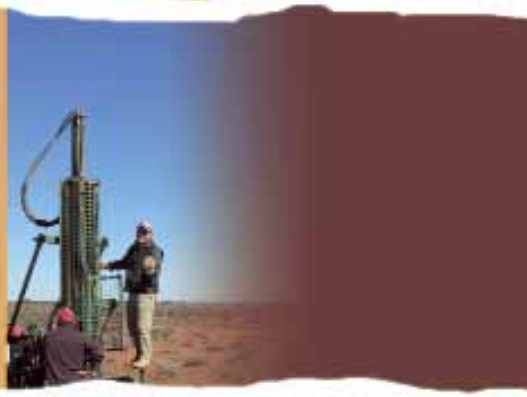
CRCLEME

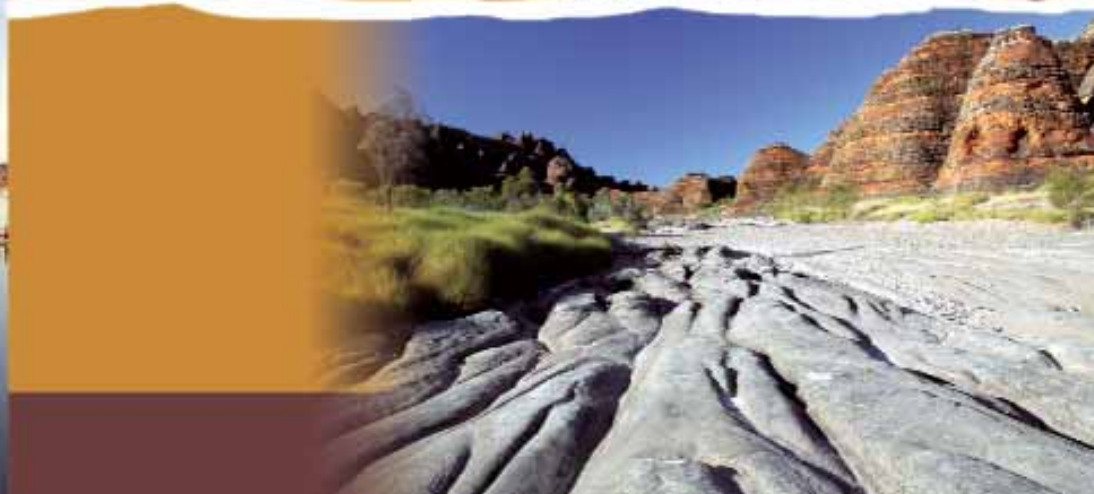
Cooperative Research Centre for
Landscape Environments
and Mineral Exploration

CRC
AUSTRALIA

2005-06

CRC LEME Annual Report





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 LEME and its core participants into global leaders in regolith research and its application to mineral exploration and natural resources management.

Contents

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

Highlights

- Publication of a paper in the prestigious international Journal *Science* on *Biomineralization of gold: biofilms on Bacterioform Gold* by LEME authors Frank Reith, Steve Rogers, Bear McPhail and Daryl Webb.
- Detection of anomalous gold concentrations in leaves of the common native grass, spinifex (*Triodia pungens*), demonstrates its effectiveness as a phyto-exploration tool for buried mineralisation.
- Release of the Northern Territory Geological Survey and LEME *Northern Territory Regolith Landform Map* and *Atlas* – the first complete State/Territory wide regolith compilation.
- Mindax Ltd and Quasar Resources Ltd have entered into partnership with LEME to embark on a new uranium hydrogeochemistry exploration project in the Western Australian Wheatbelt, following the Centre's discovery of groundwater uranium anomalies in the Upper Avon River catchment.
- Release of the LEME Open File Report *Laterite Geochemical Database for the Southwest Yilgarn Craton* stimulated significant new exploration activity in the region.
- Undergraduate regolith course student numbers peak at more than 100 students a year – the highest number in LEME history.
- Total number of postgraduate students exceed performance indicators with Honours student numbers expected to double performance target.
- Preliminary Gawler Craton regional geochemical survey results show detectable gold levels in catchments with known goldfields.
- Hydrogeological modelling that integrates enhanced LEME produced Groundwater Flow Systems (GFS) maps significantly improves correlations between measured and predicted salt outbreaks and river salt loads with important ramifications for salinity investment strategies.
- 370 copies of the thematic volumes, *Regolith-landscape Evolution Across Australia* and *Regolith Expressions of Australian Ore Systems,* sold since their September 2005 release.
- Ten oral presentations, including a keynote paper made at the IGES meeting at Perth in September 2005, with three prizes awarded to LEME students and staff.
- Airborne Electromagnetics (AEM) and ground/in-river geophysical surveys continue to provide new insights into floodplain processes, water quality variations, infrastructure leakage and recharge of aquifer systems, which will result in better informed salinity management.
- LEME's successful application of Ground Penetrating Radar and seismic reflection prompts Watercorp (WA) to undertake a major geophysical work program over 1,000 km^2 of land north of Perth.
- Significant national and international media interest in the Centre's discovery of groundwater uranium anomalies in the Western Australian wheatbelt and the gold biomineralisation publication in *Science*.
- Eight Open File Reports and two thematic volumes released during the year.

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

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

Chairman's Report

George Savell

LEME has reached full maturity in the past year, both in terms of outcomes from the scientific programs it has pursued, and in the use of its regolith science in crafting solutions to some of Australia's vexed Natural Resource Management (NRM) problems.

This is both a blessing and a curse in that while the science the Centre has pursued is only now coming to full bloom, the time left to the Cooperative Research Centre for Landscape Environments and Mineral Exploration is fast running out.

This has led to contemplation of whether regolith science is embedded to a sufficient degree in the minds of geoscientists and NRM specialists to allow it to develop further of its own volition. Whether indeed there is a need to put in place a formal vehicle to follow on from LEME to ensure that regolith science realises its full potential to support the national interest in mining, agriculture, the environment and the community generally, is now a debate we must have.

While the decision not to seek to renew LEME for the third term was valid in late 2004, the climate since that time has changed considerably. Due to this factor, the Board will shortly be reviewing its position on the future of regolith science generally.

As reported in my 2005 Chairman's Report, Dr Dennis Gee retired to pursue other interests. He passed to the new Chief Executive Officer, Dr Steve Rogers, a fully functional scientific and administrative unit.

I am pleased to report that Dr Steve Rogers has settled into the CEO position with the minimum of fuss and the organisation continues to function smoothly and effectively.

During the year it was decided to pursue a formal Fifth Year Review Process, irrespective of the fact that LEME would terminate at the end of June 2008 and the CRC Programme Secretariat had advised they did not require a formal review in these circumstances. In keeping with the Board's policy of seeking to attain high performance standards, an independent panel of highly qualified inquirers was formed to fully review the Centre's scientific programs and outcomes.

I am happy to advise an excellent report was received with valuable recommendations and advice forthcoming from the inquiry.

Not only will the advice be important in terms of shaping our approach to the final two years of the Centre's life, but it has justified the focus and subsequent outcomes of the Centre's Programs.

The Centre's Education and Training Program, which I believe is very much a core component of our business, is set to deliver 60 PhD and over 100 Honours students into the industries we serve and the community generally. As part of the run out years special awards will be made to outstanding students to commemorate their research efforts as a part of LEME. As far as we are aware this will be a first for any CRC.

A well planned program of publications is now in the process of preparation to ensure LEME's body of work is available for posterity.

During the year the Centre's need to communicate the worth of its work to the community generally saw the appointment of a dedicated communications officer, Greg Lawrence, who is very experienced in this capacity. He is also a geologist, and was awarded the position from an excellent panel of applicants.

I must pay tribute to the Managing Board which continues as a stable productive body overseeing the operations and policy of the Centre.

Although members change from time to time, that has not in any way affected the quality of the Board which is one of the best I have worked with.

The professional staff, who ensure the management of the Centre is of the highest standard, continue to deliver excellent results. We are fortunate to have staff of such a high standard.

In 2005-06, LEME was well served by its two Board Advisory Councils: The Mineral Advisory Council and the Land Use Advisory Council. Due to change instituted by the CEO they were fully drawn into the project choice, direction and budgetary processes in a much more effective way.

They rose to the occasion fully and provided valuable advice to the Board, which influenced (in a positive way) a number of decisions.

Finally, I can assure you all that when the next two years operations are concluded, this CRC will have left an indelible imprint on Australia's future.

G.A. Savell

Independent Chairman

Chief Executive Officer's Report

Dr Steve Rogers

The fifth year of LEME has arguably been the most successful yet in regards to the delivery of high profile scientific outcomes and regolith geoscience applications to the benefit of clients and end-users.

During the year, evidence of the economic benefits derived from LEME research was outlined in an Allen Consulting Group Report commissioned by the CRC Association. The Report entitled, *The Economic Impact of Cooperative Research Centres in Australia – Delivering Benefits for Australia*, examined the economic impact of the CRC Programme. It noted the following:

'Regolith and geochemical research has been used by mineral explorers to improve success rates and make exploration more efficient. Since the mid-1990s, technology developed by the CRC for Landscape Environments and Mineral Exploration has contributed to the discovery of gold deposits with an in ground value of over $3 billion.'

A summary of resource allocation during 2005-06 shows $2.90 million went on salaries, $0.78 million on the student program and $2.24 million on research operating. External income tied to projects was $1.5 million. Our forward cash flow forecast shows that research activities and salaries can be resourced to ensure research objectives are met up to the cessation of LEME in June 2008. Provision has also been made for the Centre's *Wind up* and *Exit* activities.

Our strategy to focus on biological mechanisms of trace element and mineral transport and transformation in regolith continues to deliver exciting advances. A notable scientific highlight during the year was the publication of a paper by ANU PhD student Frank Reith in the prestigious international journal *Science*. The paper explained how bacteria that precipitate gold in the regolith were isolated and identified – an achievement the Centre takes great pride in. This paper stimulated significant media interest with related articles appearing in scientific literature and popular media globally. The interest generated by this paper clearly shows that high quality research outcomes can appeal to the media and general public. While this area of research has now ceased at LEME, an ARC Linkage Project involving the University of Adelaide, SA Museum, CSIRO, Barrick Gold and Newmont Australia will continue to work in this promising area of research pioneered by the Centre.

Detection of anomalous gold concentrations in leaves of the common native grass spinifex (*Triodia pungens*), and the observation that spinifex roots can penetrate up to 30 metres down into the regolith is another unexpected outcome from LEME's native-plant focussed 'phyto-exploration' investigations. This work demonstrates the potential that this widespread native plant has as an exploration tool for buried mineralisation.

Mechanistic understanding of regolith biogeochemistry will also be a significant component of the new CSIRO-CRC LEME AMIRA P778 Predictive Geochemistry Project which commenced in mid 2006. Industry partners include BHP Billiton, Independence Gold, Inco, Barrick Gold, Cameco, Teck Cominco, SGS Minerals and Newmont Australia. In addition to research activities in Australia, the project will include a regolith geochemistry component based in Chile with the industry partners Codelco, CVRD, and Rio Tinto. LEME will be a project partner for the first two years, as the project will continue beyond the Centre's lifespan.

In the salinity-focussed NRM area, LEME's Airborne Electromagnetics (AEM) and ground/in-river geophysical surveys continue to provide new insights into floodplain processes, water quality variations, infrastructure leakage and aquifer recharge systems – outputs that will assist the creation of well informed salinity management plans.

LEME prides itself on high level delivery of outcomes to its partners and clients. A highlight this year was the launch of the *Northern Territory Regolith Map* and *Atlas* at the Annual Geoscience Exploration Seminar (AGES) in March 2006. The final output from this collaborative project with the Northern Territory Geological Survey was a 1:2,500,000-scale Regolith-landform Map of the Northern Territory. The map, and associated Geographic Information System (GIS), compiled from field observations and existing geological maps and satellite imagery, is the first of its kind in Australia. In addition, an Atlas of Regolith Materials of the Northern Territory containing supplementary information for the NT Regolith-landforms map and GIS was published. It includes more than 600 colour photographs of major regolith material types, as well as geochemical data and diagrams.

As LEME moves toward its final two years of operation, an increasing emphasis will be placed on end-user communication and technology transfer of research outcomes, with a specific focus on publishing research outputs in the international science literature. A communication plan compiled by our recently appointed communications officer, Greg Lawrence, was approved by the Board in March 2006. The plan outlines the Centre's communications strategy for the remaining two years. A core component of this strategy is to ensure that the extensive portfolio of research project outcomes is presented in such a way to ensure

their availability after the cessation of LEME activities, as a suite of 'Legacy Products.'

The publication of two thematic volumes, *Regolith-landscape Evolution Across Australia* and *Regolith Expressions of Australian Ore Systems* has been a major success. Following their release in September 2005, almost 400 copies were sold, with 60% of the purchases made by commercial companies. The volumes have also been purchased by buyers in Canada, USA, Thailand, South Africa, New Zealand, and Chile. Further thematic volumes are scheduled for release in the next two years.

A LEME regolith textbook has been commissioned to encompass the regolith geoscience advances made by LEME in the last five years. Aimed at senior undergraduate/postgraduate students, and geoscientists in both the mineral exploration and NRM sectors, the text book will feature contributions from Centre researchers. CSIRO publishing has already agreed to handle the book's publication and marketing requirements with release scheduled for early 2008.

The Centre's Education and Training Program continues to be a highlight of LEME's activities – a fact recently recognised by the Centre's Fifth Year Review Panel.

PhD students will exceed performance indicators with Honours student numbers expected to double the original performance target. An assessment of the destination of PhD graduates shows that LEME is achieving its goal of producing industry-ready postgraduate students, with a number of our graduates taking up employment in both the exploration industry and government NRM agencies. This year's Annual Report highlights a number of the Centre's student success stories.

Our focus on the integration of regolith geoscience in undergraduate training is equally as important as our postgraduate training. During 2005-06, more than 100 undergraduate students were registered on regolith courses at the three Core Participant universities – the highest number in LEME history. The delivery of short courses within LEME (coordinated by ANU's Dr Ian Roach through the Minerals Tertiary Education Council) continues to be well attended by Honours-level and post-graduate students from universities and industry professionals across Australia with 70 enrolments during 2005-06.

It is also gratifying to report that, as a result of LEME activities at ANU, a new Masters of Regolith Geoscience Course has been launched with the first intake planned for 2007. Much of the success of LEME's Education and Training Program is due to the tireless enthusiasm and leadership of Program Leader, Dr Steve Hill (U of A).

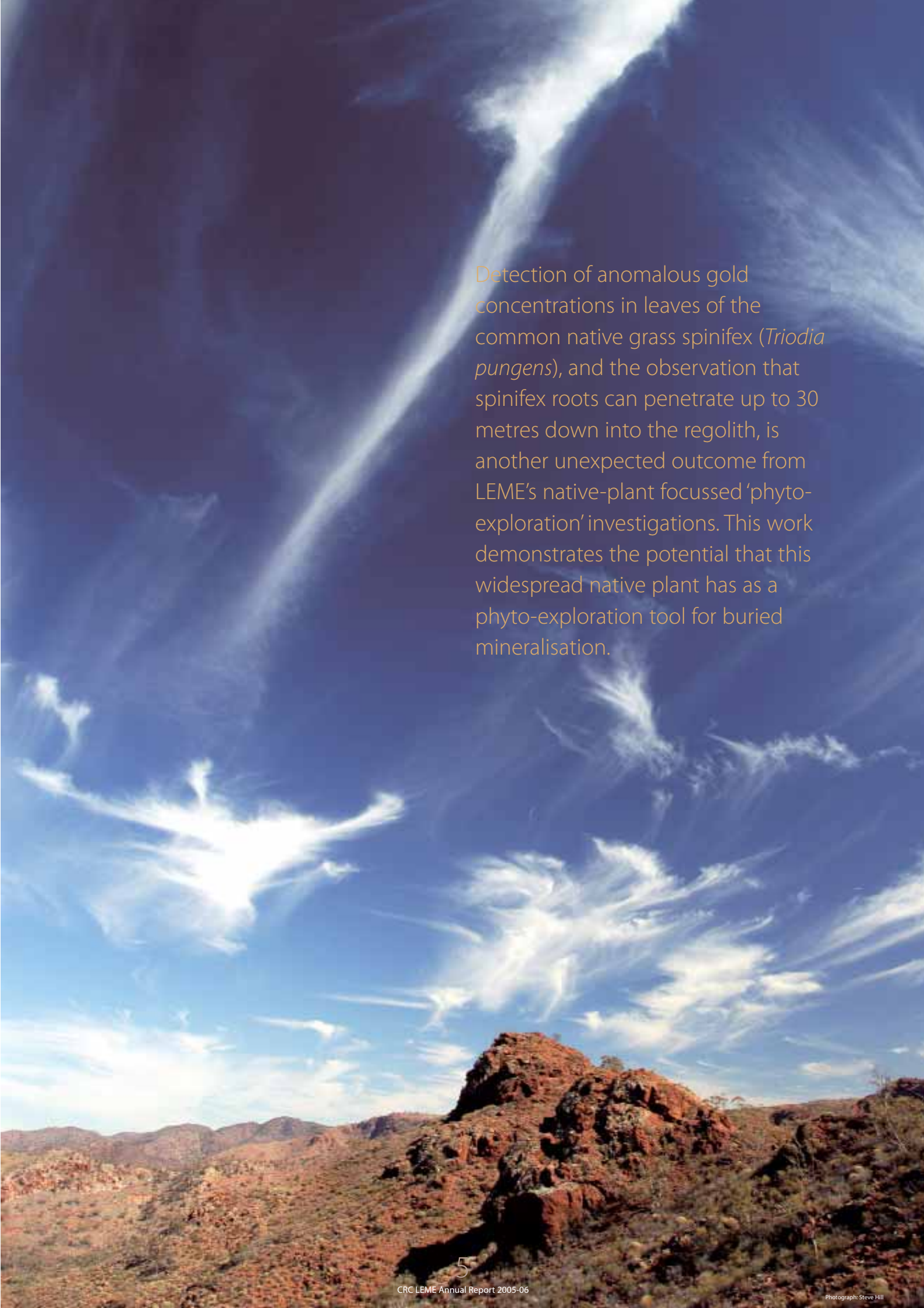
The Centre continues to develop a portfolio of collaborative 'co-investment' research projects with industry and government agency partners. For example, Mindax Ltd and Quasar Resources Ltd have joined with LEME to embark on a new uranium hydrogeochemistry exploration project in the Western Australian Wheatbelt following the Centre's discovery of groundwater uranium anomalies in the Upper Avon River catchment.

LEME and regolith geoscience in general face an interesting and challenging future. Continued high level research delivery and impact from the Centre's activities combined with the Fifth Year Review recommendations and a buoyant resources sector have all lead to the same question being asked: 'What happens after LEME?' A debate I'm sure we will be having in the coming few months.

At the end of my first year as the CEO of LEME, I would like to thank all the staff, students and research partners for an exciting and scientifically stimulating year. Our research highlights demonstrate an extremely successful year for the Centre. Recognition for these achievements must go to the researchers, Program Leaders, members of the Executive, our advisory councils and the Board of management for working together in a highly professional and co-operative manner.

Dr Steve Rogers

Chief Executive Officer CRC LEME



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Photograph: Steve Hill

Professional Memberships and Prizes (2005-06)

Personnel	Core Party	International and National Committee Membership	Date
Charles Butt	CSIRO	**Liaison Committee**, Regional Geoscience Mapping and Mineral Resources	2000 ongoing
Charles Butt	CSIRO	**Deputy Chair**, Minerals and Energy Research Institute of WA	1997 ongoing
Patrice de Caritat	GA	**Elected Fellow** of the Association of Applied Geochemists	July 2005
David Gray	CSIRO	**Organising Committee**, 22nd International Geochemical Exploration Symposium (IGES), Perth	Sep 2005
Steven Hill	U of A	**Committee Member** – Geological Society of Australia, SA Division	Mar 2005-1 yr
Ken Lawrie	GA	**Organising Committee and Session Convenor** – Australian Earth Sciences Convention 2006, Melbourne	2005-06
Ken Lawrie	GA	**Organising Committee** – 3rd International Salinity Fourm 2008 Adelaide	2005-April 08
Bear McPhail	ANU	**Session Convenor** (two sessions), 16th Annual Goldschmidt Conference, Melbourne	27 Aug-3 Sept 2006
Colin Pain	GA	**Member**, National Committee on Soil and Terrain	Jun 2001 ongoing
Colin Pain	GA	**Member**, Int Working Group for Land Use and Sustainable Development, IUGS	Jul 2003 ongoing
Colin Pain	GA	**Australian Representative**, Int Assoc of Geomorphologists (IAG), Working Group on Human Impact on the Landscape	Jan 2006 ongoing
Brad Pillans	ANU	**Member**, Subcommission on Quaternary Stratigraphy, International Commission on Stratigraphy (ICS)	2003 ongoing
Brad Pillans	ANU	**President**, Stratigraphy and Chronology Commission, International Union for Quaternary Research (INQUA)	2003 ongoing
Brad Pillans	ANU	**President**, Working Group to define the Lower-Middle Pleistocene boundary, International Commission on Stratigraphy (ICS)	2003 ongoing
Ian Robertson	CSIRO	**Organising Committee** – 22nd IGES, Perth	Sept 2005
Keith Scott	CSIRO /ANU	**Member**, Alunite Supergroup Review Committee – Commission on New Minerals and Mineral Names of the Int. Mineralogical Assoc	2004 ongoing

Personnel	Core Party	Award or Appointment/Promotion	From	Date
Grant Douglas	CSIRO	Appointed Fellow of the Royal Australian Chemical Institute	RACI	Dec 2005
Grant Douglas	CSIRO	Appointed Fellow of the Association of Applied Geochemists	AAG	Dec 2005
Gerry Govett	Retired	LEME Honorary Fellow Award – for outstanding contributions to the development and promotion of regolith geoscience	LEME	Sept 2005
Baohong Hou	PIRSA	Visiting Professor	Guilin University of Technology, China	Jan 2006 to 2011
Brad Pillans	ANU	Promoted to Professor	ANU DVC	Jan 2006
Steve Rogers	LEME	Minerals and Energy representative on the CRC Association Committee	CRC Association	May 2006
Keith Scott	CSIRO /ANU	CSIRO Honorary Fellowship	CSIRO Exploration and Mining	Jan 2006 (1 yr)
Keith Scott	CSIRO /ANU	ANU Visiting Fellow	ANU Faculty of Science	Mar 2006-07
Ray Smith	CSIRO retired	LEME Honorary Fellow Award – for outstanding contributions to the development and promotion of regolith geoscience	LEME	Sept 2005

Personnel	Core Party	Prize	Awarded By	Date
Brian Barrett, Michael Hatch, Graham Heinson	U of A	**Finalists for the Australian Museum Eureka prize** (Land and Water). For development of a fast, cost effective and efficient geophysical survey system that detects salinity in riverbed sediments, leading to the more efficient use of salt	Australian Museum	Aug 2005
Matthias Cornelius *et al*	CSIRO	Second Place – Winning Poster – 22nd IGES, Perth	Assoc of Applied	Sept 2005
Patrice de Caritat and Dirk Kirste	GA	First Place – Winner Poster – 22nd IGES, Perth	Assoc of Applied Geochemists	Sept 2005
Rob Hough *et al*	CSIRO	Third Place – Winning Poster – 22nd IGES, Perth	Assoc of Applied Geochemists	Sept 2005
Ryan Noble	CSIRO	Best student Oral Presentation – 22nd IGES, Perth	Assoc of Applied Geochemists	Sept 2005
Nathan Reid	U of A	Best Presentation – Cash Prize, 2006 Student-Industry-CRC Symposium	Industry-CRC Panel	Jun 2006
Angelo Vartesi and Travis Naughton	LEME VRU / CSIRO	Best Professional Posters (1st, 2nd and 3rd) – 22nd IGES, Perth	IGES Committee	Sept 2005

Governance Structure and Management


Photograph: Warren Hicks

Core Participants

LEME operates as an unincorporated joint venture between its eight Core Participants. They are signatories to the Commonwealth and Centre Agreements. Under these agreements, the CSIRO Division of Exploration and Mining is the Centre Agent and assumes administrative responsibility. The Core Participants are:

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

Board of Management

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

Prof Tim Brown, the Australian National University

Mrs Janet Dibb-Smith, the University of Adelaide

Dr David Garnett (Independent – Minerals Advisory Council Chair)

Mr Lindsay Gilligan, NSW Dept Primary Industries

Dr Steve Harvey, CSIRO

Mr Paul Heithersay, Primary Industries and Resources, South Australia

Mr Gary Kong, Board Secretary, LEME Business Manager

Mr Ian Lambert, Geoscience Australia

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

Mr Warwick McDonald (Independent – Land Use Advisory Council Chair

Dr Steve Rogers, LEME Chief Executive Officer (replacing Dr Dennis Gee)

Mr George Savell, Chair (Independent)

Mr Tony Tate, Curtin University of Technology

Dr Kevin Tuckwell, Minerals Council of Australia

Our Centre Visitor, Prof Gerry Govett, has a standing invitation to attend Board meetings as an ex-officio member.

The Board met on the following occasions:

8 July 2005 – Teleconference to approve the 2005-06 Budget

9 September 2005, Perth – Board Meeting and AGM

1 December 2005, Canberra

9 March 2006, Canberra

29 June 2006 – Teleconference to approve the 2006-07 Budget

These meetings were supplemented by Out of Session endorsements as necessary.

In 2005-06, the Audit Sub Committee comprised Mr George Savell (Chair), Dr Dennis Gee (CEO, June 05-Oct 05), Dr Steve Rogers (CEO, Nov 05-June 06) Dr David Garnett, Mr Gary Kong (Business Manager and Board Secretary). The Sub Committee met prior to the AGM on 9 September.

Advisory Councils

The **Minerals Advisory Council** (MAC) reviews research outcomes and advises on future priorities in line with industry and other user needs, primarily in mineral exploration. It reports directly to the Board through its Chair, Dr David Garnett.

Members at the end of the reporting period were:

Chair: Dr David Garnett – Independent

Mr Paul Agnew – Rio Tinto Exploration Pty Ltd

Prof Bob Gilkes – University of Western Australia

Dr Jon Hronsky – BHP Billiton

Dr Richard Mazzucchelli – Searchtech Pty Ltd

Dr Christopher Oates/ Dr Paul Polito – Anglo American PLC, London

Mr Bill Peters – Southern Geoscience Consultants

Dr Nigel Radford – Newmont Australia

Dr Bryan Smith – Bryan Smith Geosciences

Prof Peter Williams – University of Western Sydney

Dr Wally Witt – Independent

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

CRC LEME Board, taken 8 Sept 2006.

L-R standing: Gary Kong, Gerry Govett, Kevin Tuckwell, Charlie Thorn (replaced Tony Tate Sept 06), Tim Brown, Paul Heithersay and Ian Lambert.

L-R sitting: Janet Dibb-Smith, Dave Garnett, Steve Rogers (CEO) and George Savell (Chair).

The **Land Use Advisory Council** (LUAC) provides comment and advice on land use and environmental management issues. Its membership is drawn from governmental, semi-governmental and independent user groups, but does not necessarily represent any user group. It reports to the Board through its Chair, Mr Warwick McDonald.

Members at the end of the reporting period were:

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

Mr John Bartle – Conservation and Land Management WA

Mr Murray Chapman – Rural Plan Pty Ltd

Dr Colin Chartres – CSIRO Land and Water

Dr Richard George – Dept of Agriculture WA

Mr Mike Grundy – Dept Natural Resource and Mines Qld

Mr Gavin Hanlon – North Central Catchment Management Authority

Dr Mike McLaughlin – CSIRO Land and Water

Dr Bruce Munday – CRC for Plant Based Management of Dryland Salinity

Mr Bob Newman – Independent

Mr Colin Simpson – Consultant

Mr Ross Williams – Acting Director, Water Landscape Sciences, NSW

Mr Blair Wood – Land and Water Australia

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

Both Advisory Councils were consulted at an early development stage of the 2006-07 Research Development Portfolio with project proposals sent to the respective Council Members at the beginning of the year for comments and input. The Councils then met in May 2005 to receive presentations from Program Leaders and discuss next year's research program, as well as forward planning to the end of June 2008. Input from both Councils was assimilated prior to finalisation of the research operating budget.

Executive Committee

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

Dr Steve Rogers, Chair (CEO)

Mr Gary Kong (Business Manager)

Ms Lisa Worrall (Program 1 Leader)

Dr Ravi Anand (Program 2 Leader)

Dr Paul Shand (Program 3 Leader)

Dr Ken Lawrie (Program 4 Leader)

Dr Steve Hill (Program 5 Leader)

Assoc Prof Lindsay Collins (Assistant Director, Perth)

Mr John Keeling (Assistant Director, Adelaide)

Assoc Prof Ken McQueen (Assistant Director, Canberra)

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

Mr John Watkins, NSW Department of Primary Industry

Mrs Susan Game is the Executive Secretary and Centre Support Officer

Dr Steve Rogers replaced Dr Dennis Gee on 7 October 2005 following the retirement of Dr Gee at the conclusion of his three-year contract with the Centre. Dr Paul Shand was appointed Program 3 Leader in May 2006, replacing Dr Steve Rogers. The position of Deputy CEO ceased on 1 July 2005. Thanks and appreciation is extended to Mr Paul Wilkes who held this position for a number of years.

The Executive Committee met several times per teleconference during the year. These meetings occurred more frequently as the 2006-07 Research Portfolio and Operating Budget was formulated. The CEO takes the opportunity to meet with Executive Committee members individually when he travels and there is a continuous email liaison amongst Executive Committee Members.

On 8 March 2006, a CEO, Business Manager and Program Leader Workshop was held to define the short and long-term research priorities and final R&D delivery mechanisms for the Centre. This was followed by a joint Board/Executive meeting.

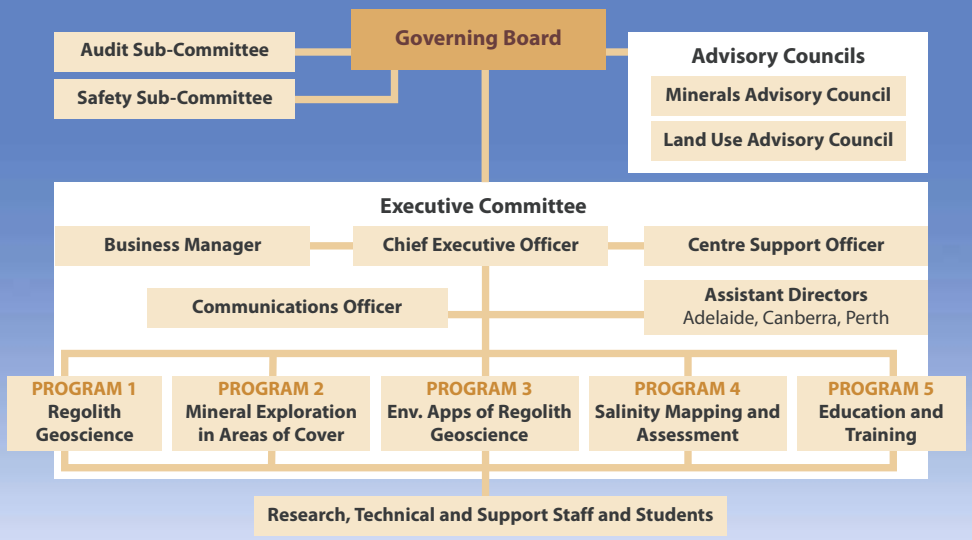
Centre Culture

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

CRC Visitor

Since its inception, LEME has derived great counsel from its longstanding Visitor – Emeritus Professor Gerry Govett – and the Board has gladly continued his role. In this capacity, Professor Govett acts as mentor and independent advisor to all LEME staff, including administrative staff, students, project staff, project leaders, Program Leaders, Executive and Board members and provides written guidance to the CEO. He is the thread of wisdom and support through the entire CRC. He has a standing invitation to attend all Board and Advisory Council meetings, all project reviews and all scientific seminars and symposia.

Governance Structure and Management



Strategic Planning

The 2002-08 Strategic Plan, adopted by the Board on 14 March 2003, remains relevant and consistent with the original concepts of the Commonwealth Agreement. It sets out objectives and strategies to meet Agreement Objectives, and indicators to measure performance, all within a framework of strategic priorities. It focuses on outcomes as well as outputs.

Preparations have begun on a Wind Up Exit Strategy Plan for the Centre, and a timeframe for its implementation. A strategy outline will be presented to the Board in September 2006 with Board endorsement sought in March 2007. The plan will be submitted to the CRC Programme in June 2007.

Photograph: John Keeling

Context and Major Developments

To deliver on its objectives LEME operates within two industry contexts, the mineral exploration and Natural Resource Management (NRM) sectors.

Mineral exploration industry context

LEME research outputs from Programs 1 and 2 are focussed on applying regolith geoscience to the challenges facing the Australian Mineral Exploration industry. While large multinational corporations are active explorers, a significant part of this sector consists of small to medium sized companies with interests in all States and Territories.

During 2005-06, the Australian resources sector continued to experience record commodity prices and demand as economies such as China and India continued to expand. However, these favourable industry and market conditions have not yet translated into a significant expansion of exploration activities for non-ferrous minerals.

A survey by Canadian company, the Metals Economic Group, has shown that while the 2005 global non-ferrous minerals exploration budget increased for the third consecutive year by 38 per cent, Australia's share of that spend fell to a record low of 13 per cent. Canada had the highest level of exploration expenditure in 2005, having displaced Australia from that position in 2002, with Australia falling to a fifth place ranking. This decline reflects the need for Australia to become more globally competitive against other countries with large mineral endowments.

A significant issue for the Australian minerals sector was the critical lack of skilled employees in all business areas – from skilled manual employees to tertiary educated professional staff.

The resurgence of nuclear energy as a potential alternative to fossil fuels has reignited the Australian mineral industry's interest in uranium exploration. As a result, a significant increase in uranium exploration activity in Australia was observed during the reporting period.

The Natural Resource Management context

Research outputs from the Programs 3 and 4 are focussed on applying regolith geoscience to environmental issues facing Australia such as salinity risk assessment, protection of ground and surface water resources from salinisation and Acid Sulfate Soil (ASS) formation.

Procurement and sustainable use of water resources is currently high on both the political and public agenda in Australia. Continuing drought in many parts of the country is focussing policy and research effort on strategies to ensure the future supply and quality of scarce water resources. The Federal Government's National Water Initiative, Salinity National Action Plans and State and Territory initiatives are the key strategic drivers in this arena.

Within this context, the NRM sector comprises a diverse group of end users and decision makers such as State and Commonwealth Government agencies, Local Government, Catchment Management Authorities (CMAs) and Landcare Groups. This diverse and complex stakeholder group requires a multi-layered targeted approach to the delivery of research outputs to ensure enduser adoption.

Key staff appointments

- Dr Steve Rogers was appointed Chief Executive Officer in October 2005 following the retirement of Dr Denis Gee. Previous to this appointment, Dr Rogers was the LEME Program 3 Leader.
- Greg Lawrence was appointed communications officer in January 2006.
- Dr Paul Shand was appointed LEME Program 3 Leader in June 2006 following the departure of Dr Steve Rogers from that position.

No purchases of major equipment occurred during the reporting period.

Photograph: John Keeling

Commercialisation, Technology Transfer and Utilisation

Intellectual Property

The Commercialisation and Intellectual Property Management Strategy aims to:

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

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

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

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

'National Good' Benefits

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

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

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

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

Potential Commercial Projects

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

LEME Regolith Spectral Logger

This project aims to develop and enhance spectroscopic logging technologies for the purposes of characterising regolith materials in an objective manner. The project involves the application of the CSIRO-developed HyChips automated spectroscopic logging technology to rapidly characterise regolith samples from exploration drill chips and core. It also involves the development of new algorithms suited to determining regolith mineralogy.

Throughout 2005-06, further advances were made in the development of unmixing algorithms for rapidly determining the relative abundance of regolith minerals in samples collected from chips and core in the field. A critical part of the work has been the identification of procedures for effectively removing background noise from reflectance spectra. To assist with vectoring, this approach will be further tested in the identification of kaolinite and mica abundances at the base of regolith profiles.

Significant differences have been noted in the application of certain algorithms and spectroscopic indices for regolith material discrimination when using chips verses pulps. For example, spectroscopic data derived from pulping result in an overestimate of halloysite abundance verses kaolinite which has a significant bearing on the interpretation of the transported/residual boundary. The results will influence recommendations on sampling/measurement strategies for the commercial application of HyLogging, particularly when dealing with regolith materials.

