James/Alan Mauger	PIRSA	2000 -	UofA
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 Suppl.	2002-	CUT
Master of Philosophy (Mphil) – 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

* denotes LEME Scholar § denotes thesis submitted, under assessment

Honours Students Associated with CRC LEME During the 2002-2003 Reporting Period

Honours Students

Student	Project Title	Program	Supervisor/s	Funding	Year	Institution
Honours Degree – graduated						
Gabriel Anderson *	Biological factors in regolith formation		John Field	LEME	2002	ANU
Ian Anderson *	Regolith and groundwater at Balladonia	3	Jonathan Clark/Patrice de Caritat	BPA/LEME	2002	ANU
Katherine Broxholme *	Investigation into the effects of 3D conductivity structures in the regolith on magnetotelluric measurements	2	Graham Heinson	LEME/MIM/ ASEG	2002	UofA
Barrett Cameron	Rapid acquisition of audio frequency magnetotellurics	2	Anton Kepic	-	2002	CUT
Carly Chor	Reconstruction of late Quaternary climates in semi-arid NE of SA, Flinders Ranges	3	Martin Williams/ Karin Barovich	PIRSA	2002	UofA
Andrew Christian *	4D regolith-landform mapping and environmental change of the Shoalhaven River Delta, NSW	1	Steve Hill/Ian Roach/ Colin Pain	LEME	2002	UC
Brendan Coleman	Innovative electrical geophysical methods for exploration beneath cover	2	Graham Heinson/Mike Sexton/Stewart Greenhalgh	UofA/ Newmont	2002	UofA
Berlinda Crowther *	An integrated remote sensing approach to regolith mapping: an example from the Cootamundra Region NSW	1, 2 & 3	Prame Chopra/Jonathan Clarke/Richard Greene	LEME	2002	ANU
Tania Dhu	Environmental monitoring using electrical resistivity tomography	2	Graham Heinson/ Stewart Greenhalgh	ASEG	2002	UofA
Katie Dowell	Origin of Precious Black Opal Lightning Ridge NSW	2	John Mavrogenes/Bear McPhail	-	2002	ANU
Reece Foster *	The use of SASW methods to image the regolith	3	Anton Kepic	LEME	2002	CUT
Karen Gillgallon	Geophysical investigations of paleochannels in the Lake Bryde area, WA	3	Paul Wilkes/Anton Kepic	DAWA/CALM	2002	CUT
Emma Halligan	Inland acidic groundwater, Swan Avon catchment, WA	3	Mehrooz Aspandiar/ David Gray	DAWA	2002	CUT
Philip Heath	Study of potential field gradient methods for exploration beneath cover	2	Stewart Greenhalgh/ Graham Heinson	LEME/ASEG	2002	UofA
Karen Hulme	Mt Gunson waste tailings a future reserve?	3	Andreas Schmidt-Mumm	-	2002	UofA

Honours Students Associated with CRC LEME During the 2002-2003 Reporting Period (cont'd)

Student	Project Title	Program	Supervisor/s	Funding	Year	Institution
Carey Johnston	The potential hydrogeochemical effects on the local environment from seepage of Ni laterite process effluent near Bandalup Hill Ravensthorpe	3	David Gray/Mehrooz Aspandiar	BHP Billiton	2002	CUT
Amy Kernich *	Regolith weathering erosion and element mobilisation at Luxembourg Cu/Au site, Curnamona Province	1	Andreas Schmidt-Mumm/ Martin Williams	LEME	2002	UofA
William Kimber *	Regolith geology and groundwater of the Pinjarra Lakes, SA	1	Jonathan Clarke/Bear McPhail	LEME	2002	ANU
Gemma King *	A comparison of 3D gravity inversion techniques over the Laverton Region of WA	2	Paul Wilkes/Jayson Meyers	LEME/ Anglogold	2002	CUT
Adam Kroll	Comparative study between AEM systems using data for the West Musgrave Complex, WA	2	Jayson Meyers	-	2002	CUT
Jane Larsen	Hydrogeological investigations, Lake Bryde, WA	3	Quadar Rathur/ Mehrooz Aspandiar	CALM	2002	CUT
Sean Mahoney	Remote sensing techniques for geological mapping and interpretation of basement and thinly covered terrains adjacent to the Tarcoola Mine Site, NW SA	1	Patrick James/ Graham Heinson/Alan Mauger	-	2002	UofA
Sam McHarg	Regolith distribution and Au geochemistry in salt lake overlying Au deposit	2	Lindsay Collins/ Mehrooz Aspandiar	Goldfields Australia	2002	CUT
Nick Nitschke	The application of regolith geoscience to geochemical and environmental problems	3	Martin Williams/ Karin Barovich	PIRSA	2002	UofA
Daniel Radulovic	Environmental assessment and mine site rehabilitation of tailings, Mt Gunson	3	Andreas Schmidt-Mumm	-	2002	UofA
Angela Ratchford	Surface and groundwater flow system development in Hovell's Creek, central west NSW; implications for dryland salinity hazard mitigation in granitic landscapes	3	Ken McQueen/Leah Moore	-	2002	UC
Jarad Townsend	Time domain electromagnetics in conductive environments – comparison of sensors for best late time response	2	Anton Kepic	-	2002	CUT
Honours Degree – commenced or continuing						
David Baker	Ground penetrating radar, DC resistivity and visualisation techniques to map 3D physical properties of regolith	2	Graham Heinson	PIRSA	2002	UofA
Kristy Bewert *	Regolith landform aspects and environmental management around the Cadia Mining Area, central NSW	2	Ken McQueen/Bear McPhail	LEME	2003	ANU
Christopher Buxton *	A lithological and geochemical investigation of the regolith at the Hercules Prospect, Southern Cross, WA	2	Mehrooz Aspandiar	LEME	2003	CUT
Allan Cadd *	Regional geophysical study of crustal architecture near Challenger, for understanding Archaean Au mineral systems and regolith development, NW Gawler Craton	2	Nick Direen	LEME	2003	UofA
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 Au exploration in the Eastern Goldfields, WA	1	Paul Wilkes	LEME	2003	CUT
Cassie Gabell	Characterisation of regolith through (hyper)spectral analysis of Fe species	1	Patrick James/Alan Mauger	-	2002	UofA
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	-	2003	UofA
Peter Haddrill	Surface and groundwater flow system development in central west NSW. Implications for dryland salinity hazard mitigation	3	Simon Benger/Leah Moore	-	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 Ni-Cu PGE sulfides on the western Gawler Craton	2	Karin Barovich	LEME	2003	UofA
Samuel McDermott *	Developing a regolith-landform mapping approach for environmental applications in the Lower Onkaparinga River, Adelaide, SA	3	Steve Hill/Patrick James	LEME	2003	UofA
Geoff Merrill	Alteration types and magnetite minor and trace element chemistry of a porphyry Cu-Au instrusive complex, Cadia NSW	2	Ken McQueen/Graham Taylor	-	2001-	UC

Honours Students Associated with CRC LEME During the 2002-2003 Reporting Period (cont'd)

Student	Project Title	Program	Supervisor/s	Funding	Year	Institution
Alexandria Pengelly	Continuous mapping of Zn-oxides under cover in the Beltana Region	1	Patrick James/Steve Hill	-	2003	UofA
Louisa Roberts *	Spatial prediction of soil properties using high-resolution gamma-ray spectrometry and EM-31/38 Data, Boorowa NSW	3	John Field	LEME	2002	ANU
Claire Robertson *	Tree growth survival and regolith in salt affected landscapes at Blackwood/Bridgetown area, SW WA	1	Ravi Anand/Paul Wilkes	LEME	2003	CUT
Edward Summerhayes *	Mobility of Zn in the regolith: Hemimorphite solubility	2	Bear McPhail/Andy Christy	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

* denotes LEME Scholar

Summer Scholars Associated with CRC LEME During the 2002-2003 Reporting Period

Summer Scholarship Students

Student	Project Title	Supervisor/s	Year	Institution
Jennifer Leonard	*Project postponed due to the Canberra bushfire disaster*	John Field	2002	ANU
Allan Cadd	Using geophysical techniques, including gravity and magnetics, to survey the Para Fault Scarp in Adelaide	Nick Direen	2002	UofA
Emma Hissey	Using self-potential geophysical electrical methods to detect sub-surface groundwater flow	Graham Heinson	2002	UofA
Jane Thomas	Using exploration geophysics techniques for further understanding of the Fowler Orogenic Belt, below cover, western Gawler Craton	Nick Direen	2002	UofA
Jason Tilley	Rare earth element concentration by albitising brines: a geochemical and mineralogical study of the Paratoo Copper deposit, SA	Joel Brugger, Karin Barovich	2002	UofA
Luke Tylkowski	Environmental geochemistry of the Mt Gunson Tailings Dam using micromine software	Andreas Schmidt-Mumm	2002	UofA
Edeltraud Von Furt	Investigation of geochemical and isotope techniques	John Foden	2002	UofA

Short Courses and Field Trips Held by CRC LEME or for Which the Centre Provided Leaders

Course Title	Presenters	Format	Venue	Date	Participants
Regolith-landform mapping shortcourse	Steve Hill, Kylie Foster	LEME field trip, 3 days	Tikalina, Curnamona province, Olary SA	8-10 July 2002	15, students
Environmental mineralogy – EMN (Hons)	Tony Eggleton, Berlinda Crowther	LEME-MTEC lectures and practical, 4 days	ANU	8-12 July 2002	9, students
Regolith mapping and field techniques – RMF (Hons)	Steve Hill, Ian Roach, Kylie Foster	LEME-MTEC field trip, 5 days	Broken Hill, NSW	8-12 July 2002	21, students and industry
Workshop on regolith geology and geochemistry	Charles Butt, David Gray	4 day workshop, lectures and field work	Sons of Gwalia Ltd, Leonora	29 July - 1 August 2002	10, staff from Sons of Gwalia Ltd
Regolith geology and mineral exploration (MSc)	Patrice de Caritat, Richard Greene, Leanne Hill, Steve Hill, Dirk Kirste, Ken McQueen, Leah Moore, Nigel Radford, Ian Roach	LEME-MTEC lectures and field trips, 12 days	UC	12-23 August 2002	13, students and industry
Workshop on regolith geology and geochemistry	Charles Butt, Ravi Anand, Ian Robertson, David Gray, Cajetan Phang, Ian Tapley, Tim Munday	13 day workshop, lectures, practicals and field visits	ARRC	2-18 September 2002	2, staff from Metal Mining Agency of Japan
Geology lectures	Nigel Radford	2 lectures on exploration fundamentals; and stream and soil geochemical analysis and interpretation	CUT	1 October 2002	Regolith geology and geochemistry 3rd year students
Geology lectures	Ian Robertson	2 lectures on soil, calcrete and lag sampling; and sample preparation and analysis	CUT	8 October 2002	Regolith geology and geochemistry 3rd year students
Geology lectures	Charles Butt	2 lectures on gold dispersion mechanisms and supergene gold deposits; and nickel laterites	CUT	29 October 2002	Regolith geology and geochemistry 3rd year students
Data analysis workshop	Ian Robertson	3 hour workshop, presentation and computer practical	CUT	22 October 2002	Regolith geology and geochemistry 3rd year students
Regolith geology and geochemistry	Charles Butt, Ravi Anand	Consulting - workshop, lectures and practicals	Dogo, Mali	23 Nov - 2 Dec 2002	11, staff from Sumicon
Regolith mapping and field techniques – RMF (Hons)	Steve Hill, Ian Roach, Kylie Foster	LEME-MTEC field trip, 5 days	UNSW Fowlers Gap research station	17-21 March 2003	17, students
Introduction to hydrogeochemistry	Dirk Kirste, Patrice de Caritat	LEME-MTEC course	University of Melbourne	7-11 April 2003	25, students
Regolith geology and geochemistry	Charles Butt, David Gray	Consulting - workshop, lectures and practicals	Harmony Gold, Kalgoorlie	5-6 May 2003	8, staff from Harmony Gold
Identifying, managing and assessing acid sulfate soils	Rob Fitzpatrick	2 papers presented, on impacts of acid sulfate soils on the environment and development in Australia; and identification and risk mapping of acid sulfate soils	CUT	12-13 June 2003	250
Environmental mineralogy	Tony Eggleton	LEME-MTEC lectures and practical, 4 days	ANU	16-20 June 2003	12, students

Research Utilisation and Applications

Applied Research

The review of CRC LEME research by the Executive has not identified any technology developments suitable for imminent commercialisation at this stage. However, many technology development projects have direct applications for end users, and significant potential for application in industry. A Commercialisation and Intellectual Property Management strategy was approved by the Board on 14 March 2003, and a watching brief is being maintained on a number of projects. Some potential developments are described below.

Audio-magnetotellurics (AMT) is a ground-based geophysical 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. Dr Anton Kepic and LEME Honours students Barrett Cameron and Brendan Corscadden 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.

Anton Kepic is also 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.

Margarita Norvill, a LEME PhD student, has developed novel signal processing algorithms to improve electromagnetic and electrical based geophysical surveys in areas with high amounts of electrical noise. Electrical noise can cause interference within 100 km of a city. The project was initially undertaken to improve data quality from MIMDAS, developed by MIM Exploration 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.

Assoc Prof Jayson Meyers has been working with Pilbara Manganese to develop novel methods of finding manganese ore below regolith. This involves utilising 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.

The project to objectively log regolith samples (core, drill chips, pulps) headed by Dr Ravi Anand is a means of rapidly measuring physical properties of regolith samples, predominantly through spectral analysis. This initiative should optimise information gained from exploration drilling, particularly in the production of three-dimensional mineral maps and in the discrimination of transported from *in situ* regolith.

Technology Transfer

An essential LEME function is to ensure that research findings are transferred to user groups. Project field trips have been an important means of demonstrating research findings by giving users direct exposure to new regolith concepts. One-on-one consultancies have been undertaken, involving professional development short courses and visits to the tenements of individual companies. These have involved Newmont Australia, Sons of Gwalia, and Gold Fields Australasia. Short courses were held in response to the needs of individual companies, and were attended by a total of 50 geoscientists.

Ravi Anand and Charles Butt completed a nine-day consultancy on regolith geology and exploration geochemistry in Mali for the Japanese company Sumicon in November 2003. Such visits provide insights into the nature of deep weathering in terrains that may represent the humid precursor to the now arid terrains of Australia.