To further develop commercial opportunities for the use of the HyChips technology, LEME began a collaboration with CSIRO to trial the HyChips Logger in the Eastern Goldfields of Western Australia, with the hardware located in a commercial analytical laboratory. This collaboration forms part of a broader strategy to encourage the wider use of spectroscopic mineralogy in exploration

by developing a knowledgeable and aware exploration community. A formal market assessment for this technology has yet to be carried out.

BiotaE

Dr Ravi Anand (CSIRO Exploration and Mining) as leader of Mineralogical and Biological Hosts Project demonstrated that certain parts of the mulga tree gave clear and reproducible chemical signatures of gold and base-metal deposits that occur under more than 20m of transported regolith – especially under cemented hardpan. The mechanism of metal transfer is uncertain; however hydraulic pumping up deep tree roots most likely plays a role in the transportation of anomalous metals into the tree's various tissue types. In 2004-05, BiotaE was protected by a Registered Trade Mark®, and discussions were held with commercial laboratories to investigate the potential provision of a geochemical fee-for-service using BiotaE.

During 2005-06, it became clear that little commercial competitive advantage could be derived from a fee-for-service arrangement. Subsequent assessment of this IP concluded it was more appropriate to place this discovery in the public domain, and to encourage the development of a diversity of exploration techniques.

Northern Territory Regolith Map and Atlas Methodology

The Northern Territory Regolith Map and Atlas were released by the Centre and the Northern Territory Geological Survey (NTGS) in March 2006. Its release made the Northern Territory the first Australian State/Territory to have its own comprehensive regional regolith-landform map and atlas of regolith materials.

The Centre's Project Team in Program 1 produced the 1:2,500,000-scale Regolith-landform Map for the Northern Territory based on a comprehensive and detailed regolith Geographic Information System (GIS) which detailed all of the Northern Territory's regolith. The map was compiled from field observations taken from more than 1,500 sites across the Territory, as well as existing geological maps and satellite imagery.

The second major product delivered to the NTGS by LEME was the *Atlas of Regolith Materials of the Northern Territory* (LEME Open File Report 196). This Atlas provides critical information to support the NT Regolith-landforms Map and GIS, and contains more than 600 colour photographs of major regolith materials, as well as tables of geochemical data and diagrams of particle size distribution for regolith materials.

Its release has generated an increased understanding of the importance of regolith knowledge in achieving effective mineral exploration and resolving NRM issues. Evidence of this uptake was shown with an agreement between LEME and the Queensland Government being reached in mid 2006 to produce a 1:2,500,000-scale regolith map and associated atlas of regolith materials for the State.

Geophysical developments at Curtin University of Technology

Curtin University has continued its development of a number of innovative geophysical techniques with LEME PhD student research input. The ownership of any resulting IP is yet to be negotiated.

Audio-magnetotellurics (AMT)

No progress was made during the year to develop this technique as there were issues related to the reliability of using ungrounded wires to detect electric fields. A group from Colorado USA has approached the Centre about the possibility of implementing this system.

Electrokinetic seismic (EKS)

After further investigations with the Australian Nuclear Science and Technology Organisation (ANSTO) prototype EKS system and discussions with ANSTO representative, Chris Waring, LEME decided to adapt existing geophysical instruments for EKS, rather than pursue working with the engineers that created the prototype. Technical progress in seismic instruments for the oil industry has outstripped the ANSTO prototype's capabilities. LEME will have no further involvement in the development of the ANSTO technology.

Signal processing algorithms

BHP-Billiton has expressed an interest in applying some of these algorithms to their successful Geoferret array TEM system. Discussions are continuing.

Knowledge and Technology Transfer

Since the full commencement of Programs 3 and 4 activities in 2002-03, LEME has successfully completed 15 contract and consultancy-type projects with the majority of projects residing in Program 4. Throughout the year, P4 researchers experienced an increasing demand for their services leading to new program research opportunities.

Consultancy projects are important because they establish the Centre's credibility and competence in the eyes of NRM and catchment management agencies. They also provide a springboard for more strategic research.

LEME carried out one-on-one consultancies, including training courses, with a range of companies and government agencies during the reporting period.

Commercialisation, Technology Transfer and Utilisation

Shown below are organisations that contributed financially towards LEME activities:

- Anglo American
- Bureau of Rural Services
- CAMECO Ltd
- Central West CMA
- CSIRO Land and Water
- CSIRO Sustainable Ecosystems
- Cobar Management
- Dept of Water Land and Biodiversity Conservation (SA)
- Dept of Environment and Conservation (WA)
- Dept of Agriculture and Food (WA)
- Dept of Water (WA)
- Geoscience Australia
- Goulburn Murray Water Authority
- Iluka Resources
- Land and Water Australia
- Lion Ore Australia
- MERIWA
- Mindax Limited
- Minerals Tertiary Education Council (MTEC)
- Murray Darling Basin Commission
- Natural Resources Mines and Water (Qld)
- Northern Territory Geological Survey
- Ord Irrigation Cooperative
- Polymetals Mining
- SA Water
- Triako Resources
- University of California, USA
- WMC Resources (now BHP Billiton)

Photograph: John Keeling

LEME Reports

CRC LEME Open File Reports are available as .pdf files downloadable for free from the web site: http://crcleme.org.au

Cornelius M, Morris PA and Cornelius AJ. 2006. Laterite geochemical database for the southwest Yilgarn Craton, Western Australia. CRC LEME Open File Report 201. pp27 and .pdf database on CD.

Gray DJ and Pirlo MC. 2005. Hydrogeochemistry of the Tunkillia Gold Prospect, South Australia. CRC LEME Open File Report 194. pp92 and .pdf version on CD.

Lamontagne S and Hicks WA, 2006. Water quality monitoring at Loveday Disposal Basin: January 2006 progress report. CRC LEME Open File Report 202, CRC LEME, Perth. pp22 and .pdf version on CD.

Lech ME, Gray MC, Pain CF and Miezitis Y. 2006. A geoscience atlas for natural resource management in the Upper Burdekin and Fitzroy catchments, Queensland, Australia. CRC LEME Open File Report 170. pp117 and a .pdf version on CD.

McQueen KM. 2006. Calcrete geochemistry in the Cobar-Girilambone Region, New South Wales. CRC LEME Open File Report 200. pp27 and .pdf version on CD.

Merry RH and Fitzpatrick RW. 2005. An evaluation of the soils of Tilley Swamp and Morella Basin, South Australia. CRC LEME Open File Report 195. pp36.

Robertson IDM, Craig MA and Anand RR. 2006. Atlas of regolith materials of the Northern Territory. CRC LEME Open File Report pp152, colour plates and .pdf version on CD.

Singh B and Cornelius M. 2005. Mineralogy and geochemistry of calcretes overlying some kimberlites in India and South Africa. CRC LEME Open File Report 187. pp19 colour plates and .pdf version on CD.

Field Guide Notes and Shortcourse / Workshop Notes

Craig, MA. 2006. Regolith Materials – Two Day Workshop Notes and Instructions. Prepared for Cameco Aust Pty Ltd. 2-3 May 2006. CRC LEME Report No 233, pp105.

de Caritat P, Cary M, Gray DJ and McPhail DC. (Presenters). Mineral exploration using groundwater geochemistry. Shortcourse Notes. 22nd International Geochemical Exploration Symposium and 1st International Applied Geochemistry Symposium, 19-23 Sept 2005, Perth, WA. Association of Applied Geochemists. pp87 plus appendices.

Eggleton T, Aspandiar M and Troitzsch (Presenters) 2006. Environmental Mineralogy (EMN) Honours Shortcourse Notes. CRC LEME Report 236. 19-23 June 2006, ANU, Canberra. pp156.

Fitzsimmons KE, 2005. A day in the dunes: Quaternary aeolian landscapes east of Lake Frome, South Australia. 2005 ANU Earth Sciences Graduate Program field trip: Flinders Ranges. In: Aikman A, Lilly K, Celerier J, Kovacs I and Estermann G (Eds). An excursion guide to the Flinders Ranges, South Australia. *Journal of the Virtual Explorer*. Electronic Edition ISSN 1441-8142. Volume 20, Paper 5.

Hill SM, Roach IC. (Presenters). Regolith mapping and field techniques. Honours Shortcourse. 10-14 April 2006, Fowlers Gap, NSW. CRC LEME Report 229. Unpaginated.

Hill SM, Aspandiar MF and Roach IC. (Presenters). Regolith geology and geochemistry. Honours Shortcourse. 20-24 February 2006, Wilsons Promontory, Victoria. CRC LEME Report 226. Unpaginated.

Kirste D, de Caritat P and Welch SA (Presenters). Introduction to Hydrogeochemistry. Honours Shortcourse. 27-31 March 2006, University of Melbourne. CRC LEME Report 227R. Unpaginated.

Lewis M, Mauger AJ and Dutkiewicz A. (Presenters), 2006. Advanced remote sensing for mineral exploration and natural resource management. Honours and Postgraduate Shortcourse Notes. CRC LEME Report 235. 5-9 June 2006, the University of Adelaide. Unpaginated.

Roach IC, Hill SM, McQueen KG, Scott KM, Robertson IDM, McPhail DC (Presenters). Regolith geology and mineral exploration. Masters Course. 3-14 April 2006, Fowlers Gap, NSW. CRC LEME Report 228. Unpaginated.

Sponsored Project Reports and Maps Under Confidentiality Agreements

Aspandiar MF, Anand RR and Gray DJ. 2006. Mechanisms of metal dispersion through transported cover: a review. CRC LEME Report 230. CRC LEME, Perth, 70pp.

Bann G and Nanson R, 2005. Simplified geology and geomorphology map of Kangaroo Valley region (with stratigraphic cross section), 1:100 000. Quandrant Resources Kangaroo Valley.

de Caritat P, 2005. Groundwater composition in the Calama region, northern Chile: Implications for mineral exploration. Prepared for Anglo American plc. CRC LEME Restricted Report No 221R, pp56 plus Appendices and CD.

Gawler Craton Team. 2006 Central Gawler GIS. Prepared for Primary Industries and Resources SA. PIRSA-LEME Report, May 2006.

Harris BD and Wilkes PG, 2005. Brookdale Geophysical Investigations, Phase 1 – Data review. Produced for CSIRO Water for a Healthy Country, August 2005. CRC LEME Restricted Report No 237R. 20pp.

Harris BD and Wilkes PG, 2005. Rural Towns Liquid Assets – Lake Grace Geophysics Summary Report. Produced for Rural Towns-Liquid Assets WA Project consortium. 15pp in Appendix.

Harris BD and Wilkes PG, 2005. Rural Towns Liquid Assets – Nyabing Geophysics Summary Report. Produced for Rural Towns-Liquid Assets WA Project consortium. 15pp in Appendix.

Harris BD and Wilkes PG, 2005. Rural Towns Liquid Assets – Woodanilling Geophysics Summary Report. Produced for Rural Towns-Liquid Assets WA Project consortium. 15pp in Appendix.

Keeling Jl, Raven MD and McClure SG, 2006. Identification of fibrous minerals from Rowland Flat area, Barossa Valley, South Australia. PIRSA Report Book 2006/02. Primary Industries and Resources SA. 23pp.

Newham LTH and Drewry JJ, 2006. Modelling catchment-scale nutrient generation. CSIRO Technical Report 28/05. National river contaminants program of Land and Water Australia. Land and Water and Australian National University. 39pp.

Paine M. 2005. Eucla Margins Heavy Mineral Project. Confidential Quarterly Report to Iluka Resources period ending 30 September 2005. CRC LEME. 18pp.

Paine M. 2005. Eucla Margins Heavy Mineral Project. Confidential Quarterly Report to Iluka Resources period ending 30 December 2005. CRC LEME. 27pp.

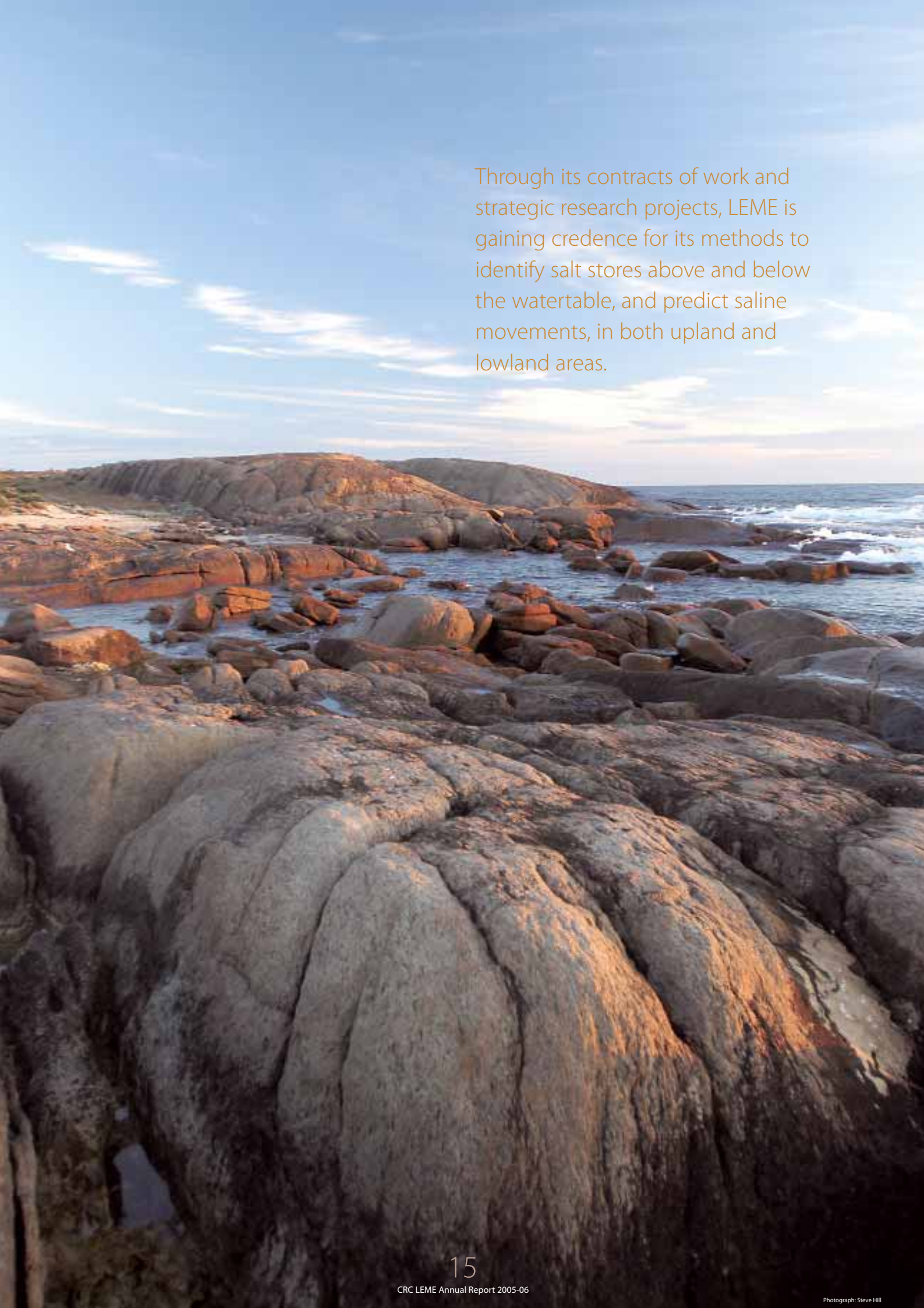
Paine M. 2006. Eucla Margins Heavy Mineral Project. Confidential Quarterly Report to Iluka Resources period ending 30 March 2006. CRC LEME. 19pp.

Pain CFP and Program 4 team, 2005. Regolith constraints on modelling salt movement in upland landscapes within the eastern Murray Darling Basin. CRC LEME Report 218R. Produced for the MDBC. CRC LEME, Canberra. 93pp, 10 appendices.

Rogers PA and Wenlong Zang, 2006. Guide to the sedimentary cover of the central Gawler Craton (Harris Greenstone Belt region). Prepared for Primary Industries and Resources SA, PIRSA Report 2006/001.

Wilkes PG, 2006. Geophysical investigations to support the Wallatin Creek-O'Brien catchment demonstration projects, WA. Produced for CSIRO Sustainable Ecosystems, March 06. CRC LEME Restricted Report 238R. 68pp and Appendix.

Wilkes PG and Harris BD, 2006. Haddelton Nature Reserve Geophysical Investigations Report. Produced for WA Dept Conservation and Land Management. CRC LEME Restricted Report 239R, April 06. 18pp.



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

Photograph: Steve Hill

Research and Collaboration

Research Activities and Achievements

Program Structure

Research is reported under the four LEME research programs:

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

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

Program 1: Regolith Geoscience

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

Program 2: Mineral Exploration in Areas of Cover

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

Program 3: Environmental Applications of Regolith Geoscience

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

Program 4: Salinity Mapping and Hazard Assessment

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

Research Themes

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

All projects must address one or more of these themes. Multi-party and multi-disciplinary projects have been consciously cultivated as the research programs develop, so the intellectual capital generated is effectively directed towards the needs of our diverse stakeholders in both mineral exploration and natural resource management. Further information about the theme statements below can be found on the LEME website (www.crcleme.org.au).

Theme 1. Understanding regolith processes

Theme 2. Models of regolith-landscape Evolution

Theme 3. Acid and alkaline soils

Theme 4. Regional mineral exploration studies

Theme 5. Making geochemistry more effective

Theme 6. Geophysical mapping and modelling

Theme 7. Salinity systems in regolith and groundwater

Theme 8. Regolith geoscience and urban Australia

Theme 9. Environmental geochemistry and the regolith

Program 1: Regolith Geoscience


Photograph: Nathan Reid


Photograph: John Joseph

Program Leader: Ms Lisa Worrall (Geoscience Australia)

Highlights

- The common native grass spinifex (*Triodia pungens*) shown to be an effective phyto-exploration tool for buried mineralisation.
- Palaeomagnetic analysis supports the hypothesis that major episodes of deep oxidation of the Australian regolith occurred during the Neogene (0-20 Ma), Early Palaeogene-Late Cretaceous (50-80 Ma) and Early Permian-Late Carboniferous (290-320 Ma).
- Dune dating in the Simpson, Strzelecki and Tirari deserts suggests that Australia's major dune fields began forming in the Late Pliocene or early Pleistocene, at a time of global cooling and ice age onset.
- Encouraging results achieved from the CHIM electrochemical exploration technique field trials.
- Central Gawler Gold Province GIS DVD released.
- Results and recommendations from an extensive geochemical calcrete study on in the Cobar-Girilambone area released.
- Four Tibooburra area regional regolith 1:100 000-scale maps compiled.
- *Northern Territory Regolith Landform Map* and *Atlas of Regolith Materials of the Northern Territory* released.
- New National Map of Physiographic Regions launched.

Overview

Program 1 aims to understand the nature and timing of regolith processes in both a detailed and regional context. It contributes strategic research in its own right, as well as forming the scientific foundation for other mineral exploration and environmental projects. Projects within this Program have been grouped into Regional Focus and Generic Process Projects.

REGIONAL FOCUS PROJECTS

Lachlan Fold Belt Synthesis – Ken McQueen, Bear McPhail, Ian Roach, Keith Scott, Roslyn Chan, Lisa Worrall, Richard Greene, Kamal Khider, Joe Schifano, Michael Neimanis, Augustine Alorbi

Activities during 2005-06 focussed on synthesising and publishing the research carried out in the Cobar-Girilambone Project (completed June 2005). Several industry funded technology transfer projects aimed at promoting and assisting the uptake of the new LEME science developed in the region were also completed during the year.

Results and recommendations from an extensive geochemical study of calcrete in the Cobar-Girilambone area were released as *CRC LEME Open File Report 200*. This report details the characteristics of calcrete in the Cobar-Girilambone area and demonstrates the successful application of calcrete sampling to mineral exploration.

Four technology transfer projects were carried out in collaboration with Jervois Mining Ltd, Triako Resources Ltd, Alkane Exploration Ltd and Polymetals Mining Services Ltd. These projects tested the potential for phyto-exploration using native tree species in areas of transported cover, examined and refined regolith sampling strategies and demonstrated how regolith-landform mapping and regolith geochemistry can be used to improve minesite rehabilitation. The projects have confirmed that white cypress pine (*Callitris columellaris*) leaves express elevated concentrations of arsenic, silver, gold, barium, nickel, cobalt and scandium over gold and ultramafic-hosted nickel deposits. It has also been established that for *in situ* soils, the coarser (> 100nm) fraction is the best geochemical sampling media.

Research on the Gilgai prospect, involving ANU Honours student Augustine Alorbi, determined the element fractionation processes that led to elevated levels of nickel and scandium occurring in a buried ferruginous weathering profile. Scandium released from primary clinopyroxene has been sequestered by chromium-rich smectite in the lower part of the profile and then concentrated in residual, goethite-rich zones at the top of the profile. Nickel released from pyroxenes and minor olivine was enriched in nickel-bearing nontronitic clays in the lower part of the profile. A previously unmapped sequence of mafic volcanic rocks in the Miandetta area was also identified.

Thomson Orogen Project – John Greenfield, Bill Reid, Kingsley Mills, Dick Glen, Steve Triggs, Gary Burton, Tim Sharp, Gary Colhoune, Steve Hill, Karen Hulme, Robert Dart, Martin Smith, Jess Davies, Sarah Gibson, Layla Tucker, Dave McAvaney, Lisa Worrall, Patrice de Caritat, Megan Lech, Amy Kernich, Adrian Fisher, Ken McQueen, Ian Roach

The Thomson Orogen is one of the last major greenfield terrains in New South Wales and is prospective for magmatic arc and ocean-crust related gold and base metal deposits. However, the thickness and variable nature of the overburden provides a complex challenge to mineral explorers.

In July 2005, LEME, with its core party NSW DPI, established the Thomson Orogen Project with the primary objective of improving regional prospectivity by developing an effective means of exploring through cover. This project forms part of a major initiative by NSW DPI into the Thomson that includes regional mapping, seismic, drilling, gas geochemistry and airborne geophysics.

The LEME project has three main components:

- Low-density geochemical surveys employing overbank sediment, lag and vegetation samples. Samples are being analysed using a number of techniques (e.g. NITON, MMI partial leach, XRF, ICPMS).

Photograph: John Keeling

- Regional regolith mapping to provide a basis for interpretation of surface and near surface material influencing geochemical results.
- Detailed regolith mapping and geochemical studies aimed at providing more accurate regional regolith maps by generating a better understanding of post-Palaeozoic landscape evolution and its influence on geochemistry.

The results of the project will be released as a GIS DVD package in 2008 along with an interpretative analysis and an explorers' guide.

Initial results from low-density geochemical surveys have highlighted elevated gold values (4.8 ppb) in the eastern (Brewarrina-Bourke-Cobar), centre (White Cliffs) and west (Tibooburra) Thomson. Localised elevated fluoride concentrations up to 370 ppm have been encountered near Tibooburra, White Cliffs, Bourke and Louth.

During the year, a landscape evolution model of the Mt Browne and Mt Poole inliers in the Tibooburra area was developed using a combination of regolith and bedrock geology mapping. The Inliers occur within a poorly understood regolith-dominated landscape renowned for gold mineralisation. Field evidence suggests the contemporary landscape has been evolving since the mid-Mesozoic with strong impacts from endogenic and exogenic geomorphological processes. The landscape model has indicated that the depth of cover is less than originally thought, potentially increasing the area's prospectivity. In addition, four regional regolith 1:100 000-scale maps covering the Tibooburra area were completed.

Previous LEME reports have demonstrated the benefits of using Regolith Carbonate Accumulations (RCAs) as geochemical sampling media. Studies of RCAs at the Tibooburra/Milparinka inliers have demonstrated that while RCAs are scarce in this landscape compared to other provinces (Yilgarn, Central Gawler, Curnamona), they are sufficiently abundant to be used as a regional sampling medium. The most common landscape setting of RCAs is in small depressions where hardpans comprised of RCAs cover metasediments. RCAs sampled in these areas, located in the Warratta Inlier, achieved gold concentrations of around 200 ppb.

Central Gawler Gold Landscapes – John Keeling, Malcolm Sheard, Baohong Hou, Wenlong Zang, George Gouthas, Melvin Lintern, David Gray, Steven Hill, Lisa Worrall

Collaborative studies on the central Gawler Craton during the past year have made significant progress toward developing effective mineral exploration strategies for this poorly exposed gold province.

Research has focused on the use of spectroscopic data to map the regolith expression of mineral systems. The mineral systems have been modelled by the CRC for Predictive Mineral Discovery (pmd*CRC). These models suggest a number of scenarios whereby mineralised fluids were channelled around the margins of the Gawler Range Volcanics and into nearby shear zones where gold was precipitated as a consequence of fluid mixing or host rock interactions. This modelling has opened up a number of new exploration plays, particularly on the margins of the Gawler Range Volcanics, where regolith cover is relatively thin.

In areas of thin cover, bedrock alteration has been mapped by LEME (this project and the Mineral Mapping Project in Program 2) using hyperspectral (HyMap) data. HyMap data from Tarcoola clearly shows sericite alteration cutting across the Paxton Granite and Tarcoola Beds. In the Paxton Granite, gold is concentrated along a fault at the margin of the alteration. In the Tarcoola Beds, the gold occurs in fractured shaly and dolomitic units.

Spectroscopic logging (CSIRO HyLogger) of drill core and cutting at Tarcoola has indicated that there is a positive relationship between white mica intensity, increased phengite composition in mica and gold grade. When the alteration is tracked into the weathering profile, the compositional information about the mica is lost, but the intensity of mica alteration can be determined using illite content. Where the weathering is exposed at surface the illite content can be mapped from the air.

Research is also continuing into regolith forming processes. A study investigating the occurrence of calcrete gold anomalies in sand dunes adjacent to the Barns Gold Deposit has shown that vegetation is bio-accumulating gold, with the highest accumulations occurring in rhizomorphs. Sensitivity analysis of plant gold accumulation and net primary production indicates the dune gold anomaly formed in less than 10,000 years. However, analysis also suggests the rhizomorph gold concentration of 9 ppb may have accumulated during a relatively short period of 30 years. Biological gold transport mechanism studies will continue at Barnes as part of the CSIRO-CRC LEME/AMIRA P778 Predictive Geochemistry Project, in Program 2.

Eocene sea-level change has been shown to have resulted in reduced sediment packages and potential traps for uranium from groundwater in fluvial and marginal marine environments. Oxidising conditions appear to have mobilised uranium in groundwater as uranyl ion complexes.

A Chinese variation of the CHIM electro-geochemical technique (see Curnaminex Project below) was trialled at Challenger Gold Mine as a tool to refine targets within anomalous areas defined by calcrete sampling. The trial produced encouraging results over extensions of the Challenger Mine gold ore shoots.

A GIS of data on the central Gawler Gold province, complied in collaboration with PIRSA and GA, was released on DVD in May 2006. The DVD includes publicly available geological, geochemical (including RCA) and geophysical data, as well as a map of the palaeodrainage network. A *Guide to the sedimentary cover of the central Gawler Craton, South Australia* by Sue Rogers (PIRSA) and Xianguang Zang (PIRSA) was included with the release. This report summarises the distribution and key characteristics of transported regolith in the central Gawler Craton. More than 50 DVDs have been taken up by companies.

Photographs: John Keeling and Nathan Reid

Curnaminex – Dirk Kirste, Adrian Fabris, John Keeling, George Gouthas, Alistair Crooks, Steve Hore, Aaron Brown, Liliana Stoian, Mark McGeough, Roger Fiddler, Malcolm Sheard, Steve Hill, Karen Hulme, John Joseph, Joel Brugger, Sue Welch, Patrice de Caritat, Luisa Ruperto, Barney Stevens, Jessie Davey, Michael Neimanis

The Curnaminex Project is a three-year project established in 2005. The project merges and expands upon a number of LEME activities in the Curnamona Region. It aims to develop comprehensive geochemical and geophysical exploration strategies to target specific mineral deposit types (primarily copper-gold, lead-zinc, gold-uranium) in areas of regolith cover. Viable exploration strategies will be established firstly by developing an understanding of how the deposit types are expressed geochemically and geophysically within the regolith, and then by determining the processes of dispersion most likely to result in the physico-chemical expression of the mineralisation at the surface. This project will apply established and new regional geochemical, biogeochemical and geophysical exploration techniques in areas of known mineralisation.

Seven prospects were assessed during an orientation survey with the Polygonum, Kalkaroo, Goulds Dam and Christmas Ball prospects chosen as follow up sites for a more detailed study. Digital regolith maps for these sites have been prepared. Samples taken during the reconnaissance trip were analysed using six leaches (Aqua Regia, Perchloric Acid, Deep Leach 3, 5, 11, 20 – AMDEL). The results were inconclusive and indicated each leach had some advantage for particular elements at each site. Overall, it was determined that Aqua Regia and Deep Leach 11 had slight advantages.

Two members from the Chinese Guilin Institute of Technology conducted 'Chinese CHIM' trials at Goulds Dam and Kalkaroo prospects. The results were promising but inconclusive. The CHIM results were significantly better than soil samples taken from the same site with elevated levels of gold, uranium, copper, tungsten and bismuth over mineralisation at the Kalkaroo Cu-Au-Mo Prospect. However, limitations on the availability of CHIM electrodes meant the CHIM surveys did not extend far enough into background. Evaluation of the CHIM technique is the subject of on-going collaboration between LEME, PIRSA and the Guilin Institute of Technology, China.

A TEM survey was conducted at the Kalkaroo Prospect during the year with the acquisition of five 500m lines. A follow up survey added three lines including a tie-line to enable 3D data modelling. The surveys have highlighted the high conductivity of cover sediments in the region. General differentiation of cover sediments was achieved, including thickness variations, dips, a fault zone and possible groundwater recharge and storage zones. This information will be used to assist with interpreting the phyto, hydro and geo-chemical results.

Two U of A PhD students, Michael Neimanis and Jesse Davey, have begun work in the project and will be studying the biogeochemical expression of uranium mineralisation and sub-Mesozoic regolith interfaces and paleosurfaces.

Tanami Project – Lisa Worrall, Steven Hill, Dirk Kirste, Anna Petts, Brad Pillans and Nathan Reid

The Tanami Desert, which straddles the Northern Territory and Western Australian border approximately 700km northwest of Alice Springs, is host to a number of significant gold deposits, however exploration is hampered by regolith cover comprised of both *'in situ'* and transported materials.

The Tanami Collaborative Regolith Research Project was established in 2005 with the objective of developing an effective means of exploring through cover in the Tanami. The collaborative partners are LEME, Geoscience Australia, Northern Territory Geological Survey, GSWA, Newmont Australia, Tanami Gold and Barrick Gold. The project's success will be measured by an increase in successful exploration activity in the region.

The Project's work plan has seven elements:

- Mapping the character and disposition of regolith materials (including groundwater) in three dimensions.
- Developing an understanding of the post-mineralisation geomorphic history of the Tanami Region.
- Characterising contemporary dispersion processes, both physical and chemical including hydro-geochemical, biogeochemical and electro-chemical processes.
- Identifying palaeo-dispersion processes.
- Developing an exploration strategy.
- Developing and implementing an effective transfer and training strategy.
- Tracking results and revising the recommended exploration strategy based on outcomes.

Two reconnaissance field work programs and one follow up field work program focussed on the areas around the Coyote Deposit in Western Australia and the Titania Deposit in the Northern Territory were completed by project staff during 2005-06.

A project highlight was the identification of spinifex (*Triodia pungens*) as an effective biogeochemical sampling medium in the Tanami Region. While spinifex is a grass species, the plants can live as long as 100 years and have the unique ability to grow deep 'tap roots.' LEME researchers have observed spinifex roots at depths of up to 30 metres. Significant gold geochemical signals have been detected in spinifex over the Coyote Gold Deposit. The widespread distribution of spinifex across Australia's arid and semi-arid landscapes highlights the plant's potential in becoming a useful sampling media for mineral explorers. Termite mounds are also being examined as a potential geochemical sampling media in this project.

LEME PHD student profile: Nathan Reid (The University of Adelaide)

PhD student Nathan Reid is already making major research breakthroughs with his discovery that spinifex biogeochemistry can be used as a new mineral exploration technique in areas of transported cover. The pioneering technique, known as phyto-exploration, looks for metal anomalies in plant tissues as an indicator for buried mineralisation.

Nathan has found that although spinifex occurs as low growing grass hummocks on the surface, their root systems can vertically penetrate more than 30 metres through transported regolith. His biogeochemical and geobotany research has contributed to major advances within the Program 1 Tanami Project. His research collaboration with the Centre and exploration companies such as Newmont Australia and Tanami Gold has been a highlight of Nathan's research experience.

The quality of Nathan's research and his presentation skills were recognised when he was awarded the 'Best Student Presentation' at the Student-2006 Industry-CRC Symposium in June 2006 at Gladstone, Queensland.

Eucla Margins – Mark Paine, Luisa Ruperto, Baohong Hou, Lindsay Collins, Liliana Stoian, Brad Pillans, Sue Welch, Lisa Worrall, Noreen Evans, Brent McInnes

Project activity, in collaboration with Iluka Resources, focussed on developing a better understanding of the character, geometry and age (facies interpretation) of mineralised sediments associated with the Jacinth, Ambrosia and Tripitaka mineral sand deposits on the margins of the Eucla Basin, South Australia. The heavy mineral suite is being characterised and domains established with heavy mineral provenance studies undertaken. One of major project outcome will be a better understanding of the prospectivity of the entire basin margin.

Remotely sensed imagery and digital elevation data have been processed to enhance Eocene shoreline mapping. This data was combined with drill hole data in the 3D modelling software GOCAD, and used to reconstruct the basement topography and identify possible basement controls on mineralisation. During the year, heavy mineral distribution trends throughout the Jacinth and Ambrosia deposits were established using AutoGeoSEM and XRD. These results were linked to particle size analyses of selected heavy mineral separates and used to determine five lithofacies that described typical beach and shoreline environments and highlighted a potential zone of mineralisation. LAICPMS of detrital zircon and rutile was then used to establish the age and possible source of the grains.

The results of project activity were reported to Iluka on a quarterly basis and are subject to a commercial-in-confidence agreement between the LEME and Iluka.

GENERIC PROCESS PROJECTS

Geochronology and Quantitative Models of Landscape Evolution – Brad Pillans, Mark Paine, Ed Rhodes, Andrew Christy, David Ellis, Jim Dunlap, Steve Eggins, David Edwards, Martin Smith, Katie Dowell, Suzanne Simmons

Paleomagnetic dating of oxidised regolith continues to demonstrate the long history of weathering across the Australian continent.

Laboratory analyses were undertaken on samples collected in 2004-05 and 2005-06 from the following sites:

- Paddington, Norseman, Kambalda and Kanowna mines in the eastern Yilgarn, Western Australia, (Eucla Margins Project).
- Several open pit mines in the Tanami Region of Western Australia (Tanami Project).
- Tennant Creek, Darwin and Alice Springs areas of the Northern Territory (NT Regolith Project).
- Challenger Mine, Gawler Craton, South Australia.
- Ballarat and Dundas Tableland areas including the Bondi Heavy Mineral Sands Prospect in western Victoria.
- The new Cobar Mine in northwest New South Wales (Lachlan Fold Belt Project).

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

Martin Smith, Steve Eggins and Jim Dunlap continued with a multi-dating method approach to regolith in northwestern NSW, including oxygen isotope analyses of clay minerals, U/Pb measurements on silcrete and (U-Th)/He dating of iron oxides.

As part of the Eucla Margins Project Mark Paine, in conjunction with Ken Farley (California Institute of Technology), undertook (U-Th)/He dating of goethitic pisoliths from inset valley-fill sediments at the Paddington Mine (Rose East pit) near Kalgoorlie. Resultant ages, uncorrected for He loss, are in the range 20-25 Ma (latest Ologocene to earliest Miocene).

History of Aridity – John Magee, John Chappell, Ed Rhodes, Brad Pillans, Kathryn Fitzsimmons

The sub-humid conditions that prevailed across most of Australia during the early and middle Cenozoic gave way to relative aridity in the later Miocene. However, according to findings of the History of Aridity Project, it was not until the later Pliocene that deserts, both stony and sandy, began to characterise the landscape of the Australia's semi-arid interior.

Photograph: John Keeling

Two techniques were used to determine the timing of aridification; Optically Stimulated Luminescence (OSL) dating and cosmogenic dating. Measurements of cosmogenic nuclides (^{10}Be, ^{26}Al and ^{21}Ne), formed by cosmic ray bombardment in regolith and rock surfaces, can give the age when a surface became exposed and can also yield the burial age of subsurface sediments. OSL dating can be used to measure the time elapsed since subsurface sediment was last at the surface. The two techniques can be combined to determine complex landscape histories. For example, sediment that was transported and buried only once will give similar OSL and cosmogenic burial ages, whereas a cosmogenic determination from sediment that has been recycled several times will indicate the aggregate burial age and will be greater than the OSL age, which indicates the time since the last burial event.

These techniques were combined to study the history of the Simpson Desert. The cosmogenic results showed that the dunefield has existed for at least 1.7 million years, while OSL dating showed the dunes have been repeatedly remobilised although, according to down-drillhole cosmogenic signatures, comparatively little sand has been added to the Simpson Desert in the last million years. Drilling also showed that some, but not all dunes, were comprised of a series of deposits separated by horizons of soft haematitic nodules, interpreted as buried soils. The presence of paleosols indicated dune building was punctuated by episodes when the dunes were stabilised by vegetation and slowly eroded by surface runoff. OSL dating indicates that dry, dune-building episodes correspond to global glacial periods and that the wetter, stable episodes correspond to global interglacial phases.

In summary, the results show the Simpson Desert dunefield existed throughout the Pleistocene and the age approaches the 2-4 million year age of stony 'gibber' deserts in the western Lake Eyre Basin, determined by cosmogenic methods. The combined cosmogenic and OSL data show the sand has been repeatedly reworked and no individual dunes are likely to be as old as the desert itself. OSL data from Kathryn Fitzsimmons' work (see below) indicate that this is also true for the Strzelecki and Tirari Deserts, and it is hypothesised that all of Australia's major dunefields began to form in the Late Pliocene or early Pleistocene; at the time of global cooling and the onset of the ice ages.

Chronologic work using OSL on the linear dunes of the Strzelecki, Tirari and Simpson deserts being carried out by Kat Fitzsimmons for her PhD thesis suggest the oldest preserved records of dune activity in the Strzelecki Desert extend to 130,000 years ago, compared with significantly younger basal dune ages in the Tirari Desert of 90,000 years. There is possible evidence for a change in wind regime reflected in dune orientation in the Tirari Desert around 60-70,000 years which resulted in widespread reworking of the Tirari dunefield. In comparison, the basal units of the Simpson Desert dunes have much older ages of possibly 400-500,000 years, suggesting that these dunes did not undergo complete reworking during the last full glacial cycle, unlike the dunes in Strzelecki and Simpson Deserts. The determined ages correlate well across the dunefields and reveal a trend of widespread dune reactivation episodes in response to arid conditions, which may be linked with global scale climatic changes. Single grain OSL work on the Simpson Desert dunes has yielded more detailed insights into the behaviour of quartz sand grains relating to age determination, and allows for greater confidence in the multiple grain dating method which has been used in the work thus far.

Macro and micro biotic influences on the solubility of alumina and the formation of bauxite (Weipa) – Tony Eggleton, Graham Taylor

Bauxite is one of the world's most important mineral resources and is generally considered to be the product of long-term weathering in tropical or monsoonal climates on a low-relief landscape. In Australia, bauxite accumulations occur across the whole continent with mines at Weipa in Qld, Gove in the NT and along the Darling Ranges of WA.

The project aims to determine the age of the Weipa Bauxite Deposit and the processes responsible for its formation. In 2005-06, further work was done to characterise the bauxite section of the Weipa weathering profile. 72 bauxite samples were analysed by XRD at ANU and 26 by XRF courtesy of Geoscience Australia, as well as 36 water samples by ICPAES at ANU in collaboration with Dirk Kirste and Sue Welch. About 1,500 individual bauxite pisoliths were examined optically with some examined using SEM. Three manuscripts and a LEME report describing the analytical results and the genesis of the bauxitic profile have been completed and will be released after clearance from the collaborating companies.

Geophysical Signatures of the Regolith – John Joseph, Graham Heinson, Nick Direen, Anton Kepic, Jayson Myers, Tania Dhu, Margarita Norvill, Anousha Hashimi, Lachlan Gibbins, Sukhyoun Kim, Michael Hatch

During 2005-06, progress continued in gaining a better understanding of the spatial and temporal variations in the geophysical properties of the regolith. Most research was done by

PhD students at U of A and CUT, resulting in numerous presentations and publications in national and international journals and magazines.

Analysis of regolith resistivity data by Tania Dhu a PhD Student at U of A has shown there is a scale length associated with the Earth's electrical response. Ongoing research will attempt to link this scale length with lithological and hydrogeological properties, through case study examination of different EM data sets (ground and airborne), numerical modelling of random resistor networks and simulation of geological scenarios and calculation of associated scale length.

Research completed during the year by Sukhyoun Kim, also a PhD student at U of A, has shown the electrokinetic groundwater exploration geophysical technique can be applied to determine groundwater flow rates and hydraulic conductivity. Significant progress was made in building a reliable Electrokinetic Seismic (EKS) instrument prototype. Effort has also gone into developing new data interpretation methodologies.

Bahman Bayat, a PhD student at CUT, collected and collated regolith/basement density data and modeled (in 3-D) the predicted Airborne Gravity Gradient (AGG) response of six gold deposits. Unlike previous studies, a full geological model was used, including regolith structure and petrophysics. All the deposits have an imprint in the regolith due to preferential weathering over the mineralisation, and most are detectable with modern AGG. Sensitivity analysis showed that AGG is basically a regolith-mapping tool and will struggle to detect all but the most massive mineral deposits.

Mike Hatch a PhD student at U of A has developed and tested an in stream Nano TEM system for surveying the electrical properties of river beds has also developed a small (3 m by 3 m) system for rapid land based TEM evaluation. The TEM system was mounted on a sledge and pulled across the ground.

COMMERCIAL PROJECTS

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

The project was completed this year with the launch of the Northern Territory Regolith Map and Atlas at the Annual Geoscience Exploration Seminar (AGES) in March 2006. The final output from this project consisted of a 1:2,500,000-scale Regolith-landform Map of the Northern Territory developed from a comprehensive and detailed regolith Geographic Information System (GIS). The map, which was compiled from field observations from more than 1,500 sites across the NT as well as existing geological maps and satellite imagery, is the first of it kind in Australia.

The Atlas of Regolith Materials of the Northern Territory (LEME OFR 196) contains supplementary information for the NT Regolith-landforms map and associated GIS. It includes 600 colour photographs of major regolith material types, as well as tables of geochemical data and diagrams of particle size distribution.

NT Regolith Project also completed a palaeomagnetic age assessment program for selected areas in the Northern Territory. The assessment revealed the Darwin coastal plains and nearby region have profiles with ages in the range of two to five million years. Further south, in the vicinity of Pine Creek, ages range from five to ten million years, while a Tennant Creek road cutting yielded a single age of 295 million years. A weathering profile at Snake Head Dam, in the vicinity of Glen Helen George, yielded an age of 47 million years. These ages are consistent with specific Northern Territory age data available from the LEME Geochronology Project and the broader pattern emerging for Australia.

The digital regolith field data collection system, integrated with Geoscience Australia's national databases and operating from a low-cost HP IPAQ Pocket PC, is also major achievement of the NT Regolith Project. The wireless (Bluetooth) based system facilitates the uploading of data into corporate databases and GIS software. It also permits rapid data analysis and interpretation in the field. The system is now being used in a number of other LEME projects and is being adapted for adoption by NTGS.

Physiographic Regions – Colin Pain, Luisa Ruperto

The Australian Collaborative Land Evaluation Program (ACLEP) provided funding to LEME during 2005-06 to prepare a national map of physiographic regions. This map, which was completed on schedule in May 2006, provided regional and national polygons for the Australian Soil Resource Information System (ASRIS), and is available in draft form from the ASRIS web site (http://www.asris.csiro.au). ASRIS was officially launched by the Minister for Agriculture, Fisheries and Forestry, Peter McGauran, at Parliament House on 12 October 2005, with LEME recognised for its contribution.

The National Physiographic Regions Map has been acknowledged as an important step in developing national standards for regolith mapping by the Chief Government Geologists, and the National Committee on Soil and Terrain. Further work in 2006-07, in collaboration with ACLEP, will develop a more rigorous approach to mapping regolith and landforms at various scales, thus providing a sound framework for further regolith landform mapping.

Outlook for 2006-07

Regional focus projects will continue to be the main vehicle for delivery of research outcomes to mineral explorers through collaboration with Program 2, and to Natural Resource Managers through collaboration with Programs 3 and 4. However, in 2006-07 increased attention will be given to the communication of research outcomes to the national and international scientific community through presentations and publications, and the production of LEME legacy products. In addition to a number of Explorers' Guides, these legacy products will include a LEME Field Guide for *Describing and Sampling Regolith Materials*, a revised edition of the LEME Guide to Regolith Dating Methods, and a LEME Atlas – which will be a digital compilation of all LEME regolith maps.

The success of the NT Regolith Map and Atlas Project has resulted in a new commercial project with the Queensland Geological Survey. This project, which will commence in 2006-07, will produce a Queensland Regolith Map and Atlas.

Program 2: Mineral Exploration in Areas of Cover

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

Photograph: John Joseph

Highlights

- Manuscript *Biomineralization of gold: biofilms on Bacterioform Gold* by LEME Authors Frank Reith, Steve Rogers, Bear McPhail and Daryl Webb published in the prestigious international Journal *Science*.
- Launch of *Regolith Landscape Evolution Across Australia* and *Regolith Expressions of Australian Ore Systems* at the International Geochemical Exploration Symposium, Perth, September 2005 with 370 copies sold since their release.
- A vital step towards making geochemical exploration predictive in areas of transported cover was taken with the start of the CSIRO-CRC LEME/AMIRA P778 Project, *Predictive Geochemistry in Areas of Transported Overburden* in June 2006.
- Release of *Laterite Geochemical Database for the Southwest Yilgarn Craton* Report (LEME OFR 201), which highlighted the potential for new mineral fields in the South West Yilgarn in March 2006, with 40 copies sold and 25 exploration tenement applications subsequently made in the south west Yilgarn.
- LEME and two junior mineral exploration companies, Mindax Ltd and Quasar Resources Ltd, embarked on a new uranium exploration project in the Western Australian Wheatbelt following the Centre's discovery of U anomalies in the bores, lakes and drains of the Upper Avon River Catchment.
- Nuclear microprobe element mapping has shown mulga phyllodes host appreciable Zn and Cu concentrations.
- Discovery that ore-grade 'laterite' deposits in the northern Yilgarn of Western Australia were created by multi-stage local to distal hydromorphic, biogenic and to a lesser degree mechanical dispersion of Au, As, Cu, Pb, Bi and Sb in pisolitic ferricrete about 5-10 Ma ago.
- Geochemical data from groundwater samples taken in the Yilgarn Craton have enabled ultramafic and non-ultramafic rock types, as well as Ni mineralised and barren geological units to be distinguished from each other – both on regional and local scales.
- Ten oral presentations, including a keynote paper, were made by Program 2 staff at the IGES meeting, Perth, September 2005, with three prizes awarded to LEME students and staff.

Overview

The aim of Program 2 is to provide new and improved tools for mineral exploration in areas of cover based on understanding metal and mineral transport and transformation processes. This knowledge will provide explorers with guidelines to assess the most suitable transported regolith environments in which metal dispersion is possible and what sample media and techniques are suitable for metal anomaly detection.

LEME researchers are applying a range of techniques such as tissue analysis of various plant species (phyto-exploration), metal geochemistry around the plant-root zone in relation to plant uptake, mass balance studies, in-house lab and greenhouse studies, groundwater geochemistry, microbial ecology, molecular biology and isotope analysis to establish the source of metal in plants and regolith, and regolith desorption analysis to test gas migration possibilities.

Projects within Program 2 have been grouped into generic process, regional-focus and technology development categories.

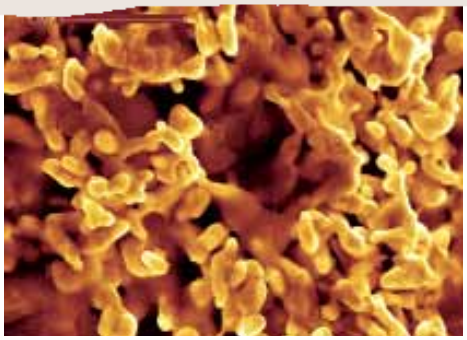
GENERIC PROCESS PROJECTS

Mechanisms of Formation of Geochemical Anomalies

Metal Mobility – Bear McPhail, Alistair Usher, Chris Gunton, Frank Reith

Research into the metallophilic bacteria detected on the surface of gold grains was completed this year. Molecular biology investigation of bacterial populations on gold grains, employing polymerase chain reaction DNA amplification of 16S rDNA regions and Denaturing Gradient Gel Electrophoresis, identified a unique bacterial micro flora inhabiting the surface of gold grains, compared to the surrounding auriferous soils. A single 16S rDNA fragment was identified on all gold grains. Subsequent cloning and DNA sequence analysis identified the bacteria as *Ralstonia metallidurans*, an organism already known to precipitate some heavy metals from solution. *In-vitro* experiments using pure cultures of this organism showed active and rapid precipitation of gold on the surface of the cells. This work was published in the prestigious international journal *Science* (Vol 313, 2006) July 2006. The work on bacterial gold precipitation will continue outside of LEME, through the establishment of an ARC Linkage Project involving the University of Adelaide, CSIRO, the South Australian Museum, Barrick Gold and Newmont Australia.

Investigations to determine the various geochemical and environmental controls that influence the mobilisation of gold and other metals through the regolith continued. UltraViolet-Visible Spectrophotometry (UV-VS) has identified the formation of gold chloride-bromide and hydroxy-chloride complexes. Their thermodynamic properties were also derived in an experimental study which showed mixed chloride-bromide complexes of oxidised gold (Au^{III}) are present at a small range of low Br/Cl ratios (approximately 0.01 to 0.07). These complexes enhance gold transport under oxidised and acidic conditions, where bromide concentrations are 1 mol% or more in groundwater.



From left to right: **LEME PhD student Frank Reith, SEM image of microbially-derived gold and Ravi Anand and Cajetan Phang leaf sampling in the field.**

Mixed hydroxy-chloride Au^{III} complexes occur between a pH of about 4-9 (a typical range for groundwater) at low chloride (e.g. 0.1 molar) and 25°C. At increasing chloride concentrations, such as seawater (0.6 molar) and higher, the hydroxy complexes predominated. These results now allow the prediction of speciation, solubility and transport of gold in oxidised, fresh to saline water environments, including the regolith and below. The outputs of this study have potential applications to improve hydrometallurgical techniques for gold ore processing.

A robust analytical method for measuring low level gold concentrations in groundwater continued to be developed. Building on previous studies, the efficiency, accuracy and detection limits are being established using pre-concentration of gold onto activated granular carbon and subsequent Instrumental Neutron Activation Analysis (INAA).

The solubility of native gold has been successfully measured at 50°C, with a pH of about 4 (buffered by acetic acid buffers) and 0-5 molar NaCl. The redox of the experiments was controlled by an argon-oxygen atmosphere. Preliminary interpretation of the results indicated a mixture of Au (I) and Au (III) chloride aqueous complexes.

The effect of pH (4-5), salinity (0-0.5 molar NaCl) and organic acid (0.1-1.0 molar acetate) on the transport of copper through goethite, hematite and goethite-kaolinite regolith was measured in column experiments. Increased chloride and acetate concentrations appear to enhance copper transport (the former is in contrast to the experimental copper adsorption studies). Both goethite and kaolinite appear important in controlling copper transport, as there was no difference in copper transport between pH 4 and 4.5, the range where copper adsorption to goethite changed dramatically. The experimental results show a combination of adsorption, reaction kinetics and mineralogy control copper transportation through regolith. Such experimental results will lead to the development of more robust numerical reactive transport models.

Metals transfer mechanisms – Ravi Anand, Mel Lintern, Rob Hough, Cajetan Phang, Mehrooz Aspandiar, Frank Reith, Ken McQueen, John Keeling, Charles Butt

A review conducted by Mehrooz Aspandiar, Ravi Anand and David Gray to address the poor understanding of various upwards metal transfer mechanisms through transported overburden, as opposed to the metal concentrations in residual regolith, uncovered several potential mechanisms, including groundwater, gas, vegetation and bioturbation. Most have limitations that require further investigation and are summarised in LEME Report 230.

Vegetation samples from gold and base metal tailings dams were collected to investigate metal distribution in different plant parts. Gold and pathfinder elements are enriched in mulga, but there are significant differences in different mulga organs. Nuclear microprobe and Synchrotron-based X-ray Fluorescence (SXRF) element mapping were used to study metals distribution within plant materials. The leaves of Acacia aneura showed detectable levels of zinc and copper. Elements such as iron, which are concentrated at the leaf edge, appear to be derived from contaminating dust adhering to the outer surface. This discovery has enabled the distinction to be made between element concentrations within plant tissue and from contamination. Plant tissue is currently being studied in three dimensions using synchrotron-based CT scanning methods. This approach will be developed further to allow the 3D visualisation of element distribution such as zinc. These studies involved collaboration with Marc Norman at the ANU (LAICPMS), and Chris Ryan, Barb Etschmann and David Belton from CSIRO Melbourne.

Research during the year has shown that gold-in-calcrete anomalies found in a sand dune near the Barns Gold Deposit on the South Australian Eyre Peninsula were probably formed by plant activity. A realistic estimated age of the anomalies' formation is put at 10,000 years. This calculation was based on mass balance, net primary production, and gold concentrations of regolith and vegetation and indicates that some geochemical anomalies in regolith materials may form very quickly. Isotopic studies show that plants get most of their strontium and calcium from atmospheric sources such as rain, dust and aerosols even though gold is sourced from bedrock. Isotopic studies also show that calcium in the gold-in-calcrete anomalies is sourced from the atmosphere, while carbon is derived from plant and microbial respiration.

'Laterite' hosted ore-grade gold deposits are common, particularly in the northern Yilgarn Craton of Western Australia. However, these surficial deposits of gold generally do not lie above primary mineralisation. Data generated by this project suggests that multi-stage local to distal hydromorphic, biogenic and, to a lesser degree, mechanical dispersion of gold, arsenic, copper, lead, bismuth and antimony in pisolitic ferricrete lead to the formation of these ore-grade deposits. Much of the gold in the pisolitic ferricrete was concentrated during the last 5-10 Ma. Recognition of three pisolith types (detrital, authigenic and residual) is essential for determining an anomaly's origin. They have formed at different times, under different bio-climatic regimes, and have distinct geochemical characteristics. Authigenic pisoliths, formed during the Mid-Miocene-Pliocene, have the greatest concentrations of gold; older detrital pisoliths (Early to Mid Tertiary) generally have the lowest gold concentrations. Significant gold occurs in late-stage goethitic cutans around detrital pisoliths. Gold appears to be broadly associated with goethite, but decreases significantly with increasing concentrations of hematite. Microanalysis of the mineral phases suggests broad goethite-copper, kaolinite-copper, goethite-hematite-arsenic, and hematite-lead-bismuth-antinomy associations.

Studies to determine the location of pathfinder elements and gold in regolith at the Moolart Well Gold Prospect north of Laverton in Western Australia during the reported period involved combined Scanning Electron Microscopy (SEM), Electron Microprobe (EMP), Laser Ablation ICPMS and Synchrotron-based X-Ray Fluorescence

(SXRF) mapping. The latter for the first time used geoPIXE software and full spectral data acquisition to produce quantitative element maps. Gold appears to be sited within authigenic nodules and cutans and was found to be 'nuggetty', most likely in the form of sub-micron particles, as they could not be further resolved by SEM.

Predictive Geochemistry in Areas of Transported Overburden – CSIRO-CRC LEME/AMIRA P778 – Ravi Anand, Mel Lintern, Frank Reith, Rob Hough, Craig Macfarlane, Cajetan Phang, Ryan Noble, Steve Rogers, Graham Carr, Mehrooz Aspandiar, Steve Hill, Enzo Lombi

The start of the AMIRA Project in June 2006 represents a significant step towards making geochemical exploration predictive in areas of transported cover. The sponsorship and support given by major mineral exploration companies including Barrick Gold Corporation, BHP Billiton Minerals Exploration, Inco Resources (Australia) Pty Ltd, Independence Group NL, Newmont Australia Limited, SGS Minerals, Teck Cominco Ltd, Rio Tinto, CVRD, Codelco and Cameco Corporation emphasises the project's importance. The primary aim of the project is to determine the mechanisms for geochemical anomaly formation in transported overburden in a variety of Australian and Chilean environments. Based on these mechanisms, the project's secondary aim is then to develop effective and reliable geochemical exploration techniques. More specifically, the project team will use innovative approaches to systematically study the potential role of various chemical and/or biological mechanisms in geochemical anomaly formation in areas of transported overburden.

Field and experimental work has begun at several Australian sites including Jaguar (volcanogenic massive-sulfides), Barns (gold), Rose Dam (gold), Moolart Well (gold), Gnaweeda and Miitel North (nickel).

LEME PhD Graduate profile: Ryan Noble, Curtin University of Technology

Ryan submitted his PhD thesis entitled *Distribution of arsenic in regolith above buried mineralisation: implications for exploration and environmental management* in June 2006. His thesis was subsequently accepted in September 2006.

Towards the end of his PhD research, Ryan gained full time employment as a research scientist for CSIRO Exploration and Mining. Ryan is currently involved in a range of LEME funded projects, including the AMIRA P778 Predictive Geochemistry Project, to examine nickel, gold and uranium hydrogeochemistry, reactive transport modelling in regolith, and undertaking various and biogeochemistry experiments.

Biogeochemistry of Calcrete – Andreas Schmidt Mumm, Frank Reith

Research on biological calcrete formation continued throughout the year. Gold enrichment in carbonates produced through *in-vitro* biological activity was successfully demonstrated in the laboratory. Regolith samples taken from the Barns Gold Deposit in South Australia were incubated in standard microbiological liquid shake cultures. Micro-organisms present in the regolith samples (resident microflora) were shown to grow during the incubation. Carbonate precipitation via urease activation was then achieved in gold-free and gold-bearing shake cultures. Carbonate was subsequently analysed with LAICPMS. The carbonate precipitated showed a gold enrichment of two to three orders of magnitude relative to the gold-bearing solution.

REGIONAL FOCUS PROJECTS

Yilgarn Laterite Atlas – Matthias Cornelius, Paul Morris, Amanda Cornelius, Charles Butt, Ian Robertson

A report entitled *Laterite Geochemical Database for the Southwest Yilgarn Craton, Western Australia* (LEME OFR 201) highlighting the potential for new mineral fields in the South West Yilgarn Craton of Western Australia was released in March 2006. The publication and associated database is the first release of a 53-element dataset generated from about 2,000 laterite samples taken in the region. The report outlines regional laterite geochemical anomalies at a spacing close enough to recognise geochemical trends, major rock types and dispersion halos around significant mineralisation. Since its release, there has been a significant uptake of tenements in the South West Yilgarn. The project, led by Matthias Cornelius (CSIRO) and Paul Morris from the Geological Survey of Western Australia (GSWA), was funded by the Minerals and Energy Research Institute of WA (MERIWA), CSIRO Exploration and Mining and LEME.

Data examination suggests there is potential for gold and base-metal mineralisation outside known greenstone belt areas of the southwestern Yilgarn Craton. The chalocphile element index showed potential for gold and base-metal mineralisation in the western most part of the Yilgarn Craton. Chromium concentrations in granitic terrain also indicate there may be mafic-ultramafic remnants outside known greenstone belts.

A regional mercury anomaly trending northwest for more than 500 km from Wongan Hills in the north to Jerramungup in the south, and further to the east-northeast along the Proterozoic units of the Albany-Fraser Province was observed.

Work continued in the northwestern quadrant of the Yilgarn Craton and approximately 1,300 samples have been collected in the field or taken from in-house collections. Analytical work on these samples is on-going. Release of the final report for the western Yilgarn Craton is now expected in mid-late 2007.

Program 2: Mineral Exploration in Areas of Cover

WA Wheatbelt Uranium – Grant Douglas, David Gray, Ryan Noble, Steve Rogers

LEME and junior mineral exploration companies Mindax Ltd and Quasar Resources Ltd have embarked on a new uranium exploration project in the Western Australian Wheatbelt. The partnership was formed following the Centre's discovery of anomalous uranium, cobalt and other metals in the bores, lakes and drains of the Upper Avon River Catchment. The discovery was one of the outcomes from the Program 3 WA Wheatbelt Acid Drainage Project.

On the basis of the anomalies identified in the first year of the study, a second year of confirmation and in-fill sampling around existing anomalies was proposed. U-Th series isotope analyses will be undertaken to assess the technique's potential in defining prospective areas of uranium mineralisation. Initial research activities have concentrated on the analysis of U-series isotopes (Multi-Collector ICP-MS) of U-rich water samples in collaboration with the GEMOC National Key Centre at Macquarie University. Preliminary results show high uranium concentrations (up to *ca.* 900 ug/L) and show the $^{234}U/^{238}U$ ratio is near equilibrium (1.13-1.43). This is much lower than $^{234}U/^{238}U$ ratios normally determined in waters from arid environments. In addition, measured $^{234}U/^{238}U$ activity ratios in the uranium ore deposits of Yeelirrie, Western Australia, are similar to those measured in the waters analysed by this study (1.12-1.37). Assuming that uranium mineralisation is dissolved congruently, similar ratios can be anticipated in waters surrounding unknown uranium deposits. Results so far are consistent with, but not a confirmation of, the presence of economic uranium mineralisation and more evidence is required before this technique can be validated.

The project will also analyse samples for novel $^{236}/^{238}U$ isotopic ratios with the Department of Nuclear Physics at the Australian National University. Elevated $^{236}/^{238}U$ ratios are known to be associated with ore-grade uranium deposits.

Hydrogeochemistry for Mineral Exploration – Patrice de Caritat, David Gray, Bear McPhail, Dirk Kirste, Ken McQueen

During the year, research focussed on the hydrogeochemistry in and around the Peak Gold Mine located near Cobar, northwestern New South Wales. Groundwater from environmental monitoring bores and diamond drill holes was sampled and indicated that hydrogeochemistry may be useful in exploring for new gold deposits in the region. The results also indicated that gold is transported at concentrations of 10s of ppt under current groundwater conditions.

Hydrogeochemistry technology transfer was achieved through the presentation of a short course on *Mineral Exploration Using Groundwater Geochemistry* at the 22nd International Geochemical Exploration Symposium (IGES) at Perth in September 2005. The course was organised and presented by Patrice de Caritat (LEME) David Gray (LEME), Bear McPhail (LEME) and Michelle Carey (BHP-Billiton). Fifteen registrants mainly from industry attended the course and provided positive feedback.

The nickel hydrochemistry project analysed 265 ground water samples collected along a 300 km-strike line in the northern Yilgarn Craton, Western Australia. Another 48 groundwater samples were taken from the copper-zinc deposit at Jaguar, near the historic Tectonic Bore Gold Mine, and another five from the nickel sulfide deposit at Miitel located in the southern Yilgarn. A model was developed for the evolution and variation in groundwater chemistry with depth for sulfide enriched rocks and regolith. The results have shown that geochemical indices from the groundwater samples can distinguish ultramafic from non-ultramafic rock types, and areas of mineralisation from barren geological units on both regional and local scales. Outputs from this project have implications for nickel exploration in the Yilgarn Craton.

TECHNOLOGY DEVELOPMENT PROJECTS

Objective Regolith Logging – Tim Munday, Cajetan Phang, Ravi Anand, David Gray

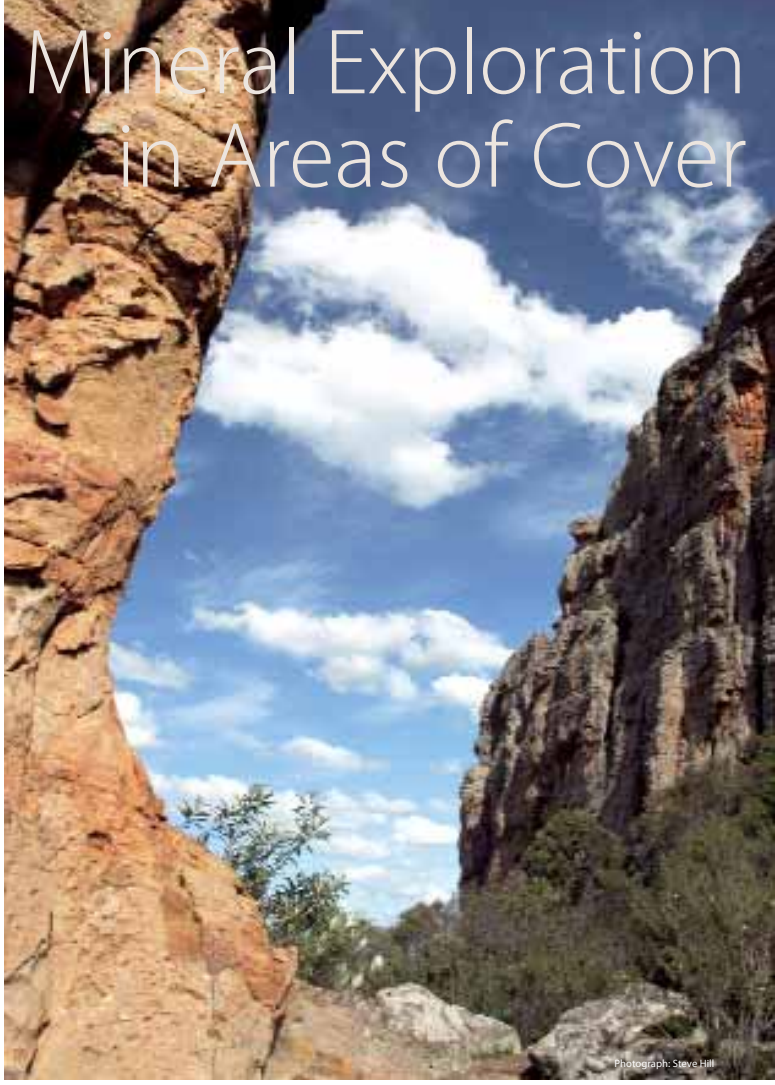
This project is developing and enhancing spectroscopic logging technologies for the purposes of characterising regolith materials in an objective manner. The project involves the application of the CSIRO-developed HyChips automated spectroscopic logging technology to rapidly characterise regolith samples from exploration drill chips and core. It also involves the development of new algorithms that predict regolith mineralogy from near infra-red spectra.

Throughout 2005-06, further advances were made in the development of unmixing algorithms for rapidly determining the relative abundance of regolith minerals in samples collected from chips and core in the field. A critical part of the work has been the identification of procedures for effectively removing background noise from reflectance spectra. To assist with vectoring, this approach will be further tested in the identification of kaolinite and mica abundances at the base of regolith profiles.

Significant differences have been noted in the application of certain algorithms and spectral indices for regolith material discrimination when using chips verses pulps. For example, spectroscopic results derived from pulping result in an overestimate of halloysite abundance verses kaolinite, which has a significant bearing on the interpretation of the transported/residual boundary. The results will influence recommendations on sampling/measurement strategies for the commercial application of HyLogging, particularly when dealing with regolith materials.

To develop further commercial opportunities for the use of the LEME HyChips technology, LEME began a collaboration with CSIRO to trail the HyChips logger in the Eastern Goldfields of Western Australia with the commercial analytical company Genalysis. This collaboration forms part of a broad strategy to encourage the wider use of spectroscopic mineralogy in exploration by developing a knowledgeable and aware exploration community.

Program 2: Mineral Exploration in Areas of Cover


Photograph: Steve Hill

Mineral Mapping (South Australia) – Alan Mauger, John Keeling, Graham Heinson

This project applies the same spectroscopic technology used in the HyChips logger to differentiate regolith mineral assemblages associated with mineralisation from regional regolith materials.

During the year, variations in illite abundance and crystallinity were observed in sample chips associated with drill holes at Tarcoola, South Australia. Further investigation revealed these variations could be linked to systematic alteration zonation associated with known gold mineralisation in the area. Where the illite signature is crosscutting stratigraphy, hydrothermal alteration can now be inferred.

Three-dimensional mineral distribution models from HyLogged drill cuttings were prepared at Tunkillia to assist in targeting gold concentrations within the pervasively altered Yarlbrinda shear zone.

The identification of two new kimberlitic intrusions by John Keeling (PIRSA), Alan Mauger (PIRSA) and Vicki Stamoulis (PIRSA) in the Terowie area of South Australia, through the application of regolith geochemistry to follow up targets defined by hyperspectral characteristics was a key highlight during the year. This outcome has shown that during weathering, phlogopite and serpentinite in the kimberlite alters to vermiculite and Mg-smectite, with the latter characterised by a spectral adsorption feature at 2,303-2,309 nm. This feature is sufficiently different from the broad dolomite adsorption that discrete anomalies, including the two newly found kimberlites, could be defined. The integration of spectroscopic and detailed magnetic data offers a means of prioritising subtle features (in both data sets) that might otherwise be overlooked.

Outlook for 2006-07

Most projects will be finalising field work in the coming year and moving into the delivery phase. The AMIRA P778 Project is an exception as it will continue beyond the cessation of LEME in June 2008. Generic processes orientated work continues with significant progress towards an improved understanding of metal dispersion processes anticipated. Most processes work will be done as part of AMIRA P778 and metal mobility projects. The Program's research emphasis will remain on biotic and chemical processes both experimental and in the field. Researchers will use a combination of field and analytical techniques derived from soil science, botany, molecular microbiology, geochemistry, plant chemistry, hydrogeochemistry and regolith geology to achieve their objectives.

Work on the Laterite Geochemical Atlas will continue in the northwestern quadrant of the Yilgarn Craton. Release of the final report for the western Yilgarn Craton is now expected by mid to late 2007.

Application of hydrogeochemistry for base metals, nickel and gold exploration research will continue with emphasis on developing cost-effective sampling and analytical methods. On the basis of the uranium anomalies identified in the first year of study, a second year of confirmation and in-fill sampling around existing anomalies will continue. In addition, U-Th series isotope analyses will be undertaken to assess the technique's potential in defining areas of uranium mineralisation.

A combined approach to develop and test further the objective logging initiative using spectroscopic mineralogy, spectral indices and chemistry (portable XRF) is being considered. Collaboration with CSIRO will continue to develop commercial opportunities for the use of the LEME HyChips facility in the Eastern Goldfields.

Program 3: Environmental Applications of Regolith Geoscience

Program Leader: Dr Paul Shand (CSIRO Land and Water)

Highlights

- Unexpectedly it has been discovered that more than 60% of Playa lakes in the WA Wheatbelt have a pH less than 4.5 and therefore have a minimal neutralising capacity to treat acid drainage, limiting acid drain disposal options.
- Based in part on advice from LEME, flooding of the Loveday Disposal Basin began on 1 June 2006 to prevent the atmospheric exposure of sulfide minerals and production of noxious smells.
- Preliminary results from the Gawler Craton Low Density Geochemical Survey show its methodology has mineral exploration potential with gold levels detected in catchments with known goldfields.
- Development of new regional multi-disciplinary toposequence models to assess Acid Sulfate Soil risk.
- Policy advice on ASS provided to COAG Standing Ministerial Committee on Natural Resource Management and the National Committee for ASS.

Overview

The aim of Program 3 is to apply regolith science to environmental problems with an emphasis on geochemistry and environmental hazards. Using the multi-disciplinary skills of the LEME Core Participants, project outcomes are focussed on supporting decisions made by management and policymakers. Key areas of research include regolith characterisation, process understanding, biogeochemical controls and the development of risk assessment strategies underpinned by high-quality science. The projects are multi-disciplinary and involve active collaboration with external research groups, agencies and other end-users.

WA Wheatbelt Drainage – Acidic Groundwater: Geochemical Risk Assessment and Evaluation of Management Options – Brad Degens (Department of Water, WA), Steve Rogers, Paul Shand, Rob Fitzpatrick, David Gray, Grant Douglas, Ryan Noble, Claire Wright, Margaret Smith, Adam Lillicrap and Richard George (Department of Agriculture and Food, WA)

Significant progress was made in characterising the extent of geochemical impacts from acid drainage on receiving water-bodies in the agricultural region of the Avon Catchment, Western Australia. This supported the initial drainage and ground-water surveys conducted in 2004-05, with 49 playa lakes in the north-eastern, eastern and south-eastern Avon and Upper Blackwood Catchments sampled and analysed for a wide suite of major and trace elements. These lakes represent a range of artificial and natural disposal sites for acid saline drainage waters and include appropriate reference sites (i.e. those not receiving acid saline drainage waters). This work was complemented by a detailed mineralogical survey in February 2006 of 14 selected lakes. Sediment samples were analysed for basic regolith properties, mineralogy and composition using XRD and XRF.