Open File Reports

An indication of the transfer of LEME products and knowledge to industry and other end users is given by the rate of uptake of Open File Reports and related material. During the reporting period, 75 LEME publications were sold, with particular interest shown in the monograph *Calcrete: Characteristics, Distribution and Use in Mineral Exploration* (11 copies), the *Regolith Glossary* (14

copies) and the Open File Report *Genesis, Classification and Atlas of Ferruginous Materials, Yilgarn Craton* (eight copies).

The calcrete monograph has chapters on morphology, origins, classification, mineralogy and chemistry, mineral exploration and distribution. It also includes a CD and map showing the occurrence of calcrete. The chapter on mineral exploration is of particular interest to those exploring in arid and semi-arid areas of Australia for gold and base metals. Numerous case histories outline the how, why and where for using calcrete. It is anticipated that the book will be a best-seller for mineral explorers, both nationally and internationally.

Material freely available as downloadable PDF files from the LEME website (http://crcleme.org.au) also generated a large amount of interest, with 11 776 hits recorded during the reporting period.

Research Collaborators and Users

The following table lists external companies and other organisations that were end users of LEME research outputs during the reporting period, or that collaborated in some manner with the Centre to secure those outputs.

Research Collaborators and Users 2002-2003

Research Collaborators and Users			
Small to Medium Enterprises (generally less than 100 employees)			
Research User	**Activity**	**Interaction**	**LEME Personnel**
Abelle Ltd	Objective logging project	Research collaboration	**Ravi Anand**, Ian Robertson, Cajetan Phang, Charles Butt, David Gray, Tim Munday, Amanda Cornelius, Mehrooz Aspandiar, John Keeling, Alan Mauger
Adelaide Resources Ltd	Project proposals for central Gawler Gold	Planning for future research collaboration	**David Gray**
AngloGold Australia	Comparison of 3D gravity inversion methods on regional and detailed data sets in the Laverton District of WA	Student research	**Gemma King**, Jayson Meyers, Paul Wilkes
APAI Farm Map Consulting Pty Ltd and Tesla 10 Pty Ltd	Interpretation of geophysics for catchment management	Student research	**Greg Street**, Jayson Meyers
Apex Minerals	Detailed aeromagnetic surveying to resolve the geometry, structural evolution, and mineral potential of the Windimurra and Narndee layered igneous complexes in WA	Research collaboration	**Jayson Meyers**
Australian Water Environments	Development of river-based geophysical surveys for salinity mapping	Student research	**Brian Barrett**, Graham Heinson
Barrick Gold	Rapid acquisition of audio frequency magnetotellurics	Student research	**Barrett Cameron**, Anton Kepic
Consolidated Minerals	Constraints on inversion of tdhem data for near surface conductivity mapping and innovative geophysical and geochemical exploration for high-grade manganese ore under cover in the E Pilbara of WA	Student research	**Anousha Hashemi**, Jayson Meyers
Dominion Mining Ltd	Regolith logging, mineralogy, relation to AEM and 3D modelling at Challenger Au deposit, SA	Research collaboration	**David Gray**, Melvyn Lintern
Dominion Mining Ltd	Production of Open File Report discussing geochemical exploration techniques for Au in Gawler Craton	Supporting participant	**Melvyn Lintern**, Malcolm Sheard, George Gouthas
Gold Fields Australasia Pty Ltd	Regolith distribution and Au geochemistry in salt lake overlying Au deposit	Student research	**Sam McHarg**, Lindsay Collins, Mehrooz Aspandiar
Gold Fields Australasia Pty Ltd	Project planning and strategic development	Research collaboration	Dennis Gee, Ravi Anand, Jayson Meyers, David Gray, Charles Butt
Gold Fields Australasia Pty Ltd	High resolution geophysical methods for Au exploration under regolith cover - Songvang Prospect, Agnew, WA	Student research, research collaboration	**Nigel Cantell,** Jayson Meyers, Tim Munday
Helix Resources Ltd	Hydrogeochemistry of Au	Research collaboration	**David Gray**
Helix Resources Ltd	Electrical geophysics	Student research	Philip Heath, Tania Dhu
Independence Gold NL	In-mine EM system for detecting Ni sulfide ore	Student research	**Kim Bone**, Jayson Meyers
Lightning Ridge Miners Association	Black opal occurrence and formation	Student research	Katie Dowell
Metals Quest Australia Ltd	Geophysical applications for detection of blind NiS deposits near the Black Swan Mine in WA	Research collaboration	Jayson Meyers, Anton Kepic
MIM Ltd	The use of distributed sensor arrays in electromagnetic imaging	Student research	**Margarita Norvill**, Anton Kepic

Research Collaborators and Users 2002-2003 (cont'd)

Research User	Activity	Interaction	LEME Personnel
Minotaur Resources	Development of down hole geophysics for exploration under cover	Student research	**Hashim Carey**, Graham Heinson
Oroya Mining Ltd	Mineral hosts for Au and trace elements in the regolith project	Research collaboration	**Rob Hough**, Ravi Anand, Ken McQueen, Bear McPhail, Keith Scott, Charles Butt, Ray Smith, Amanda Cornelius
Pasminco Ltd	Using lithogeochemistry to map cryptic alteration: Elura and Century case studies	Student research	**Michael Whitbread**, Ken McQueen
Peak Gold Mines Pty Ltd	Study of the Yarrawonga lag anomaly, Cobar goldfield	Research collaboration	**Ken McQueen**, Dougal Munro
Perilya Ltd	Paleomagnetic and K/Ar dating, Beltana mine, SA	Research collaboration	**Brad Pillans**, Jim Dunlap
Perilya Ltd	Formation of willemite deposits, dispersion of zinc in the regolith, HYMAP imaging of alteration	Research collaboration	**Bear McPhail**, Joël Brugger, Alan Mauger, Pat James, John Keeling
Pilbara Manganese	Pilbara Manganese Part 2 Projects	Research collaboration	**Jayson Meyers**, Anousha Hashemi, Don Hunter
Pima Mining NL	Geochemical dispersion, Mt Torrens area, SA	Research collaboration	**Marian Skwarnecki**, Rob Fitzpatrick
Range River Gold NL	Gold targeting below cover at Ararat, Vic	Research collaboration	**Jayson Meyers**
Stawell Gold Mine Ltd	Distribution of As and Sb in regolith overlying vein Au ore bodies	Research collaboration and student research	Jon Dugdale, Ron Watkins, Ryan Noble
Straits Resources Ltd	Regolith landform studies in the Nifty area to evaluate sampling methodology	Research collaboration	Matthias Cornelius
Striker Resources NL	Origin of detrital gold particles and metalogenesis of the N Kimberly gold prospects, WA	Research collaboration and consultancy	Jayson Meyers, Paul Wilkes, Ravi Anand
Tasman Resources NL	Geophysical applications for discovery of iron oxide Cu/Au deposits below Adelaidian cover near Olympic Dam, SA	Research collaboration	Jayson Meyers
Teck-Cominco Ltd (Cam Allen)	Numerical modelling of low-temperature Zn geochemistry	Research collaboration	Bear McPhail
Tensor Geophysics	Development of down hole geophysics for exploration under cover	Student research and teaching	**Hashim Carey**, Graham Heinson
Triako Resources Ltd	Understanding the mineralogy and geochemistry of regolith profiles at Mineral Hill, NSW	Research collaboration	Keith Scott
Zonge Engineering Research Organisation	Development of river-based geophysical surveys for salinity mapping	Student research	**Brian Barrett**, Graham Heinson

Large Companies

Research User	Activity	Interaction	LEME Personnel
BHP Billiton	The potential hydrogeochemical effects on the local environment from seepage of Ni laterite process effluent near Bandalup Hill, Ravensthorpe	Student research	**Carey Johnston**, David Gray, Mehrooz Aspandiar
Consolidated Minerals Ltd	Application of innovative geophysical methods for exploration of Mn ore under regolith cover in the E Pilbara, WA	Consultancy and research collaboration	**Jayson Meyers**, Tim Munday, Anousha Hashimi
MIM Exploration	Development of processing methods for geophysics over thick regolith	Student research	**Katherine Broxholme**, Graham Heinson
Newmont Australia	Objective logging of the regolith	Research collaboration	**Ravi Anand** and others
Newmont Australia	Development of down hole geophysics for exploration under cover	Student research	**Hashim Carey**, Graham Heinson
Newmont Australia	Palaeomagnetic dating of regolith in Yilgarn and Tanami areas	Research collaboration	Brad Pillans
Newmont Australia	Innovative electrical geophysical methods for exploration beneath cover	Student research	**Brendan Coleman**, Graham Heinson, Stewart Greenhalgh
SA Water Corporation	Development of river-based geophysical surveys for salinity mapping	Student research	**Brian Barrett**, Graham Heinson
Sons of Gwalia Ltd	Characterisation of genesis of gossans	Student research	**Chris Buxton**, Mehrooz Aspandiar, Ravi Anand
WMC	Comparative study between AEM systems using data for the West Musgrave Complex, WA	Student research	**Adam Kroll**, Jayson Meyers
WMC	Forward modelling of the AEM response of two massive sulfide ore bodies in W Musgrave of WA	Research collaboration	**Jayson Meyers**
URS Corporation	Development of geophysical techniques for groundwater mapping	Student research and research collaboration	**Graham Heinson**, Damien Skinner

Research Collaborators and Users 2002-2003 (cont'd)

Government Organisations and Universities

Research User	Activity	Interaction	LEME Personnel
Australian Nuclear Science and Technology Organisation (ANSTO)	Regolith dating for fault hazard assessment	Consultant	**Brad Pillans**, Colin Pain
ANSTO	High resolution acoustic and electrical methods for direct layer detection of regolith features	Research collaboration	**Anton Kepic**, Graham Heinson, Jayson Meyers, Paul Wilkes
ANSTO	Development of strategic research planning	Strategic planning	Ken Lawrie, Anton Kepic, Jayson Meyers, Paul Wilkes, Colin Pain
Dartmouth University, Hew Hampshire, USA (Arjun Heimsath)	Weathering of major and trace elements, pilot project on granite weathering	Research collaboration	Sue Welch
Ballarat University	Paleomagnetic dating of regolith	Research collaboration	Brad Pillans
Burdekin Dry Tropics Board	Advice on salinity and NRM in the Burdekin Delta area	Planning for future research collaboration	Ken Lawrie, Colin Pain
Burdekin Dry Tropics Board	Advice on salinity and NRM in the upper Burdekin catchment	Planning for future research collaboration	Ken Lawrie, Colin Pain
Bureau of Rural Sciences	Project management and technology transfer - SA SMMSP	Research collaboration	**Tim Munday**, John Wilford, Ken Lawrie, Dave Gibson, Heike Apps
Bureau of Rural Sciences	Landscape evolution and regolith materials of the Angas-Bremer Plains, SA	Research collaboration	**David Gibson**, John Wilford, Piang Kok Tan, Rob Fitzpatrick, Heike Apps, Tim Munday
Bureau of Rural Sciences	Angas-Bremer Hills - regolith landforms, salt stores and water quality	Research collaboration	**John Wilford**, Piang Kok Tan, Heike Apps, Rob Fitzpatrick, Dave Gibson
Bureau of Rural Sciences	3D regolith architecture of the Jamestown area, SA - implication for environmental management	Research collaboration	**John Wilford**, Heike Apps, Piang Kok Tan, Rob Fitzpatrick, Tim Munday
Bureau of Rural Sciences	Investigation of mobilisation of salt and associated elements and their impact on water quality: Murray-Darling Basin	Research collaboration	**Andrew Herczeg** and 16 LEME researchers from various core parties
Bureau of Rural Sciences	Evaluation of airborne geophysics for salinity and groundwater mapping in a major fluvial floodplain environment, Lower Balonne Catchment, Qld	Research collaboration	**Ken Lawrie**, Colin Pain, John Wilford, Penny Kilgour, Dave Gibson, Amy Kernich
Corangamite and Glenelg Hopkins Catchment Management Authorities (CMAs)	Characterising and mapping salinity in regolith	Research collaboration	Rob Fitzpatrick
Cotton Growers and Department of Land and Water Conservation NSW (DLWC)	Groundwater quality, recharge and sustainability in the lower Namoi Valley	Student research	**Wendy McLean**, Patrice de Caritat
CSIRO Exploration and Mining [non-LEME; (Weihua Liu)]	Thermodynamic modelling of metals in brines	Research collaboration	Bear McPhail
CSIRO Land and Water, Townsville, Healthy Country	Evaluation of geoscience data for salinity and NRM mapping in the Burdekin and Fitzroy Catchments, Qld	Research collaboration	Colin Pain, Ken Lawrie
CSIRO Land and Water, Townsville, Healthy Country	Research on salinity and NRM in the Burdekin Delta area	Research collaboration	Ken Lawrie, Colin Pain
Department of Earth Sciences, LaTrobe University	Dating neotectonic movement in Gippsland	Research collaboration	Derek Fabel
Department of Environment Australia, Department for Environment, Heritage in SA (DEH)	Characterising and mapping coastal acid sulfate soils	Research collaboration	**Rob Fitzpatrick**, Phil Davies, Richard Merry
Department of Agriculture WA	Inland acidic groundwater, Swan Avon catchment, WA	Student research	**Emma Halligan**, David Gray, Mehrooz Aspandiar
Department of Agriculture WA and WA Department of Conservation and Land Management (CALM)	Hydrological investigation, Lake Bryde catchment, WA	Student research	**Jane Larsen**, Mahrooz Aspandiar
Department of Agriculture WA	Hydrogeological study of the Merredin Region, WA	Student research	**Phillip Costello**, Mehrooz Aspandiar
Department of Agriculture WA and CALM	Geophysical investigations of palaeochannels in the Lake Bryde area, WA	Student research	**Karen Gillgallon**, Anton Kepic, Paul Wilkes
Department of Water, Land and Biodiversity Conservation SA (DWLBC)	Effect of drains on soil properties in SA	Student research	**Michael Durkey**, David Chittleborough, Steve Hill

Research Collaborators and Users 2002-2003 (cont'd)

Research User	Activity	Interaction	LEME Personnel
DWLBC	SA salinity mapping and monitoring project, conducted under the auspices of the National Action Plan for Salinity and Water Quality (NAP)	Research collaboration	**Tim Munday**, John Wilford, Andy Hertzeg, Jim Cox, Dave Gibson, Piang Kok Tan
DWLC	Dryland salinity hazard mitigation along the Booberoi-Quandialla Transect, central west NSW	Student research	**Michael Holzapfel**, Xiangyang Chen
DWLBC	Combining remote sensing and terrain analysis with conceptual toposequence models in two dry saline land affected areas, for upscale root zone constraints	Student research	**Mark Thomas**, Graham Heinson, Rob Fitzpatrick
DWLBC	Evaluation and development of use of multitemporal imagery for water condition monitoring, environmental and wetland management in the SE of SA	Student research	**Sean Mahoney**
DLWBC	Project Management and Technology Transfer - SA SMMSP	Research collaboration	Tim Munday, John Wilford, Ken Lawrie, Dave Gibson, Heike Apps
Environment ACT	Assessment of paleontological site	Consultant	Brad Pillans
Fitzroy Basin Association	Advice on salinity and NRM in the Fitzroy Catchment	Planning for future research collaboration	Colin Pain, Ken Lawrie
Flinders University	Laboratory-scale electrical resistivity tomography experiments	Student research	**Tania Dhu**, Graham Heinson
Geological Survey of Canada	Joint study of the palaeodrainage history of the Cobar region	Research collaboration	**Ken McQueen**, Roslyn Chan
Geological Survey of WA	Minerals Exploration Project development and planning	Strategic planning	Dennis Gee, Ravi Anand, Keith Scott
Greening Australia, ACT Branch	Trees, land and salinity research	Strategic planning	Colin Pain, Ken Lawrie, Glenn Bann
Indonesian Government and Water Corporation WA	Groundwater investigations using the seismo-electric method	Student research	**Mohammad Rosid**, Anton Kepic
Melbourne University	Research on age of calcrete using U-Th isotopes	Research collaboration	Melvyn Lintern
Monash University (Leone Spiccia, Peter Kershaw)	Advisor and student supervision for research projects in vineyard soils and mineral processing (Au)	Research collaboration	Bear McPhail
Murray-Darling Basin Commission	Development of strategic research planning	Strategic planning	Keith Scott, Colin Pain, Dennis Gee, Paul Wilkes
Natural Resources and Environment in Victoria	Characterising and mapping salinity in regolith	Research collaboration	Rob Fitzpatrick
NSW Department of Infra-structure, Planning and Natural Resources	Dryland salinity hazard mitigation along the Booberoi-Quandialla Transect, Central West NSW	Student research	**Michael Holzapfel**, Xiangyang Chen
NSW Department of Minerals and Resources	Black opal occurrence and formation	Student research	Katie Dowell
Northern Territory Geological Survey	Minerals Exploration Project development and planning	Strategic planning	Dennis Gee, Ravi Anand, Mike Craig
Oklahoma University, USA	Laboratory-scale electrical resistivity tomography experiments	Student research	**Tania Dhu**, Graham Heinson
PIRSA – NAP salinity	Characterising and mapping salinity in regolith	Research collaboration	**Rob Fitzpatrick**, Mark Thomas, Phil Davies, Richard Merry
Qld Department of Natural Resource Management	Investigating mobilisation of salt and associated elements and their impact on water quality, Murray-Darling Basin	Research collaboration	**Andrew Herczeg**, and 16 other LEME staff from various core parties
Qld Department of Natural Resource Management	Evaluation of airborne geophysics for salinity and groundwater mapping in a major fluvial floodplain environment, Lower Balonne Catchment, Qld	Research collaboration	**Ken Lawrie**, Colin Pain, John Wilford, Penny Kilgour, Dave Gibson, Amy Kernich
Qld Department of Natural Resources and Mines (QDNRM)	Investigating mobilisation of salt and associated elements and their impact on water quality, Murray-Darling Basin	Research collaboration	**Andrew Herczeg**, and 16 other LEME staff from various core parties
QDNRM	Evaluation of geoscience data for salinity and NRM mapping in the Burdekin and Fitzroy Catchments, Qld	Research collaboration	Colin Pain, Penny Kilgour, Ken Lawrie
QDNRM	Evaluation of airborne geophysics for salinity and groundwater mapping in a major fluvial floodplain environment, Lower Balonne Catchment, Qld	Research collaboration	**Ken Lawrie,** Colin Pain, John Wilford, Penny Kilgour, Dave Gibson, Amy Kernich
Rural Industries Research and Development Corporation (RIRDC)	Trees, land and salinity research	Strategic planning, project development	Colin Pain, Ken Lawrie, John Wilford
Smart Rivers – St George Water Harvesters and Dirranbandi District Irrigators	Evaluation of airborne geophysics for salinity and groundwater mapping in a major fluvial floodplain environment, Lower Balonne Catchment, Qld	Research collaboration	**Ken Lawrie**, Colin Pain, John Wilford, Penny Kilgour, Dave Gibson, Amy Kernich
Thailand Government, Chulalongkorn University, Bangkok and WA Dept of Industry and Resources	Geophysical prospecting and mineral potential of the Leoi district in Thailand and comparison of tropical regolith of Thailand with Australian regolith	Research collaboration	Jayson Meyers, Kachen Neosuparp (visitor)

Research Collaborators and Users 2002-2003 (cont'd)

Research User	Activity	Interaction	LEME Personnel
University of South Australia	Radar and GIS – salinity and waterlogging mapping	Research collaboration	**Phil Davies**, Rob Fitzpatrick, Mark Thomas
University of Wollongong	Regolith dating	Research collaboration	Brad Pillans
University of Wollongong	Discussions on collaborative research opportunities	Strategic planning	Paul Wilkes
WA Department of Environment, Water and Catchment Protection	Characterising and mapping coastal and inland acid sulfate soils	Research collaboration	Rob Fitzpatrick
WA Department of Conservation and Land Management (CALM)	Tree growth survival and regolith in salt-affected landscapes of the Blackwood/Bridgetown area, WA	Student research	**Claire Robertson**, Ravi Anand, Paul Wilkes
Water Corporation WA and CALM	Hydrogeology of the Cape Range karst and coastal plain aquifiers, NW Australia	Student research	**Sam Lee**, Lindsay Collins
Water Corporation WA	A multi-disciplinary approach to modelling catchment hydrogeology	Student research	**Kirsty Beckett**, Jayson Meyers
Water Corporation WA	Innovative geophysical methods for aquifer geometry in the Blackwood Catchment	Research collaboration	**Jayson Meyers**, Anton Kepic
Waters and Rivers Commission, WA	Acidification of shallow sediments and groundwater in Perth metropolitan area	Research collaboration and student research	**Ron Watkins**, Steve Appleyard, Bobak Willis-Jones, Troy Cook, John Angeloni
Working Group for Land Resource Assessment	Technical advice on land-related matters to the Council of Australian Governments (COAG)		Colin Pain
Working Group for Land Resource Assessment	Development of the Australian Soil Resources Information System	Research collaboration	Colin Pain

Cooperative Research Centres

Research User	Activity	Interaction	LEME Personnel
CRC for Greenhouse Accounting	Tree growth survival and regolith in salt-affected landscapes of the Blackwood/Bridgetown area, WA	Student research	Claire Robertson, Ravi Anand, Paul Wilkes
CRC for Plant-based Management of Dryland Salinity	Increasing spatial resolution of soil maps using geophysics and GIS	Student research	David Mitchell
CRC for Plant-based Management of Dryland Salinity	Characterising and mapping salinity in regolith and soils	Research collaboration	**Rob Fitzpatrick**, Mark Thomas, Graham Heinson
CRC for Plant-based Management of Dryland Salinity	Regolith mapping and land assessment	Research collaboration	Colin Pain
CRC for Renewable Energy	Planning of research strategy	Research collaboration	Ray Smith
CO2 CRC	Forward modelling microgravity response of reservoir changes	Consultancy to Woodside	Jayson Meyers
pmd* CRC	Development of web based database of thermodynamic properties	Research collaboration	**Bear McPhail**, Joel Brugger
pmd* CRC	Development of linked research projects between LEME and pmd	Strategic planning	**Bear McPhail**, David Gray, Paul Roberts (pmd)

Industry Associations

Research User	Activity	Interaction	LEME Personnel
Academy of Technological Sciences and Engineering Committee (ATSE)	WA Branch Committee	Strategic planning	Ray Smith
AMIRA International	Isotopic discrimination of partial leach geochemical anomalies in covered terrains (CRC LEME-AMIRA Project 618)	Research collaboration	**Geoff Denton**, David Gray, Keith Scott
AMIRA International	Minerals Exploration Project development	Strategic planning	Dennis Gee, Keith Scott, Ravi Anand
AMIRA International	Support and assistance with project 407b, airbone EM inversion	Sponsorship and collaboration	Jayson Meyers, Anton Kepic, Ken Lawrie, Tim Munday, Paul Wilkes, Richard Lane
Association of Mining and Exploration Companies (AMEC)	Member of the Exploration and Technical Committee	Technology transfer	Ray Smith
AMEC	Development of strategic research projects	Strategic planning	Dennis Gee
Australian Society of Exploration Geophysicists (ASEG)	Study of potential field gradient methods for exploration beneath cover	Student research	**Philip Heath**, Stewart Greenhalgh, Graham Heinson
Australia New Zealand Geomorphology Group (ANZG)	Organising Kalgoorlie 2002, the 10th Meeting of the Group, plus field trips	Research collaboration	Colin Pain
Society of Economic Geologists (SEG)	Organising Committee for 2004 International Conference	Technology transfer	Ray Smith

Photograph by Steve Hill

Staffing and Administration

Mr Gary Kong, Business Manager

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

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

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

CRC LEME has at its disposal world-class expertise in regolith geoscience, and the supporting disciplines such as geochemistry, hydrogeochemistry, geophysics and geochronology. In this second year of funding CRC LEME had a total complement of 130 staff, of whom 119 were professional geoscientists. This distilled down to 63.1 FTE scientists (compared to 73.3 last year), made up of 47.3 in-kind, and 15.8 cash-funded scientists. The downward change from last year relates to the withdrawal of Bureau of Rural Sciences and the University of Canberra last year, as well as the associated delay in the implementation of cash-funded positions.

Additionally, skilled staff provide technical, administrative, cartographic, illustrative, laboratory and field support. Students have also made a valuable contribution to the research during this time. Staffing resources, in terms of FTEs, are shown in the following tables.

Specified Personnel

Specified personnel, contributed by the Core Participants as required by the Commonwealth Agreement, are shown opposite. At the beginning of the financial year, Dr Ray Smith, the then CEO, stepped aside to undertake research, and his position was filled in an acting capacity by Paul Wilkes from 8 July 2002. Dr Dennis Gee took up the position on 5 November 2002. Since the resignation of Program Leader Dr Nigel Radford in October 2002, Keith Scott of CSIRO has been acting Program 2 Leader.

Workplace Safety and Environmental Policy

CRC LEME follows fully the occupational health and safety policies and procedures of its Core Participants. Additional policies for staff working in the field have been prepared by the Safety Sub-committee. These have been endorsed by the Board, and drawn to the attention of all staff by way of the LEME intranet. This is described in more detail in the Safety section of this report.

There were no reports of work-related lost time injuries affecting LEME staff or students within the reporting period.

Staff and Team Development

LEME staff and students are encouraged to undertake continuing professional and scientific training, by attending conferences, meetings and workshops relevant to their professional development. Development of the Centre Culture is encouraged through team planning and execution of research, movement of staff, conference representation, the newsletter, *LEME News*, and the LEME intranet.

Assistant Directors at the nodes have been active in facilitating scientific and social interaction.

New Equipment and Computing

During 2002-2003 we received the first instalment of Western Australian Government Infrastructure Funding. The following items of capital expenditure were incurred:

- ASD FieldSpec Pro Spectroradiometer. This instrument was purchased by CSIRO Exploration and Mining. It is portable, suitable for laboratory and field use, and digitally collects spectra of regolith materials, permitting the identification of most regolith minerals.
- Ultra Pure Water System, batteries, laptop lock and software, purchased by CSIRO Exploration and Mining.
- Metrohm Modular Ion Chromatograph, purchased by CSIRO Exploration and Mining.
- SMARTem Receiver System. This was purchased by Curtin Department of Exploration Geophysics. It is used for field collection of electromagnetic data.
- Leica DC 300 Digital Imaging System, MapInfo Professional software and license and two Intel PIV 1.8Ghz computer systems for LEME research work at Curtin Department of Applied Geology.