Lake waters showed a bi-modal distribution of pH with more than 60 per cent of the playa lakes having a pH less than 4.5, the remaining sites have pH levels exceeding 7. Although many acidic playa lakes were receiving acid drainage, as identified in the initial drain surveys of this project, the acidity of some lakes was not associated with deep drainage disposal. Playa lake sediments receiving drainage water were extremely acidic with pH below 3.5 in many cases. These sediments were characterised by a layer of thin iron oxide rich gel overlying acidic red, brown or grey clays. Measurement of the total acid storage in these sediments will be carried out in 2006-07.

Initial results suggest that utilising the neutralising capacity of existing playa lakes to treat acid drainage waters as a means of short-term pH and metals management may not be possible in many parts of the Avon Catchment. If considered, the extent of acid storage in lake sediments indicates future remediation options may need to include the addition of neutralising materials into the sediments, as well as addressing surface water acidity.

Aquatic life was found in some low pH (<4.5) lake systems, indicating that factors other than pH play a role in the survival of aquatic ecosystems. These factors may play an important role in determining the risks posed by drainage waters, since sites accumulating significant trace element concentrations with macro-aquatic life pose a greater ecological risk than those where macro-aquatic life is absent. Geochemical modelling work is being used to predict the fate of acidity and trace metals in surface environments under different drainage management scenarios. This has involved determining empirical relationships between the major and minor ions using multivariate statistical techniques. The results will provide a basis for modifying geochemical equations in the PHREEQC software. The high water salinities and the need to predict the behaviour of acidity and trace metals through a series of evaporation and re-suspension scenarios present new challenges for geochemical modelling and will be addressed by this project.

Scaling effects and interpreting limited spatial data have been a challenge, especially for addressing impacts on receiving environments, which vary in size, history of drainage discharge and connectivity with different surface and ground water bodies. This is particularly the case for sediment chemistry which is spatially and temporally variable.

Loveday Basin Floodplain Projects

Studies centred on the Loveday Basin, located in the Riverland Region of South Australia, were a major focus of the Program 3 Acid Sulfate Soil (ASS) research in the Murray Basin. The Loveday Basin was formerly an ephemeral wetland, which was subsequently used as a disposal basin between 1970 and 2000. This research, in

collaboration with the South Australian Department of Water, Land and Biodiversity Conservation (DWLBC), will provide regolith, biogeochemical and hydrogeochemical inputs into strategies for the site's rehabilitation. The Loveday Basin was chosen as a test case to assess the impact of reflooding with the aim of restoring the basin to an ephemeral river-red-gum-dominated wetland.

1. Drawdown Geochemistry – Sebastien Lamontagne, Warren Hicks

The Loveday Drawdown Project aims to develop the knowledge and procedures that will enable the safe management of the Loveday Basin water level regime.

This will be achieved through:

- A reconstruction of historic water, salt and sulfur balances for the wetland between 1970 and 2000 (when the wetland was used as a disposal basin).
- Monitoring surface water quality to follow water level impact variations over two years (May 2005 – May 2007).
- A literature review on mechanisms causing noxious smells in sulfide-rich wetlands.
- An estimation of gaseous sulfur losses from the wetland in partnership with the DWLBC Odour Control Program.

The current sulfur storage in the basin and the assessment of biogeochemical processes active in sediments during wetting-drying operations will be examined through the Program 3 Geomicrobiology and Geochemistry of Acid Sulfate Soils Project.

Based in part on advice from LEME, flooding of the Loveday Disposal Basin began on 1 June 2006. This decision contributed to the remediation strategy for the basin to permanently flood the wetland, thus preventing the atmospheric exposure of sulfide minerals. Water quality monitoring during the flooding phase was carried out and will continue as planned until 2007. While the 'noxious smells' problem may have been satisfactorily managed with the current strategy, the issue of elevated salinity is still present, as water is not recirculated from the Basin. Future studies will develop tools to predict the salinity behaviour under different water management regimes.

Project field work is on track, but the review of historical, salt, water and sulfur balances and the literature review for noxious gas emissions from wetlands has been delayed until 2006-07. Although local agencies have not been able to deliver the necessary hydrological data, an agreement was reached to complete this review. The objective of measuring sulfur gases emissions from the basin has been abandoned due to technical complexities.

2. Geomicrobiology and Geochemistry of Acid Sulfate Soils

– Sue Welch, Sara Beavis, Dirk Kirste, Bear McPhail, Luke Wallace, Sarah Tynan

This project covers the physical, chemical and biological controls on sulfur and metal cycling in actual and potential ASS environments of the Loveday Basin. Fieldwork focussed on a thorough sampling of near surface sediments for sulfur stores, measurement of physical, chemical and biological properties, collection of surface and groundwater samples, and '*in situ*' measurements of pH, water infiltration and salt flux from the sediments. Microbial processes were studied using molecular techniques at CSIRO Land and Water in Adelaide.

Final estimates of sulfur storage, gross acidification and acid neutralisation potential in the Loveday Wetland were completed. The distribution of oxidised and reduced sulfur in the basin was extremely heterogeneous and is largely related to the presence and distribution of water. The most recent survey showed reduced sulfur contents of up to ~ 10 weight % in the flooded northern part of the basin.

Although the site is often referred to as a potential AAS due to it's abundance of sulfidic material, most of the site is not actually acidic. However, areas of acidity are more abundant than previously suspected in the 2004 survey. Jarosite mottles were common along wet-dry zones in the northern and southern parts of the basin. Acid Neutralisation Capacity (ANC) measurements of the sediments ranged from < 0.1 to > 5 meq/g. In general, sediments containing abundant Acid Volatile Sulfides (AVS) had the highest ANC, whereas sandier material in the southern part of the basin had significantly less potential to neutralise acidity.

Slurry experiments were conducted to estimate salt and sulfur flux from the sediments under different conditions. An initial rapid release of salt to solution was encountered which slowed down over time. Salt composition and concentration were variable with highest concentrations found in surface sediments that experienced wetting and drying. Total salt concentrations in sediment ranged from ~ 30 to 200 mg/g. Sulfur flux was dominated by gypsum dissolution. In subsequent experiments, this initial salt pulse was removed and sediments were reacted with water, dilute acid, and ferric iron. Results were unexpected as neither dilute acid nor ferric iron (pH ~ 2-3) substantially increased sulfur flux to solution, compared to the reaction in water. Experiments conducted with extremely sulfidic material showed that microbes increased sulfide oxidation when compared to the abiotic experiments. However, the abiotic controls were also oxidised and became acidic over time.

A total of 24 water samples were collected comprising standing water (2), shallow pits dug at the surface (4), temporary piezometers (8) and permanent piezometers (10) for the analysis of major, minor and trace species composition, as well as isotopes of O and H in H_2O, S and O in SO_4 and C and O in CO_3. The data indicates a complex relationship between the different waters encountered. Sulfur and oxygen isotopes indicate that saline

shallow pore water is evaporated and sulfide oxidation dominates the sulfate content. The groundwater compositions are generally controlled by mixing between regional groundwater and a reflux brine related to the surface water. The data suggests that reflux brine can also be created locally by the mixing between the reflux brine/regional groundwater and near surface pore water. This indicates that the groundwater aquifer is reasonably well connected to the surface system.

Low-Density Geochemical Surveys – Patrice de Caritat, Megan Lech, Amy Kernich

A new regional geochemical survey in the New South Wales section of the Thomson Orogen, located in the far northern and western parts of the State (Brewarinna-Cobar-Wilcannia-Tiboburra), was initiated this year in collaboration with the Program 1 Thomson Orogen Project.

A reconnaissance pilot field trip in the region was carried out in October 2005, with surface and deeper overbank sediments sampled from the floodplains of 19 selected catchments, using the successful methodology developed in the Riverina Geochemical Survey. Site and soil descriptions were made and field parameters determined during the trip. Analyses using portable XRF were carried out in the field during the trip with mixed results. The portable XRF instrument will be tested further to refine the methodology for improved field applications.

In the lab, EC 1:5, pH 1:5 and laser particle size distributions were measured. After appropriate sample preparation, splits were analysed by XRF and by ICP-MS (after 4-acid digestion) for total element concentrations. Gold was measured by GF-AAS analysis after aqua regia digestion and fluoride by ion specific electrode. Selective leach analyses by Mobile Metal Ions (MMI-M) were conducted in collaboration with MMI Technologies.

A major field trip was carried out in March-April 2006, when 57 sites were sampled for overbank sediments following the same methodologies previously described. Vegetation samples (Black Box, Coolibah, Bimble Box and River Red Gum) along with more lag samples were collected. All these samples were prepared for analysis late in the reporting period.

Progress made to complete the Riverina and Gawler Geochemical surveys was slower due to the re-prioritisation to the Thomson Project. Final reports for both studies will be completed during 2006-07. Results from the Central Gawler Craton showed that regolith samples/fractions have detectable gold concentrations in most catchments with known gold deposits or occurrences. The results demonstrate the survey's methodology has potential application to the mineral exploration industry. This potential will be further tested when the complete datasets become available. Groundwater was also sampled as part of the survey with the associated report to be completed during 2006-07.

Inland Acid Sulfate Soils (ASS) – Rob Fitzpatrick, Warren Hicks, Richard Merry, Andrew Baker, Graham Heinson

Significant progress has been made in linking pedological, geophysical (gamma ray radiometrics, electromagnetics, magnetics and ground penetrating radar), clay mineral (layer silicates, oxyhydroxides, sulfides, etc) and remote sensing data to deduce sub-surface geochemical processes and understand how specific properties impact on ASS. The development of analytical techniques for application in ASS studies has progressed significantly. Development of XRF methods for determining major and trace elements by the fusion method is nearing completion. Progress has also been made in testing the speciation potential of XRF for the characterisation of pyrite minerals in ASS, with good correlations observed with the chromium reducible method for pyrite.

Several new mechanistic models were developed for regions using the toposequence approach, which integrates pedological, mineralogical, hydrological, biogeochemical, geological, climatic and land-use information. Areas studied during the year included the Tilley Swamp and South Para Morella Basin, Riverland near Loxton, South Australia, the Western Australian Wheatbelt, and the Dundas Tableland, Victoria. Improved risk assessment and land management systems for ASS were completed for these study areas.

A user-friendly 'Soil Identification Key' for ASS was developed, based on a study along the River Murray. High levels of selenium were found in salt efflorescences along the river corridor. In some soil materials, chromium and antimony were above the trigger value specified by the Australian and New Zealand Guidelines. The salt efflorescence, or evaporite deposits, were found to be an assemblage of sulfate-containing minerals. Movement and accumulation of such soluble salts is typical of drained soils. The salt efflorescences contained a complex assemblage of sulfate-containing evaporite minerals: (hexahydrite ($MgSO_4.6H_2O$), wattevilleite [$Na_2Ca(SO_4)_34H_2O$], konyaite [$Na_2Mg(SO_4)_25H_2O$], thenardite (Na_2SO_4), gypsum ($CaSO_4.H_2O$) and barite ($BaSO_4$). Insights have been gained into the spatial relationships amongst secondary precipitates and the mineral assemblages represent good environmental indicators of soil-water processes.

The project has continued to provide technical and policy advice on Inland ASS. This has been achieved through (i) invited papers/keynote addresses at workshops/conferences in Australia and overseas; (ii) information at national (NatCASS/NRM Standing/Ministerial Committees) and international (IUSS) committees; (iii) information to mineral exploration companies; (iv) lecturing at international and Australian universities and agencies to successfully ensure that Inland ASS is recognised as a 'Geohazard to environments of the world.' During the year, a workshop dealing with Environmental Forensics was organised in Perth highlighting many advances in mineralogy and geochemistry developed in LEME.

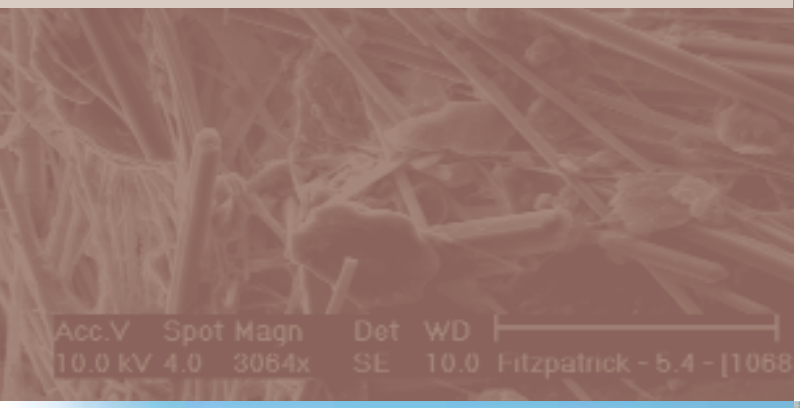
Program 3: Environmental Applications of Regolith Geoscience

LEME PhD student profile: Andrew Baker, The University of Adelaide

LEME PhD student Andrew Baker is studying the formation of inland Acid Sulfate Soils and their implications for base metal exploration in the Mt Lofty Ranges of South Australia. As part of his studies, Andrew has chosen a sulfidic wetland site that occurs adjacent to a known area of primary sulfide mineralisation.

Andrew's preliminary findings have shown that the sufidic wetland contains high metal concentrations. These elevated metal concentrations are most likely due to the wetland's proximal location to primary sulfide mineralisation coupled with a disturbance event that created environmental conditions favourable to metal mobilisation.

His findings have potential implications to the environmental management of sulfidic wetlands and application to the mineral exploration industry. Andrew anticipates he will submit his thesis during 2006-07.



Outlook for 2006-07

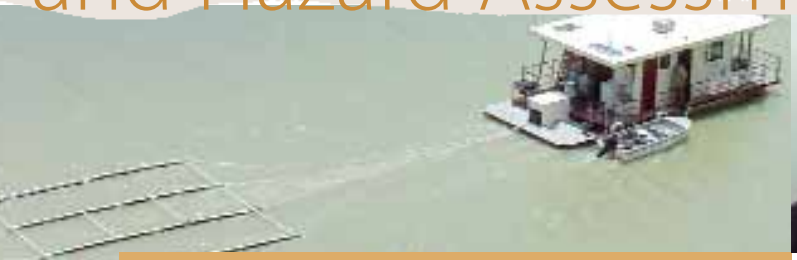
Most reported projects will continue towards final delivery in 2006-07. The Western Australia Wheatbelt Drainage Project being the exception which will expand beyond the Avon Catchment to include the Yarra Yarra and Blackwood catchments, as well as the south coast of Western Australia. This expansion will include pilot geochemical evaluation of specific engineering projects, assessment of potential trace-element risks, risks to receiving environments and active management of acidic trace element-rich drainage waters. Treatment technologies will also be studied as part of a WA Department of Water-Avon Catchment Council Project that will include the construction of pilot-scale treatment/evaporation basins, in-stream treatments and mixing with alkaline surface water. Acid drainage projects will continue beyond the cessation of LEME in 2008.

Monitoring will continue at the Loveday Basin to assess the post-flooding water quality. Field and laboratory studies in the geomicrobiology project will focus on the role of iron and sulfur bacteria in the generation and consumption of acidity, cycling of trace metals in acid sulfate soils and storage and behaviour of sulfur under wetting-drying cycles, for completion in mid 2007.

The Low-density Geochemical Survey Project will complete its work in the two pilot study regions and assess the 'market readiness' of the geochemical sampling methodology developed by LEME.

Work will begin on the production of a thematic volume encompassing the distribution, properties, significance and management of inland ASS in Australia and world-wide. Incorporation of inland ASS into the National ASS Map of Australia will be a focus for the coming year.

Program 4: Salinity Mapping and Hazard Assessment



Highlights

- New multi-scale Groundwater Flow System (GFS) products have been developed for modelling and salinity prediction in dryland erosional landscapes in the Murray-Darling Basin.
- LEME products shown to provide improvements in salinity correlations between salt scalds and new LEME GFS maps in central-west New South Wales.
- Collaborative work with CRC for the Plant-based Management of Dryland Salinity (CRC PBMDS) shows hydrogeological modelling, which integrates enhanced LEME produced GFS maps, significantly improves correlations between measured and predicted salt outbreaks and river salt loads in the Victorian Bet Bet Catchment – this work has important ramifications for targeting salinity investment strategies.
- Preliminary interpretation of Chowilla Project datasets shows Airborne Electromagnetics (AEM) provides new insights into floodplain processes which have significance for salinity management in the Murray River Floodplain Corridor.
- Ord Stage 1 Irrigation Area geophysics and regolith studies demonstrate EM techniques can successfully delineate sand and gravel aquifers, clay-rich layers, and the regolith-basement interface, with significance for groundwater and salinity managment.
- Ground and in-river geophysical surveys demonstrate specific Electromagnetic (EM) techniques can map water quality variations, infrastructure leakage and recharge of aquifer systems in the Burdekin Delta, North Queensland.
- A regolith-landform map of the Mt Lofty Ranges in South Australia is providing new insights into regolith, bedrock and geomorphological controls on hydrological and salinity processes in nested landscape scales.
- Published potassium-argon ages for Cainozoic basalts and other igneous rocks from eastern Australia, along with locations, have been collated into a GIS layer allowing rapid assessment of rates and timing of landscape development when displayed with other digital data.
- New calibration methods of frequency-domain helicopter AEM data developed by the Airborne EM Project improves the accuracy of electrical conductivity mapping of regolith.
- Successful trialling of Ground Penetrating Radar combined with other achievements in ground time domain electromagnetics and seismic reflection prompts Watercorp (WA) to undertake a major geophysical work program over 1,000 km^2 of land north of Perth in the next three years.

Program Leader: Dr Ken Lawrie (Geoscience Australia)

Overview

A highlight of 2005-06 was the culmination of the upland areas dryland salinity research sub-program. This has been marked by the development and testing of a new suite of multi-scale products that enhance existing GFS frameworks for the management of dryland salinity. These products are underpinned by a new understanding of the scale at which landscape processes operate. Work with CRC PBMDS and other clients is on-going to use this new understanding and product range to underpin salinity investment frameworks for the dryland salinity management. These products have the potential to form the next generation of maps to strengthen salinity mapping and management in Australia in areas such as the Murray-Darling Basin.

Preliminary AEM survey results in the south eastern Murray Floodplains and Chowilla Projects provided valuable new insights into floodplain processes. The results from this project have significance for salinity management in the Murray River Corridor and have led to significant return business and additional projects in the area.

Several case studies have been completed that focussed on integrated salinity and groundwater management in floodplain landscapes and are now ready for broader adoption and technology transfer. For the remainder of the Centre's life, activities in this program will build case studies in different landscapes and management scenarios for salinity and groundwater resource management applications. Reducing salt export from upland landscapes is considered an important 'emerging' science where significant progress was now being made.

Collaborative Projects with the Murray-Darling Basin Commission – Ken Lawrie, John Wilford, Larysa Halas, Heike Apps

Value-adding to GFS Frameworks for Managing Dryland Salinity in Australia

As part of a portfolio of projects, LEME has been tasked by the Murray Darling Basin Commission to develop a new methodology to provide more detailed GFS framework models to calibrate Salt Balance Models (eg 'CAT 3D' and '2C Salt') in upland landscapes in the Murray-Darling Basin. Products have been developed in trial areas within the Macquarie and Lachlan catchments in NSW and the Bet Bet sub-catchment in Victoria.

The new methodology utilises a hierarchical, multi-scale, multi-disciplinary mapping using a nested scale approach which provides a framework for identifying the spatial extents of landscapes with similar 3D regolith character. This in turn enables the design of

more detailed farm and sub-catchment scale hydrogeological investigations to characterise salinity processes.

While the approach maximises the use of existing geoscientific data, limited acquisition of new regolith and hydrogeological data was also needed. This included stream salinity surveys, acquisition of new 3D regolith data from surface mapping, analysis of existing or new boreholes and limited ground geophysics and groundwater data. Information was then used to provide an understanding of salt stores, groundwater and salinity dynamics, to create more detailed GFS maps, and provide inputs to decision support models such as Salinity Investment Framework III (SIF3).

Preliminary results from both study areas have been most encouraging. In the Lachlan and Macquarie catchments, more detailed GFS maps show a much improved correlation with salt scalds. In this area, the Centre's research has revealed significant variability in regolith landscape complexity and salt stores between sub-catchments.

Delineation of landscape-scale GFS units over the Bet Bet Sub-Catchment has improved the understanding of groundwater salinity processes in the area. In particular, it has provided a better understanding of the relationships between regolith composition, thickness, architecture and hydrological properties, as well as bedrock geology (lithology and structure), and salinity salt stores, saline groundwater flow and its surface expression. New thematic coverage including soils, regolith and bedrock structures have been incorporated within a CAT3D hydrogeological model. The results show significant improvements in correlations with salinity scalds and salt export in streams.

In summary, a key outcome of this research has been a more detailed characterisation of the regolith landscapes of the upper Murray-Darling Basin that better represents its true complexity. As this regolith layer is the main store for salts, and the groundwaters that mobilise these salts, resolving this regolith architecture is a high priority for calibrating salinity models.

Physiographic region mapping carried out in Program 1 has enabled the boundaries of these changes in landscape complexity to be determined. The boundaries appear to place important constraints on landscape complexity, regolith thickness and potential salt stores. Variations occur at several scales, ranging from hundreds to tens of kilometres. These variations are not recorded on any existing maps, yet this information has the potential to significantly influence the use of GFS and other groundwater and salinity models in Australia.

LEME has now developed a suite of products at a range of scales for salinity assessment in upland/erosional catchments. These products can be tailored on the basis of data and resource availability, and range from high-resolution (sub-catchment to farm scale) through to sub-catchment and catchment scales.

Examples of these products are:

- High resolution (sub-catchment to farm scale) GFS+ products.
- Moderate resolution (sub-catchment to catchment scale) GFS+ products.
- 3D map of depth to bedrock beneath valleys.
- 3D models of valley infill.
- Physiographic regions maps (Program 1).

Upland Landscapes – John Wilford

A new regolith-landform map of the Mt Lofty Ranges in South Australia has been completed to improve the understanding of salt mobilisation and distribution in the region. The map has been compiled using digital terrain analysis techniques, regional gamma-ray spectrometry imagery, and existing geological and soil-landscape mapping. It has provided a regional framework to help interpret detailed local-scale hydrological and regolith studies using ground geophysical datasets and drill hole information. This work has provided insights into regolith, bedrock and geomorphological controls on hydrological and salinity processes in nested landscape scales.

Chowilla/SE Murray Floodplains – Tim Munday, Andrew Fitzpatrick, KP Tan

Preliminary interpretation of Airborne Electromagnetic (AEM) datasets has provided valuable new insights into floodplain processes. Conductivity models predicted from helicopter Electromagnetic (EM) data have helped identify local recharge and discharge areas and links with river salinity. More specifically, the data has delimited an extensive flushed zone adjacent to the Murray River, which has provided insights into its geometry. Near surface conductivity data has correlated well with recharge maps developed from an interpretation of multi-temporal satellite data and vegetation mapping.

Observed variations in conductivity mapped at depth suggest the helicopter EM data is mapping variations in the porosity of the Loxton Sands below the Monomon Formation. This may have implications for the siting of proposed bores for salt interception and ecological protection. The three-dimensional distribution of salinity in the saturated and unsaturated zones has been incorporated into hydrogeological models for the Chowilla Floodplains to assess future management strategies.

Inverted RESOLVE EM data taken from a section of the Murray River at Bookpurnong, South Australia, has been compared against the in-stream ground-based Time Domain Electromagnetic (NanoTEM) and available river-bed core data. The helicopter EM data shows very similar trends in conductivity variation mapped in the corresponding NanoTEM data. For this reach of the river, the helicopter EM data effectively maps where salt enters and is lost from the system and provides insight into the interplay between an irrigation induced groundwater mound, the regional groundwater system and river salinity.

As the technique has now proved its application in these systems, economic and logistical issues involving the acquisition of helicopter EM are the main considerations in the further adoption of this successful technology.

Ord Irrigation Area – Ken Lawrie, Jon Clarke, Paul Wilkes, Heike Apps, Mike Hatch

Existing hydrogeological models of aquifer systems in the Ord Irrigation Area (ORIA) of Western Australia are inadequate to explain observed groundwater flows between these aquifers and the deeply incised river system and drainage works.

In the ORIA Stage One, a pilot study was carried out to assess existing data, knowledge gaps, and the appropriateness of ground and airborne EM techniques to delineate aquifer systems and map water quality variations, recharge and infrastructure leakage. A re-assessment of aquifer stratigraphy and connectivity was also undertaken. Ground and borehole geophysical surveys combined with a re-examination of soil and regolith data have demonstrated that specific EM techniques can successfully delineate sand and gravel aquifers, clay-rich layers, and the regolith-basement interface.

However, in most of the ORIA Stage One irrigation Area, there is insufficient water quality and electrical contrast between surface and groundwaters for EM techniques to map water quality variations and channel leakage, demonstrating the limitations of this technology.

While acquisition of AEM datasets is recommended, scale, technology choice and survey design are critical factors. More generally, a key to the successful use of airborne geophysics for salinity and groundwater mapping and management is the identification of key management questions, integration of AEM data with appropriate hydrogeological data, and incorporation of these products into hydrogeological models and broader NRM strategies.

Lower Burdekin – Ken Lawrie, Andrew Fitzpatrick, Jon Clarke, Heike Apps

The geometry and proportion of sand, clay and gravel bodies implied by previous geological models of the Burdekin Delta have provided important constraints for hydrogeological modeling of sub-surface aquifer systems. New insights into the 3D geometry of the aquifers has come from sub-surface sediments studies of borehole materials and geophysical logs, as well as from new high resolution Digitally Elevated Model (DEM) interpretation that revealed considerable detail about present-day and past river geomorphology. Depositional features include first, second and third order lobes and channels. First order lobes are three to eight km wide and 12-20 km long, second order are three km long and one km wide, and third order lobes are one km long and less than one km wide. First order channels are about 500 m wide, second order 100 m wide, and third order less than 100 m wide. Only the main incised channel is active, the others are relict features. This detailed interpretation is valid for sediments in the top 20-25 m of the delta.

Recognition of a fan-delta origin and geometry for the Burdekin has major implications for modelling of groundwater flow in the irrigation region, whether for groundwater resource estimation, artificial recharge calculation, or managing salt water intrusion. Previous interpretations emphasised the presence or absence of interstitial mud which represented the succession as being mud-dominant with isolated channel sands. Fan-delta geometry implies the reverse, with isolated lenses or drapes of mud locally separating stacked bodies of gravelly sand. The greatest variability in hydraulic properties is likely to be down fan, with variations of approximately 14 orders of magnitude predicted in fan systems. This contrasts with conventional deltas where variability is greater across the distributary system.

Furthermore, new ground, in-river, in-irrigation channel and borehole electromagnetic (EM) surveys, combined with a re-examination of soil and regolith data, have demonstrated that specific EM techniques can map water quality variations, and hence map infrastructure leakage and recharge of aquifer systems. These techniques are particularly effective in the coastal zone where there is a contrast in water quality and electrical conductivities in the shallow sub-surface between irrigation and river waters, and more saline groundwaters related to salt water intrusion. In more inland areas of the delta, contrasts are also evident where dryland salinity processes are present.

Rural Towns – Liquid Assets – Paul Wilkes, Brett Harris, Anton Kepic

The Rural Towns – Liquid Assets Project is developing effective salinity controls by turning locally sourced saline groundwater into a resource.

LEME is a research partner in this major three year (2004-07) multi-agency project lead by the WA Department of Agriculture and Food in collaboration with CSIRO (through the Water for a Healthy Country Flagship), the WA Chemistry Centre, the University of Western Australia (UWA), the WA Water Corporation and 16 WA rural shire councils.

The project is working on 16 of the most salt affected town shires in rural WA to devise and deliver water management plans with four main components aimed at water abstraction and re-use.

They are:

- Groundwater control strategies to alleviate salinity and water logging impacts on natural and built assets.
- Analysis of groundwater treatment and disposal options.
- Evaluation of water use options, including economic analysis of water use and reuse.
- Social benefits derived from increased water availability.

LEME's role is to provide regolith geoscience understanding for these towns and to help provide workable saline water management for the 16 shire councils. In 2005-06, geophysical investigations took place near Dowerin, Moora, Pingelly and Wongan Hills to determine the depth to bed rock, three-dimensional electrical conductivity variations and locate geological features such as faults. Reports summarising the findings were then written as part of the

Shire Water Management Plans for Lake Grace, Nyabing and Woodanilling. Fieldwork in 2005-06 included downhole geophysical logging (Moora), gravity (Dowerin, Moora, Pingelly and Wongan Hills), magnetic (Pingelly) and seismic surveys (Moora and Dowerin).

Haddleton Creek – Paul Wilkes, Brett Harris

This project, in collaboration with the WA Department of the Environment and Conservation, is designed to locate possible paleochannels in the Haddleton Nature Reserve east of Collie, Western Australia, to help define salinity mitigation strategies for the region. Gravity and time domain electromagnetic methods used during the year have confirmed the previously inferred main paleochannel location was correct. In addition, this project has shown the combination of gravity and electromagnetic geophysical techniques provided consistent results.

Southern River Project – Paul Wilkes, Brett Harris

In collaboration with CSIRO's Water for a Healthy Country Flagship, this project aims to acquire new hydrogeological information for a near urban environment located in southern eastern Perth. During the year, ground geophysical data was acquired through Time Domain Electromagnetics (TEM), Ground Penetrating Radar (GPR) and Gamma Radiometric Methods (GRM). In combination, these methods proved effective in gaining a better understand of the area's hydrogeology. New and faster ways to obtain ground electromagnetic data were developed and successfully trialled.

Wallatin Creek Project – Paul Wilkes, Brett Harris

In collaboration with Wallatin Wildlife and Landcare Inc, WA Department of Agriculture and Food, CSIRO Sustainable Ecosystems and Viv Reid and Associates, this Catchment Demonstration Initiative Project aims to assist in the creation of salinity mitigation strategies in the area through the use of groundwater pumps and syphons, drainage engineering and plant-based options. The Wallatin Creek Catchment lies north of the central Western Australian Wheatbelt town of Kellerberrin, located about 200 km east of Perth.

During the year, airborne geophysical datasets provided regional information which was supplemented by more detailed ground electromagnetic, gravity ground penetrating radar, magnetic and gamma radiometric surveys. EM surveys showed variations in electrical conductivity in relation to salinity and regolith. Gravity measurements were used to map depth to bedrock and locate paleochannels. Magnetics were used to assist geological mapping and identify mafic dykes. Communication with the local farmers remains a key part of this project.

Yarra Yarra – Paul Wilkes

Through the use of funds from The National Action Plan for Salinity and Water Quality (NAPSWQ) and the Natural Heritage Trust (NHT), this project is collaborative with the WA Department of Agriculture and Food and the Yarra Yarra Catchment Management Group. The project is designed to investigate how new soil maps derived from airborne radiometric data, Landsat and vegetation mapping can be created for the area. During 2005-06, about 900 field sites were selected from new airborne radiometric images. A decision tree approach was then used to define soil types for mapping. The resulting maps were presented to the Yarra Yarra Catchment Management Group for evaluation.

A paleochannel project began during the year at six sites within the Yarra Yarra Catchment to investigate possible linkages between present day drainage and underlying hydrogeological features. Variations in gravity have been measured along the six transects with EM measurements to follow up.

Landscapes Analysis – Dave Gibson, Colin Pain, Jon Clarke, Larysa Halas

This project is developing regolith-landscape model architecture for Cainozoic basins-initially the Murray Darling Basin. During the reporting period, work focussed on value-adding to existing datasets. Published K-Ar ages for Cainozoic basalts and other igneous rocks from eastern Australia, along with locations and other data for 770 analyses, encompassing about 500 locations, were collated. Data from western Victoria and northern Queensland is still being assessed. These ages and locations will be built into a GIS layer to allow rapid assessment of rates and timing of landscape development when displayed with DEMs and geology and regolith information. Some locations are recorded as yard grid references, and migrating these into MGA grid references is continuing. Samples have also been collected for palaeomagnetic dating, results and a final report will be delivered in mid-2007.

Salinity Dynamics – Richard Cresswell, Jim Cox, KP Tan, David Rassam, Phil Davies, Dirke Kirste, Matt Gilfedder, John Dighton, Matthew Stenson, Richard Greene

This year, project focus shifted from the description and characterisation of salinity through the use of mapping, ground-truthing and interpretation of air-borne geophysics, to understanding the hydrogeology and hydrogeochemistry behind salinity and the drivers that cause its expression. Target catchments have been selected in Queensland (Condamine, Fitzroy and Moonie Basins) and Victoria (Corangamite Region) while work continues in the Bland Catchment in central NSW, with two PhD theses currently being written up using materials derived from this area.

During the year, two drilling programs and four sampling trips were undertaken, yielding several hundred regolith and more than 100

groundwater samples for chemical and isotopes analysis. Interpretation of this data will be completed by 2006-07.

Hydrogeological frameworks were developed for the Corangamite Region and for Hodgson Creek in the Condamine Catchment. Hydrogeochemical models are being developed for Hodgson Creek and for the Goondoola Basin in the Moonie Catchment. During the year, data collation from the Fitzroy Basin was undertaken and a rapid stream survey carried out to help identify hot-spots for further salinity investigation. All this work has been carried out in close collaboration with State and regional agencies.

Reviews of solute transport models, catchment salinity models, salinity drivers and salt in the Australian landscape are in progress with numerous conference presentation and seminars given throughout the year. Most presentations are being developed into papers for peer-reviewed publications.

A highlight of the year was the commencement of a national rainfall collection network which covers the whole continent and will remain in active for five years. This nationwide collection of precipitation, which will be analysed for anions, cations and stable isotopes, will provide invaluable data for catchment salt balance calculations and as chemical inputs for solute transport models.

Corangamite Sub-project

A high resolution LIDAR DEM (2 m pixels, vertical noise ~ 10 cm) and airborne geophysics was used in a study of weathering of Cainozoic basalt in the Lake Corangamite Catchment in Victoria. The DEM allowed new, very detailed regolith landform polygons over basalt to be defined, which showed that previous interpretations of the extrusive lava flow order and degree of weathering were partially incorrect. The radiometric response of each unit studied showed a correlation between the (Th/K) ratio and depth/degree of basalt weathering, whereas there was poor correlation between the individual channels and degree of weathering. This was probably due to variable original basalt chemistry. The results show the Th/K ratio is useful in determining the degree of weathering and can differentiate between basalts of different age – thus the degree of soil formation and weathering.

Aquifer Parameterisation – Anton Kepic

This project applied high resolution seismic reflection methods to regolith problems such as aquifer modelling.

Considerable work was carried out during 2005-06 to use seismic and Electrokinetic Sounding (EKS) methods to gather information about aquifer formation as these techniques have high resolving power and are sensitive to porosity and permeability characteristics.

Further analysis of seismic reflection data taken from the Burdekin Delta in central Queensland using petroleum industry methodologies has shown promise in identifying sandy layers. In particular, normalised reflectivity analysis showed that a contrast reflection is coincident with a significant aquifer. This result was anticipated, as a higher contrast with a low porosity/permeability formation would suggest a better formation for groundwater. It was also able to clearly show basement faulting beneath sediments, which could act as possible fluid conduits into the system. EKS method trials at the Burdekin Catchment were successful with borehole and surface tests at all three sites providing interpretable results. Initial borehole data analysis has revealed that a relatively strong EKS signal is generated at significant aquifer boundaries. This test was done in conjunction with researchers from the University of New Brunswick, Canada.

Seismic reflection method trials conducted at the WA wheatbelt town of Moora, done jointly with other geophysics trials as part of the Rural Towns – Liquid Assets Project, enabled the Centre to accurately map a clay layer too deep for other geophysical methods to resolve.

Ground Penetrating Radar (GPR) was trialled for Watercorp (WA) at the Gnangara Mound, an unconfined aquifer located north of Perth, WA, to see if an iron-rich water retentive formation could be accurately defined. The trials were successful in the sandy environment of Gnangara mound and confirmed that GPR data, when combined with borehole logging, can provide extra data density to properly model the superficial aquifer recharge patterns over a wide area. However, the analytic model used by Watercorp (PARAMS) needed more data to provide public confidence in water extraction planning.

The successful GPR trial data and the other achievements in ground TEM and seismic reflection in this and in other LEME projects during the year has prompted Watercorp (WA) to undertake a major geophysical work program over 1,000 km^2 of land north of Perth during the next three years. The combined methods will produce data for aquifer modelling from the superficial aquifer (near-surface) to up to 1,000 m deep and characterise two aquifer recharge sites that are to be used for water storage.