Specified Personnel Contributed by Core Participants

Name	Contributing Organisation	% of total working time in CRC LEME	Role in Centre
Dr R Dennis Gee	Paid from the CRC Grant, employed by CSIRO	100% from 4 Nov 2002	Chief Executive Officer
Dr Colin F Pain	GA	100%	Program Leader
Dr Ken Lawrie	GA	100%	Program Leader
Assoc Prof Graham Taylor	UC	75% to 31 Dec 2002	Key Researcher
Dr Charles R M Butt	CSIRO	75% from 1 July 2002	Key Researcher
Dr Ravi R Anand	CSIRO	100%	Program Leader
Mr Keith Scott	CSIRO	70% from 27 Oct 2002	Acting Program Leader
Dr Ray Smith	CSIRO	100% to 1 July 2002	Chief Executive Officer
Dr Ray Smith	CSIRO	100% from 2 July 2002	Key Researcher
Assoc Prof Patrick James	UofA	70% from 25 Feb 2002	Program Leader
Prof Nigel Radford	CUT	100% from 15 Jan 2002 to 26 Oct 2002	Program Leader
Mr Paul Wilkes	CUT	100% from 8 July 2002 to 3 Nov 2002	Acting CEO
Mr Paul Wilkes	CUT	100% from 4 Nov 2002	Deputy CEO

Research Staff In-Kind Contribution

Name	Main Activity	Total % of Time	% Spent on Research Program					% Spent on		
			Regolith Geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
Australian National University										
Chappel J	R	50	50				50			
Chopra D	R	20		15			15	5		
Cristy A	R	10	10				10			
DeDeckker P	R	20	20				20			
Ellis D	R	15	5	5			10	5		
Fabel D	R	25	25				25			
Field J	R	15		5			5	10		
Greene R	R	30		25			25	5		
Magee J	R	25	25				25			
McPhail D	R	100	10	85			95	5		
Opdyke B	R	20		15			15	5		
Pillans B	R	50	50				50			
Dunlap J	R	20	20				20			
Spooner N	R	5	5				5			
		405	**220**	**150**	**0**	**0**	**370**	**35**	**0**	**0**
University of Canberra										
Taylor G	E	38		33			33	5		
McQueen K	R	37	7	17			24			13
Benger S	R	10		8			8	2		
		85	**7**	**58**	**0**	**0**	**65**	**7**	**0**	**13**

Research Staff In-Kind Contribution (cont'd)

Name	Main Activity	Total % of Time	% Spent on Research Program					% Spent on		
			Regolith Geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
Geoscience Australia										
Apps H	R	100				100	100			
Brodie R	R	25				25	25			
Chan R	R	100	40	60			100			
Craig M	R	100	100				100			
Gibson D	R	100			20	80	100			
Kernich A	R	10				10	10			
Kilgour P	R	100			50	50	100			
Kirste D	R	95		95			95			
Lambert I	R	10			5	5	10			
Lawrie K	R	100			20	80	100			
Pain C	R	100	20		60	20	100			
Wilford J	R	100			20	80	100			
		940	**160**	**155**	**175**	**450**	**940**	**0**	**0**	**0**
Curtin University of Technology										
Aspandiar M	R	50	30				30	20		
Collins L	R	60	10				10	20		30
Fagan R	R	10					0	10		
Kepic A	R	40	5	5	30		40			
Meyers J	R	50	5	10	35		50			
Nemchin A	R	50	50				50			
Rather A	R	90		60			60	30		
Uren N	R	5					0	5		
Watkins R	R	70					0	70		
Watling J	R	20		20			20			
		445	**100**	**95**	**65**	**0**	**260**	**155**	**0**	**30**
University of Adelaide										
Barovich K	R	70	25	45			70			
Brugger J	R	10		5			5	5		
Chittleborough D	R	10	10				10			
Direen N	R	70	20	25	25		70			
Foden J	R	35	5	25			30	5		
Greenhalgh S	R	25	5	15			20	5		
Heinson G	R	60	25	10	15		50	10		
James P	R	70	20				20	50		
Lang S	R	15	15				15			
McKirdy D	R	25	25				25			
Schmidt-Mumm A	R	45	10		20		30	15		
Williams M	R	10	5				5	5		
		445	**165**	**125**	**60**	**0**	**350**	**95**	**0**	**0**
Primary Industries and Resources, South Australia										
Crooks A	R	10	10				10			
Fabris A	R	100	100				100			
Gouthas G	R	100	50	50			100			
Hou B	R	100	100				100			
Keeling J	R	80	55				55			25
Mauger A	R	80	75				75	5		
Painter J	R	30		30			30			
Rogers P	R	100	100				100			
Sheard M	R	100	30	70			100			
Stamoulis V	R	50	45				45	5		
		750	**565**	**150**	**0**	**0**	**715**	**10**	**0**	**25**
Bureau Rural Sciences										
Coram J	R	5			5		5			
Cresswell R	R	10			10		10			
Pestov I	R	5			5		5			
		20	**0**	**0**	**20**	**0**	**20**	**0**	**0**	**0**
New South Wales Department of Mineral Resources										
Barratt R	R	40		40			40			
Buckley P	R	100		100			100			
Fleming G	R	30		30			30			
Hicks M	R	100		100			100			
Mills K	R	20		20			20			
Stevens B	R	10		10			10			
		300	**0**	**300**	**0**	**0**	**300**	**0**	**0**	**0**

Research Staff In-Kind Contribution (cont'd)

Name	Main Activity	Total % of Time	% Spent on Research Program					% Spent on		
			Regolith Geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
CSIRO										
Anand R	R	100	90	5			95	5		
Andrew A	R	10		10			10			
Bui E	R	20			20		20			
Butt C	R	60	25	25			50	10		
Cornelius M	R	60	15	45			60			
Cox J	R	30	30				30			
Davies P	R	30	30				30			
Dighton J	T	20	20				20			
Fitzpatrick R	R	35	35				35			
Gray D	R	80	30	45			75	5		
Herczeg A	R	40	40				40			
Hicks W	R	5	5				5			
Hough R	R	100	100				100			
Lamontagne S	R	35	35				35			
Lefournour M	R	20	20				20			
Lintern M	R	80	65	15			80			
Longman D	R	85		85			85			
McEwan K	R	25	25				25			
Merry R	R	5	5				5			
Munday T	R	80				80	80			
Phang C	R	75	75				75			
Pirlo M	R	100	100				100			
Raven M	R	10	10				10			
Robertson I	R	70	25	40			65	5		
Rogers S	R	15	15				15			
Scott K	R	55	5	50			55			
Smith R	R	50	50				50			
Stauffacher M	R	5	5				5			
Tapley I	R	35	35				35			
Walker G	R	5			5		5			
		1340	**890**	**320**	**25**	**80**	**1315**	**25**	**0**	**0**
TOTAL RESEARCH STAFF: IN-KIND CONTRIBUTIONS		**4730**	**2107**	**1353**	**345**	**530**	**4335**	**327**	**0**	**68**

KEY: 100 = 1 person year

Research Staff CRC LEME Funded

Name	Employer	Main Activity	Total % of Time	% Spent on Research Program					% Spent on		
				Regolith Geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Applications	Admin-istration
CRC Grant Funded											
Kirste D	ANU	R	5	5				5			
McQueen K	ANU	R	35		35			35			
Pillans B	ANU	R	50	50				50			
Roach I	ANU	R	50					0	50		
Skwarnecki M	ANU	R	25		25			25			
Welch S	ANU	R	5	5				5			
Hill S	UC	R	50		35			35	15		
Roach I	UC	R	50					0	50		
Skwarnecki M	UC	R	50		50			50			
de Caritat P	GA	R	100		60	40		100			
Fitzpatrick A	GA	R	50				50	50			
Lane R	GA	R	15				15	15			
Aspandiar M	CUT	R	50	25				25	25		
Radford N	CUT	R	40		40			40			
Wilkes P	CUT	R	100	20		25		45	30		25
Hill S	UofA	R	50	25		10		35	15		
Joseph J	UofA	R	70	30	20	20		70			
Cornelius A	CSIRO	R	20	20				20			
Cox J	CSIRO	R	10	10				10			
Davies P	CSIRO	R	15	15				15			
DeBroekert P	CSIRO	R	40	40				40			
Dighton J	CSIRO	R	10	10				10			

Research Staff CRC LEME Funded (cont'd)

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 (cont'd)											
Fitzpatrick R	CSIRO	R	5	5				5			
Gardner B	CSIRO	R	40		40			40			
Herczeg A	CSIRO	R	15	15				15			
Lamontagne M	CSIRO	R	15	15				15			
Lefournour M	CSIRO	R	10	10				10			
McEwan K	CSIRO	R	5	5				5			
Raven M	CSIRO	R	10	10				10			
Rogers S	CSIRO	R	5	5				5			
Singh B	CSIRO	R	5	5				5			
Smith R	CSIRO	R	50	50				50			
			1050	**375**	**305**	**95**	**65**	**840**	**185**	**0**	**25**
Industry or Externally Funded											
Tan K P	ANU	R	50			50		50			
Tan K P	UC	R	50			50		50			
Maly B	GA	R	50				50	50			
Please P	GA	R	50				50	50			
Reisz A	GA	R	30				30	30			
Bryce A	CSIRO	R	15		15			15			
Butt C	CSIRO	R	10	10				10			
Carr G	CSIRO	R	5		5			5			
Cornelius M	CSIRO	R	15		15			15			
Denton G	CSIRO	R	55		55			55			
Gatehouse S	CSIRO	R	10		10			10			
Gray D	CSIRO	R	20		20			20			
Korsch M	CSIRO	R	15		15			15			
Law A	CSIRO	R	15		15			15			
Lintern M	CSIRO	R	20		20			20			
Longman D	CSIRO	R	15		15			15			
Munday T	CSIRO	R	20				20	20			
Phang C	CSIRO	R	25	25				25			
Robertson I	CSIRO	R	30	30				30			
Scott K	CSIRO	R	15		15			15			
Tapley I	CSIRO	R	15	15				15			
			530	**80**	**200**	**100**	**150**	**530**	**0**	**0**	**0**
TOTAL RESEARCH STAFF: CRC GRANT AND EXTERNAL FUNDS			**1580**	**455**	**505**	**195**	**215**	**1370**	**185**	**0**	**25**

KEY: 100 = 1 person year

Summary of Research Staff Resources

	Total Equivalent Person Years	Person Years Spent on Research Program					Person Years Spent on		
		Regolith Geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
Total in-kind contributed	47.3	21.07	13.53	3.45	5.3	43.35	3.27	0	0.68
CRC grant funded	10.5	3.75	3.05	0.95	0.65	8.4	1.85	0	0.25
Industry funded	5.3	0.8	2	1	1.5	5.3	0	0	0
Total funded by CRC LEME	15.8	4.55	5.05	1.95	2.15	13.7	1.85	0	0.25
Grand total	63.1	25.62	18.58	5.4	7.45	57.05	5.12		0.93
Proportion of total professional staff resources in each activity (100%)	100	41	29	9	12	90	8	0	1

Photograph by Ian Roberson

Administration and Technical Staff

Name	Position	Main Activity	Total % of Time
In-kind Contributions			
NIL			0
CRC Grant Funded			
Australian National University			
Edwards D	Research Support Officer	T	5
Shelley J	Education Support Officer	A	25
			30
University of Canberra			
Kovacs B	Education Support Officer	A	50
			50
Geoscience Australia			
Walsh M	Program Support Officer	A	50
			50
Curtin University of Technology			
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
Hink H	Program Support Officer	A	50
Kong G	Business Manager	A	100
Gee D	Chief Executive Officer	A	65
Mills J	Financial Accountant	A	80
			455
			635
Industry or Externally Funded			
NIL			0
TOTAL ADMINISTRATION AND TECHNICAL STAFF:			635

KEY: 100 = 1 person year

Publications

Publications by LEME staff or students published during the reporting period are listed below. Publications by LEME associates are also listed when they are contained within a LEME program and are supported by the Centre. No patents nor provisional patents were lodged by the Centre during the reporting period.

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Photograph by Steve Hill

Communication and Public Relations

Communication Policy

CRC LEME aims to promote and communicate regolith knowledge so that it is recognised by all stakeholders and decision makers as having an important part to play in modern mineral exploration, natural resource management and land use issues. In the reporting period the Centre has directed its scientific communications and promoted its technical capabilities to its clearly defined stakeholders - namely mineral explorers and land managers. However, we recognise that as the salinity and environmental programs grow and deliver, there will be a need to promote the significant potential for the application of regolith geoscience in land remediation schemes to the wider community. A Communications Officer has not as yet been appointed, but a coalition of LEME staff, particularly the CEO, Deputy CEO and Executive committee, has been active in Centre communication and promotion.

To date, communication of research activities and scientific results has been through a number of mechanisms:

- Regular updates of the website, **http://crcleme.org.au** and intranet site, so that it is a resource for all participants to transfer knowledge and to release interim findings.
- The production of an Annual Report which satisfies the reporting needs of the CRC Secretariat, and which delivers relevant information about activities and achievements to a mailing list of over 800 recipients.
- Release of comprehensive technical reports through the successful and long-running LEME Open File Report series.
- Publication of scientific communications and products in national and international publication outlets, such as scientific journals.
- Staging and participating in conferences, seminars and workshops under the LEME banner.
- Production and free circulation of the quality newsletter *LEME News*.
- Sponsoring multi-disciplinary multi-agency scientific and technical events.

Publication Policy

A publication policy addressing format, style and guidelines for technical publications is currently being developed, and at years end was in substantial draft form. It aims to provide direct and speedy benefits to our major stakeholders. The policy is based on the premise of clear written communication and "continuous disclosure" – making information and data of value available to stakeholders as soon as possible, preferably in electronic format. The basis of this will be the continued delivery of progress summaries on the website, and LEME Reports via CD-ROM, observing the constraints imposed by confidentiality and intellectual property issues.

Website

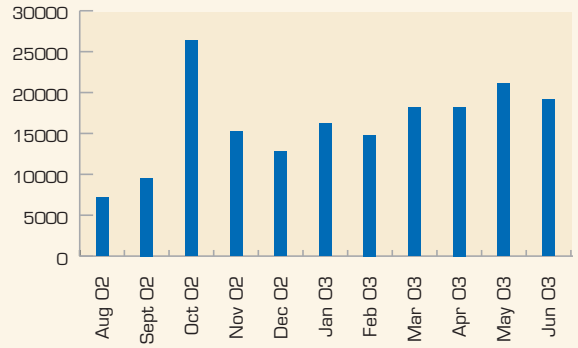
During the reporting period the website and intranet have been significantly developed, both in terms of content and functionality. The upgraded site was publicly launched on 2 October 2002, with a new domain name: **http://crcleme.org.au**. It is now the main medium for conveying LEME activities and research results to staff, clients and stakeholders. It contains a staff directory, the Strategic Plan, news and events, an upcoming conferences list, information on short courses, and student scholarship information, as well as links to all Core Participant websites.

The scientific content is steadily increasing, with summary information available for every project, and progress reports added on a regular basis. Abstracts for all Open File Reports are available, and some entire reports are downloadable as PDF files. Order forms for the range of LEME publications are also available from the site.

The staff-only intranet is central to internal Centre communication, and is used to post minutes from Executive meetings, reports to staff, procedural proformas, policy directives and full project schedules.

Both the number of visits to the site and the number of pages accessed have increased significantly since the launch of the new site.

CRC LEME Webpages Accessed



Publications

LEME publications include regolith material from pre-1995 through to the present, in the form of reports, books, maps, and conference presentations. These are added to regularly as research projects are completed and private sponsor reports are released from confidentiality. New publications produced during the reporting period are listed in the Publications section of this report.

The CRC LEME newsletter, *LEME News*, reaches more than 800 stakeholders with each edition. Although it is anticipated that it will continue to be published on a biannual basis, the intention is to decrease reliance on a hard-copy publication as delivery of information via the web becomes more widely accepted.