Eyre Peninsula – Andrew Fitzpatrick, Tim Munday

This project examined the applicability of airborne geophysical technologies, particularly Airborne Electromagnetics (AEM), for mapping critical boundary surfaces relevant to the definition of groundwater resources in the southern Eyre Peninsula of South Australia. A scoping study was undertaken to determine whether AEM could resolve critical aspects of the sedimentary aquifer system in the Coffin Bay Area. This provided guidance to the relative performance of different AEM systems, indicating which ones may be best suited for mapping select targets in the area. This scoping work suggests that in the Uley South Area, AEM data could be used to resolve the depth to unweathered basement (the lower aquifer boundary), provide some indication of the thickness of the Tertiary sequence, and map the thickness of the Quaternary sedimentary sequence and the base geometry of the Quaternary aquifer. When combined with available borehole data it is likely that an AEM survey would provide valuable hydrolgeological information to assist the management of groundwater resources in the region.

The forward modelling has indicated a range of EM systems, including high resolution helicopter and fixed-wing, suited to mapping critical bounding surfaces in the study area, although their suitability varied depending on the target.

Acquisition and processing of AEM data in this region will be carried out during 2006-07.

Airborne EM – Tim Munday, Andrew Fitzpatrick, Richard Lane

The Airborne EM Project, also known as AMIRA P407B commenced in August 2003, and is scheduled to finish in September 2006.

The project's objectives are to:

- Improve the accuracy and resolution of imaging quasi-layered conductivity structures.
- Develop 2D and 3D models and interpretation methods.
- Document the software developed over several previous collaborative research projects.

LEME sponsorship of this project has allowed access to cutting-edge software used for analysing, processing and interpreting EM data over a wide range of applications. More specifically, it has provided access to the research version of EMFLOW, which handles all data from ground and airborne EM systems. The software has been successfully applied to several environmental projects and complements other processing programs developed by the Centre.

These new methods for calibration frequency-domain helicopter AEM data have improved the accuracy of electrical conductivity mapping in regolith, which will be of benefit to land managers. LEME sponsorship of this project has enabled researchers to influence research directions and leverage new funding opportunities.

Salinity Communications – Ken Lawrie, Colin Pain

This project aims to communicate Program 4 salinity project outcomes to a national and international client, stakeholder and peer base. While regolith geoscience has gained broad acceptance within the minerals exploration community, there is still a need to raise awareness of regolith geoscience within the salinity management community. Specific challenges exist for LEME to convince key peer groups about the value of regolith science to salinity management. Key NRM stakeholder groups include hydrogeological modellers, NRM modellers, policy makers, and client and stakeholder groups, particularly in the eastern States, such as State agencies and Catchment Management Authorities (CMAs).

In order to demonstrate the quality and value of LEME science to help resolve NRM issues, particular attention will be given in the remaining two years of the Centre to gaining peer acceptance in national and international forums through publications in relevant journals and conference presentations coupled with activities such as workshops to familiarise potential clients with LEME methods and products.

Several Program 4 staff attended the Modelling and Simulation Conference (MODSIM) in Melbourne during December 2005. All presentations were well received, and led to an invitation to researcher, Dr Colin Pain, to edit a special collection of papers on DEMs. Staff also attended the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP) 2006, in the United States. Planning for the International Salinity Forum (ISF08), to be held in Adelaide, South Australia in April 2008, was at an advanced stage of development with a program structure now in place.

At the 2006 Australian Earth Science Convention (AESC), Program 4 Leader Ken Lawrie will be the convenor of the major symposium entitled *Environmental and Geological Hazards and Risks to Australasia* as well as three parallel environmental symposia. LEME is a major sponsor and participant at this convention with specific products being developed with Centre staff acting as editors and contributors.

A book for decision makers and the general public documenting LEME's present understanding of the Environmental and Geological Hazards and Risks to Australasia will be presented at AESC. Preparations were also underway for a LEME field trip prior to the convention.

Program 4: Salinity Mapping and Hazard Assessment

Outlook for 2006-07

An increase in demand for Program 4 services from a range of clients in 2005-06 is being translated into new externally-funded contracts and/or project funding proposals between 2006 and 2008. In several cases, this is in the form of return business with existing clients in South Australia, Burdekin and the Ord. Overall, the Program is demonstrating an increasing number of examples where multi-disciplinary geoscience approaches are seen to be important for tackling NRM issues. There is growing interest in using regolith geoscience to understand and manage groundwater management and salinity management issues.

Projects in the remaining two years will continue to be a mix of Centre-funded strategic research projects and externally-funded co-investment projects with an increasing emphasis on the development of legacy products.

Contracts have recently been signed for projects that will conclude in 2008. AEM-related projects include the Bureau of Rural Sciences (BRS)-funded AEM Salinity Mapping Project in the Murray Corridor in Victoria. In this project, LEME has been sub-contracted to Geoscience Australia (GA) and BRS for the analysis and interpretation of an AEM survey in the Murray River floodplain.

A contract has also been signed with Goulburn-Murray Water for an AEM project looking at salinity interception and disposal in the Sunraysia District of Victoria. Contracts are being developed for AEM projects in Coffin Bay and Stockyard Plains regions of South Australia. Other AEM projects at an advanced stage of discussion include the Beaufort Palaeochannels in Western Australia, the principal aim of which is to define a fresh water resource in an otherwise saline landscape. There are proposals underway for extensions of existing projects in the Ord and Burdekin River catchments.

A contract has been signed with the Central-West Catchment Management Authority to evaluate and test our new series of GFS maps in that catchment, while joint projects with the MDBC will focus on value-adding to GFS-products in selected catchments in Victoria and New South Wales. MDBC-co-funded projects will also focus on knowledge transfer and developing legacy products, and input into the MDBC's mid-term review of salinity registers has been requested. Collaborative research with CRC PBMDS will continue in these dryland landscapes in order to maximise the value and impact of LEME products.

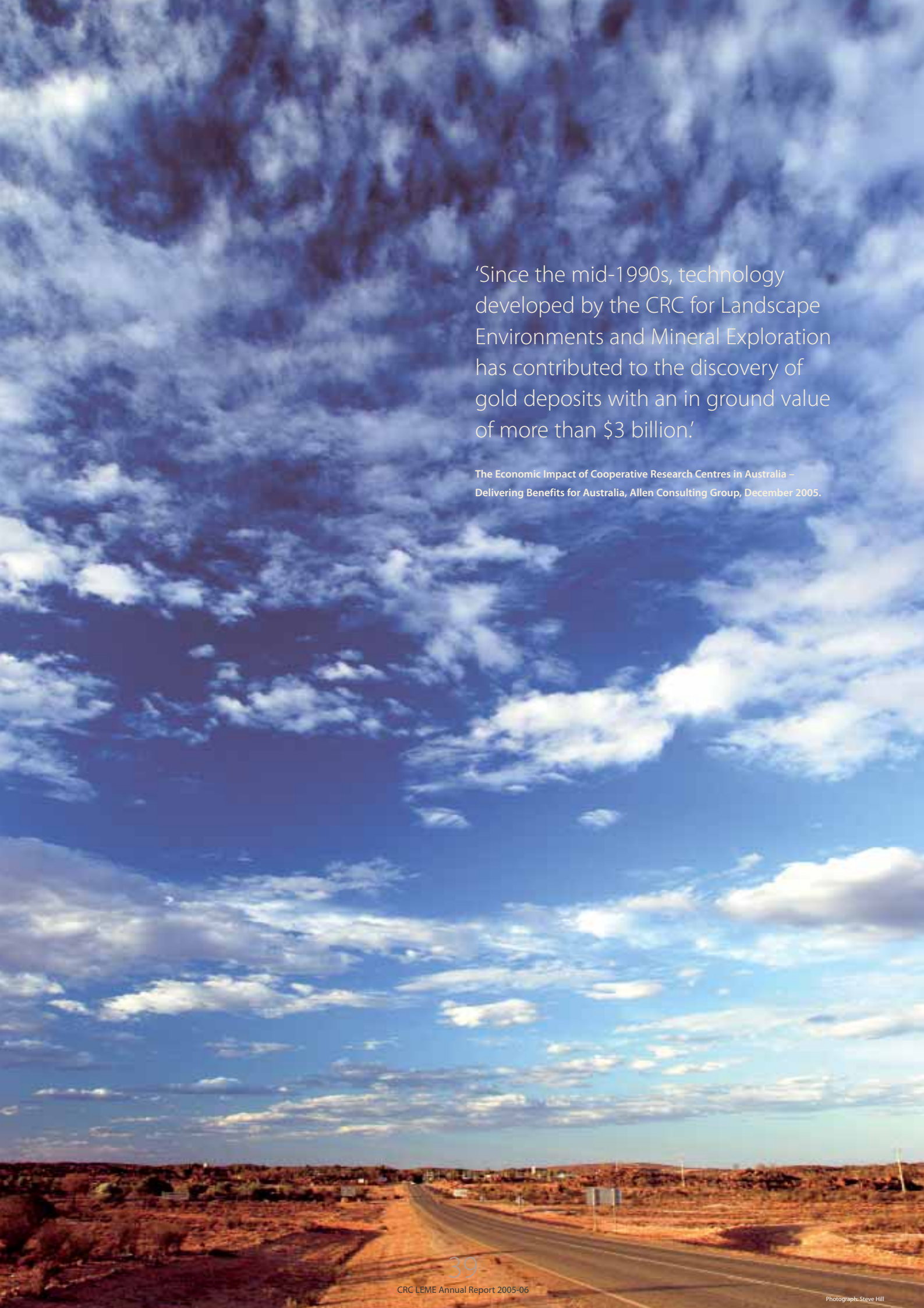
Work will commence on key delivery/legacy products:

- Special thematic publication in the Australian Journal of Earth Sciences (AJES) volume from SA NAPSWQ projects (in final edit stages, for publication in December 2006).
- International Association of Sedimentologists Special Publication on Australian Cainozoic Cratonic Basins. Jon Clarke and Colin Pain are editors of this volume, with several Centre contributors. Its release is planned to coincide with a 2008 International Salinity Forum (ISF08) Workshop.
- A special LEME thematic volume on Environmental Geophysics featuring contributions from Centre staff, edited by Paul Wilkes and Richard Lane. This publication will be released at ISF08.
- International Salinity Forum will be held from 31 March to 3 April 2008 in Adelaide, South Australia.

  Products from this meeting will include:

  1. Peer reviewed journal volumes with special issues of on salinity mapping, salinity management, catchment characterisation and salinity processes.
  2. Enduser workshops: One on the use of AEM for mapping and managing salinity and a second workshop on basins and catchment characterisation.

- ISF 08 and NAPSWQ – sponsored information session for CMAs and decision makers (invited workshop).



'Since the mid-1990s, technology developed by the CRC for Landscape Environments and Mineral Exploration has contributed to the discovery of gold deposits with an in ground value of more than $3 billion.'

The Economic Impact of Cooperative Research Centres in Australia – Delivering Benefits for Australia, Allen Consulting Group, December 2005.

Photograph: Steve Hill

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EDITORSHIPS AND INVITED PAPERS

Personnel	Core Party	Editorships and Invited papers	Publisher	Date
Ravi Anand	CSIRO	**Co-editor**, Thematic Volume: Regolith Landscape Evolution Across Australia	LEME	Sept 2005
Charles Butt, Ian Robertson, Keith Scott, Matthias Cornelius	CSIRO	**Co-editors**, Thematic Volume: Regolith Expression of Australian Ore Systems	LEME	Sept 2005
Charles Butt	CSIRO	**Invited paper (co-author)**, Nickel exploration, Yilgarn Craton: Economic Geology Special volume	Economic Geology	In Press
Charles Butt	CSIRO	**Co-editor**, Proceedings volume of 22nd IGES, Perth and Committee Member	Association of Applied Geochemists	2005
Charles Butt	CSIRO	**Invited paper (co-author)**, Lateritic ore deposits, Economic Geology, 100th Anniversary edition	Economic Geology	Oct 2005
Charles Butt	CSIRO	**Associate Editor**, Geochemistry: Exploration, Environment, Analysis	Geological Society of London and the Association of Applied Geochemists	2000 to June 2006
Grant Douglas	CSIRO	**Editorial Board**, International Journal of Sediment Research	Int Assoc for Sediment and Water Science	2004 onwards
Patrice de Caritat	GA	**Editorial Board**, Geochemistry: Exploration, Environment, Analysis	Geological Society of London and the Association of Applied Geochemists	Jul 2005 onwards
David Grey	CSIRO	**Editorial Board**, Geochemistry: Exploration, Environment, Analysis	Geological Society of London and the Association of Applied Geochemists	2001 onwards
Steven Hill	U of A	**Editorial Committee**, Aust Journal of Earth Sciences	Australian Journal of Earth Sciences	Jan 2006 – 3 yrs
Tim Munday	CSIRO	**Invited Review**, New Geophysical techniques for mapping soil salinity. Journal on Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources	CAB Publishing	2006
Colin Pain	GA	Editorial Executive, Aust Journal of Earth Sciences	Australian Journal of Earth Sciences	Jan 1997 onwards
Brad Pillans	ANU	**Editorial Board**, Quaternary Science Reviews	Elsevier	1996 onwards
Brad Pillans	ANU	**Editorial Board**, Catena	Elsevier	1998 onwards
Brad Pillans	ANU	**Section Editor**, Encyclopaedia of Quaternary Science	Elsevier	2005 onwards
Ian Robertson	CSIRO	**Editorial Board**, Geochemistry: Exploration, Environmental, Analysis	Geological Society of London and the Association of Applied Geochemists	2001-05
Steve Rogers and Frank Reith	LEME and CSIRO	**Invited Chapter**, Exploration Geomicrobiology the new frontier In: Biogeochemical Exploration	Elsevier	2006
John Wilford	GA	**Invited Paper**, Digital Mapping: an introductory perspective	Elsevier	2005-06

Research Collaboration

During the five years of LEME, the level of collaboration both internally and externally has continued to increase maintaining effective linkages between its eight Core Participants, the users of its research in industry, the scientific research community, government authorities and community stakeholders.

Internal Research Linkages

Cross-program linkages continued to evolve during the year as new geochemical and hydrogeochemical initiatives from Program 3 resulted in spin-offs into Programs 1 and 2. One example was the Program 3 acid-drainage studies of the Western Australian Wheatbelt which encountered anomalously high uranium levels during the year – up to 10 ten times higher than background levels. The outcomes from this project resulted in junior mineral explorers Mindax Ltd and Quasar Resources Pty Ltd entering into a two-year collaborative research project with LEME, known as the *Uranium Anomalies in Waters of the Western Australian Wheatbelt*, to locate the source of anomalous uranium.

Multi-party and multi-disciplinary projects remain an integral part of LEME research. They ensure that regolith knowledge remains directed at the needs of the diverse set of stakeholders in both mineral exploration and natural resource management industries. Of the 59 projects funded by the Centre, most involved more than one Core Participant. The 'one-party' projects concentrated on technology developments such as geochronology dating methods or specialist services that will be applied across the full spectrum of LEME research.

Student Program Linkages

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

Student projects benefit from support and linkages with WA Department of Environment and Conservation, WA Department of Agriculture and Food, WA Department of Water, DWLBC South Australia, ANSTO, as well as commercial companies, Tanami Gold, Newmont Australia, BHP Billiton, Barrick Gold, Anglo American and Zonge Engineering. Further details about these linkages are provided in the Research, Commercialisation, Technology Transfer and Utilisation Section and the Education and Training sections of this Annual Report.

The Education and Training Program with assistance from the Minerals Council of Australia provides regolith science training to industry geoscientists throughout Australia.

Linkages with Industry and other End Users

Of the Centre's 59 core research projects, 32 are classified as industry/commercial projects. These projects draw cash contributions from a range of Australian and State Government NRM agencies, as well as mining companies for mineral-related projects. In addition to the cash contributions, there is a significant external in-kind contribution to all LEME projects.

The LEME Minerals Advisory Council (MAC) and Land Use Advisory Council (LUAC) provide mineral exploration and NRM external stakeholders with opportunities to interact with and advise on LEME research activities. Through these Councils, stakeholder networks are continuously expanded, facilitating research cooperation and technology transfer.

A highlight during 2005-06 was the completion and successful launch of the Northern Territory Regolith Map and associated Atlas of NT Regolith Materials (LEME OFR 196). The project was completed by LEME geologists Mike Craig (Geoscience Australia) and Ian Robertson (CSIRO Exploration and Mining) in collaboration with the Northern Territory Geological Survey (See Program 1 Highlights). Following the launch of the Northern Territory Regolith Map at the Annual Geoscience Exploration Seminar (AGES) in March 2006, a LEME Regolith Workshop was held for Cameco Australia, a Darwin-based uranium Exploration Company, in May 2006.

Linkages with Centre research users are also generated through staff and student participation in conferences and industry workshops which publicise LEME research and facilitate networking. Further details of these activities are provided in the section on Communication Strategy. LEME personnel presented at ten international conferences and 30 public conferences/seminars within Australia during the reporting period. Also, LEME conducted or sponsored 12 seminars and symposia that attracted an audience of more than 800 attendees.

International Linkages

LEME is continuing to develop international linkages where knowledge generated in the Australian regolith environment can be applied to similar landscapes overseas and vice versa. During 2005-06, LEME engaged in two international collaborations with mineral explorer Angelo America. Through ANU researcher, Bear McPhail, LEME has analysed the groundwater compositions of the Calama Region of North Chile, as well as the Hinta and Kayar regions of northwest India.

Evaluation of the CHIM chemical technique continued during 2005-06. This evaluation is subject to on-going international collaboration between LEME, PIRSA and the Guilin Institute of Technology, China. During 2005-06, two members of the Guilin Institute of Technology conducted *Chinese CHIM* trials at Goulds Dam and Kalkaroo prospects with LEME Researcher, Baohong Hou. The collaborative evaluation of this technique will continue during 2006-07.

Photograph: Steve Hill

A new international linkage between the Centre and the University of Chile was established during the year with the commencement of Program 2's AMIRA P778 Project in June 2006. As part of the project, LEME will collaborate with the University of Chile in the collection, analysis and interpretation of geochemical data from selected Chilean study sites.

LEME's pioneering work, especially in salinity research, continued to gain greater international recognition. This fact has been reflected by Program 4 Leader, Ken Lawrie's involvement in organising the 2008 International Salinity Forum.

Collaboration with CRCs and other research providers

Two major projects have generated close collaboration with other research agencies during the year. The Yilgarn Regolith Atlas Project has continued the Centre's work with the Geological Survey of Western Australia (GSWA) sponsored by the Minerals and Energy Research Institute of WA (MERIWA). A highlight of this collaboration was the release of Open File Report 201- *Laterite Geochemical Database of the South West Yilgarn Craton, Western Australia* in February 2006. This report has proven to be very popular amongst mineral explorers.

The success of the Northern Territory Regolith Map and associated LEME Atlas of NT Regolith Materials has resulted in a new collaborative project with the Queensland State Government. In collaboration with the Geological Survey of Queensland, LEME researchers will produce a state-wide Queensland Regolith Map. Starting in July 2006, the project will provide a regolith-landform framework of Queensland for mineral exploration and land management based on the same principles LEME established with the Northern Territory Geological Survey. The Queensland Regolith Map, which is expected to be completed by June 2008, is the second step towards achieving a nation-wide regolith map.

LEME has continued to benefit from it's collaboration with the CRC PBMDS through the contribution of articles to its quarterly technical magazine, *Focus on Salt*. The publication has a circulation of some 5,000 recipients with CRC PBMDS responsible for the overall editing, layout and production. During 2005-06, LEME contributed some 15% of editorial material and production costs.

Two PhD student projects have been undertaken jointly with CRC PBMDS on *Dryland salinity, biodiversity and geodiversity* (Glen Bann ANU) and *Predictability of surface soil properties from geophysical remote sensing and regolith information* (David Mitchell U of A). Both students are expected to submit their theses during 2006-07.

A joint research project involving Bear McPhail (LEME) and Dr Evgeniy Bastrakov from the CRC for Predictive Mineral Discovery (pmd*CRC) is continuing to develop reliable geochemical modelling methods for element transport in regolith and ore-forming environments.

The outcome of the project to date has been the establishment of the FreeGs thermodynamic database project, a web-based thermodynamic database of geologically related substances. The database can be used with geochemical modelling software to calculate geochemical reactions between minerals, water and gases over wide ranges of temperature, pressure and composition.

LEME participates in the Cooperative Research Centre Association (CRCA) Minerals and Energy Sector activities to produce joint promotional material and identify opportunities for strategic alignments in long-term research projects. An example of such an initiative organised by the Sector was series of *Cutting Edge* articles written by science journalist Julian Cribb in Australia's Mining Monthly Magazine. These articles often featured LEME research. Steve Rogers joined other CRC Chief Executive Officers from the Minerals Sector to present at the MCA Minerals Week 2006. He is a member of the CRCA Management Committee and represents LEME on the 2007 CRCA Conference Organising Committee to be held in Perth, Western Australia.

Collaboration, Technology Transfer and Utilisation

The following tables list organisations that collaborated with the Centre to secure research outputs or were end users of LEME research outputs during the reporting period. Most of these organisations contributed in-kind – eg travel costs, equipment.

COMMERCIAL ORGANISATIONS – SMALL AND LARGE

Research User/ Collaborator	Project – Activity	Interaction	Leader, Student / Supervisors	Core Party
Alkane Exploration	Lachlan Project synthesis: Tomingley biogeochemistry	Research contract	Ian Roach	ANU
Anglo American	Nickel Hydrogeochemistry	Research project	David Gray	CSIRO
Anglo American	HydroMinex	Research project	Patrice de Caritat	GA
Anglo American	Groundwater composition in the Calama Region, Northern Chile: Part 2	Research collaboration	Bear McPhail	ANU
Anglo American	Groundwater composition in the Hinta and Kayar regions of northwestern India	Research collaboration	Bear McPhail	ANU
Anglo American	Interpretation of groundwater chemistry on exploration tenements	Research collaboration	Patrice de Caritat and Bear McPhail	GA, ANU
Barrick Gold	Predictive Geochemistry AMIRA P778	Research project	Ravi Anand	CSIRO
Barrick Gold	Exploration through cover in the Tanami	Research project	Lisa Worrall	GA
BHP Billiton	Predictive Geochemistry AMIRA P778	Research project	Ravi Anand	CSIRO
Cameco Australia	Predictive Geochemistry AMIRA P778	Research project	Ravi Anand	CSIRO
Cameco Australia	Cameco Workshop	Workshop regolith processes and modelling	Mike Craig	GA
Cameco Australia	Northern Territory Regolith	Research project	Mike Craig	GA
Comalco Aluminium Ltd	Weipa Bauxite	Research project	Tony Eggleton, Graham Taylor	ANU
Dominion Mining Ltd	CuraMinex (exploring through cover in the Curnamona)	Research project	Dirke Kirste, John Keeling, Baohong Hou	ANU, PIRSA, U of A
Exco Resources NL	Regolith geochem and biogeochem of the White Dam Cu-Au prospect, Curnamona Province, SA	Student research	**Aaron Brown**, Steve Hill	U of A
Exco Resources NL	Researching the origin and distribution of calcrete in Southern Australia	Student research	**Robert Dart**, Karin Barovich, Steve Hill	U of A
Gold Fields Australasia	Analysis of soils at the Lockington Au prospect, Vic	Research contract	Keith Scott	CSIRO, ANU
Goulburn-Murray Water	Chowilla Floodplains – geophysics in salt interception	Research contract	Tim Munday	CSIRO
Iluka Resources	Eucla Margins: Placer deposit study	Research contract	Mark Paine	CUT
Inco Technical Services	Nickel Hydrogeochemistry	Research project	David Gray	CSIRO
Inco Technical Services	Predictive Geochemistry AMIRA P778	Research project	Ravi Anand	CSIRO
Independence Gold	Predictive Geochemistry AMIRA P778	Research project	Ravi Anand	CSIRO
LionOre Australia	Nickel Hydrogeochemistry	Research project	David Gray	CSIRO
Mindax Ltd	Uranium in WA Wheatbelt waters	Research project	Grant Douglas	CSIRO
Minotaur Exploration	Origin of 'true' and 'false' calcrete Au anomalies in the Tunkillia region, SA	Student research	**Robert Dart**, Karin Barovich, Steve Hill	U of A
Newmont Australia	History of aridity	Research project	John Magee	ANU
Newmont Australia	Predictive Geochemistry AMIRA P778	Research project	Ravi Anand	CSIRO
Newmont Australia	Metal Mobility	Research project	Bear McPhail	ANU
Newmont Australia	Exploration through cover in the Tanami	Research project	Lisa Worrall	GA
Newmont Australia	Biogeochemistry of regolith associated with Au deposits in the Tanami, WA and NT	Student research	**Nathan Reid**, Steve Hill	U of A
Newmont Australia	Termitaria and other landscape indicators of sub-surface regolith	Student research	**Anna Petts**, Steve Hill	U of A
Newmont Australia	Hydrogeochemistry in mineral exploration at Cobar, NSW	Research collaboration	Bear McPhail	ANU

COMMERCIAL ORGANISATIONS – SMALL AND LARGE (cont'd)

Research User/ Collaborator	Project – Activity	Interaction	Leader, Student / Supervisors	Core Party
Ord Irrigation Cooperative	Ord Irrigation Salinity	Research contract	Ken Lawrie	GA
Peak Gold Mines – a subsidiary of Wheaton River Minerals	Hydrogeochemistry in mineral exploration at Cobar, NSW	Research collaboration	Bear McPhail	ANU
Perilya Mines Ltd	Metal Mobility	Research project	Bear McPhail	ANU
Quasar Resources PL	Uranium in WA Wheatbelt waters	Research project	Grant Douglas	CSIRO
Regis Resources	Hydrogeochemistry in mineral exploration at Cobar, NSW	Research collaboration	Bear McPhail	ANU
SGS Minerals	Predictive Geochemistry AMIRA P778	Research project	Ravi Anand	CSIRO
Tanami Gold NL	Exploration through cover in the Tanami	Research project	Lisa Worrall	GA
Tanami Gold NL	Biogeochemistry of regolith associated with Au deposits in the Tanami, WA and NT	Student research	**Nathan Reid**, Steve Hill	U of A
Tanami Gold NL	Termitaria and other landscape indicators of sub-surface regolith	Student research	**Anna Petts**, Steve Hill	U of A
Tech Cominco	Predictive Geochemistry AMIRA P778	Research project	Ravi Anand	CSIRO
Triako Resources Ltd	Lachlan Fold Belt	Research contract	Ken McQueen	ANU
Triako Resources Ltd	Analysis of soils at the Hera Au Prospect, NSW	Research contract	Keith Scott	CSIRO, ANU
WMC Resources (now BHP Billiton)	Nickel Hydrogeochemistry	Research project	David Gray	CSIRO
Zonge Engineering and Research Organisation	The use of shallow geophysical techniques to help characterise hydrological parameters	Student research	**Michael Hatch**, Graham Heinson	U of A

GOVERNMENT ORGANISATIONS AND UNIVERSITIES

Research User/ Collaborator	LEME Project – Activity	Interaction	Leader, Student / Supervisors	Core Party
Agriculture Forestry and Fisheries Australia (Federal Dept) (AFFA)	Inland Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
Australian Nuclear Science and Technology Organisation (ANSTO)	Salinity Dynamics (Australia-wide network to measure rainfall chemistry and isotopic composition)	Research collaboration	Richard Cresswell	CSIRO
ANSTO	Aquifer parameters	Research contract	Anton Kepic	CUT
Avon Catchment Council	EEI-Geochem Phase III	Research contract	Paul Shand	LEME
Aust Collaborative Land Evaluation Program	Physiographic regions	Research contract	Colin Pain	GA
Australian Water Environments	The use of shallow geophysical techniques to help characterise hydrological parameters	Student research	**Michael Hatch**, Graham Heinson	U of A
Bureau of Meteorology	Salinity Dynamics (Australia-wide network to measure rainfall chemistry and isotopic composition)	Research collaboration	Richard Cresswell	CSIRO
Bureau of Rural Science	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**, Colin Pain	ANU, GA
Conservation and Land Management WA (CALM)	Resource assessment and coastal management, WA	Research contract	Lindsay Collins	CUT
CALM	Haddelton Reserve WA regolith investigations	Research contract	Paul Wilkes	CUT
Catchment Management Authority, NSW	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	Glen Bann, Colin Pain	ANU, GA
Central West Catchment Management Authority	Central west NSW GFS	Research project	John Wilford, Jeremy James	GA
Corangamite Catchment Management Authority	Dynamics of salinity (Hydrogeological and hydrogeochemical models of groundwater)	Research project	Richard Cresswell	CSIRO
CSIRO Sustainable Ecosystems	Wallatin Creek WA geophysical surveys	Research contract	Paul Wilkes	CUT

GOVERNMENT ORGANISATIONS AND UNIVERSITIES (cont'd)

Research User/ Collaborator	LEME Project – Activity	Interaction	Leader, Student / Supervisors	Core Party
CSIRO Land and Water	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**, Colin Pain	ANU, GA
CSIRO Water for a Healthy Country (CWHC)	Acid Drainage WA	Research project	Steve Rogers – Grant Douglas	CSIRO
CWHC	Southern River WA geophysical surveys	Research contract	Paul Wilkes	CUT
CWHC	Wallatin Creek WA geophysical surveys	Research contract	Paul Wilkes	CUT
CWHC	WA Rural Towns – salinity control	Research contract	Paul Wilkes	CUT
CSIRO West Linfield, Sydney	3-D automated inversion of potential field tensor data	Student research	**Phillip Hatch**, Stewart Greenhalgh	U of A
Dept Agriculture and Food WA (DAFWA)	EEI-Geochem Phase II	Research contract	Steve Rogers	LEME
DAFWA	Acid Drainage WA	Research project	Paul Shand, Grant Douglas	CSIRO
DAFWA	WA Rural Towns – salinity control	Research contract	Paul Wilkes	CUT
DAFWA	Yarra Yarra Soil Mapping	Research project	Paul Wilkes	CUT
DAFWA	Wallatin Creek WA geophysical surveys	Research contract	Paul Wilkes	CUT
DAFWA	Inland Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
Dept Environment and Heritage WA (DEHWA)	EEI-Geochem Phase II	Research contract	Paul Shand	LEME
DEHWA	Acid Drainage WA	Research project	Paul Shand	LEME
DEHWA	Inland Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
DEHWA	Inland Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
Dept Primary Industries, Vic	MDBC Bet Bet Sub Project	Research project	John Wilford, Jeremy James	GA
Dept Primary Industries, Vic	Inland Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
Dept Water Land and Biodiversity Conservation (DWLBC SA)	Drawdown Geochemistry and Geomicrobiology of ASS	Research project	Simon Lamontagne	CSIRO
DWLBC SA	Inland Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
DWLBC SA	Morella Basin	Research contract	Steve Rogers	CSIRO
DWLBC SA	Tilley Swamp	Research contract	Rob Fitzpatrick	CSIRO
DWLBC SA	Chowilla Floodplains – geophysics in salt interception	Research contract	Tim Munday	CSIRO
DWLBC SA	River Nano TEM	Research project	Graham Heinson	U of A
Engineering Evaluation Initiative WA (EEI)	Acid Drainage WA	Research project	Paul Shand	LEME
EEI	EEI-Geochem Phase II	Research contract	Paul Shand	LEME
Environment ACT	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**, Colin Pain	ANU, GA
Environment and Heritage (Federal Dept)	Inland Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
Eurobodalla Shire Council	Sediment and nutrient modelling in Moruya and Tuross River catchments, NSW	Student research	**Baihua Fu**, John Drewry	ANU
Geological Survey of Norway	Element sources and cycles at the Earth's surface	Research collaboration	Patrice de Caritat	GA
Geological Survey WA	Yilgarn Laterite Atlas	Research collaboration	Matthias Cornelius	CSIRO
Guilin University of Technology, China	CurnaMinex (exploring through cover in the Curnamona)	Research project	Dirke Kirste, John Keeling, Baohong Hou	ANU, PIRSA, U of A
Land and Water Australia	David Allen's Review	Review contract	Paul Wilkes	CUT
Murray Darling Basin Commission (MDBC)	MDBC Project	Research contract	Ken Lawrie	GA
MDBC	Salinity Dynamics (Australia-wide network to measure rainfall chemistry and isotopic composition)	Research contract	Richard Cresswell	CSIRO
National Heritage Trust and National Land and Water Resources Audit 2	Geochemical risk assessment and evaluation	Research collaboration	Rob Fitzpatrick	CSIRO

GOVERNMENT ORGANISATIONS AND UNIVERSITIES (cont'd)

Research User/ Collaborator	LEME Project – Activity	Interaction	Leader, Student / Supervisors	Core Party
National Heritage Trust and National Land and Water Resources Audit 2	Atlas of Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
National Action Plan for Salinity and Water Quality (NAPSWQ)	Inland ASS	Research project	Rob Fitzpatrick	CSIRO
NAPSWQ	Wallatin Creek WA geophysical surveys	Research contract	Paul Wilkes	CUT
Northern Agricultural Catchment Council	NACC Project – Resource assessment and coastal management, WA	Research project	Lindsay Collins	CUT
NSW Dept of Infrastructure, Planning and Natural Resources (NSW DIPNR)	Inland Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
NSW DIPNR	Next generation central west groundwater flow systems	Research project Jeremy James	John Wilford	GA
NT Geological Survey	Northern Territory Regolith	Research contract	Mike Craig	GA
Queens University, Canada	Groundwater composition in the Calama Region, Northern Chile: Part 2	Research collaboration	Bear McPhail	ANU
Queens University, Canada	Groundwater composition in the Hinta and Kayar regions of northwestern India	Research collaboration	Bear McPhail	ANU
Qld Dept Natural Resources and Mines (QNRM)	Salinity Dynamics (Goondoola Basin Qld)	Research collaboration	Richard Cresswell	CSIRO
QNRM	Salinity Dynamics (Hodgson Creek Catchment, Qld)	Research collaboration	Richard Cresswell	CSIRO
QNRM	Salinity Dynamics (Geochemistry of seawater intrusion, Pioneer Valley, Qld)	Research collaboration	Richard Cresswell	CSIRO
QNRM	Inland Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
SA Dept Environment and Heritage	Inland Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
SA Centre for Natural Resource Management	SA Murray Floodplains – geophysical surveys	Research contract	Tim Munday	CSIRO
SA Water Corporation	Eyre Peninsular – airborne geophysical survey	Research contract	Tim Munday	CSIRO
SA Water Corporation	Inland Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
Southern Cross University	Inland Acid Sulfate Soils	Research collaboration	Rob Fitzpatrick	CSIRO
South Burdekin Water Board	Lower Burdekin salt and groundwater mapping	Research project	Ken Lawrie	GA
University of Western Australia	WA Rural Towns – salinity control	Research contract	Paul Wilkes	CUT
Wallatin Wildlife and Landcare Inc	Wallatin Creek WA geophysical surveys	Research contract	Paul Wilkes	CUT
WA Chemistry Centre	WA Rural Towns – salinity control	Research contract	Paul Wilkes	CUT
WA Water Corporation	WA Rural Towns – salinity control	Research contract	Paul Wilkes	CUT
University of Oxford and Sheffield University, UK	Complexities in the preservation and interpretation of late Quaternary dune records	Student – Research collaboration on conference paper	Kathryn Fitzsimmons	ANU
Yarra Yarra Catchment Management Group	EEI-Geochem Phase II	Research project	Steve Rogers	LEME
Yarra Yarra Catchment Management Group	Yarra Yarra Soil Mapping	Research project	Paul Wilkes	CUT

Bold: Students

COOPERATIVE RESEARCH CENTRES

Research User/ Collaborator	LEME Project – Activity	Interaction	Leader, Student / Supervisors	Core Party
CRC Plant Based Management of Dryland Salinity (PBMDS)	MDBC Bet Bet Sub Catchment Project	Research project	John Wilford, Jeremy James	GA
PBMDS	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**, Colin Pain	ANU, GA
PBMDS	Predictability of surface soil properties from geophysical remote sensing and regolith information	Student research	**David Booth**	U of A

INDUSTRY ASSOCIATIONS

Research User/ Collaborator	LEME Project – Activity	Interaction	Leader, Student / Supervisors	Core Party
American Society of Soil Science	Inland ASS	Research project	Rob Fitzpatrick	CSIRO
Association of Applied Geochemists	Shortcourse – Mineral Exploration using Groundwater Geochemistry – Perth, 17 Sept	Research teaching David Gray, Bear McPhail	Patrice de Caritat,	GA, CSIRO, ANU
Aus Mineral Industries Research Association (International)(AMIRA)	Predictive Geochemistry AMIRA P778	Research project	Ravi Anand	CSIRO
Greening Australia	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**, Colin Pain	ANU, GA
Environmental Research and Information Consortium	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**, Colin Pain	ANU, GA
Minerals and Energy Research Institute WA	Yilgarn Laterite Atlas	Research financial support	Matthias Cornelius	CSIRO
Southern Tablelands Farm Forestry Network	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	Student research	**Glen Bann**, Colin Pain	ANU, GA

Bold: Students

GRANTS AND SPONSORSHIPS

Personnel	Core Party	Activity	Research Grant	Period of Grant	Amount	Relationship to CRC Research
Ravi Anand	LEME	WA State Government Grant	Equipment funding	2005-06 2002-07	$10,000	Objective Logging Project
Matthias Cornelius	CSIRO	Laterite Geochemical map of Western Yilgarn Craton	MERIWA	Oct 2004 – 3 years	$100,047	Collaborative Project
Kathyrn Fitzsimmons	ANU – PhD	IGCP500 – grant to attend Southern Hemisphere Deserts Conf, Chile 2005	International Geoscience Program	Jan 2006 to Jan 07	US$500	Conference attendance to present LEME work
Baohong Hou	PIRSA	Application of integrated geoscientific technologies in exploring for concealed ore deposits	Australia-China Special Fund for Scientific and Technological Cooperation	Jun 2006 to Jul 09	$44,500	Exchange of technology with China
Robert Hough	CSIRO	Scholarship for international mineralogical conference attendance and study	Perth Convention Bureau	Jan 2006	$10,000	Mineralogy research
Anna Petts	U of A – PhD	Eric Rudd Travel Scholarship for Economic Geology	U of A	Dec 2005	$5,000	Travel overseas to extend and enhance LEME research
Vanessa Wong	ANU – PhD	ASSSI Travel Scholarship	Australian Soil Science Society	Jun 2006	$1,500	Conference attendance at World Congress in Soil Science to present LEME research

VISITORS TO THE CENTRE

Visitor	Visitor Organisation	LEME Host	Research Collaboration	Date
Dr Cliff Stanley	Acadia University, Nova Scotia, Canada	David Gray, CSIRO, Perth	Laterite Atlas, groundwater geochemistry	July 2005 to June 2006
Mr George Duval	Ecole et Observatoire des Sciences de la Terra, Institut de Physique du Globe, Strasbourg, France	Graham Heinson, U of A	Intern student – regolith geophysics project	June to Sept 2005
Dr Jill Banfield and Ms Claudia Jones	University of California Berkeley, US	Sue Welch, ANU	Geomicrobiology of Acid Sulfate Soils	Aug 2005
Dr Chris Oates and Dr Peter Winterburn	Anglo American, UK	Bear McPhail, ANU	Collaborative research – hydrogeochemistry and groundwater composition	Sept 2005
Professor Kurt Kyser	Queens University, Canada	Bear McPhail, ANU	Collaborative research – hydrogeochemistry and groundwater composition	Sept 2005
Prof Xianrong Luo	Guilin University of Technology, China	Baohong Hou, PIRSA, Adelaide	CurMinex Project and CHIM trials	Sept to Oct 2005
Prof Nanshi Zeng	Guilin University of Technology, China	Baohong Hou, PIRSA, Adelaide	CurMinex Project and CHIM trials	Sept to Oct 2005
Prof Tom Ammons	University of Tennessee, US	Ryan Noble and Ron Watkins, CUT	Dispersal mechanisms of arsenic and antimony in regolith and surface deposits (NW Vic), implications for gold prospectivity and environmental management	May to July 2005

VISITS FROM THE CENTRE – LEME STAFF ON SABBATICAL

LEME Visitor	To	Host	Research Collaboration	Date
Dr Richard Greene, ANU	University of Winsconsin-Madison – Geography Dept, US	Prof Joe Mazon	Aeolian dust project – presentation given by Dr Greene	30 March 1 June 2005
Dr Sue Welch, ANU	CSIRO Land and Water, Adelaide	Dr Steve Wakelin	Molecular biology study of Loveday Basin	20 May to 1 June 2006

Photograph: Steve Hill

Education and Training

Program Leader: Dr Steve Hill
(The University of Adelaide)

The Centre has one of the highest graduate outputs and employment uptake by industry of any CRC.