Conferences, Seminars and Meetings

A regolith conference, sponsored by CRC LEME and the Minerals Council of Australia, was held at University of Canberra over 21-22 November 2002, and attracted 75 participants. Delegates from ANU, CSIRO Land and Water, Geoscience Australia, Department of Natural Resources and Energy Victoria, New South Wales Department of Land and Water Conservation, New South Wales Department of Minerals Resources, Macquarie University, University of Melbourne and University of Adelaide attended, in addition to LEME staff and students.

CRC LEME was a partner in the launch on 29 November 2002 of geoscientific information packages of the Broken Hill region as part of an exploration initiative of the New South Wales Department of Mineral Resources. LEME data included the first release of regolith-landform maps of the Mt Gipps, Pinnacles and Tibooburra regions. These were well received by exploration company representatives. The Hon Peter Black MP (deputising for the New South Wales Minister of Mineral Resources) and Lindsay Gilligan (Assistant Director, NSW DMR) addressed the gathering and praised the regolith work being done as part of the CRC LEME western New South Wales project, under the leadership of Dr Steve Hill and Dr Patrice de Caritat.

A geochronology workshop was held in Canberra in November 2002, bringing together interested geoscientists who will participate in the introduction of the fourth dimension of time into three-dimensional regolith modelling projects.

Jointly with the Association of Mining and Exploration Companies (AMEC), CRC LEME presented the very successful industry-oriented *Minerals Exploration Seminar* on 18 June at ARRC in Perth. This conveyed to mineral explorers the results of recent research, including work recently out of moratorium, and attracted 95 delegates.

Our CEO Dr Dennis Gee was invited by AMEC to give an address and present the Prospector of the Year Award to Mark Bennett of LionOre Mining International. Dennis Gee was also guest lecturer at the annual technical presentations of the Geological Survey of Western Australia, and guest speaker at a meeting of the Australian Geoscience Information Association. Dennis Gee was also invited to present a paper at the AMIRA Biennial Exploration Managers Conference on "Regolith Geology and Geochemistry – Outstanding Exploration Problems".

CRC LEME has committed to be part-sponsor of the 17th Australian Geological Convention, and to run a technical session on regolith geoscience. It will be held in Hobart in February 2004. LEME personnel were active participants in a number of other regional, national and international conferences, seminars and meetings.

Media Releases

A number of media releases were distributed during the year. The subsequent media response is listed in the table overleaf.

Conferences, Seminars and Meetings 2002-2003

Event	Location	Date	CRC LEME Participants	CRC LEME Role
16th Australian Geological Convention	Adelaide	1-5 July 2002	John Keeling (LEME Coordinator), Graham Heinson	Conference organising committee
			Richard Greene, Ravi Anand, Ian Anderson, Patrice de Caritat, John Clarke, Adrian Fabris, Rob Fitzpatrick, Dave Gibson, David Gray, Stewart Greenhalgh, Graham Heinson, Leanne Hill, Steve Hill, Baohong Hou, Pat James, Dirke Kirste, Ken Lawrie, Ian Lau, Mel Lintern, Annamalai Mahizhnan, Alan Mauger, Bear McPhail, Ken McQueen, Andreas Schmidt-Mumm, Malcolm Sheard, Marian Skwarnecki, Martin Smith, Colin Pain, Brad Pillans, Nigel Radford, John Wilford, Paul Wilkes and Honours and PhD students from CUT, UC, ANU and UofA.	LEME booth, session chairs, presenters, posters, attendees. 20 presentations and 9 posters in total
Collaborative workshop for Solutions for Catchment Management	BRS, Canberra	17 July 2002	Rob Fitzpatrick	Invited speaker
ASEG Salinity Land Management and New Technologies	Katanning, WA	29 July 2002	Ken Lawrie, Colin Pain, Paul Wilkes	Presenter and participants
AGIA Symposium: Geoscience data in the new millenium	ARRC, Perth	31 July 2002	Colin Pain, Ken Lawrie, Paul Wilkes, Ray Smith	Presenter and participants

Conferences, Seminars and Meetings (cont'd)

Event	Location	Date	CRC LEME Participants	CRC LEME Role
CRC LEME - Talks	GA, Canberra	August - December 2002	Jonathan Clarke, Lynda Radke, John Chappell, Kylie Foster, Ancret Lewis, Matilda Thomas, Karen Earl, Juan Pablo Bernal, Colin Pain, Derek Fabel, Alejandra Duk-Rodkin (GS Canada), Philip Giles (St Mary's University, Canada)	CRC LEME presenters and invited speakers
17th World Congress of Soil Science, Symposium 25 "Mineralogy and geochemistry of regolith"	Bangkok, Thailand	14-21 August 2002	Keith Scott, Rob Fitzpatrick	Symposium convenor and presenters
Sustainable development in practice (Mine closure/ completion)	Perth	15-16 August 2002	Ian Tapley	Attendee
Girilambone Project - presentation to the Central West Exploration Discussion Group	Orange, NSW	21 August 2002	Ken McQueen, Roslyn Chan, Mike Hicks, Guy Fleming, Peter Buckley	CRC LEME event, 55 attended
5th International Acid Sulfate Soils Conference	Tweed Heads, NSW	25-30 August 2002	Rob Fitzpatrick	Conference organising committee
IMA 2002 Conference	Edinburgh, UK	25 August - 12 September 2002	Ken Lawrie, Ken McQueen	Presenter, attendee, posters
Dowerin Field Day	Dowerin, WA	27-29 August 2002	Mehrooz Aspandiar, Ron Watkins, Margarita Norvill, Reece Foster	LEME booth
11th Australasian Remote Sensing and Photogrammetry Conference	Brisbane	1-6 September 2002	Ian Tapley	Speaker, session chairman
			Pat James, Alan Mauger, Ian Lau, Sean Mahoney	Attendees, posters
University of WA Student Night: Monthly talks	Perth	3 September 2002	Annamalai Mahizhnan	Presenter
2nd Hyperspectral Workshop	Flinders Ranges	9-13 September 2002	Vicki Stamoulis, Alan Mauger	Organisers
			John Keeling	Attendee
Victorian Universities Earth Sciences Conference	University of Melbourne	September 2002	Kathryn Fitzsimmons	Presenter and poster
8th National Conference on Productive use and rehabilitation of saline lands (PURSL)	Perth	16-20 September 2002	Rob Fitzpatrick	Presenter
			Paul Wilkes	Attendee
Rhys' Day: Research reports and celebration in memory of Rhys Maengwyn Jones	Society of Antiquaries, London	21 September 2002	John Magee	Presenter
10th Australian New Zealand Geomorphology Conference	Kalgoorlie, WA	30 September - 4 October 2002	Colin Pain	Coordinator
			Ravi Anand, Ros Chan, John Chappell Jon Clarke, Derek Fabel, Baohong Hou, Pat James, Richard Lane, Brad Pillans, Martin Williams	Presenters, attendees, field trip organisers
Australian Synchrotron Workshop	University of Melbourne	3-4 October 2002	Bear McPhail, Chris Gunton	Attendees
Society of Exploration Geophysicists (SEG) Conference	Salt Lake City, USA	6-10 October 2003	Stewart Greenhalgh	Attendee
National Institute for Environment	ANU Public Lecture Series, Canberra	15 October 2002	John Chappell	Public lecture
Curtin University, Department of Applied Geology - Talk	Perth	30 October 2002	Ravi Anand	Invited speaker
International Symposium on Remote Sensing	Korea	30 October - 1 November 2002	Ian Tapley	Presenter, session chair and workshop leader
Honours Geoscience Seminars 2002	Adelaide University	15 November 2002	Amy Kernish, Kate Selway, Nick Nitschke, Carly Chor, Tania Dhu, Karen Hulme, Daniel Radulovic, Sean Mahoney, Philip Heath, David Baker	Student presenters
LEME Honours Student Seminar Series	Geology Department, ANU, Canberra	November 2002 - April 2003	Kirsty Bewert, Berlinda Crowther, Katie Dowell, William Kimber, Edward Summerhayes, Jodi Web	Student presenters
Academy of Technological Sciences and Engineering (ATSE) Fellows' Seminar, AGM and Annual Symposium	Sydney	17-19 November 2002	Ray Smith	Delegate
CRC LEME Geochronology Group Workshop	ANU, Canberra	20 November 2002	Jim Dunlap, Martin Smith, Brad Pillans, John Chappell, Derek Fabel	CRC LEME event, presenter, attendee
Regolith and Landscapes in Eastern Australia Conference	UC	21-22 November 2002	Ian Roach (Convenor)	CRC LEME event and display
			31 LEME presentations	Presenters, posters, attendees. 75 attended

Conferences, Seminars and Meetings (cont'd)

Event	Location	Date	CRC LEME Participants	CRC LEME Role
Release of Broken Hill regolith landform maps and data	NSW DMR, Sydney	29 November 2002	Steve Hill, Keith Scott, Patrice de Caritat, Kylie Foster	Participants
Australian Diamond Conference	Perth	2-3 December 2002	Jayson Meyers	Attendee
Geoscience Australia Seminar	GA, Canberra	4 December 2002	Derek Fabel	Presenter
Gawler Craton 2002: State of Play	Adelaide	5-6 December 2002	Dennis Gee, Keith Scott, Mel Lintern, Malcolm Sheard, John Keeling, David Gray, Baohong Hou, Ian Lau	Presenters, attendees
CSIRO Land and Water Seminar	Perth	9 December 2002	Tim Munday	Presenter
Farming Systems Forum	Narromine, NSW	10-11 December 2002	Richard Green	Invited speaker
ASCILITE Conference	Auckland, NZ	8-11 December 2002	Pat James	Attendee
Symposium, Living with Climate Change	Australian Academy of Science, Canberra	18-19 December 2002	John Chappell	Invited presentation
23°S Archaeology and Environmental History of the Southern Hemisphere Deserts	National Museum of Australia, Canberra	15-18 January 2003	John Magee	Presenter
Australasian Quaternary Association, Biennial Meeting	Westport, NZ	3-7 February 2003	John Magee	Presenter
			Kathryn Fitzsimmons	Attendee
Australian Society of Exploration Geophysics, 16th Geophysical Conference	Adelaide	16-19 February 2003	Ken Lawrie	Keynote speaker
			Jayson Meyers, Tim Munday, Pat James, John Keeling, Paul Wilkes, Philip Heath	Presenters, participants, posters, CRC LEME booth
Third International Symposium on 3D Electromagnetics (3D EM-3: 3D EM at Work)	Adelaide	20-21 February 2003	Graham Heinson	Conference organising committee
			Tania Dhu	Attendee
NT Geological Survey AGES 2003: Exploration Opportunities in the NT	Alice Springs	25-26 February 2003	Ravi Anand	Attendee
Earth System Science and Sustainability - Open Meeting	University of Melbourne	26-27 February 2003	Ken Lawrie, Colin Pain, Paul Wilkes	Attendees
Geoscience Australia Seminar	GA, Canberra	5 March 2003	Colin Pain	Presenter
Association of Mining and Exploration Companies (AMEC) Seminar	Perth	5 March 2003	Dennis Gee, Ray Smith, Charles Butt	Presenters, attendee
LEME Canberra Node Seminar Series	ANU	March - June 2003	Ken McQueen, John Chappell, Paul Link (Idaho Uni), Juan Pablo Bernal, Sue Welch	CRC LEME event, presenters
AMIRA Sponsors Meeting Airborne EM project and P407b	Perth	14 March 2003	Jayson Meyers, Anton Kepic, Paul Wilkes	Presenter, attendees
Hong Kong Regional Group, Technical Meeting	Geological Society of London, Hong Kong	19-20 March 2003	Colin Pain, Graham Taylor	Presenters
Australian Institute of Geoscientists, (AIG) Exploration Strategies Symposium	Perth	19 March 2003	Ravi Anand, Charles Butt, Matthias Cornelius, Ray Smith	Attendees
NT Workshop	Alice Springs	25-26 March 2003	Ravi Anand	Attendee
National Dryland Salinity Program (NDSP) Research and Development Workshop	Adelaide	25-26 March 2003	Rob Fitzpatrick	Presenter
AMIRA 5th Biennial Exploration Managers Conference, "Regolith geology and geochemistry - outstanding exploration problems"	Margaret River, WA	26-28 March 2003	Dennis Gee	Invited speaker
Saltwater Intrusion and Coastal Aquifers Conference (SWICA)	Merdi, Mexico	27-29 March 2003	Sam Lee	Attendee
Drainage Forum: To drain or not to drain - engineering options for salinity management	Adelaide, SA	3 April 2003	Rob Fitzpatrick	Presenter
CRC LEME Talk	CSIRO, Perth	7 April 2003	Bear McPhail	Presenter
Central Gawler Gold Sub-Project Planning Workshop	PIRSA, Adelaide	14 April 2003	John Keeling, David Gray and others	Presenters and attendees
Annual Conference, Korean Society of Geosystem Engineering	Daejeon	22 April 2003	Ron Watkins	Invited international speaker
International Conference of Korean Society of Environmental Geology	Kwanhju City	25-26 April 2003	Ron Watkins	Invited keynote speaker

Conferences, Seminars and Meetings (cont'd)

Event	Location	Date	CRC LEME Participants	CRC LEME Role
Australian Institute of Geo-scientists (AIG) Symposium on the Mineral Potential of China	Perth	12 May 2003	Jayson Meyers	Attendee
AMIRA Project Development Meeting	Perth	13 May 2003	Ravi Anand	Presenter
			Dennis Gee, David Gray, Keith Scott, Michael Whitbread	Attendees
Weekly Seminar, Geology and Geophysics, UofA	Adelaide	14 May 2003	Martin Williams	Presenter
Acid Sulfate Soils - Million Dollar Soils - Science and Policies	BRS Public Seminar, Canberra	16 May 2003	Rob Fitzpatrick	Invited speaker
NSW Exploration Investment Conference	Sydney	22-23 May 2003	Dennis Gee, Keith Scott, Ken McQueen, Patrice de Caritat, Kylie Foster	CRC LEME booth, attendees
5th International Symposium on Applied Isotope Geochemistry	Heron Island	26-30 May 2003	Patrice de Caritat	Presenter
CRC Association Conference	Canberra	28-29 May 2003	Dennis Gee, Ross Fardon, Pat James	Attendees
Opal Symposium	Sydney University	6 June 2003	Katie Dowell	Presenter
Workshop on Identifying, Managing and Assessing Acid Sulfate Soils	CUT, Perth	12-13 June 2003	Rob Fitzpatrick	Two invited presentations
LEME - AMEC Minerals Exploration Seminar	CSIRO, Perth	18 June 2003	Mehrooz Aspandiar (Convenor)	CRC LEME event, 12 presentations, display, 95 attended
			Dennis Gee, Ravi Anand, Tim Munday, David Gray, Charles Butt, Mel Lintern, Jayson Meyers, Keith Scott, John Joseph, Ian Robertson, Sue Game, Jennie Campbell	

Media Reports and Releases

Subject	CRC LEME Talent	Publication	Date
$12M rock-solid investment in geological research and training	Pat James	Adelaidean (News from the University of Adelaide Vol II, No 6, p. 3)	July 2002
Acid sulfate soils in mangroves at St Kilda, SA	Rob Fitzpatrick, Brett Thomas	Totally Wild: Channel 10 TV Network	2 September 2002
Dust	Richard Greene	2BL (ABC News)	14 November 2002
		WIN News, ACT	28 November 2002
LEME Regolith mapping in the Broken Hill Region	Steve Hill, Glen Fisher, Anthony Senior, Patrice de Caritat, Kylie Foster, Richard Barratt, Kingsley Mills, Barney Stevens, Martin Smith, Lea Hill, Pat James, Keith Scott	NSW regional ABC Television	29 November 2002
		Barrier Daily Truth (no 29577, page 1)	30 November 2002
Black opal	Katie Dowell	Black Opal Advocate	9 March 2003
		Lightning Ridge News	12 March 2003
Broken Hill information products release		Minfo (the quarterly newsletter of Exploration NSW), Vol 77-78 p. 4	3 June 2003

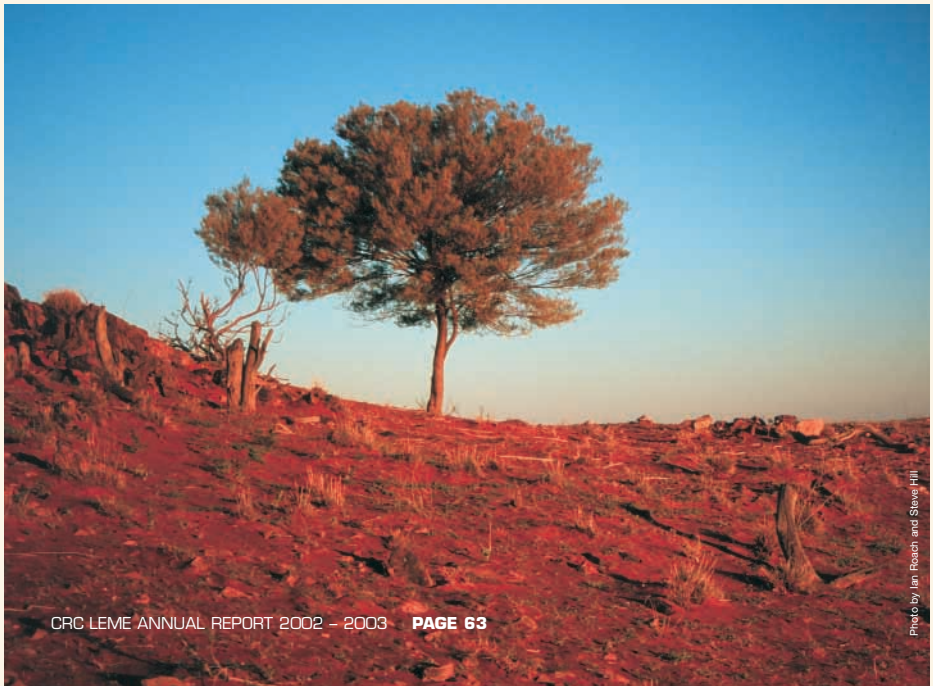


Photo by Ian Roach and Steve Hill

Visitors

Dr Alejandra Duc-Rodin from the Geological Survey of Canada was a visitor to the Centre in 2002, as part of a CRC LEME academic exchange arrangement. She worked predominantly with Geoscience Australia in Canberra.

Kachen Neosuparp from Chulalongkorn University in Thailand was a visitor to CRC LEME in 2003, working with Dr Jayson Meyers at CUT as part of his PhD on geophysical prospecting and mineral potential of the Loei district in Thailand and comparison of tropical regolith of Thailand with Australian regolith. Kachen is sponsored by the Thailand Government and the Western Australian Department of Industry and Resources.

Visitors

Visitors from the Centre (LEME staff to other institutions)

Name and Core Participant	Host Organisation and Location	Host staff	Project / Activity	Date
Stewart Greenhalgh, UofA	Institute for Geophysics, ETH Zurich	Prof Klaus Hollinger, Dr Hansrudi Mehrer	Environmental geophysics	13-21 July 2002
Bear McPhail, ANU	Monash University, Melbourne	Prof Jim Cull	Student supervision and collaboration	September 2002 and May 2003
John Magee, ANU	Research Lab for Archaeology and History of Art, University of Oxford, UK	Dr Ed Rhodes	Calibrating gamma spectrometer	September 2002
John Magee, ANU	Centre for Dryland Research, Sheffield University, UK	Prof D Thomas	Viewing facilities, consultation, presenting a lecture: Long term environmental history of the Australian arid zone	September 2002
Ian Tapley, CSIRO	Geo-Information and Space Technology Development Agency, Thailand	Dr Suvit Vibulsresth, Director	AIRSAR data processing and applications workshop	7-11 October 2002
Stewart Greenhalgh, UofA	University of Copenhagen, Denmark	Dr Oli Gudmundsson	Seismic imaging	28-30 September 2002
Bear McPhail, ANU	Australian Institute of Nuclear Science and Engineering (AINSE), Sydney	Dr Dennis Mather	Advisory Board for Environmental Research	May 2003

Visitors to the Centre (non-LEME researchers to CRC LEME)

Visitor	Organisation and Location	LEME Host	Location	Date
Dr Alejandra Duk-Rodkin	Terrain Sciences Division, Geological Survey of Canada	Colin Pain, Roslyn Chan	GA	May - July 2002
Ms Parla Coratza, PhD student	University of Moderna, Italy collaborating with UWA	Ian Robertson	CSIRO, Perth	July 2002
Dr Wendy Jarvie, Deputy Secretary	Commonwealth Department of Education, Science and Training	Nigel Radford	CSIRO and CUT, Perth	August 2002
Mr Geoff Bowley, State Manager	Commonwealth Department of Education, Science and Training	Gary Kong	CSIRO and CUT, Perth	August 2002
Prof George Helz	University of Maryland, USA	Bear McPhail	ANU	August 2002
Mr Rob Watchorn	Abelle Ltd	Ravi Anand	CSIRO, Perth	August 2002
Prof Del Fanning	University of Maryland, Washington, DC, USA	Rob Fitzpatrick	CSIRO Land and Water, Adelaide	16-24 September 2002
Ms Michelle Carey	Monash University	Bear McPhail	ANU	December 2002
Prof Paul Link	Idaho State University, USA	Bear McPhail	ANU, Sabbatical - collaborative research	October 2002 - March 2003
Mr Kachen Neosuparp	Chulalongkorn University, Bangkok and WA Department of Industry and Resources	Jayson Meyers	CUT, Perth	February - December 2003
Dr Dave Snyder	Geological Survey of Canada, Ottawa	Stewart Greenhalgh	UofA	14-17 January 2003
Mr Grant Roberts	Subsurface Imaging Pty Ltd, Wellington NZ	Stewart Greenhalgh	UofA	5-6 February 2003
Dr John Earthrowl	Exploration Geochemist, NT	Ravi Anand	CSIRO, Perth	February 2003
Dr Richard Harper	WA Department of Conservation and Land Management (CALM)	Ravi Anand	CSIRO, Perth	February 2003
Dr Peter Lightfoot	INCO Global Nickel, Canada	Malcolm Sheard	PIRSA	February 2003
Prof Alan Chivas	University of Wollongong	Ravi Anand	CSIRO, Perth	March 2003
Dr Nigel Radford	Newmont Australia	Ravi Anand	CSIRO, Perth	April 2003
Mr Ian Lau	PhD student UofA	Ravi Anand	CSIRO, Perth	7-12 April 2003
Dr Tushar K Sen	National Institute of Technology, Rourkela, India	Bear McPhail	ANU	June - July 2003

Grants and Awards

Awards and Appointments

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

Ravi Anand and Mark Paine recently received the prestigious Stillwell Award from the Geological Society of Australia for the best paper in the *Australian Journal of Earth Sciences* (AJES) in 2002, for their paper, "Anand, R. and Paine, M. 2002. Regolith Geology of the Yilgarn Craton, Western Australia: Implications for Exploration, 49, 3-162". Their award will be presented at the *17th AGC* to be held in Hobart, February 2004.

Colin Pain was awarded an Annual Citation for Excellence in Reviewing 2002, by Dr Tony Cockbain, the editor of the *Australian Journal of Earth Sciences*. Colin also received an honorary appointment as Adjunct Professional Associate - Regolith Science, in the School of Resource, Environmental and Heritage Sciences, at the University of Canberra.

Ian Robertson and Mel Lintern from CSIRO Exploration and Mining in Perth were recipients of the inaugural CSIRO Occupational Health and Safety Achievement Award, announced in December 2002. Their *Field Safety Initiative* has standardised field safety authorisation, communication and emergency procedures across CSIRO Exploration and Mining.

Patrick James was one of four winners of the 2002 "Stephen Cole the Elder" prizes. These prizes are awarded annually by the University of Adelaide to academic staff whose teaching is regarded of excellent quality, both by students and academic colleagues.

Rob Fitzpatrick was elected chairman of the International Union of Soil Sciences Commission VII: Soil Mineralogy, at the *17th World Congress of Soil Science* held in Bangkok in August 2002.

Keith Scott attended the same conference and made a poster presentation *Behaviour of geochemical pathfinder elements during weathering and pedogenesis in southeast Australia.* Graphic design for the poster was by Travis Naughton in the LEME Visual Resources Unit, Perth. It won the best poster award for its session, and then, out of 65 session winners, won one of eight "Outstanding Poster Awards" for "the presentation of a poster with supreme scientific content, structure and layout". The conference organisers were so impressed by the poster that they requested it remain in Thailand as a permanent reference!

Ron Watkins efforts as a founding member and secretary of the Asia-Pacific branch of the International Society of Environmental Geochemistry and Health was recognised through his appointment to the Executive Board of the Society in August 2002.

Student Success

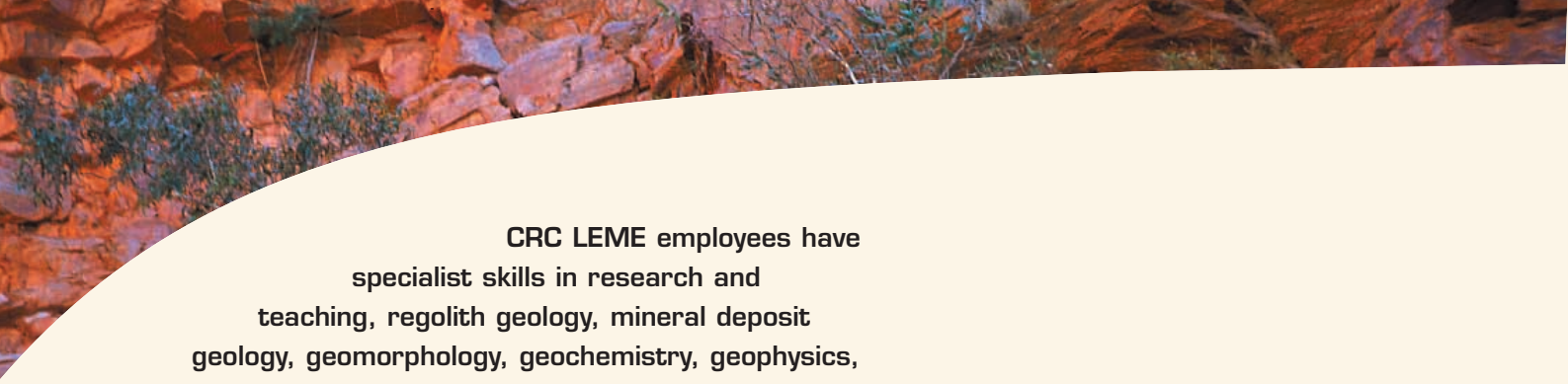
Our students also made their mark during the year, winning a number of awards at conferences (overleaf).

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 (overleaf).

Awards and Appointments

LEME Personel	Organisation	Achievement	Awarded By	Date
Keith Scott, Travis Naughton	CSIRO	Outstanding Poster Award	17th World Congress of Soil Science, Bangkok, Thailand	August 2002
Rob Fitzpatrick	CSIRO	Appointment - Elected Chairman of Commission vii - Soil Mineralogy	Internal Union of Soil Science	August 2002
Ron Watkins	CUT	Appointment - Executive Board	International Society of Environmental Geochemistry and Health (SEGH)	August 2002
Patrick James	UofA	Stephen Cole the Elder Prize for excellence in teaching	UofA	October 2002
Rob Fitzpatrick	CSIRO	Appointment (2 yrs) - Vice President	Royal Society of SA	November 2002
Melvyn Lintern, Ian Robertson	CSIRO	Occupational Health and Safety Achievement Award, for development of Occupational Health and Safety Field Safety Procedures	CSIRO Corporate	December 2002
Colin Pain	GA	Citation for Excellence in Reviewing 2002	Australian Journal of Earth Sciences	January 2003
Colin Pain	GA	Appointment - Adjunct Professional Associate	UC	March 2003
Ray Smith	CSIRO	Australian Centenary Medal, for Services to Australian society in Geology	Governor General and Prime Minister (Australian Government)	April 2003
John Chappell	ANU	Australian Centennial Medal, for contributions to Earth Sciences	Governor General and Prime Minister (Australian Government)	April 2003
Stewart Greenhalgh	UofA	Australian Centenary Medal, for Services to Australian Society in Geophysics	Governor General and Prime Minister (Australian Government)	April 2003
Rob Fitzpatrick	CSIRO	Appointment (ongoing) - Editorial Committee, Transactions of RSSA	Royal Society of South Australia	June 2003
Ravi Anand, Mark Paine	CSIRO and CUT	Stillwell Award 2002, for the best paper in the Australian Journal of Earth Sciences	Geological Society of WA to be awarded February 2004 at the 17th AGC in Tasmania	June 2003,



CRC LEME employees have specialist skills in research and teaching, regolith geology, mineral deposit geology, geomorphology, geochemistry, geophysics, hydrogeology, hydrology, sedimentology, isotope geochemistry, geochronology, microbiology, geo-botany, bio-geochemistry, computation, GIS, soil science and many more.