Highlights

- Total number of postgraduate students on target to exceed performance indicators with Honours student numbers expected to double the performance target.
- Postgraduate and Honours student intake remains strong and is expected to continue beyond the LEME Scholarship Program term at some Core Participant universities.
- Graduates readily gain employment in the minerals or NRM industries.
- Students continue to contribute to major scientific research breakthroughs particularly in the area of phyto-exploration.
- LEME students have received external awards and prizes for their outstanding contributions to the scientific community, as well as external research grants.
- Undergraduate regolith geology courses now form a major part of Core Participant university curricula.
- Undergraduate regolith course student numbers peak at to more than 100 students a year – the highest number in LEME history.
- Regolith shortcourses continue to make an important contribution to the Minerals Tertiary Education Council (MTEC) Program.
- Regolith Symposia held in Adelaide and Canberra in November 2005 with a proceedings volume *Regolith 2005: Ten Years of CRC LEME* published in hard copy and available in digital form from the LEME website.
- Master of Regolith Geoscience coursework degree begins in 2007 at ANU.
- U of A to appoint a tenure-track regolith geoscientist to assist in undergraduate regolith teaching programs.

LEME's Education and Training (E&T) Program aims to provide world-class education and training in regolith geoscience and is recognised as a world class provider of quality geoscience graduates and researchers to the scientific community, and the mineral exploration and environmental management industries. The Centre has one of the highest graduate outputs and employment uptake by industry of any CRC.

More specifically, the Centre's E & T Program:

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

These specific objectives are consistent with the milestones stated in the Commonwealth Agreement.

The E&T Program is managed by Dr Steve Hill. He is supported by the E&T Committee comprising Dr Ian Roach (Deputy Leader and Minerals Council of Australia Lecturer) and representatives from Core Party Universities, Dr Karin Barovich (U of A), Dr Bear McPhail (ANU) and Dr Mehrooz Aspandiar (CUT).

HONOURS AND POSTGRADUATE SCHOLARSHIP PROGRAM

Post-graduate Students

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

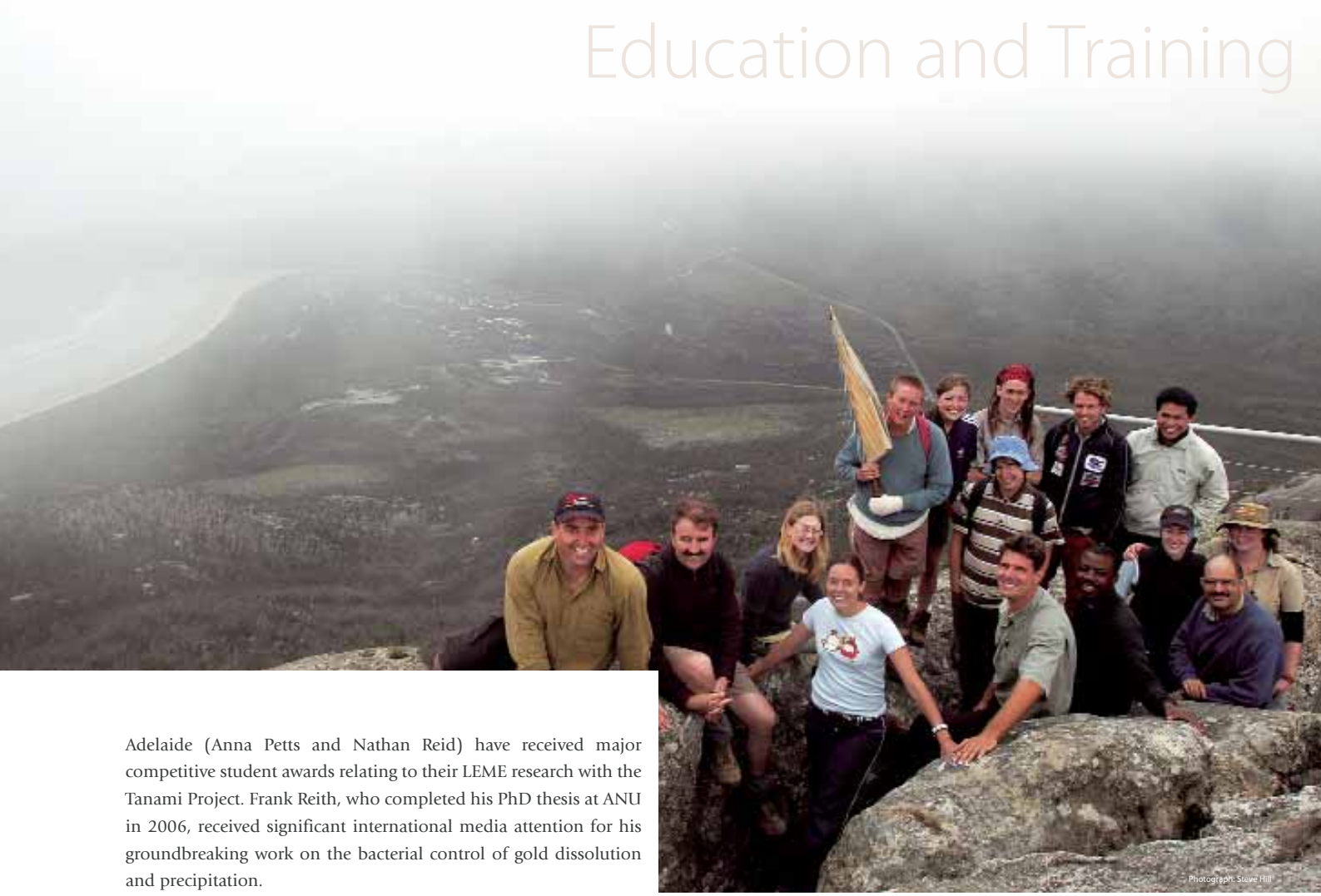
- Full PhD stipend and operating scholarship ($18.5K stipend plus up to $10K operating expenses per year).
- PhD top-up stipend and operating scholarship (typically a $5K top-up plus up to $10K operating per year).
- PhD operating only (up to $10K operating per year).
- PhD supervision and operating derived from research project funds.

As LEME scholarship funds have been completely allocated, the postgraduate scholarship program is now drawing to a close. As a result, LEME has become increasingly reliant upon attracting high-quality students that have gained scholarships from other sources (such as Commonwealth Government and university-derived scholarships). This year, LEME has five PhD students at U of A (Nathan Reid, Mike Hatch, Jessie Davey, David Haberlah and Michael Neimanis) who contribute to the Centre's research through such an arrangement. The contributions and intake of these students indicate that LEME's postgraduate research program has the viable potential to continue beyond its initial scholarship investments and become a major and ongoing legacy for the Centre.

Overall, LEME is on track to exceed its KPI target of 60 PhD and MSc students. To the end of the 2005-06 year, the Centre had 13 graduates and presently has 62 students progressing towards their degrees. These figures make LEME's postgraduate student group one of the largest for any CRC in Australia.

A number of PhD students submitted their theses this year, and the Centre is poised to have its largest number of postgraduate completions and graduations in 2006-07.

Postgraduates make invaluable contributions to Centre research projects with many students gaining co-supervision and external operating support from their studies. This collaboration and support greatly enhances the experience and student research quality which in turn is expressed by the high quality of student theses. Two of our continuing PhD students at the University of



Photograph: Steve Hill

Adelaide (Anna Petts and Nathan Reid) have received major competitive student awards relating to their LEME research with the Tanami Project. Frank Reith, who completed his PhD thesis at ANU in 2006, received significant international media attention for his groundbreaking work on the bacterial control of gold dissolution and precipitation.

Honours Students

The Centre offers Honours scholarships, plus operating funds, for many of its Honours students ($5K plus up to $5K operating per year). Although there is an increasing number of students contributing to LEME with Centre staff supervision without LEME scholarships funding, financial assistance has been provided through the operating budgets from within the research project budgets.

LEME is on target to double its KPI of 60 graduating Honours students. To the end of the 2005-06 year, the Centre has graduated 89 Honours students and presently has 16 students. This year, LEME has eleven students graduating from the Honours program; all have already found employment in the minerals industry or government with three students deciding to continue with PhD research projects within LEME.

SHORTCOURSES, WORKSHOPS AND SEMINARS

LEME contributes to an extensive program of activities:

- National Honours programs;
- National Masters programs;
- Generic Courses; and,
- Industry workshops.

A major contributor to the continued development and delivery of shortcourses within LEME has been the Mineral Council of Australia (MCA) through the Minerals Tertiary Education Council (MTEC). The MCA provides a significant salary component for Dr Ian Roach, a lecturer in regolith geoscience based at the ANU, as well as operating expenses for course delivery.

Honours Shortcourses

LEME conducted five national Honours level shortcourses during the year:

- Regolith Geology and Geochemistry (20-24 February, Wilsons Promontory, Vic).
- Introduction to Hydrogeochemistry (27-31 March, University of Melbourne).
- Regolith Mapping and Field Techniques (10-14 April, Fowlers Gap, NSW).
- Advance Remote Sensing (5-9 June, U of A Waite Campus).
- Environmental Mineralogy (19-23 June, ANU, Canberra).

These form part of the MCA's MTEC Program of Honours-level courses. More than 70 Honours-level and post-graduate students from universities and industry professionals across Australia enrolled in E&T Program courses during 2005-06.

Masters Shortcourses

LEME offers a Masters-level Regolith Geology and Mineral Exploration shortcourse within MTEC's national Minerals Geoscience Masters Program. This year, a two week field-based course was run at Fowlers Gap concurrently with the *Regolith Mapping and Field Techniques Course.*

Generic Courses

Generic courses in field safety, first-aid and four-wheel drive training are arranged on an annual basis for LEME students. Most of these are organised through Core Participant universities. The

Education and Training

Regolith Mapping and Field Techniques Shortcourse includes a major component of field safety and communications training. Workshops on thesis writing, publishing research manuscripts and scientific oral presentations were also held.

Industry Workshops

During the year, 'one on one' courses and workshops for individual companies and government groups were run through the research projects in Programs 1 to 4. The courses were aligned with individual research projects, such as:

- Tanami regolith geology for mineral explorers' workshops (Newmont Australia and Tanami Gold) organised through Program 1.
- Hydrogeochemistry for mineral exploration workshop (IGES conference) organised through Program 2.
- Hydrogeochemistry for mineral exploration (Anglo American), organised through Program 2.
- Acid Sulfate Soil characteristics and management workshop organised through Program 3.
- Salinity mapping and management workshops organised through Program 4.

Regolith Symposia

Regolith Symposia were held in Adelaide and Canberra in November 2005. More than 75 presentations by LEME students and staff were included in these meetings with a 345-page refereed proceedings volume published in both hard copy and as .pdf available for download from the LEME website.

Student awards presented at the 2005 Regolith Symposia are shown in the table below:

	Adelaide	Canberra
Taylor and Eggleton Book award for best overall oral and written presentations	Nathan Reid	Alistair Usher
Editor's award for best written presentation	Jointly awarded to Jessie Davey and Sarah Gibbons	Jointly awarded to David Little and Luke Wallace
Encouragement awards for excellence	Anna Petts Lachlan Reid Anna Mayo Robert Dart	Jennifer de Livera

UNDERGRADUATE STUDENTS

Undergraduate Students and Summer Scholarships

Undergraduate regolith geology courses are coordinated and taught by LEME staff at U of A, ANU and CUT. They provide an important springboard for future geoscientists and provide an insight into regolith issues. More than 100 undergraduates were introduced to the fundamentals and applications of regolith geology while attending these courses during 2005-06.

These regolith courses were:

- U of A teaches three main regolith courses within its undergraduate program at both second and third year levels *Surficial Geology II*, *Surficial Geology III*, and *Surficial Geology III Field Program*, as well as other undergraduate courses with some regolith geology components. Student enrolment numbers in these courses are approximately 50 students at the second year level and 40 at the third year level, making this the largest undergraduate regolith geology course within Australia.
- ANU teaches one fundamental regolith course at third year level, *Regolith and Hydrology*, with enrolments typically around 15 students.
- CUT teaches one main regolith and exploration course and three undergraduate courses with a significant regolith component. A third year regolith and exploration geochemistry course (*Regolith Exploration 314*) is exclusively a regolith geology course applied to mineral exploration and had 22 third year students during the year. Other courses with regolith component are second year *Remote Sensing 208* (50 students) incorporating landform and regolith identification *Field Mapping 391* (25 students) with an introduction to regolith mapping, and an Honours short course *Remote Sensing 503*.

The LEME National Undergraduate Regolith Geology School (NURGS) is the annual undergraduate regolith geology field camp at the Fowlers Gap Research Station in western New South Wales. This field camp incorporates some of the Centre's research from the Curnamona Province and Thomson Orogen, and provides students with regolith geology field experience. LEME staff involved include Steve Hill (U of A), Ian Roach (MCA/ANU), John Field (ANU) and Graham Heinson (U of A). In 2005-06, more than 50 students from U of A and ANU attended the field camp, many of whom have now entered the LEME Honours Program.

LEME's Regolith Teaching Materials Project makes a major contribution to the delivery and development of teaching materials associated with undergraduate courses, in particular the regolith geology undergraduate field camp at Fowlers Gap.

Photograph: Ian Roach

Outlook for 2006-07

New, Ongoing and Graduating students

LEME is poised to have its largest number of completing and postgraduate students in the coming financial year. It is anticipated that the Centre is able to maintain a consistent intake of Honours students, ranging between 10-15 students per year.

Continuation of the MCA's MTEC shortcourse program

The Centre anticipates the highly successful MTEC regolith shortcourse program for Honours and Masters students and industry professionals can be continued. The MTEC Program is planning a renewal rebid at the end of 2006, from which LEME's Core Participant universities may be positioned to continue the course's legacy beyond the term of the Centre (ie post mid-2008). An industry panel has been convened by MCA to consider the Program's renewal.

Regolith Symposium 2006

The 2006 Symposium will bring all Centre staff and students together at the Hahndorf Resort located in the Adelaide Hills of South Australia in early November.

Undergraduate and post-graduate teaching

LEME's undergraduate teaching program is set to continue into the 2006-07 year and beyond. A new Centre project entitled *Regolith Teaching and Training Materials* will extend the outputs of the superseded *Virtual Regolith Worlds Project* and ensure the continued development of written and digital regolith teaching materials for undergraduate, postgraduate and industry courses.

U of A's decision to advertise a tenure-track regolith geologist position will assist the future development of undergraduate teaching programs beyond the term of the Centre. This will be the first tenure-track position advertised by an Australian university entirely within the regolith field of geology, and is a strong endorsement of the significant contributions made by the teaching and research program at U of A. Regolith will also continue to feature strongly in ANU Undergraduate Program in 2007, and will be taught in the new second year *Surficial Processes Course* and third year *Environmental and Regolith Geoscience* and *Groundwater Courses*. A new Master of Regolith Geoscience coursework degree has been developed at ANU and enrolment is scheduled to begin in 2007. This new degree will contribute to the provision of postgraduate and professional shortcourses, including key regolith components of the MTEC Shortcourse Program and to continue LEME's strong minerals and natural resources legacy beyond mid-2008.

LEME PhD Graduates Destination 2001-06

The Centre has been advised of the following.

LEME PhD Graduates	Destination
Leanne Hill	DEH Graduate Program, then Parliament House Researcher, Canberra.
Annamalai Mahizhnan	Contractor, BHP Billiton.
Ian Lau	CSIRO Researcher, Perth.
Wendy McLean	NSW Government Hydrogeologist.
Andrew McPherson	Geoscience Australia Geologist.
Mark Paine	Curtin University of Technology Lecturer, then Rio Tinto Geologist.
Greg Shirtliff	ERA Geologist, Darwin.
Micheal Whitbread	ioGlobal Contractor.
Juan-Pablo Bernal	University Researcher, Caltech, USA.
Shawn Laffan	Remote Sensing Analyst.
Melissa Spry	Tourist Guide, Northern Australia.
Brett Harris	Geophysist.
Frank Reith	Post-doc Researcher, CSIRO then the University of Adelaide Research Fellow.
Ryan Noble	CSIRO Researcher, Perth.
Martin Smith	Thesis submitted.
Victor Waclawik	Thesis submitted.
Phillip Heath	Thesis submitted.

LEME PhD graduate profiles

Karen Hulme (The University of Adelaide)

Karen Hulme's PhD research on river red gum biogeochemistry has led to the discovery of hidden Broken Hill type mineralisation near the Pinnacles Mine in western New South Wales. An earlier LEME pilot study by Dr Steve Hill (U of A) found anomalous values of lead, zinc and silver in river red gum leaves around the Pinnacles Mine. Follow up research by Karen has not only duplicated the earlier elevated metal assays, but revealed a more detailed spatial pattern for the biogeochemical metal anomaly.

This prompted the excavation of alluvial sediments near one of the trees which lead to the discovery of a previously unknown extension of the Pinnacles mineralisation. The discovery has confirmed that river red gums are able to extract metal signatures from mineralisation underneath transported regolith and their leaves can provide a readily sampled expression of buried mineralisation.

Until Karen's development of this new and innovative exploration application, more than 100 years of mineral exploration had failed to find a mineralised extension of this well established base-metal deposit.

Frank Reith (Australian National University)

Research by LEME PhD student, Frank Reith, has led to the discovery of bacteria *Ralstonia metallidurans* that precipitates gold out of solution in the regolith. His research was published in the prestigious journal *Science* in August 2006. Following the article's release, Frank's paper gained significant global media attention including feature articles in the *New York Times, The Standard* (Chinese Business Newspaper), *The Mumbai Mirror* and *Nature*.

Frank's research has involved travel and collaboration across many of the LEME Core Participants, including ANU, CSIRO and U of A.

Mark Paine (Curtin University of Technology)

After completing his PhD with LEME in 2005, Mark spent time as a regolith lecturer and researcher for CUT before gaining employment with Rio Tinto to help assess their vast deposits of iron ore in the Pilbara region of Western Australia.

Mark's PhD research on the regolith and landscape evolution of the Dundas Tableland in western Victoria has provided an ideal platform for him to be employed in such a high-profile position.

LEME PhD student profiles

Anna Petts (The University of Adelaide)

Anna has had a busy year of research and receiving awards that acknowledge the quality of her research on the role that termites and their mounds (termitaria) play in regolith evolution, and in applications to mineral exploration.

In late 2005, Anna was awarded the Eric Rudd Travel Scholarship in Economic Geology at the University of Adelaide. This highly competitive $5,000 travel prize will enable Anna to travel to Africa in late 2006 to visit mineral exploration tenements where termites have had a major impact on regolith evolution. In early July 2006, Anna was also awarded *Best Student Poster* at the Australian Earth Science Convention, Melbourne. Her poster entitled: *Nature's drillers and geochemical samplers: termites and their implications for regolith geochemistry in northern Australia*, highlighted how important these animals may be in providing physical and chemical links between surface soils and underlying regolith.

Aaron Brown (The University of Adelaide)

Aaron is now close to concluding his research on the expression of the White Dam copper-gold ore deposit through transported cover. His research has implications that could improve mineral exploration successes over the highly prospective Curnamona Province in South Australia and New South Wales.

Aaron's research has found that as little as one metre of the mixed aeolian, sheetflow and alluvial cover is enough to conceal buried mineralisation from conventional soil sampling techniques. His research has shown that surface exploration through this transported cover can be more effective by using a combination of detailed regolith-landform maps that show the surficial geochemical dispersion vectors, as well as by sampling twigs from bladder saltbush shrubs. The saltbush samples were able to detect elevated copper and gold contents from mineralisation through five to ten metres of transported cover, that surface soil samples were less effective in expressing. Considering how widespread saltbush is across semi-arid Australia, this research will have major implications for increasing the number of effective exploration options available to minerals explorers.

LEME Honours graduate profiles

Michael Neimanis (Australian National University/The University of Adelaide) and Jessie Davey (The University of Adelaide)

After Michael Neimanis and Jessie Davey completed their LEME Honours research projects with first-class results, both have embarked on their LEME PhD research projects at the University of Adelaide. For his Honours, Michael studied mine site rehabilitation at the Mt Boppy Mine near Cobar, New South Wales. For his PhD, Michael is now researching uranium phyto-exploration techniques, where he has already sampled a wide range of plant species overlying buried uranium mineralisation in the Curnamona Province of South Australia.

For her Honours, Jessie researched the regolith and landscape evolution of the Mt Browne and Mt Poole inliers as part of the Program 1 Thompson Orogen Project. Now, as part of her PhD, she has extended her investigation across the Thompson Orogen, Curnamona Province and Gawler Craton to look at Mesozoic regolith and landscape reconstruction of the Southern Eromanga Basin. Already, she has found the regolith interface at the base of the Eromanga Basin is a very important target for regional mineral exploration programs.

Paul Wittwer (The University of Adelaide) and Kate Pfeiffer (The University of Adelaide)

Both Kate Pfeiffer and Paul Wittwer graduated with first-class Honours after completing their LEME Honours projects at the University of Adelaide in 2004. For her Honours project, Kate researched *Predictive geophysics in regolith-covered, gold-hosting terrains with specific reference to the Callie-DBS-Granites area, Tanami Gold Province*, while Paul looked into *Calcrete-gold anomalies in the Curnamona Province of South Australia*.

Their skills and knowledge, as well as the high quality of their research, were highly sort after by the minerals exploration industry.

Kate now works as a geophysicist with Newmont Australia and Paul is employed as a geologist with Dominion Gold at the Challenger Gold Mine in South Australia.

Photograph: Steve Hill

HONOURS STUDENTS 2005-06

Honours Degree – completed 2005-06

Student	Project	Program	Supervisor(s)	Funding	Year	University
Fern Beavis	Mobilisation of anthropic Pb in the regolith	3	David Ellis, Sue Welch	LEME	2005	ANU
Jessie Davey	Regolith and landscape evolution of the Mt Browne and Mt Poole inliers, Thompson Fold Belt, NSW	1	Steve Hill	Nil LEME	2005	U of A
Jennifer de Livera	Copper and zinc mobility in the regolith	2	Bear McPhail, Dirk Kirste	LEME	2005	ANU
Sarah Gibbons	Gold nuggets and calcretes in the Tibooburra-Milparinka goldfields, NW, NSW	1	Steve Hill	Nil LEME	2005	U of A
Cameron Jones	Modelling and visualization of geology, regolith and geophysics to assist nickel exploration in the Kambalda area, WA	2	Paul Wilkes	LEME + Independence Group	2005	CUT
Anna Mayo	Plant biogeochemistry in the Central Gawler Gold Province, SA	1	Steve Hill	Nil LEME	2005	U of A
Michael Neimanis	Mine site rehabilitation at Mt Boppy Mine, NSW.	3	Ken McQueen, Richard Greene	LEME	2005	ANU
Jacob Paggi	Regolith investigations using geophysical methods for mineral exploration in the Cue Region, Western Australia	2	Paul Wilkes	LEME + Independence Group	2005	CUT

Honours Degree – commenced or continuing 2005-06

Student	Project	Program	Supervisor(s)	Funding	Year	University
Lisa Bambic	Eutrophication in closed environments	3	David Ellis, Sara Beavis	Nil LEME	2006	ANU
Cynthja Bolton	Dating of the Willandra history of Aridity in western NSW	1	Ed Rhodes, Rainer Gruun	LEME	2006	ANU
Kieran Coupe	Acid generation and chemical release from the south Undup dredge spoils storage facility : scale and environmental sig	3	Ron Watkins	LEME	2005	CUT
Owen Davis	Detection of uranium bearing stratigraphy beneath cover	1	Jayson Meyers	LEME	2006	CUT
Russell Eade	Geophysical signatures of gold bearing epithermal high sulphidation systems	1	Paul Wilkes	LEME	2006	CUT
Nathan Emselle	Mineralogy, geochemistry and zinc dispersion in the regolith overlying the Reliance non-sulfide ore body, SA	1	Bear McPhail, Sue Welch	LEME	2005-2006	ANU
Andrew Higgins	Physicochemical properties of regolith in the Loveday Basin SA	3	Sue Welch, Sara Beavis	LEME	2006	ANU
Simon Hui	Sources and sinks of uranium in the regolith	2	Bear McPhail, Patrice de Caritat (GA)	LEME	2006	ANU
Rochelle Irwin	Mineralogy of acid drain sediments in the WA Wheatbelt	3	Bob Gilkes (UWA), Steve Rogers (LEME)	Nil LEME	2005	UWA
Kevin Kinnison	Partition of acid in acid sulfate soils		Dirk Kirste, Sue Welch, Sara Beavis	Nil LEME	2005	ANU
Erik Kristainsen	Geophysical investigations to assist hydrogeological studies and salinity mitigation	4	Paul Wilkes	LEME	2006	CUT
David McAveney	New Bendigo – South Warratta landscape evolution	1	Steve Hill, Alan Collins	Nil LEME	2006	U of A
Stefania Madonna	Regolith geochemistry and calcretes across the Archean/Proterozoic terrain boundary near Wudinna, Gawler Craton, SA	2	Andreas Schmidt-Mumm, Steve Hill	Nil LEME	2005	U of A
Jason Raappana	Biogeochemical indicators of mineralisation	2	John Field, Richard Greene	LEME	2006	ANU
Jacob Smith	Hardrock seismic to image near-vertical structures	1	Anton Kepic	LEME	2006	CUT
Layla Tucker	New Bendigo plant biogeochemistry	1	Steve Hill	Nil LEME	2006	U of A

POSTGRADUATE STUDENTS 2005-06

Student	Project	Program	Supervisor(s)	Funding	Year	University
Master of Science (MSc) Graduated						
Ralph Kreige	Determination of interfaces within the regolith structure of the Whirling Dervish site (Yilgarn) using near surface geophysical and petrographic methods	2	Anton Kepic	LEME Op.	2005	CUT
Master of Science (MSc) Commenced or Continuing						
Katie Dowell	Silicification in the regolith using opal as an indictor	1	John Mavrogenes John Chappell Bear McPhail	APA + LEME Top-up	2003-	ANU
Doctor of Philosophy (PhD) – Graduated						
Leanne Hill	Chemical dispersion pathways in a variety of landscapes	1	Tony Eggleton	APA + LEME Top-up	1999-2003	ANU
Ian Lau	Minerals, lithologies and structural mapping using integrated technologies incorporating hyperspectral, airborne magnetics, and radiometrics of regolith covered terrains (Olary Domain, South Australia)	1	Patrick James	LEME/U of A	2002-2005	U of A
Annamalai Mahizhnan	Red-brown hardpans on the Yilgarn	1	Ravi Anand	APA Robe River Mines	1997-2004	CUT
Wendy McLean	Groundwater quality, recharge and sustainability in the lower Namoi Valley	3	Jerzy Jankowski, Patrice de Caritat	APA/ Cotton Growers/ DLWC/LEME Top-up	1999-2003	UNSW
Andrew McPherson	Salts sources and development of the Regolith Salt Store in the Upper Billabong Creek Catchment, SE NSW	3	Tony Eggleton	LEME	2000-2004	ANU
Mark Paine	Regolith and landscape evolution of the Dundas Tableland, Western Victoria, with implications for salinity management and heavy mineral exploration	1	Mehrooz Aspandiar	CUP + LEME Top-up	2001-2005	CUT
Greg Shirtliff	Weathering of wasterock at Ranger Uranium Mine, NT, Australia	1	Tony Eggleton	EWL Sciences Pty Ltd	1999-2004	ANU
Martin Smith	Geochronology of long-term landscape evolution, North Western NSW (Graduated 2005-06)	1	Brad Pillans	ANU + LEME Top-up	2005-2006	ANU
Michael Whitbread	Using lithogeochemistry to map cryptic alteration: Elura and Century case studies	2	Ken McQueen and Leah Moore	PASMINCO + + LEME Top-up	1999-2005	UC
Doctor of Philosophy (PhD) – commenced/continuing/graduand 2005-06						
Simon Abbott	Application of geophysical technologies for 3D visualization of palaeochannels and use of this information for management of dryland salinity in Western Australia	4	Jayson Meyers, Anton Kepic, Keith Smettem	CUPS + LEME Top-up	2004-	CUT
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, John Foden	APA + LEME Top-up	2002-	U of A
Glen Bann,	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	4	Colin Pain	LEME	2003-	ANU
Bahman Bayat	Indirect exploration of ore deposits in weathered terrains with airborne gravity gradiometry	2	Anton Kepic, Jayson Meyers	LEME Op. only	2005-	CUT
Fern Beavis	Diagenetic and anthropogenetic transformations of metals and other elements in regolith	2	David Ellis, Sue Welch	APA	2006	ANU
Kirsty Beckett	Multispectral analysis of high spatial resolution, 256-channel radiometrics for soil and regolith mapping	3&4	Jayson Meyers, Anton Kepic, Richard George	CUPS + LEME Top-up	2002-	CUT
Aaron Brown	Regolith geochemistry and biogeochemistry of the White Dam Cu-Au deposit, Curnamona Province, SA	1	Steve Hill	LEME	2002-	U of A
Paul Carlile	Development of semi-distributed catchment hydrology model for simulation of land-use change, streamflow and groundwater recharge within the Little River Catchment, NSW	3	Tony Jakeman, Brian Lees	LEME	2004-	ANU
Troy Cook	Geochemical investigation into the acid generating potential of wetland sediments of the Gnangara and Jandakot Mounds : Implications for long-term water quality	3	Ron Watkins	APA + LEME Top-up	2004	CUT
Steven Cotter	The nature, origin and geochemistry of chert breccias at Mt Isa	1	Graham Taylor, Ravi Anand	APA + LEME Top-up	1998-	UC
Mike Craig	Regional regolith and landscape evolution in the eastern Goldfields, Yilgarn Craton, Western Australia	1&2	Ken McQueen, Graham Taylor, Colin Pain	GA	1998-	UC
Robert Dart	Research the origin and distribution of calcrete in Southern Australia	2	Karin Barovich, David Chittleborough	LEME/U of A	2004-	U of A
Jessie Davey	Mesozoic regolith in SW Eromanga Basin	1	Steve Hill	APA	2006	U of A
Tania Dhu	Electrical and EM studies of regolith and sub-regolith structure	1	Graham Heinson, Stewart Greenhalgh	LEME/U of A	2003-	U of A
John Drewry	Modelling nutrient generation in Australian catchments: land use, regolith and management factors affecting surface and groundwater quality	3	Tony Jakeman	ANU + LEME Top-up	2004-	ANU
Michael Durkey	Effect of drains on soil properties in SE SA	4	David Chittleborough, Steve Hill	U of A/ DWLBC	2003-	U of A

POSTGRADUATE STUDENTS 2005-06 (cont'd)