LEME Student Prizes

Student	Institution	Achievement	Awarded By	Date
Brian Barrett	UofA	Best student paper at Conference	16th AGC	July 2002
Sean Mahoney	UofA	Best Poster - "Geological and mineral mapping of the Tarcoola Goldfield SA using hyperiod space-borne imager"	11 Australian Remote Sensing and Photogrammetry Conference, Brisbane	September 2002
Frank Reith	ANU	Taylor and Eggleton Award for Best Student Presentation	RA Eggleton and G Taylor	November 2002
Tania Dhu	UofA	Best student presentation at ASEG student night	ASEG SA Branch	November 2002
Leanne Hill	ANU/UC	Editors Prize, awarded in recognition of excellence for abstracts and oral presentation, awarded at the Regolith and Landscapes in Eastern Australia Conference	UC	November 2002
Katherine Brohoxlme	UofA	Newmont Prize for Top Geophysics student	UofA	December 2002
Angela Ratchford	UC	Regolith Glossary Award for Excellence in Presentation	UC	November 2002
Philip Heath	UofA	Bursary - Most Active Member 2002	AusIMM	Febuary 2003

Grants to LEME Personnel

Recipient and Core Party	Title of Project for which grant awarded	Source of Grant	Period of Grant	Amount of Grant
John Chappell and others, ANU	Millenial-scale instability of sea level and the climate system: new analysis from coral terraces in PNG	ARC Discovery	2003-2005	$295,000
John Chappell, Derek Fabel and others, ANU	Production and transport of soil and sediments, determined by cosmogenis radionuclides and noble gases	ARC Discovery	2003-2005	$290,000
Stewart Greenhalgh, Graham Heinson, UofA	Optimisation of signal to noise ratio in electrical and EM investigations	ARC Linkage	2002-2003	$59,00
Stewart Greenhalgh, UofA	Non-linear seismic inversion incorporating later arrivals	ARC Large	2001-2003	$228,000
Martin Williams, Stewart Greenhalgh and others, UofA	South Australian supercomputing facility	ARC LIEF	2003-2004	$600,000
Stewart Greenhalgh, B Zhou and others, UofA	Resistivity imaging to map economically important changes to coal seams	ACARP	2003-2004	$175,000
Derek Fabel, ANU	Constraining neotectonic movement using cosmogenic burial dating	Australian Institute of Nuclear Science and Engineering (AINSE)	2003-2004	$13,012

Performance Indicators

Our Key Performance Indicators (KPIs), along with milestones and outputs detailed elsewhere in this Annual Report, provide a numerical measure of performance against the stated objectives of CRC LEME. These KPIs are those itemised in Schedule 6 of the Commonwealth Agreement, for which quantitative measures were developed and presented in the previous Annual Report. By including those indicators from last year, we are now able to commence time-series charts to develop benchmarks and compare annual performances.

The qualitative nature of many of the KPIs is addressed in other sections of the Annual Report, particularly the sections on Cooperative Linkages, Education and Training, Communication and Public Relations, and Research Programs.

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's future.
- The Centre will increase the number of companies, user 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, user agencies and institutions overseas.

Objectives of the Centre

Performance Indicator	2001-2002	2002-2003
Number of external research collaborators	47	86
Number of sponsors and the annual value of sponsorship	13/$756,540	13/$616,000
Number of overseas researchers visiting CRC LEME sites	4	10
Number of overseas visits by CRC LEME staff	19	7
Number and value of overseas research projects	1/$27,489	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.

Quality and Relevance of the Research Program

Performance Indicator	2001-2002	2002-2003
Number of published journal articles per year	54	23
Number of conference papers presented per year	50	134
Number of books or chapters in books	20	40
Other forms of publications/maps	28	21
Number of CRC LEME Technical Reports released	36	6
Number of confidential reports, maps	18	9
Number of keynote addresses given	4	2
Number of sabbatical leaves taken by overseas personnel at CRC LEME sites	3	2
Number of awards to CRC LEME researchers and educators	3	8
Number of professional appointments awarded to CRC LEME researchers and educators	7	5
Number of ARC Discovery and Linkage Grants awarded to CRC LEME researchers	3/ $694,000	4/ $872,000

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 users of the research.
- 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 user organisations.
- Secure adequate funding from companies, agencies and institutions for Centre projects.

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

Strategy for Utilisation and Commercialisation of Research Outputs

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

Education and Training

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

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

As part of the strategic plan, CRC LEME aims to produce at least 60 new PhD graduates and 60 Honours graduates throughout the lifetime of the Centre. We are well on our way to achieving this goal.

Education and Training

Performance Indicator	2001-2002	2002-2003
Number of postgraduate students working on LEME research projects	38	51
Number of postgraduate awards each year	1	7
Number of BSc Honours graduates completing LEME projects	16	11
Number of BSc Honours students commenced/continuing LEME projects	37	20
Number of external supervisors of research students	20	12
Number of student class hours of instruction in Masters by coursework degrees related to the regolith	80	80
Number of Honours graduates produced over the lifetime of CRC LEME	16	27
Number of PhD graduates produced over the lifetime of CRC LEME	1	3

Collaborative Arrangements

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

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

Photograph by Kim McQueen

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

Resources and Budget

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

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 and students working in any of the Core Participants.

Financial Statements and Budget

As at 30 June 2003, most of the CRC Core Participants met or exceeded their in-kind contribution target defined in the Commonwealth Agreement. The total cash income received for collaborative activities from industry and other users in Year 2 was $0.81M. These are significant achievements considering the general downturn in the mineral industry and the global economic downturn.

The leverage of actual contributed resources to CRC Program funding from the Commonwealth is 5.1:1, at the end of Year 2.

Actual Contributed Resources

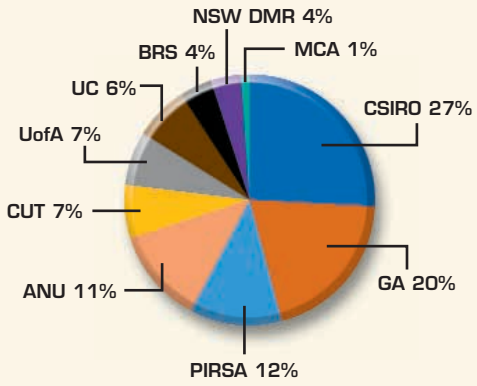
Item	Value
Total Cash from Industry and Other Users, and from Core Participants	$4.62M
Total In-Kind Resources from Participants	$12.07M
Total Actual Contributed Resources	$16.69M
CRC Program Funds	$3.3M

Financial Reports for 2002-2003

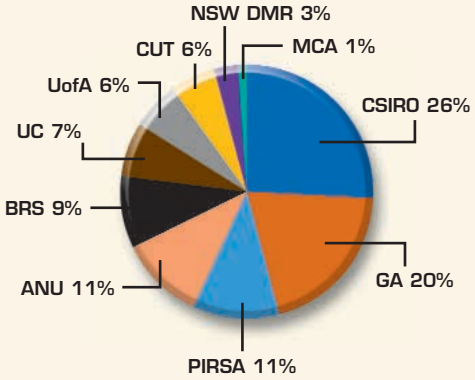
The following statements and accounting policy notes represent the known financial status as at 30 June 2003.

Core Participant equity positions are summarised as follows:

Core Participant Actual Cumulative Equity as at 30 June 2003 (Years 1 and 2)



Core Participant Equity as per Commonwealth Agreement as at 30 June 2003 (Years 1 and 2)



Total External Income

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

Total External Income

	Year 1 ($'000)	Year 2 ($'000)	Cumulative ($'000)
Budget	765	1,080	1,845
Actual	892	811	1,703
Variance	127	-269	-142

Table 1: In-kind Contributions From Partners (Dollars in '000s)

	Expenditure			Cumulative Total to Date		Projected expenditure					Grand Seven-Year Total			
	YEAR 1 2001/02 Actual	YEAR 2 2002/03 Actual	YEAR 2 2002/03 Agreement	Actual	Agreement	YEAR 3 2003/04 Agreement	YEAR 4 2004/05 Agreement	YEAR 5 2005/06 Agreement	YEAR 6 2006/07 Agreement	YEAR 7 2007/08 Agreement	Actual Total	Revised Agreement	Difference	Original Agreement
ANU														
Salaries	474	431	403	905	787	423	445	467	490	515	3,245	3,127	118	3,127
Capital			-	-	-	-	-	-	-	-	-	-	-	-
Other	1,126	1,169	1,133	2,295	2,093	1,190	1,249	1,311	1,233	1,212	8,490	8,288	202	8,289
Total	1,600	1,600	1,536	3,200	2,880	1,613	1,694	1,778	1,723	1,727	11,735	11,415	320	11,416
UC														
Salaries	314	81	81	395	343	-	-	-	-	-	395	343	52	2,289
Capital			-	-	-	-	-	-	-	-	-	-	-	-
Other	852	329	329	1,181	1,114	-	-	-	-	-	1,181	1,114	67	4,339
Total	1,166	410	410	1,576	1,457	-	-	-	-	-	1,576	1,457	119	6,628
GA														
Salaries	974	839	839	1,813	1,531	783	792	832	873	917	6,010	5,728	282	5,627
Capital			-	-	-	-	-	-	-	-	-	-	-	-
Other	1,973	1,928	1,928	3,901	4,153	2,424	2,575	1,732	1,747	1,794	14,173	14,425	(252)	14,812
Total	2,947	2,767	2,767	5,714	5,684	3,207	3,367	2,564	2,620	2,711	20,183	20,153	30	20,439
CUT														
Salaries	329	423	351	752	658	368	387	406	427	448	2,788	2,694	94	2,694
Capital			-	-	-	-	-	-	-	-	-	-	-	-
Other	469	646	590	1,115	932	620	651	683	629	611	4,309	4,126	183	4,126
Total	798	1,069	941	1,867	1,590	988	1,038	1,089	1,056	1,059	7,097	6,820	277	6,820
UofA														
Salaries	314	403	379	717	666	399	418	439	462	484	2,919	2,868	51	2,868
Capital			-	-	-	-	-	-	-	-	-	-	-	-
Other	373	626	649	999	991	680	715	751	717	710	4,572	4,564	8	4,565
Total	687	1,029	1,028	1,716	1,657	1,079	1,133	1,190	1,179	1,194	7,491	7,432	59	7,433
PIRSA														
Salaries	506	523	408	1,029	797	428	449	472	495	520	3,393	3,161	232	3,161
Capital			-	-	-	-	-	-	-	-	-	-	-	-
Other	1,984	521	406	2,505	2,294	427	448	470	494	518	4,862	4,651	211	4,651
Total	2,490	1,044	814	3,534	3,091	855	897	942	989	1,038	8,255	7,812	443	7,812
BRS														
Salaries	193	16	16	209	208	-	-	-	-	-	209	208	1	1,563
Capital			-	-	-	-	-	-	-	-	-	-	-	-
Other	139	12	12	151	150	-	-	-	-	-	151	150	1	1,126
Total	332	28	28	360	358	-	-	-	-	-	360	358	2	2,689
NSW DMR														
Salaries	224	235	230	459	448	242	254	266	280	294	1,795	1,784	11	1,783
Capital			-	-	-	-	-	-	-	-	-	-	-	-
Other	29	30	29	59	57	31	32	34	36	38	230	228	2	228
Total	253	265	259	518	505	273	286	300	316	332	2,025	2,012	13	2,011
MCA														
Salaries	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Capital			-	-	-	-	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CSIRO														
Salaries	1,333	1,398	1,398	2,731	2,340	1,039	1,090	1,145	1,201	1,262	8,468	8,077	391	7,670
Capital			-	-	-	-	-	-	-	-	-	-	-	-
Other	2,559	2,457	2,457	5,016	5,193	3,111	3,268	3,173	2,932	2,844	20,344	20,521	(177)	21,026
Total	3,892	3,855	3,855	7,747	7,533	4,150	4,358	4,318	4,133	4,106	28,812	28,598	214	28,696
Supporting Contributions														
Salaries	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Capital			-	-	-	-	-	-	-	-	-	-	-	
Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total In-kind Contributions														
Salaries	4,661	4,349	4,105	9,010	7,778	3,682	3,835	4,027	4,228	4,440	29,222	27,990	1,232	30,782
Capital	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other	9,504	7,718	7,533	17,222	16,977	8,483	8,938	8,154	7,788	7,727	58,312	58,067	245	63,162
Grand Total (In-kind)														
	14,165	12,067	11,638	26,232	24,755	12,165	12,773	12,181	12,016	12,167	87,534	86,057	1,477	93,944

Table 2: Cash Contributions (Dollars in '000s)