Student	Project	Program	Supervisor(s)	Funding	Year	University
Doctor of Philosophy (PhD) – commenced/continuing/graduand 2005-2006 (cont'd)						
Kathryn Fitzsimmons	Relationships between regional landform patterns and landscape history in the Lake Eyre Basin dunefields	1	John Magee	APA + LEME Top-up	2003	ANU
Luke Foster	Landscapes, geochemistry, and GIS at Marlborough Qld.	2	Tony Eggleton, Colin Pain	LEME	1997	ANU
Mark Fritz	Baseline geochemistry of South Australian saline and acid sulfate soils	1	Rob Fitzpatrick	LEME/U of A	2003	U of A
Lachlan Gibbins	Measuring hydraulic conductivity with streaming potentials	1	Graham Heinson	LEME/U of A	2004	U of A
Chris Gunton	Element dispersion and mobility in the regolith	2	Bear McPhail	APA + LEME Top-up	2002	ANU
David Haberlah	Aeolian dust accessions to regolith	1	Martin Williams, Steve Hill	IRPS	2006	U of A
Anousha Hashemi	Innovative geophysical exploration for high-grade manganese ore under regolith and sedimentary cover in the East Pilbara of Western Australia	2	Jayson Meyers, Anton Kepic, Tim Munday	LEME	2003	CUT
Michael Hatch	The use of shallow geophysical techniques to help characterise hydrological parameters	4	Graham Heinson	Nil LEME	2005	U of A
Philip Heath	3-D automated inversion of potential field tensor data	2	Stewart Greenhalgh, Nick Direen	LEME/U of A	2003	U of A
Karen Hulme	Biogeochemistry of river red gums (*Eucalyptus camaldulensis*) in the Curnamona Province and adjacent parts of SA and NSW	1&2	Steve Hill, Steve Rogers	LEME/U of A	2003	U of A
Kamal Khider	Regional chemical dispersion processes in the regolith of Cobar Nymagee area, Central West, NSW	2	Ken McQueen, Bear McPhail	LEME	2002	ANU
Sukhyoun Kim	Electrokinetic groundwater exploration	4	Graham Heinson	Nil LEME	2004	U of A
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
Matthew Lenahan	Origin, nature and mobility of salt in the regolith	2	Bear McPhail, Dirk Kirste	LEME	2003	ANU
Mel Lintern	The role of biological and non-biological factors in the formation of Au anomalies in calcrete	2	Lindsay Collins, Mehrooz Aspandiar, Ravi Anand	Nil LEME	2001	CUT
David Little	Investigate, quantify and model rhizosphere in regolith formation in temperate landscapes in SE Australia	1	John Field	LEME	2003	ANU
Sean Mahoney	Evaluation and development of use of multitemporal imagery for water condition monitoring, environmental and wetland management in the SE of SA	4	Megan Lewis, Bertram Ostendorf	U of A/ DWLBC	2003	U of A
Aija Mee	Lacustrine and soil organic matter as proxies for mid -latitude Holocene environmental change in SE Australia	1	David McKirdy, Martin Williams	APA + LEME Top-up	2003	U of A
Nicole Mikkelson	Freshwater-saline water interactions in aquifers	–	David Ellis, Sarah Beavis	APA	2006	ANU
David Mitchell	Increasing spatial resolution of soil maps using geophysics and GIS	4	Megan Lewis, Bertram Ostendorf	U of A/PBMDS	2003	U of A
Michael Neimanis	Uranium biogeochemistry in plants	1	Steve Hill	APA	2006	U of A
Ryan Noble	Dispersal mechanisms of arsenic and antimony in regolith and surface deposits in the vicinity of buried gold ore bodies, northwest Victoria: implications for gold prospectivity and environmental management	2	Ron Watkins	APA + LEME Top-up	2003	CUT
Margarita Norvill	The use of distributed sensor arrays in electrical imaging	2	Anton Kepic, Jayson Meyers	APA + LEME Top-up	2002	CUT
Anna Petts	Termitaria and other landscape indicators of sub-surface regolith	2	Steve Hill, Lisa Worrall	LEME/U of A	2004	U of A
Nathan Reid	Biogeochemistry of regolith associated with Au deposits in the Tanami, WA and NT	1	Steve Hill, David Lewis	Nil LEME	2005	U of A
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/U of A	2003	U of A
Frank Reith	Interactions of microbes and gold in regolith in moderate, arid and tropical climates	1	Bradley Opdyke, Bear McPhail	IPRS + LEME Top-up	2002	ANU
Mohammad Rosid	Groundwater investigations using the seismo-electric method	3	Anton Kepic, Jayson Meyers	Nil LEME	2001	CUT
Suzanne Simons	U-Th-Pb systematics of opaline silica: implications for the dating of surface processes	1	Alexander Nemchin	LEME	2002	CUT
Margaret Smith	Groundwater acidification process with the Lake Muir-Unicup natural diversity recovery catchment, Western Australia	3	Ron Watkins, David Gray	APA + LEME Top-up	2005	CUT
Michael Smith	The geochemical evolution of alkaline salt-affected soils on the western slopes of northern New South Wales	4	Bear McPhail, Dirk Kirste	ANU + LEME Top-up	2003	ANU
Peter Somerville	Dryland salinity in the Widden Creek Valley in the Upper Hunter Valley NSW	4	Ian White	LEME Op. only	2005	ANU
Siriporn Soongpankhao	Mineral hosts and biogeochemistry for gold and trace element in regolith	2	Mehrooz Aspandiar	LEME OP. only	2005	CUT
Sorensen, Camilla	Mapping of the regolith using Passive Seismics in combination with other geophysical methods	4	Ken Lawrie	Nil LEME	2005	ANU

POSTGRADUATE STUDENTS 2005-06 (cont'd)

Student	Project	Program	Supervisor(s)	Funding	Year	University
Doctor of Philosophy (PhD) – commenced/continuing/graduand 2005-2006 (cont'd)						
Greg Street	Interpretation of geophysics for catchment management	3	Jayson Meyers	Nil LEME	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	U of A
Michael Turner	Three dimensional pore scale characterisation of the permeability and porosity of regolith materials	4	Bear McPhail	APA + LEME Top-up	2002	ANU
Sarah Tynan	Geochemistry of heavy metals in coastal and inland sediments	3	David Ellis	LEME	2005	ANU
Alistair Usher	Gold mobility and geochemistry in hypersaline solutions	2	Bear McPhail	APA + LEME Top-up	2003	ANU
Victor Waclawik	The regolith geology and landscape evolution of Umbum Creek, West Lake Eyre, South Australia	1	Simon Lang, Steve Hill	LEME/U of A	2003	U of A
Luke Wallace	Geochemistry and hydrogeology of inland acid sulfate environments	3	Bear McPhail	LEME	2004	ANU
Paul Wilkes	Geophysics in the search for diamonds	2	Jayson Meyers, Simon Wilde	Nil	2000	CUT
Vanessa Wong	The effects of salinity and sodicity on soil carbon stocks and fluxes	3	Richard Greene, Graham Farquhar	ANU + CRC Greenhouse + LEME Top-up	2004	ANU
Martin Worthy	Major water quality degrading events in the Cotter River Catchment : characteristics and management	3	Robert Wasson, Mike Hutchinson	ACTEW + LEME Operating	2004	ANU
Pierre-Allain Wulser	Mobility of uranium and rare earth in the Mt Painter-Lake Frome-Curnamona Craton Regions, SA : Geochemical and temporal controls	2	Joel Brugger, John Foden	IPRS + LEME Top-up	2003	U of A

Colour key:

: Commenced 2006.
: Thesis submitted, awaiting assessment.

Photograph: Steve Hill

Specified Personnel

Business Manager,
Mr Gary Kong, CPA

LEME values that guide Centre activities are:

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

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

Staff Complement

LEME has world-class expertise in regolith geoscience and supporting disciplines such as mineralogy, geochemistry, hydrogeochemistry, sedimentology, geophysics, pedology, geochronology, microbial biogeochemistry and molecular biology. In this fifth year of operation, LEME had a total complement of 148 staff, of which 138 were professional geoscientists. This comprised 69.4 FTE scientists, made up of 45.8 in-kind contributed and 23.6 cash funded.

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

Specified Personnel

Specified personnel are the science leaders and managers, as required by the Commonwealth Agreement. They form the core of the Executive, and comprise the following:

Dr Ravi Anand, Program 2 Leader, CSIRO, 100%

Dr Charles Butt, Key Researcher, CSIRO, 75%

Dr R Dennis Gee, Chief Executive Officer, CSIRO, 100%* to 5 Oct 05

Dr Steven Hill, Program 5 Leader, U of A, 100%*

Dr Ken Lawrie, Program 4 Leader, GA, 100%

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

Dr Colin Pain, Key Researcher, GA, 100%

Dr Steve Rogers, Chief Executive Officer, CSIRO, 100%* from 7 Oct 05. Program 3 Leader, CSIRO, 70% from 1 Jul to 5 Oct 05

Dr Paul Shand, Program 3 Leader, CSIRO, 85% from 22 May 06

Ms Lisa Worrall, Program 1 Leader, GA, 100%

**Paid from the CRC Grant*

Staff OH&S Matters

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

A manual entitled *CRC LEME Policy and Procedures on Field Safety* prepared by Geoscience Australia – in consultation with the Occupational Health and Safety representatives from the other Core Participants is used by LEME staff. This manual draws together best-practice material from companies in the exploration industry and provides essential reference material for all staff and students. An abridged manual: *The Glove Box Guide to Health and Safety in the Field* is also available.

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 and are permanently available through the LEME intranet.

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. Two notifiable OH&S vehicle incidents occurred during the reporting year. Medical assistance was required for one incident due to minor tissue injury. However, no days were lost through injury.

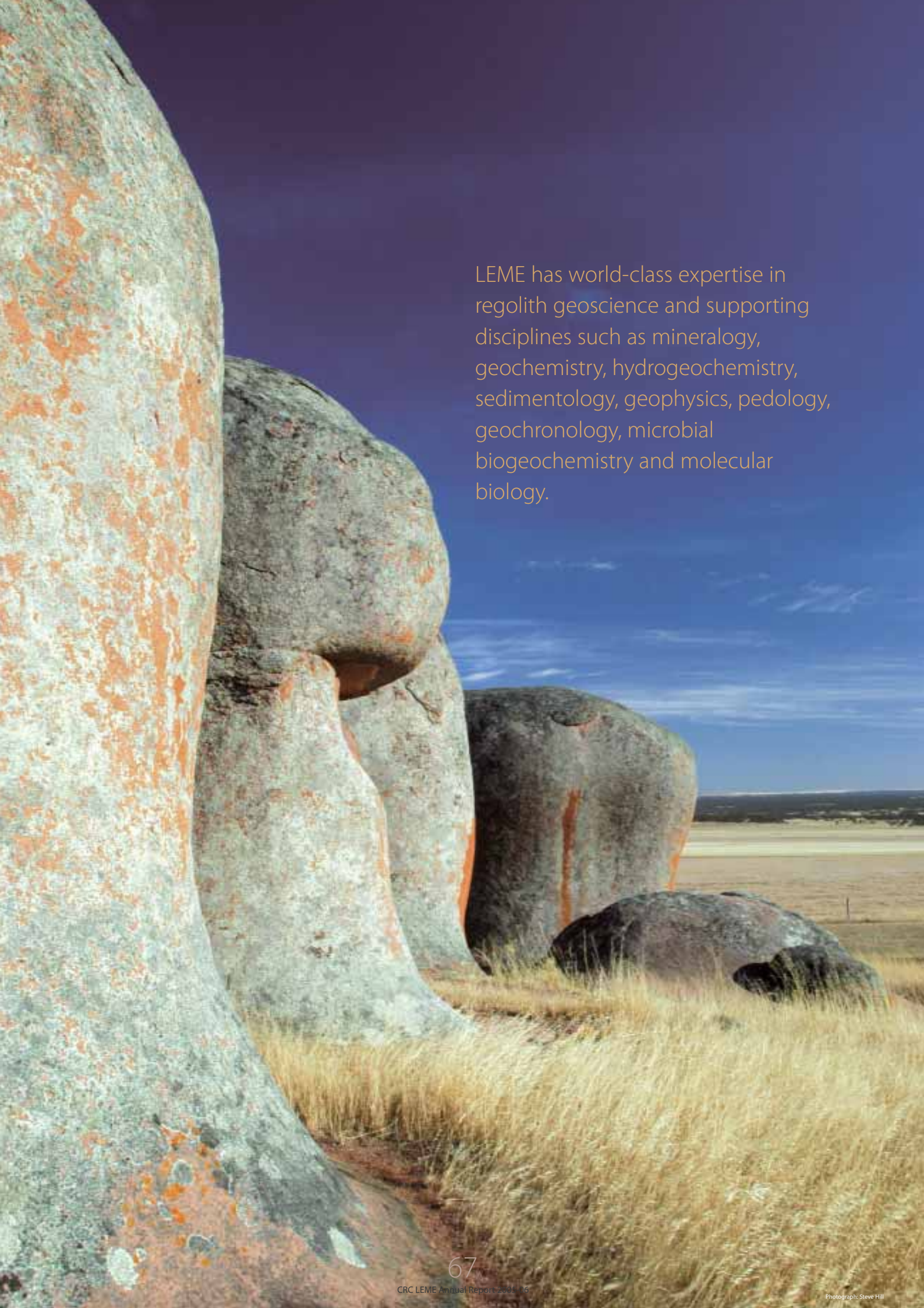
Research Staff In-kind Contribution

Name	Main Activity	Total % of Time	% Spent on Research Program					% Spent on CRC		
			Regolith Geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
The Australian National University (ANU)										
Arculus R	R	20			20		20			
Beavis S	R	25			25		25			
Chappel J	R	50	50				50			
Chopra P	R	20	20				20			
Christy A	R	25		25			25			
Croke B	R	20	20				20			
DeDeckker P	R	20	20				20			
Dunlap J	R	25	25				25			
Eggins S	R	20	20				20			
Ellis D	R	25	25				25			
Field J	R	50	50				50			
Fifield K	R	10				10	10			
Greene R	R	30	10			10	20	10		
Grun R	R	15				15	15			
Harrold B	R	20				20	20			
Jakeman T	R	20				20	20			
Lees B	R	40	40				40			
Magee J	R	25	25				25			
McMorrow L	R	25				25	25			
McPhail D	R	100	30	45	25		100			
Norman M	R	10				10	10			
Opdyke B	R	20	20				20			
Pillans B	R	50	50				50			
Reeves J	R	100				100	100			
Rhodes E	R	25	25				25			
Troitsch U	R	25				25	25			
White I	R	20	20				20			
Williams I	R	10				10	10			
		845	450	70	70	245	835	10	0	0
Geoscience Australia (GA)										
Apps H	R	100				100	100			
Chan R	R	80				80	80			
Craig M	R	100	100				100			
Gibson D	R	80				80	80			
Lawrie K	R	100				100	100			
Pain C	R	100	20			80	100			
Wilford J	R	100				100	100			
Worral L	R	100	100				100			
		760	220	0	0	540	760	0	0	0
Curtin University of Technology (CUT)										
Aspandiar M	R	50		50			50			
Collins L	R	60	60				60			
Collins PLF	R	30	30				30			
Fagan R	R	20	20				20			
Harris B	R	40	40				40			
Kepic A	R	50				50	50			
Meyers J	R	50	20			30	50			
Rathur A	R	70	70				70			
Wartho J	R	15	15				15			
Watkins R	R	40	40				40			
Watling J	R	20	20				20			
Wilde S	R	10	10				10			
		455	325	50		80	455	0	0	0
The University of Adelaide (U of A)										
Barovich K	R	70	70				70			
Brugger J	R	10	10				10			
Direen N	R	70	70				70			
Foden J	R	30	30				30			
Heinson G	R	55	35	5	5	10	55			
Lang S	R	5	5				5			
McKirdy D	R	20	20				20			
Schmidt-Mumm A	R	45	5	40			45			
Williams M	R	10	10				10			
		315	255	45	5	10	315	0	0	0

Research Staff In-kind Contribution (cont'd)

Name	Main Activity	Total % of Time	% Spent on Research Program					% Spent on CRC		
			Regolith Geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
Primary Industries and Resources, South Australia (PIRSA)										
Cooper B	R	10	10				10			
Fabris A	R	100	100				100			
Gouthas G	R	100	100				100			
Hou B	R	100	100				100			
Keeling J	R	70	40	30			70			
Mauger A	R	80		75			75	5		
Painter J	R	30		30			30			
Sheard M	R	100	90	10			100			
Stamoulis V	R	50	50				50			
Stoian L	R	50	50				50			
Zang Wen Long	R	50	20	30			50			
		740	560	175	0	0	735	5	0	0
New South Wales Department of Primary Industries (NSW DPI)										
Brown B	R	25	25				25			
Burton G	R	20	20				20			
Campbell L	R	20	20				20			
Dawson M	R	30	30				30			
Gilmore P	R	25	25				25			
Glen R	R	20	20				20			
Greenfield J	R	30	30				30			
Healy M	R	30	30				30			
Mills K	R	20	20				20			
Musgrave R	R	20	20				20			
Reid W	R	95	95				95			
Triggs S	R	20	20				20			
Vickery N	R	25	25				25			
Watkins J	R	10	10				10			
Commonwealth Scientific and Industrial Research Organisation (CSIRO)										
Butt C	R	70		70			70			
Cudahy T	R	10		10			10			
Gray D	R	100	10	60	30		100			
Robertson I	R	100	50	50			100			
Fitzpatrick R	R	40			40		40			
Anand R	R	100	15	80	5		100			
Cornelius M	R	100		100			100			
Evans N	R	15		15			15			
Fitzpatrick A	R	20				20	20			
Hough R	R	100		100			100			
McDonald B	R	15	15				15			
Munday T	R	100		45		55	100			
Pirlo M	R	50		50			50			
Reith F	R	75		75			75			
Cox J	R	25				25	25			
Cresswell R	R	20				20	20			
Davies P	R	20				20	20			
Dighton J	R	15				15	15			
Douglas G	R	10				10	10			
Hicks W	R	20			20		20			
Lamontagne S	R	20			20		20			
Rassam S	R	20				20	20			
Rogers S	R	20			20		20			
Shand P	R	10			10		10			
		1075	90	655	145	185	1075	0	0	0
TOTAL RESEARCH STAFF: IN-KIND CONTRIBUTIONS		4580	2290	995	220	1060	4565	15	0	0

KEY: 100 = 1 person year



LEME has world-class expertise in regolith geoscience and supporting disciplines such as mineralogy, geochemistry, hydrogeochemistry, sedimentology, geophysics, pedology, geochronology, microbial biogeochemistry and molecular biology.

Photograph: Steve Hill

Communication Strategy

Communication Policy

LEME promotes and communicates it's advances in regolith knowledge to its **immediate end-users** so that regolith science becomes an accepted and integral part of new applications in mineral exploration and land management. The strategy to optimise uptake is by way of demonstration projects, and to promote on **delivery** rather than **intent**. It is recognised that as LEME's salinity and environmental programs grow and deliver, there will be a need to promote to the general community the widening application of regolith geoscience in land remediation schemes and environmental applications.

LEME communicates its research activities and scientific results through the following mechanisms:

- Frequent updates of the website (http://crcleme.org.au), a public domain outlet for interim and final releases of information such as research news and conference details.
- Production of an Annual Report which a) satisfies the reporting requirements of the CRC Programme and b) is a publicly available summary of activities mailed to more than 800 recipients and available as a .pdf from the LEME website.
- Release of comprehensive technical reports through the LEME Open File Report series and various monographs both as hard copies and .pdfs.
- Publication of scientific communications in national and international scientific journals.
- Staging conferences, seminars and workshops under the LEME banner, for example Mineral Exploration Seminars, and the Annual Regolith Symposia.
- LEME researchers presenting their findings at national and international events.
- Distribution of the quarterly electronic newsletter *Minerals Brief* to some 600 recipients.
- Contribution to *Focus on Salt* – a newsletter (5000 circulation) to NRM stakeholders, produced jointly with CRC PBMDS.
- Sponsoring multi-disciplinary multi-agency scientific and technical events.
- Technical articles in special interest journals and industry magazines.
- Regular media releases on significant research outputs.

LEME communication activities were enhanced during 2005-06 with the appointment of a full-time communications officer, Greg Lawrence, at Head Office in January 2006. Following the appointment, the Centre's communication activities were further defined with the development and approval by the Board of a Communications Strategic Plan 2006-08.

The key objectives of the Communications Strategic Plan 2006-08 are:

- Provide and deliver consistent, concise and scientifically robust information on how LEME is achieving its research aims and objectives targeted to internal and external stakeholders.
- Create consistent and professional LEME corporate branding for the Centre's external communication.
- Effectively communicate the significance of LEME research activities and results to stakeholders with particular emphasis on the scientific community, potential clients such as exploration companies and CMAs and the general public.
- Ensure LEME publications and associated publicity, whether published by the Centre or other persons, contain appropriate acknowledgement of the Centre's funding by the Commonwealth via the CRC Programme.
- Produce the LEME Annual Report in accordance with the CRC Programme Guidelines.
- Publish a separate hard copy version of the Centre's Annual Report for general distribution which maximises promotion of LEME achievements.
- Promote regolith geoscience and its applications in Australia and overseas by communicating LEME results to the scientific community, mineral explorers and natural resource managers through targeted trade exhibitions and the Centre's attendance and sponsorship at relevant conferences.
- Enhance internal communication processes to create consistency and awareness.
- Review and enhance LEME's current external communication tools and publications to find ways of improving the communication process and achieving new efficiencies, captures and market access.
- Increase the exposure of LEME research in geoscience, and environmental sectors through high quality international peer-reviewed, refereed scientific publications popular science publications, trade/industry publications and popular press.
- Improve coordination and targeting of LEME communication and adoption and technology transfer activities.
- Prepare LEME legacy outputs that synthesise the state of the art knowledge on regolith geoscience by December 2008.
- Evaluate the effectiveness of research communication and adoption mechanisms.

Communication Strategy

LEME promotes and communicates it's advances in regolith knowledge to its immediate end-users so that regolith science becomes an accepted and integral part of new applications in mineral exploration and land management.

Publication Policy

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

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

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

The LEME Internet and Intranet continued to be the main medium for publicising research, developments and news to stakeholders, staff and students. It contains program and project descriptions, research and technical papers, and .pdfs of Open File Reports and monographs/case histories. More than 800 .pdf files of technical papers are now available for download from the website. Order forms for LEME products and regolith landform maps can be downloaded from the website.

The website contains regularly updated personnel directories (staff, students, Board, Advisory Councils), the LEME Annual Reports, Strategic Plan, news and events, upcoming conferences, as well as links to all Core Participant websites. The education section advertises MCA Courses, scholarships and proposed student projects while providing a forum for students to report their progress.

The Intranet is integral to LEME internal communications and is used to post minutes from Executive Meetings, reports to staff, procedures and templates, policy directives and the approved project summaries of the Centre's entire research portfolio.

Publications

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

The Centre has a series of some 201 Open File Reports, dating back to LEME 1. A total of seven new OFR Reports were published during the reporting period, which are listed in the Research and Collaboration section of this report. Two new thematic volumes, *Regolith Landscape Evolution Across Australia* and *Regolith Expression of Australian Ore Systems* were released during the year. Since their release in September 2005, both publications have proven to be very popular with mineral explorers across Australia and internationally.

Conferences, Seminars and Meetings

In November 2005, LEME Regional Regolith Symposia were staged in Canberra and Adelaide. These events provide an opportunity for scientists and students to present research updates, deliver results in advance of more formal publication, and to share their evolving science with peers. This enhances the quality of research, and promotes cross-fertilisation of ideas. Presentations cover the full spectrum of LEME research and therefore are of relevance to all stakeholders. Fully reviewed proceedings were published as the 345-page *Regolith 2005* in the LEME monograph series. These are available in hard copy, .pdf and CD.

During the year, LEME staff were involved in the organisation of the 2006 Australian Earth Science Convention (AESC) including finalising presentations, developing media strategies and organising two LEME research-focussed field trips. More than 35 abstracts were received by the organising committee from LEME researchers. LEME's physical presence will be further enhanced with a booth profiling Centre research. The AESC will be held in Melbourne 2-7 July 2006.

In early 2006, the first meeting of the International Steering Committee and Technical Committee for the 2008 International Salinty Forum was held with Ken Lawrie present as the LEME representative. The conference will be held in Adelaide from 30 March to 4 April 2008. LEME is a foundation sponsor of the conference.

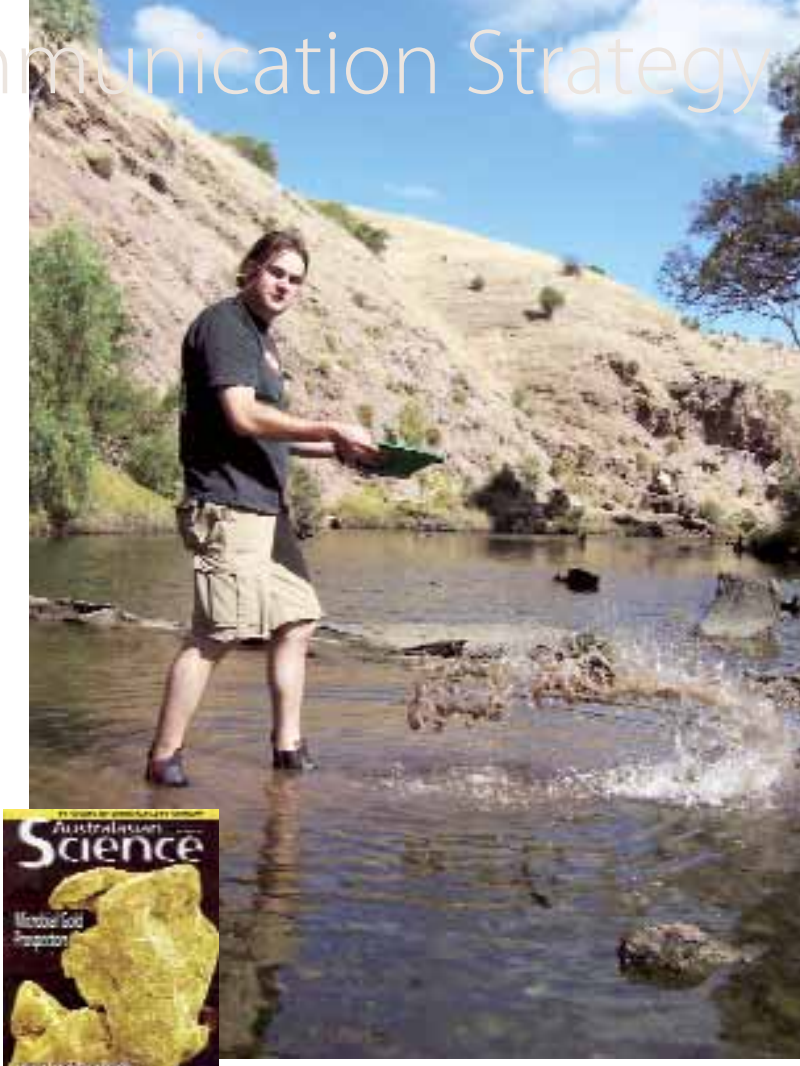
Conference Activity (2005-06)

Event	Location	LEME Personnel	Date	Activity
American Geophysics Union, 2006 Fall Meeting	San Francisco	David Little, ANU	27 Aug-1 Sept 2005	Presenter
ANU-LEME Seminar Series	Canberra	Luke Wallace, ANU	8 Jul 2005	Presenter
NSW Exploration and Investment Conference	Sydney	Patrice de Caritat and Lisa Worrall, GA	1 Sept 2005	Participants and LEME booth
Future Directions in Stratigraphy III	Leuven, Brussels	Brad Pillans, ANU	1-5 Sept 2005	Invited Speaker – 'The Quaternary'
Int Meeting on Organic Geochemistry	Seville, Spain	Aija Mee, U of A	Sept 2005	Presentation and Poster
6th Int Symposium on Applied Isotope Geochemistry	Prague, Czech Republic	Dirke Kirste, ANU	11-16 Sept 2005	Presenter
22nd International Geochemical Exploration Symposium	Perth	Ravi Anand, Charles Butt, Ian Robertson, Matthias Cornelius, David Gray, Robert Hough, Mel Linten, Ryan Noble, Mark Pirlo, Keith Scott, Balbir Singh CSIRO Robert Dart, Steve Hill, Karen Hulme, Anna Petts, U of A Patrice de Caritat, Megan Lech, GA Ken McQueen, ANU	19-23 Sept 2005	Keynote Speaker, Organising Committee, Speakers, LEME booth
NSW PUR$L Workshop 05. Salinity from the ground up	Wellington, NSW	Ken Lawrie, Colin Pain, John Wilford, Dave Gibson, Jeremy James, GA	25-27 Oct 2005	Presenters
LEME Regolith Symposia	Adelaide and Canberra	62 LEME presentations from staff and students – published in refereed volume	2-4, 9-10 Nov 2005	LEME event
World Diamond Conference	Perth	Vickie Stamoulis and John Keeling, PIRSA	21-22 Nov 2005	Presenters
HyLogger Workshop		Alan Mauger and J Keeling, PIRSA	23 Nov 2005	Organisers and Presenters
NewGenGold 2005	Perth	LEME Attendees	28-29 Nov 2005	LEME Booth
Ecological Society of Australia Annual Conference	Brisbane	Glen Bann, ANU	29 Nov – 2 Dec 2005	Presenter
Where Waters Meet, (NZ Hydrological Soc, Int Assoc Hydrogeologists, NZ Soc of Soil Sciences)	Auckland, New Zealand	Margaret Smith, CSIRO	28 Nov – 2 Dec 2005	Presenter
MODSIM05 (Modelling and Simulation Developments	Melbourne	K Lawrie, J Clark, C Pain, A Fitzpatrick, Baihua Fu, Heike Apps, J Cox, T Dhu, J Fiwls, KP Tan, RSB Greene, I Halas, GA	12-15 Dec 2005	Presenters
12th ANZ Geomorphology Group Conference	New Zealand	Brad Pillans, Roslyn Chan, Ed Rhodes, Kathryn Fitzsimmons, Glen Bann, Michael Craig, John Chappell, ANU Jon Clarke, David Gibson, GA	13-17 Feb 2006	Keynote Address Presenters
GSA Seminar	Canberra	Kathryn Fitzsimmons, ANU	Feb 2006	Invited presentation
Annual Geoscience Exploration Seminar	Alice Springs, NT	Mike Craig GA	28-29 Mar 2006	Invited speaker – NT Regolith-landscape framework
Natural Resource Management Ministerial Council	Sydney	Rob Fitzpatrick, CSIRO	21 April 2006	Presenter – Acid Sulfate Soils
Kalgoorlie 2006, Conference – AIG-AMEC	Kalgoorlie, WA	Ravi Anand, CSIRO Ken McQueen ANU	30 Apr – May 2006	Keynote Speaker Presenter
SA Explorers Conference, Adelaide	Adelaide	John Keeling, PIRSA	3 May 2006	Presenter
ANU-LEME Seminar Series	Canberra	Patrick de Deckker, ANU	9 May 2006	Presenter
CAMECO – LEME Regolith Workshop (Uranium)	Darwin, NT	Mike Craig, GA	9-10 May 2006	Workshop author and Presenter to
CRC Association Conference	Brisbane	Steve Hill, U of A	17-19 May 2006	Invited Speaker
ACT Canberra Institute of Technology	Canberra	Mike Craig, GA	24 May 2006	Presenter – NT Regolith products
Mines and Wines – GS NSW and Sydney Mineral Exploration Discussion Group	Cessnock, NSW	John Greenfield, Bill Reid, NSW DPI	24-26 May 2006	Presenters
Qld Dept Natural Resources Mines and Water, GS Qld	Brisbane	Mike Craig, GA	29 May 2006	Presenter and Negotiator – initiated project agreement
Penrose Conference: Beyond the GSSP – The Future of Chronostratigraphy	Graz, Austria	Brad Pillans, ANU	3-9 June 2006	Invited Speaker
North Ainslie Primary School	Canberra	Mike Craig, GA	14 June	Presenter – CRC regolith products, field specimens and photos
ANU – LEME Seminar Series	Canberra	Richard Greene, ANU	20 June 2006	Presenter
Mineral Exploration Through Cover Conference – PIRSA, CRC LEME, U of A	Adelaide	Steve Rogers Andreas Schmidt Mumm, Graham Heinson, Philip Heath, Frank Reith, Steve Hill, Nathan Reid	23 June 2006	Keynote Speaker Presenters
NSW Dept Natural Resources: Cowra Research Station	Cowra, NSW	Vanessa Wong, ANU	26 June 2006	Invited presentation

Media Releases

The appointment of a full-time communications officer during the reporting period has notably increased the output of LEME media communications. This increased output has paralleled the Centre's acceleration of science deliverables and improved exposure of LEME research outputs to the general media and specialist mining and environmental journals and magazines.

A highlight for the year was the significant international media interest shown in the research by LEME PhD graduate Frank Reith which led to the discovery of the bacteria (*Ralstonia metalliduran*) which is able to precipitate gold out of solution. Initially, his discovery was published in the prestigious journal *Science* in July 2006. Following the paper's release and the release of a combined CSIRO Exploration and Mining and LEME media statement, Frank's research gained global media attention that resulted in feature articles appearing in the *New York Times*, *The Standard* (Chinese Business Newspaper), *The Mumbai Mirror* and *Nature*, as well as numerous radio interviews.



LEME PhD student Frank Reith pans for gold.

Media Releases, Magazine Articles and Radio Interviews

Subject	LEME contact	Publication	Date
Media Statement: Wheatbelt salinity study helps mineral explorers look for uranium	Greg Lawrence		Jan 2006
Mindax expands in WA with Quasar JV	Steve Rogers	www.yahoo.com	Jan 2006
Explorers join hunt for uranium in Wheatbelt	Steve Rogers	The West Australian	Jan 2006
Mindax expands in WA with Quasar JV	Steve Rogers	www.minebox.com.au	Jan 2006
New uranium data for Mindax	Steve Rogers	MiningNews.net	Jan 2006
Media statement: Publication gives Australian regolith research snapshot to geoscientists and environmental managers	Greg Lawrence		Feb 2006
Wheatbelt Study helps mineral explorers look for uranium	Steve Rogers	ScienceAlert.com.au	Feb 2006
Using salinity to find uranium	Steve Rogers	Esperance Express	Feb 2006
Media Statement: Nominations sought for geoscience research medal	Greg Lawrence		Feb 2006
Radio Interview: Wheatbelt salinity tests reveal uranium	Steve Rogers	ABC National News	Feb 2006
Media Statement: New geochemical data highlights mineral potential of WA's wheatbelt	Greg Lawrence		Feb 2006
Data highlights WA wheatbelt potential	Matthias Cornelius	MiningNews.net	March 2006
Study may hold uranium key	Steve Rogers	Paydirt	March 2006
Uranium discovery: Salty tale has a grain of truth	Steve Rogers	www.ferret.com.au	March 2006
Salt into Power	Steve Rogers	Australian Mining Monthly	March 2006
Wheatbelt salinity study helps mineral explorers look for uranium	Steve Rogers	The Mining Chronicle	March 2006
Partnership searches for wheatbelt wealth	Steve Rogers	Science Network WA	March 2006
Ten Years of CRC LEME (Regolith 2005)	Ian Roach	GeoOz – The Electronic Geologist	March 2006
Call for Nominations – Butt Smith Medal	Steve Rogers	AIS News, Australian Institute of Geoscientists	March 2006
Publication gives Australian regolith research snapshot to geoscientists and environmental managers	Ian Roach	Explore Magazine 130	March 2006
Award for Research (Butt-smith Medal Winner – Richard Mazzucchelli)	Steve Rogers	Earth Matters	March 2006
Nomination sought for geoscience research medal	Steve Rogers	Explore Magazine 130	March 2006
Nominations sought for geoscience research medal	Steve Rogers	GeoOz – The Electronic Geologist,	March 2006
Media Statement: Nominations closing soon for geoscience	Greg Lawrence		April 2006

Media Releases, Magazine Articles and Radio Interviews

Subject	CRC LEME contact	Publication	Date
Media Statement: New regolith-landform map and atlas for NT mineral explorers	Greg Lawrence		April 2006
Radio Interview: NT leading the country in mapping deposits	Steve Rogers	NT Country Hour Program	April 2006
Signposts to wealth. Cutting Edge Column	Ian Roach	Australian Mining Monthly	April 2006
Reading the landscape – Barrier Daily Truth (Broken Hill), 18 April 2006	Ian Roach	Barrier Daily Truth (Broken Hill)	April 2006
Regolith – landform map and atlas of NT	Mike Craig	www.bizzsourcer.com	May 2006
Regolith – landform map and atlas of NT	Mike Craig	www.ferret.com.au	
Media Statement: Online interactive map now available for central Queensland natural resource managers	Greg Lawrence		June 2006
Radio Interview: New online map for central Queensland natural resource managers	Colin Pain	ABC MacKay and Tropical North Queensland Local News	June 2006
Media Statement: LEME mineral exploration research showcased at seminar	Greg Lawrence		June 2006
LEME Media Statement: Seminar shows spinifex may hold the secrets of the desert	Greg Lawrence		June 2006
Map for minerals and water	Mike Craig	Earth Matters	June 2006
Online interactive map now available for central Queensland natural resource managers	Colin Pain	Earth Matters	June 2006
Ask Our Scientists: Dr Andrew Fitzpatrick	Andrew Fitzpatrick	Earth Matters	June 2006
Map gives new insight into NT regolith	Mike Craig	Gold and Minerals Gazette	June 2006
Planet study uncovers anomalies	Ravi Anand	Gold and Minerals Gazette	June 2006
LEME mineral exploration researched at seminar	Ravi Anand	Mining Chronicle	July 2006
Media Statement: The Midas Bug – the bacterial alchemy of gold	Greg Lawrence		
Microbes aid mineral explorers	Frank Reith	Paydirt Magazine	July 2006
Bacteria help grow nuggets from dirt	Frank Reith	Science Magazine	July 2006
The smallest gold diggers in the world	Frank Reith	Nature Magazine	July 2006
Evolution of gold	Frank Reith	Adelaide Advertiser	July 2006
Secret of the Ancient Alchemists	Frank Reith	www.unknowncountry.com	July 2006
Bacteria linked to gold nugget formation	Frank Reith	ABC News Online	July 2006
Tiny bugs makes gold nuggets	Frank Reith	Science Network WA	July 2006
The Midas Bug	Frank Reith	Mumbai Mirror	July 2006
Tiny microbe may just have the Midas touch	Frank Reith	Germany Mining News	July 2006
Australian research shows microbes may turn dust into gold	Frank Reith	www.Physorg.com	July 2006
Bugs are the best gold-diggers	Frank Reith	New Kerala Online Newspaper, India	July 2006
Bugs turn dust into gold	Frank Reith	ABC.net: News in Science	July 2006
Australian's capture gold bug	Frank Reith	The Standard, China	July 2006
The Midas microbe	Frank Reith	www.Perthnow.com	July 2006
Bacteria help form gold in the wild	Frank Reith	People's Daily Online, China	July 2006
Bacteria found growing for gold	Frank Reith	The Border Mail, Victoria	July 2006
Thar's gold in them thar microbes	Frank Reith	www.CNN.com	July 2006
Microbial alchemists under the microscope	Frank Reith	Chemistry World	July 2006
Microbe can turn dust into gold, say Aussie researchers	Frank Reith	Taipei Times	July 2006
Tips for prospectors: Follow the bacteria	Frank Reith	New York Times	July 2006
Researchers find gold-collecting bacteria	Frank Reith	The Detroit News	July 2006
Gold, grown by bacteria!	Frank Reith	Nigerian Tribune	July 2006
Australians uncover Midas microbes	Frank Reith	www.Cnews.com	July 2006
The Midas Bacteria	Frank Reith	www.neatorama.com	July 2006
Gold – bacteria aid gold nugget formation	Frank Reith	The Asian Miner	July 2006
Australian science discovery is pure gold for alchemists	Frank Reith	Courier Mail	July 2006
Eureka! Bacteria Have the Midas Touch	Frank Reith	Livescience.com	July 2006
The Midas Bug – the bacterial alchemy of gold	Frank Reith	Micromedex.com	July 2006

Magazines and Newsletters

Magazines and newsletters, coupled with LEME presentations at conferences, seminars and workshops and the Centre's own quarterly electronic publications *Minerals Brief*, continued to be an effective way to communicate LEME's research to stakeholders nationally and internationally.