	Contribution			Cumulative Total to Date		Projected expenditure					Grand Seven-Year Total			
Partners	YEAR 1 2001/02 Actual	YEAR 2 2002/03 Actual	YEAR 2 2002/03 Agreement	Actual	Agreement	YEAR 3 2003/04 Agreement	YEAR 4 2004/05 Agreement	YEAR 5 2005/06 Agreement	YEAR 6 2006/07 Agreement	YEAR 7 2001/02 Agreement	Total	Revised Agreement	Difference	Original Agreement
ANU	100	150	150	250	250	200	200	200	200	200	1,250	1,250	-	700
UC	100	50	50	150	150	-	-	-	-	-	150	150	-	700
GA	100	150	150	250	250	100	100	100	100	100	750	750	-	700
CUT	100	100	100	200	200	100	100	100	100	100	700	700	-	700
UofA	100	100	100	200	200	100	100	100	100	100	700	700	-	700
PIRSA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BRS	810	-	-	810	810	-	-	-	-	-	810	810	-	3,794
NSW DMR	250	250	250	500	500	250	250	250	150	-	1,400	1,400	-	1,400
MCA	100	100	100	200	200	100	-	-	-	-	300	300	-	300
CSIRO	150	100	100	250	250	100	100	100	100	100	750	750	-	750
Total Cash From Participants	1,810	1,000	1,000	2,810	2,810	950	850	850	750	600	6,810	6,810	-	9,744
Supporting Participants	-	300	150	300	150	150	150	-	-	-	600	450	150	450
Other Cash														
Non Participants	-	-	500	-	900	600	400	-	-	-	1,000	1,900	(900)	1,900
External Grants	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contract Research	696	599	400	1,295	700	600	800	900	1,000	1,100	5,695	5,100	595	5,100
Commercialisation	-	-	120	-	150	355	520	640	640	640	2,795	2,945	(150)	2,945
Education	86	17	45	103	65	88	120	120	120	120	671	633	38	633
Interest Income	110	195	15	305	30	15	15	15	15	15	380	105	275	105
Total	892	811	1,080	1,703	1,845	1,658	1,855	1,675	1,775	1,875	10,541	10,683	(142)	10,683
CRC Grant	2,754	3,300	3,300	6,054	6,054	3,300	3,300	3,300	2,700	1,546	20,200	20,200	-	20,200
Total CRC Cash Contribution	5,456	5,411	5,530	10,867	10,859	6,058	6,155	5,825	5,225	4,021	38,151	38,143	8	41,077
Cash carried over from previous year*	777	2,504	3,566			3,566	2,939	2,837	1,508	1,781				
Less Unspent Balance	2,504	3,566	4,747		2,810	2,939	2,837	1,508	1,781	756				
Total Cash Expenditure	3,729	4,349	4,349	8,078	8,049	6,685	6,257	7,154	4,952	5,046	38,172	38,143	29	38,114
Allocation of Cash Expenditure Between Heads of Expenditure														
Salaries	1,916	1,898	2,182	3,814	4,082	3,139	2,995	2,794	998	1,048	14,788	15,056	(268)	15,324
Capital	-	245	245	245	245	205	-	-	-	-	450	450	-	450
Other	1,813	2,206	1,922	4,019	3,722	3,341	3,262	4,360	3,954	3,998	22,934	22,637	297	22,340

* 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 Centre (Dollars in '000s)

				Cumulative Total							Grand Seven-Year Total			
	YEAR 1 2001/02 Actual	YEAR 2 2002/03 Actual	YEAR 2 2002/03 Agreement	Actual	Agreement	YEAR 3 2003/04 Agreement	YEAR 4 2004/05 Agreement	YEAR 5 2005/06 Agreement	YEAR 6 2006/07 Agreement	YEAR 7 2001/02 Agreement	Total	Revised Agreement	Difference	Original Agreement
Grand Total (In-kind)	14,165	12,067	11,638	26,232	24,755	12,165	12,773	12,181	12,016	12,167	87,534	86,057	1,477	93,944
Grand Total (Cash Expenditure)	3,729	4,349	4,349	8,078	8,049	6,685	6,257	7,154	4,952	5,046	38,172	38,143	29	38,114
Total Resources Applied to Activities of Centre	17,894	16,416	15,987	34,310	32,804	18,850	19,030	19,335	16,968	17,213	125,706	124,200	1,506	132,058
Allocation of Total Resources Applied to Activities of Centre Between Heads of Expenditure														
Total Salaries (Cash and In-kind)	6,577	6,247	6,287	12,824	11,860	6,821	6,830	6,821	5,226	5,488	44,010	43,046	964	46,106
Total Capital (Cash and In-kind)	-	245	245	245	245	205	-	-	-	-	450	450	-	450
Total other (Cash and In-kind)	11,317	9,924	9,455	21,241	20,699	11,824	12,200	12,514	11,742	11,725	81,246	80,704	542	85,502

Table 4: Allocation of Resources Between Categories of Activities

Program	Resource Usage			
	$ Cash ('000s)	$ In-kind ('000s)	Contributed (In-kind) Staff (FTEs)	CRC Funded Research Staff (FTEs)
Research	2,668	10,465	43.35	13.70
Education	795	1,019	3.27	1.85
External Communications				
Commercialisation/Technology Transfer	4	0	0.00	0.00
Administration	882	582	0.68	0.25
Total	4,349	12,066	47.30	15.80

Significant Accounting Policies

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

Income

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

Expenditure

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

Intellectual Property

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

Capital Expenditure/Other Expenditure Commitments

There were no capital expenditure commitments approved and/or entered into as at 30 June 2002, and for which goods had not been receipted at 30 June 2003.

Other Notes

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

Costing of Salaries and On-costs by the Core Participants

Core Participant	Salary on-costs as a multiple of base salary
ANU	0.2889
CUT	0.2806
UofA	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	0.330
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:

Infrastructure overhead multipliers of core participants

Core Participant Infrastructure overheads as a multiple of base salary		
	For in-kind staff	For CRC funded staff
ANU	2.3656	2.3656
CUT	1.28	1.2800
UofA	1.54	1.5400
UC	1.5	1.5000
CSIRO	1.34	1.3400
GA	2.15	2.1500
PIRSA	1.255	1.2550
BRS	0.9095	0.9095
NSWDMR	0.17	0.1700
MCA	N/A	N/A

Details of Capital Expenditure

Major items of capital expenditure (individual items exceeding $20K) incurred in the financial year ended 30 June 2003 are detailed in the section on Staffing and Administration.

The Budget and Finances report was prepared with the assistance of the Centre accountant, John Mills.

PRICEWATERHOUSECOOPERS

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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 2003, section 14), the sources of funding and the application of that funding for the year ended 30 June 2003.

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

Scope

The financial information and directors' responsibility

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 2003. 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.

The board of management is responsible for the preparation and presentation of the financial information in accordance with the Commonwealth 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 Commonwealth Agreement dated 13 August 2001 and the needs of the Commonwealth.

Audit approach

We conducted an independent audit of the financial information in order to express an opinion on it 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.

Liability is limited by the Accountant's Scheme under the Professional Standards Act 1994 (NSW)

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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 Commonwealth 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 report.

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

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

Independence

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

PricewaterhouseCoopers

PricewaterhouseCoopers

John O'Connor
Partner

Perth
4 September 2003

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*

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

In situ: in its original place

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*

Mafic: rock or mineral of high magnesium and iron content*

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: 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: vegitation-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*

Sphalerite: zinc-blende

Surficial: at the surface, especially the surface of the earth*

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

ACARP: Australian Coal Association Research Program

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

AGSO: Australian Geological Survey Organisation (now Geoscience Australia)

AIG: Australian Institute of Geoscientists

AIMM/AusIMM: Australasian Institute of Mining and Metallurgy

AINSE: Australian Institute of Nuclear Science and Engineering

AJES: Australian Journal of Earth Sciences

AMEC: Association of Mining and Exploration Companies

AMIRA International: Australian Mineral Industries Research Association (International)

AMT: Audio-magnetotellurics

ANU: The Australian National University

ANSTO: Australian Nuclear Science and Technology Organisation

ANZG: 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

BPA: Balladonia Progress Association

BRS: Bureau of Rural Sciences

CALM: Western Australian Department of Conservation and Land Management

CDI: Conductivity Depth Image

CD-ROM: Compact Disc - Read Only Memory

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

CRC LEME: Cooperative Research Centre for Landscape Environments and Mineral Exploration

CSIRO: Commonwealth Scientific and Industrial Research Organisation

CUPS: Curtin University Postgraduate Scholarship

CUT: Curtin University of Technology

DAWA: Department of Agriculture, Western Australia

DC: Direct Current

DEH: Department for Environment, Heritage in South Australia

DEM: Digital Elevation Model

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

EKS: Electrokinetic Seismic

EM: Electromagnetic

ERA: Energy Resources Australia

FTE: Full Time Equivalent

GA: Geoscience Australia

GIS: Geographic Information System

GPS: Global Positioning System

GSWA: Geological Survey of Western Australia

HEM: Helicopter Frequency Domain Electromagnetic

ICPMS: Inductively Coupled Plasma Mass Spectrometry

IMA: International Mineralogical Association

IP: Induced Polarisation

IPRS: International Postgraduate Research Scholarship

MCA: Minerals Council of Australia

MDBC: Murray-Darling Basin Commission

MIM: Mount Isa Mines

MIPCP: Minerals Industry Postgraduate Coursework Program

MTEC: Minerals Tertiary Education Council

Nap SWQ: National Action Plan (for Salinity and Water Quality)

NDSP: National Dryland Salinity Program

NGTN: National Geoscience Teaching Network

NMR: Nuclear Magnetic Resonance

NRM: Natural Resource Management

NSW DMR: New South Wales Department of Mineral Resources

NSW DLWC: New South Wales Department of Land and Water Conservation

PBMDS: Plant-based Management of Dryland Salinity

PIRSA: Primary Industries and Resources South Australia

pmd*CRC: CRC for Predictive Mineral Discovery

PDF: Portable Document Format

PURSL: Productive Use and Rehabilitation of Saline Lands

QDNRM: Queensland Department of Natural Resources and Mines

RIRDC: Rural Industries Research and Development Corporation

RSSA: Royal Society of South Australia

SASW: Spectral Analysis of Surface Waves

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

SRCC: Safety Rehabilitation and Compensation Commission

TDHEM: Time Domain Helicopter Electromagnetic

TEM: Transmission Electron Microscopy/Microscope

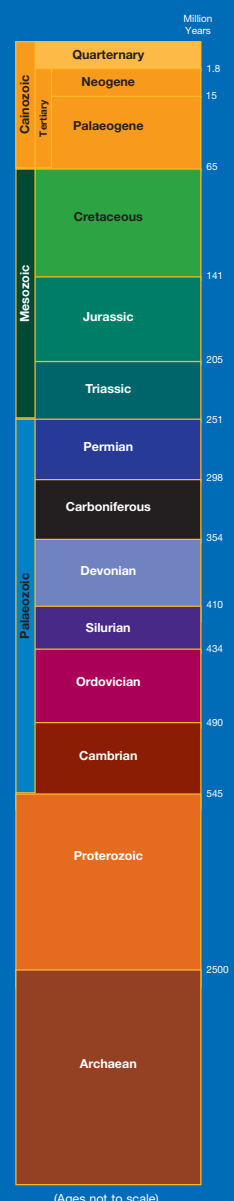
TIMS: Thermal Ionisation Mass Spectrometry

UC: University of Canberra

UofA: The University of Adelaide

UWA: The University of Western Australia

XRD: X-Ray Diffraction



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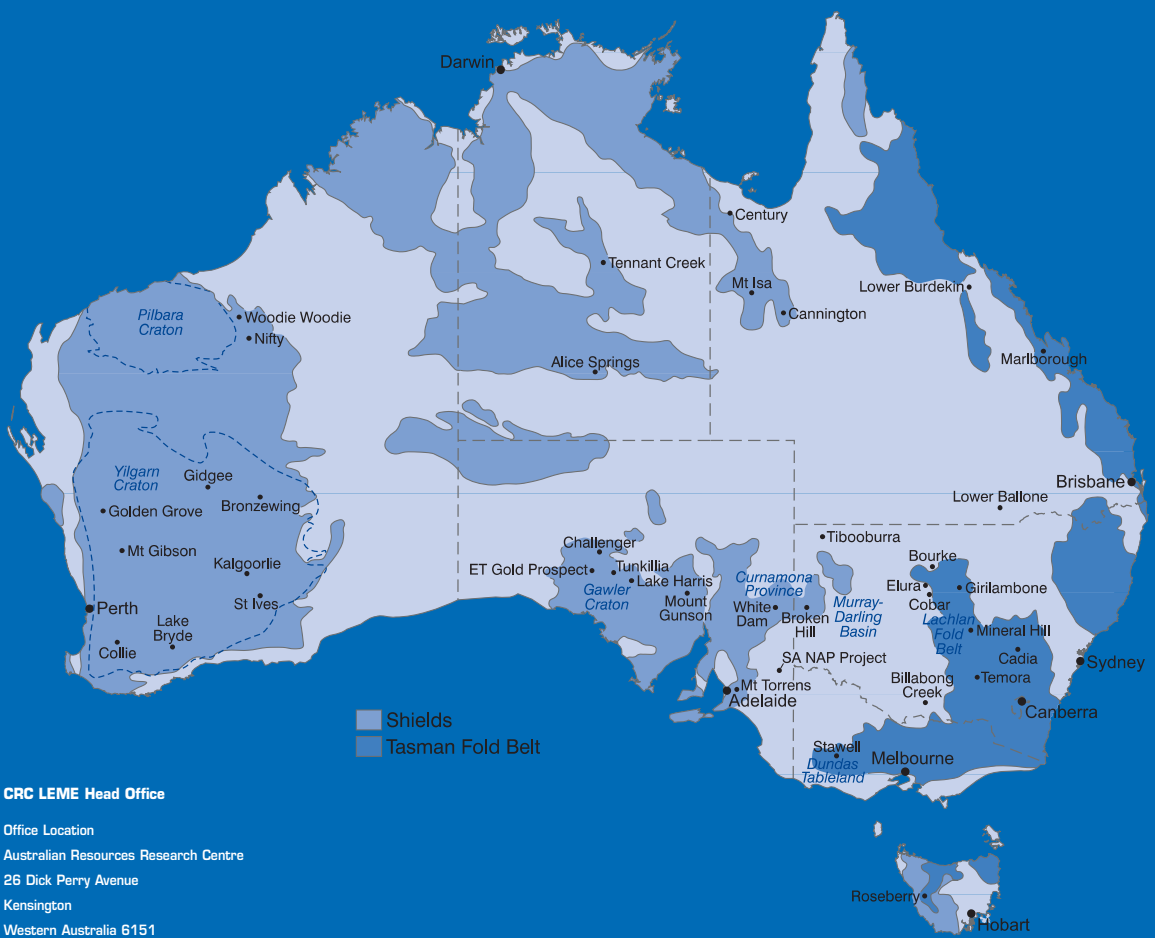
CRC LEME Research Locations



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