During the year, progress made by the Centre's mineral exploration research programs was profiled to the Australian resources sector through the continuation of a series articles featured in the *Cutting Edge* section of *Australian Mining Monthly* Magazine.

These articles were written as part of a contractual arrangement with Professor Julian Cribb, the leading Australian science journalist and the CRCA Mining and Energy Sector. Articles that highlighted LEME research appeared under appealing headings such as: *The Future of Minerals*, *Ion Hunters*, *Know Your Regolith*, and *Signposts to Wealth* and *Salt into Power*.

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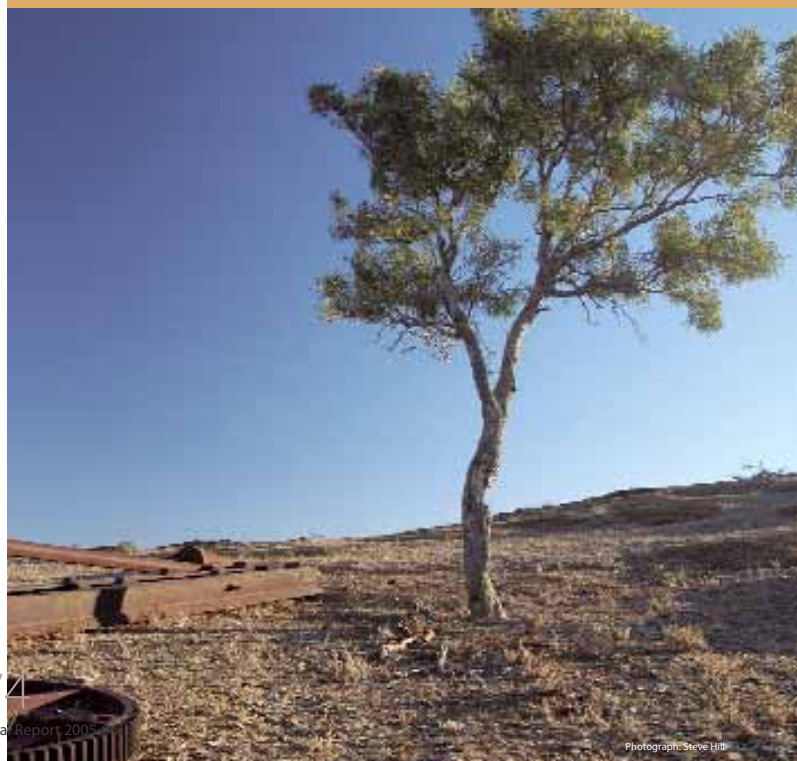


Photograph: Steve Hill

Performance Measures

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

Objectives of the Centre

Broad indicators of progress towards Centre Objectives are:

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

Centre Objective Outcomes

1 Collaboration with external researchers

2 Gaining external sponsorship

3 Gaining international recognition

Centre Objectives Performance Indicators

Output/Outcome	Performance Indicator	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006
1	Number of external research collaborators	47	86	75	80	80
2	Number of commercial contracts and the annual value of sponsorship	13 $756,540	13 $616,000	14 $1,183,000	16 $1,662,000	32 $1,363,000
3	Number of overseas researchers visiting LEME sites	4	10	10	6	8
3	Number of overseas visits by LEME staff	19	7	8	9	2
3	Number and value of overseas research projects	1 $27,489	0	0	1 $12,000	1 $8,300

LEME has continued to sustain a high level of external collaboration and funding. The relatively low level of overseas research projects reflects the Centre's focus and commitment to addressing the regolith science challenges facing Australia.

Quality and Relevance of the Research Programs

To ensure the quality and relevance of its research programs, 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

Output/Outcome	Performance Indicator	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006
3	Number of published journal articles per year	54	23	18	40	30
4/5	Number of conference papers presented per year	50	134	186	210	146
1/4	Number of books or chapters in books	20	40	41	28	174
4	Other forms of publications includes maps, short course notes, field guides, electronic newsletters	28	21	19	16	13
2	Number of LEME Technical Reports released, includes Open File Reports	36	6	10	26	18
2	Number of confidential reports, maps	18	9	8	8	12
6	Number of keynote addresses given	4	2	6	7	5
6	Number of sabbatical leaves taken by overseas personnel at LEME sites	3	2	2	3	2
6	Number of awards to LEME researchers and educators	3	8	8	9	7
6	Number of professional appointments awarded to LEME researchers and educators	7	5	9	15	10

Of note is the significant increase in publications containing LEME research outputs, as reflected by the *Number of books or chapters in books* performance indicator. This increase during 2005-06 is largely attributed to the release of two LEME thematic volumes on Australian regolith geoscience.

Strategy for Utilisation and Knowledge Transfer of Research Outputs

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

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

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

Utilisation and Knowledge Outputs

1 Short course workshops

2 Products sold/released

Utilisation and Knowledge Outcomes

3 Media/industry magazine coverage

4 External LEME Collaborators

Strategy for Utilisation and Knowledge Transfer of Research

Output/Outcome	Performance Indicator	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006
1	Number of short courses and workshops	7	11	6	4	9
3	Number of media reports and releases	8	9	21	17	39
2	Number of items sold (open file reports, manuals, course notes)	120	75	101	119	464
3	Number of articles in prospecting magazines	3	1	9	11	22
2	Number of reports to sponsors and companies	15	9	13	8	12
4	Number of collaborative projects with industry users and user organisations	49	48	56	60	55
4	Annual external research income	$782,000	$616,000	$1,183,000	$1,662,000	$1,331,000
1/2	Number of scientific outputs per FTE staff	2.4	3.4	4.2	4.4	5.25
4	Increase in external revenues from contract research	NA	-21%	+92%	+41%	-20%

Most outputs increased during 2005-06. Some of these increases can be attributed to communications officer's activities. However, the increase in the number of Centre items sold strongly reflects the popularity of the two LEME thematic regolith publications since their release in September 2005.

Education and Training

To enhance the regolith knowledge of current and future geoscientists in Australia, 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, LEME aims to produce at least 60 new PhD graduates and 60 Honours graduates throughout the lifetime of the Centre. For the purpose of meeting PIs, the Centre defines a LEME student where:

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

Education and Training Outputs

1 Number of CRC LEME PhD and Honours Graduates

Education and Training Outcomes

2 External interest in supervising LEME students

Education and Training

Output/Outcome	Performance Indicator	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006
1	Number of postgraduate students working on LEME research projects	38	51	50	59	62
1	Number of MSc and PhD completions, each year/cumulative	1	7/8	7/15	5/20	1/21
1	Number of BSc Honours graduates completing LEME projects	16	11	21	17	12
1	Number of BSc Honours students commenced/continuing LEME projects	37	20	10	13	12
2	Number of external supervisors of research students	20	12	16	21	14
1	Number of student class hours of instruction in Masters by Coursework degrees related to the regolith	80	80	80	80	80
1	Number of Honours graduates produced over the lifetime of LEME (incl graduands)	16	27	58	77	89

The Education and Training Performance Indicators for the year show the total number of postgraduate students is on target to exceed performance indicators benchmarks. Honours student graduate numbers are expected to double the performance target set out in the original Commonwealth Agreement. Postgraduate and Honours student intake remained strong during 2005-06 and is expected to continue beyond the life of the LEME Scholarship Program term at some Core Participant universities.

Collaborative Arrangements

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

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

- Increase the extent of PhD and Honours student involvement in research activities.
- Develop and extend an Associate network of Supporting Participants.
- Support the interchange of personnel among different sites within the Centre.

Collaborative Arrangements Outputs

1 LEME Collaborative activities

Collaborative Arrangements Outcomes

2 External involvement in international collaborations

Collaborative Arrangements

Output/Outcome	Performance Indicator	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006
1	Number of Centre-funded projects involving staff from more than one core party	28 (of 30)	27 (of 29)	38 (of 59)	33 (of 45)	32 (of 60)
1	Number of external stakeholders involved in the direction of LEME through the Governing Board and Advisory Councils	14	27	26	22	24
2	Number of projects involving international collaborators	6	0	5	1	5

The figures show an increase in international collaborative projects during 2005-06 which reflects the increasing relevance and recognition of LEME outputs to the international community.

Resources and Budget

Performance Indicator	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006
Total resources (cash and in-kind excluding CRC Grant)	$17.6M	$16.7M	$19.8M	$17.4M	$21.65M
FTE research staff (excluding students)	73.3	63.1	70.0	63.3	69.38
FTE technical and other support staff	11.1	6.35	7.05	6.9	6.30

Safety

As part of the Centre strategic plan and safety policy, LEME aims to have a Lost Time Injury Frequency Rate (an industry standard measure) of zero throughout the life of the CRC. There were two reportable incidents involving LEME staff during 2005-06.

As at 30 June 2006, all Core Participants met or exceeded their in-kind contribution target defined in the Commonwealth Agreement and the Deed of Release and Variation. The total cash income received for collaborative activities from industry and other users in Year 5 is $1.5M.

The leverage of actual contributed resources to CRC Programme funding from the Commonwealth is 5.3:1, for the reporting year.

Actual contributed resources 2005-06:

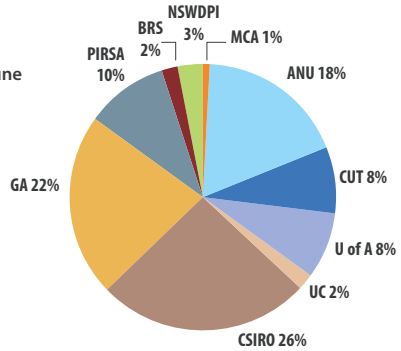
- Total Cash from Industry and other users, and from Core Participants: $2.53M;
- Total In-Kind resources from participants $15.09M, giving a total of $17.62M.
- CRC Programme funds: $3.3M.

Financial Reports for 2005-06

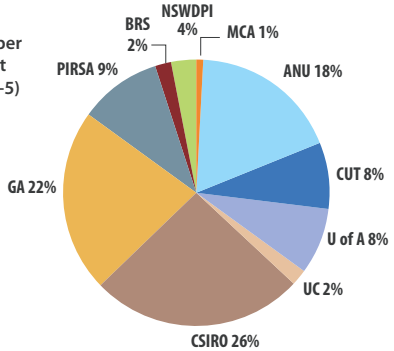
The following statements and accounting policy notes represent the known financial status as at 30 June, 2006.

Core Participant equity positions are summarised as follows:

Core Participant Actual Cumulative Equity as at June 2006 (Years 1-5)



Core Participant Equity as per Commonwealth Agreement as at 30 June 2006 (Years 1-5)



Total External Income

	Year 1 $'000	Year 2 $'000	Year 3 $'000	Year 4 $'000	Year 5 $'000	Cumulative $'000
Budget	765	1,080	1,658	1,869	1,675	7,047
Actual	892	811	1,509	1,294	1,522	6,028
Variance	127	-269	-149	-575	-153	-1,019

Significant Accounting Policies

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

Income

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

Expenditure

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

Intellectual property

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

Capital expenditure and other expenditure commitments

There were no capital expenditure commitments approved and/or entered into as at 30 June 2005, and for which goods had not been receipted at 30 June 2006.

OTHER NOTES

Costing of contributions

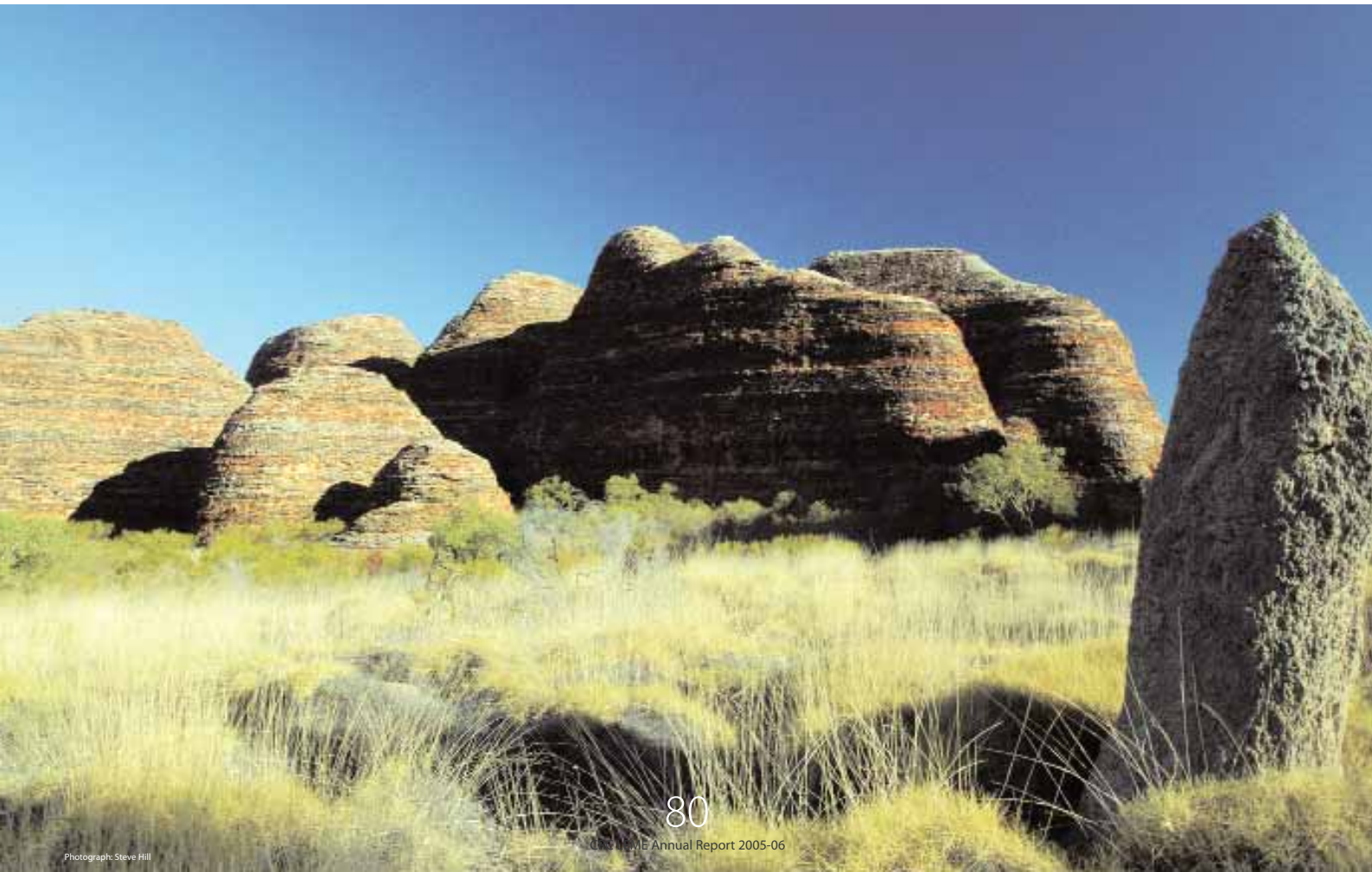
Costing of salaries and on-costs contributed by the Core Participants is as reported to the Centre by each Core Participant. In no case does the reported amount of salary on-costs exceed the agreed valuation of on-costs shown in Schedule 4 of the Commonwealth Agreement, viz:

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

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

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

The Budget and Financial report was prepared by the Business Manager Gary Kong with assistance from Centre Accountant, John Mills.



Photograph: Steve Hill

TABLE 1: IN-KIND CONTRIBUTIONS (PER PARTICIPANT) (Dollars in '000s)

	ACTUAL						CUMULATIVE		PROJECTED				GRAND TOTAL		
	YEAR 1 2001 / 02 Actual	YEAR 2 2002 / 03 Actual	YEAR 3 2003 / 04 Actual	YEAR 4 2004 / 05 Actual	YEAR 5 2005 / 06 Actual	YEAR 5 2005 / 06 Agreement	TOTAL TO DATE Actual	TOTAL TO DATE Agreement	YEAR 6 2006 / 07 Projected	YEAR 6 2006 / 07 Agreement	YEAR 7 2007 / 08 Projected	YEAR 7 2007 / 08 Agreement	Projected Total 7 Years	Agreement 7 Years	Difference 7 Years
CORE PARTICIPANTS															
THE AUSTRALIAN NATIONAL UNIVERSITY															
SALARIES	474	431	765	798	877	809	3,345	3,115	758	834	781	859	4,884	4,808	77
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	1,126	1,169	2,336	2,352	2,547	2,512	9,530	9,296	2,263	1,723	1,854	1,687	13,647	12,706	941
TOTAL	1,600	1,600	3,101	3,150	3,424	3,321	12,875	12,411	3,021	2,557	2,635	2,545	18,531	17,513	1,018
UNIVERSITY OF CANBERRA															
SALARIES	314	81	-	-	-	-	395	343	-	-	-	-	395	343	53
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	852	329	-	-	-	-	1,181	1,114	-	-	-	-	1,181	1,114	68
TOTAL	1,166	410	-	-	-	-	1,576	1,456	-	-	-	-	1,576	1,456	120
GEOSCIENCE AUSTRALIA															
SALARIES	974	839	814	846	805	785	4,278	3,957	766	741	789	764	5,833	5,462	371
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	1,973	1,928	2,457	2,600	2,573	2,304	11,531	11,507	2,623	2,012	1,917	1,942	16,071	15,461	610
TOTAL	2,947	2,767	3,271	3,446	3,378	3,089	15,809	15,464	3,389	2,753	2,706	2,706	21,904	20,923	981
CURTIN UNIVERSITY OF TECHNOLOGY															
SALARIES	329	423	433	486	500	483	2,171	2,043	468	497	482	512	3,121	3,052	70
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	469	646	629	765	784	788	3,293	3,121	727	670	719	689	4,739	4,480	259
TOTAL	798	1,069	1,062	1,251	1,284	1,271	5,464	5,164	1,195	1,167	1,201	1,201	7,860	7,532	329
ADELAIDE UNIVERSITY															
SALARIES	314	403	400	363	315	427	1,795	1,842	254	522	270	538	2,319	2,902	(583)
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	373	626	753	728	950	813	3,430	3,263	959	691	978	710	5,367	4,664	703
TOTAL	687	1,029	1,153	1,091	1,265	1,240	5,225	5,105	1,213	1,213	1,248	1,248	7,686	7,566	120
PRIMARY INDUSTRIES & RESOURCES,SOUTH AUSTRALIA															
SALARIES	506	523	551	594	586	584	2,760	2,499	677	601	698	619	4,135	3,719	416
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	1,984	521	584	627	619	617	4,335	4,095	710	634	730	652	5,775	5,381	394
TOTAL	2,490	1,044	1,135	1,221	1,205	1,201	7,095	6,594	1,387	1,235	1,428	1,271	9,910	9,100	810
BUREAU OF RURAL SCIENCES															
SALARIES	193	16	-	-	-	-	209	208	-	-	-	-	209	208	1
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	139	12	-	-	-	-	151	150	-	-	-	-	151	150	1
TOTAL	332	28	-	-	-	-	360	358	-	-	-	-	360	358	2
NEW SOUTH WALES DEPARTMENT OF PRIMARY INDUSTRIES															
SALARIES	224	235	223	318	374	364	1,374	1,347	390	373	391	382	2,155	2,102	53
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	29	30	63	76	83	81	281	276	85	83	85	84	451	443	8
TOTAL	253	265	286	394	457	445	1,655	1,623	475	456	476	466	2,606	2,545	61
MINERALS COUNCIL OF AUSTRALIA															
SALARIES	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	-	-	35	35	35	35	105	105	35	35	35	35	175	175	-
TOTAL	-	-	35	35	35	35	105	105	35	35	35	35	175	175	-
CSIRO															
SALARIES	1,333	1,398	1,169	1,285	1,289	1,144	6,474	5,916	1,465	1,202	1,524	1,263	9,463	8,381	1,082
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	2,559	2,457	2,511	2,772	2,747	2,405	13,046	12,690	2,931	1,904	2,684	1,987	18,661	16,581	2,080
TOTAL	3,892	3,855	3,680	4,057	4,036	3,549	19,520	18,606	4,396	3,106	4,208	3,250	28,124	24,962	3,162
SUPPORTING PARTICIPANT															
SALARIES	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL IN-KIND CONTRIBUTIONS															
SALARIES	4,661	4,349	4,355	4,690	4,747	4,596	22,802	21,269	4,778	4,770	4,935	4,937	32,515	30,976	1,539
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER	9,504	7,718	9,368	9,955	10,338	9,555	46,883	45,617	10,333	7,752	9,002	7,786	66,218	61,154	5,064
GRAND TOTAL (IN-KIND)	**14,165**	**12,067**	**13,723**	**14,645**	**15,085**	**14,151**	**69,685**	**66,886**	**15,111**	**12,522**	**13,937**	**12,722**	**98,733**	**92,130**	**6,603**

TABLE 2: CASH CONTRIBUTIONS (Dollars in '000s)

	ACTUAL						CUMULATIVE		PROJECTED				GRAND TOTAL		
	YEAR 1 2001 / 02 Actual	YEAR 2 2002 / 03 Actual	YEAR 3 2003 / 04 Actual	YEAR 4 2004 / 05 Actual	YEAR 5 2005 / 06 Actual	YEAR 5 2005 / 06 Agreement	TOTAL TO DATE Actual	TOTAL TO DATE Agreement	YEAR 6 2006 / 07 Projected	YEAR 6 2006 / 07 Agreement	YEAR 7 2007 / 08 Projected	YEAR 7 2007 / 08 Agreement	Projected Total 7 Years	Agreement 7 Years	Difference 7 Years
Core participants															
ANU	100	150	200	200	200	200	850	850	100	100	100	100	1,050	1,050	-
CURTIN UNI	100	100	100	100	100	100	500	500	100	100	100	100	700	700	-
ADELAIDE UNI	100	100	100	100	100	100	500	500	100	100	100	100	700	700	-
UNI OF CANBERRA	100	50	-	-	-	-	150	150	-	-	-	-	150	150	-
CSIRO	150	100	150	200	200	200	800	800	100	100	100	100	1,000	1,000	-
GEOSCIENCE AUST	100	150	100	100	113	100	563	550	100	100	100	100	763	750	13
PIRSA	-	-	-	100	100	100	200	200	100	100	100	100	400	400	-
BRS	810	-	-	-	-	-	810	810	-	-	-	-	810	810	-
NSW DPI	250	250	250	100	100	100	950	950	50	50	-	-	1,000	1,000	-
MCA	100	100	105	80	80	80	465	460	40	40	-	-	505	500	5
TOTAL	1,810	1,000	1,005	980	993	980	5,788	5,770	690	690	600	600	7,078	7,060	18
Supporting Participants	-	300	-	141	10	10	451	451	-	-	-	-	451	451	-
OTHER CASH															
Non Participants	-	-	-	-	-	-	-	1,900	-	-	-	-	-	1,900	(1,900)
External Grants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contract Research	696	599	1,286	1,075	1,331	900	4,987	3,000	1,650	1,325	1,102	1,100	7,739	5,425	2,314
Commercialisation	-	-				640	-	1,665	-	640	-	640	-	2,945	(2,945)
Education	86	17	24	33	32	120	192	393	20	120	20	120	232	633	(401)
Interest Income	110	195	199	187	159	15	850	89	80	15	-	15	930	119	811
TOTAL	892	811	1,509	1,294	1,522	1,675	6,028	7,047	1,750	2,100	1,122	1,875	8,900	11,022	(2,122)
CRC FUNDING	2,754	3,300	3,300	3,300	3,300	3,300	15,954	15,954	2,700	2,700	1,546	1,546	20,200	20,200	-
TOTAL CRC CASH CONTRIBUTION (T2)	5,456	5,411	5,814	5,715	5,825	5,965	28,221	29,222	5,140	5,490	3,268	4,021	36,629	38,733	(2,104)
Cash carried over from previous year Note (a)	777	2,504	3,566	3,492	3,087	3,087	-	-	2,349	2,453	906	2,708	-	-	-
Less Unspent Balance	2,504	3,566	3,492	3,087	2,349	2,453	-	1,196	906	2,708	-	1,257	-	-	-
TOTAL CASH EXPENDITURE	3,729	4,349	5,888	6,120	6,563	6,599	26,649	28,026	6,583	5,235	4,174	5,472	36,629	38,733	(2,104)
ALLOCATION OF CASH EXPENDITURE BETWEEN HEADS OF EXPENDITURE															
SALARIES	1,916	1,898	2,541	2,794	2,788	2,913	11,937	13,442	2,918	1,254	1,898	1,162	16,753	15,858	895
CAPITAL	-	245	-	190	16	-	451	451	-	-	-	-	451	451	-
OTHER	1,813	2,206	3,347	3,136	3,759	3,686	14,261	14,133	3,665	3,981	2,276	4,310	19,425	22,424	(2,999)

Note (a): Balance brought forward at 1.7.01 relates to residual funds from CRC LEME 1 brought into CRC LEME 2

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

	ACTUAL						CUMULATIVE		PROJECTED				GRAND TOTAL		
	YEAR 1 2001 / 02 Actual	YEAR 2 2002 / 03 Actual	YEAR 3 2003 / 04 Actual	YEAR 4 2004 / 05 Actual	YEAR 5 2005 / 06 Actual	YEAR 5 2005 / 06 Agreement	TOTAL TO DATE Actual	TOTAL TO DATE Agreement	YEAR 6 2006 / 07 Projected	YEAR 6 2006 / 07 Agreement	YEAR 7 2007 / 08 Projected	YEAR 7 2007 / 08 Agreement	Projected Total 7 Years	Agreement 7 Years	Difference 7 Years
GRAND TOTAL (IN-KIND) From Table 1	14,165	12,067	13,723	14,645	15,085	14,151	69,685	66,886	15,111	12,522	13,937	12,722	98,733	92,130	6,603
GRAND TOTAL (CASH EXPENDITURE) from Table 2	3,729	4,349	5,888	6,120	6,563	6,599	26,649	28,026	6,583	5,235	4,174	5,472	37,406	38,733	(1,327)
APPLIED TO ACTIVITIES OF CENTRE	17,894	16,416	19,611	20,765	21,648	20,750	96,334	94,912	21,694	17,757	18,111	18,194	136,139	130,863	5,276
ALLOCATION OF TOTAL RESOURCES APPLIED TO ACTIVITIES OF THE CRC BETWEEN HEADS OF EXPENDITURE															
TOTAL SALARIES (CASH AND IN-KIND)	6,577	6,247	6,896	7,484	7,535	7,509	34,739	34,711	7,696	6,024	6,833	6,099	49,268	46,834	2,434
TOTAL CAPITAL (CASH AND IN-KIND)	-	245	-	190	16	-	451	451	-	-	-	-	451	451	-
TOTAL OTHER (CASH AND IN-KIND)	11,317	9,924	12,715	13,091	14,097	13,241	61,144	59,750	13,998	11,733	11,278	12,096	86,420	83,578	2,842
TOTAL	17,894	16,416	19,611	20,765	21,648	20,750	96,334	94,912	21,694	17,757	18,111	18,194	136,139	130,863	5,276

TABLE 4: ALLOCATION OF RESOURCES BETWEEN CATEGORIES OF ACTIVITIES

PROGRAM	RESOURCE USAGE			
	$ CASH (000's)	$ IN-KIND (000's)	CONTRIBUTED (IN - KIND) RESEARCH STAFF (FTEs)	CRC FUNDED RESEARCH STAFF (FTEs)
RESEARCH	4,533	13,571	45.65	21.88
EDUCATION	782	633	0.15	1.70
EXTERNAL COMMUNICATIONS	-	-	-	-
COMMERCIALISATION/TECHNOLOGY TRANSFER	-	-	-	-
ADMINISTRATION	1,248	881	-	-
TOTAL	6,563	15,085	45.80	23.58

Photograph: Steve Hill

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Independent audit report to the Cooperative Research Centre for Landscape Environments and Mineral Exploration

Scope

We have audited the attached financial information, which comprises the statement of in-kind contributions (per participant), the statement of cash contributions, the summary of resources applied to activities of the centre and the allocation of resources between categories of activities for the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME) for the year ended 30 June 2006. It has been prepared for distribution to the Cooperative Research Centres Program, Department of Education, Science and Training (the Commonwealth) for the purpose of fulfilling the requirements of the Commonwealth Agreement dated 13 August 2001 ("the Agreement"), the Deed of Release and Variation dated 27 June 2005.

The board of management of CRC LEME is responsible for the preparation and presentation of the financial information in accordance with the Agreement. We conducted an independent audit of the financial information in order to express an opinion on it to the board of management of CRC LEME. 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 board of management of CRC LEME and the Commonwealth, or for any purpose other than that for which they were prepared.

Our audit was conducted in accordance with Australian Auditing Standards. Our procedures included the examination, on a test basis, of evidence supporting the amounts disclosed in the financial information. These procedures have been performed to assess whether in all material respects the financial information is presented fairly in accordance with the Agreement (specifically those provisions referred to in Section 6 of the CRC Program Guidelines for Annual Reports 2005-06), which does not require the application of all Accounting Standards and other mandatory financial reporting requirements in Australia.

This audit opinion expressed in this report has been formed on the above basis.

Audit opinion

In our opinion:

a) the attached financial information for the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME) presents fairly, in accordance with Australian Accounting Standards and the provisions of the Commonwealth Agreement dated 13 August 2001, the Deed of Release and Variation dated 27 June 2005, the sources

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of funding and the application of that funding for the year ended 30 June 2006;

b) Contributions, both cash and in-kind, have been made and recorded in accordance with the Budget;
c) Cash contributions have been paid into and expended from the CRC's Account;
d) The application of Commonwealth Funding and Contributions for the Activities of the CRC has been only for the Activities specified in Schedule 1 of the Commonwealth Agreement;
e) The CRC has met its obligations in relation to the treatment of Heads of Expenditure/Expense categories, IP and Capital items; and
f) In accounting for the Commonwealth Funding and Contributions, the CRC has exercised proper accounting standards and controls.

PricewaterhouseCoopers

PricewaterhouseCoopers

S.T. Maher

S T Maher
Partner

Perth
6 September 2006

Glossary and Acronyms

Glossary *

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

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

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

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

Anaerobic: capable of living without free oxygen

Aquifer: a permeable layer carrying accessible water

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

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

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

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

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

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

Cover: see Regolith

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

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

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

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

Ferruginous: pertaining to or containing iron

Goethite: common, yellow-brown iron oxide mineral

Hematite: black/blue-black or red mineral, hexagonal close-packed structure

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

***In situ*:** in its original place

Kaolinite: white clay mineral

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

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

Lag: surface accumulation of divers materials, eg regolith, rock

Mafic: rock or mineral of high magnesium and iron content

Magnetite: mineral of the spinel family, strongly ferromagnetic

Mahegmite: magnetic mineral formed by the oxidation of magnetite

Morphology: shape, form, external structure or arrangement

Nanoparticulate: made up of particles with dimensions of a few nanometres (10-9 m)

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

Pedology: the study of soil morphology, genesis and classification

Permeability: the capacity of a rock for transmitting fluid

Phyto-exploration: the technique of looking for metal anomalies in plant tissues as an indicator of buried mineralisation.

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

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

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

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

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

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

Rhizomorphs: root-like structure in plants

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

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

Tdhem: time domain helicopter electromagnetic

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

Traverse: a line surveyed across a plot of ground

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

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

Acronyms

3D: Three-Dimensional

4D: Four-Dimensional (spatial + time)

4WD: Four-Wheel Drive

ACLEP: Australian Collaborative Land Evaluation Program

AEM: Airborne ElectroMagnetics

AFFA: Australian Government Department of Agriculture, Fisheries and Forestry

AGC: Australian Geological Convention

AGES: Annual Geoscience Exploration Seminar

AGIA: Australian Geoscience Information Association

AIG: Australian Institute of Geoscientists

AusIMM: Australasian Institute of Mining and Metallurgy

AINSE: Australian Institute of Nuclear Science and Engineering

AJES: Australian Journal of Earth Sciences

AM: Aeromagnetic

AMEC: Association of Mining and Exploration Companies

AMIRA: Australian Mineral Industries Research Association (International)

AMT: Audio-magnetotellurics

ANC: Acid Neutralisation Capacity

ANU: The Australian National University

ANU RSES: ANU Research School of Earth Sciences

ANSTO: Australian Nuclear Science and Technology Organisation

ANZGG: Australia New Zealand Geomorphology Group

APA: Australian Postgraduate Award

APAI: Australian Postgraduate Award (Industry)

ARC: Australian Research Council

ARRC: Australian Resources Research Centre

ASCILITE: Australasian Society for Computers in Learning in Tertiary Education

ASRIS: Australian Soil Resource Information System

ASEG: Australian Society of Exploration Geophysicists

ASS: Acid Sulfate Soils

ASSS: Australian Society of Soil Science Inc

ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer

AVS: Acid Volatile Sulfides

ATSE: Academy of Technological Sciences and Engineering

AutoGeoSEM: Automatic Geological Scanning Electron Microscope

BRS: Bureau of Rural Sciences

BRS: Bacterial Sulfate Reduction

CDI: Conductivity Depth Image

CD: Compact Disc

CEM: CSIRO Exploration and Mining

CLW: CSIRO Land and Water

CMA: Catchment Management Authority

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

CRC: Cooperative Research Centre

CRM: Chemical Remnant Magnetism

CSIRO: Commonwealth Scientific and Industrial Research Organisation

CUPS: Curtin University Postgraduate Scholarship

CUT: Curtin University of Technology

DAWA: Department of Agriculture and Food, Western Australia

DNA: Deoxyribonucleic Acid

DEH: Department for Environment and Heritage, South Australia

DEM: Digital Elevation Model

DIPNR: Former NSW Dept of Infrastructure Planning and Natural Resources

DLWC: NSW Dept of Land and Water Conservation

DNR: New South Wales Department of Natural Resources

DNRM: Department of Natural Resources and Mines Queensland

DPI: Department Primary Industries Victoria

DTB: Depth To Basement

DTM: Digital Terrain Mapping

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

EKS: Electrokinetic Seismic

EMflow: Airborne EM interpretation

EM: Electromagnetic

EMP: Electron Microprobe

FDEM: Frequency Domain Electromagnetics (could be either ground or airborne)

FTE: Full Time Equivalent

GA: Geoscience Australia

GAB: Great Artesian Basin

GEMOC: The ARC National Key Centre for Geochemical Evolution and Metallogeny of Continent at Macquarie University, NSW

geoPIXE: Software for quantitative and non-destructive Particle-Induced X-ray Emission (PIXE) analysis and imaging

GFS: Groundwater Flow Systems

GIS: Geographic Information System

GPS: Global Positioning System

GPR: Ground Penetrating Radar

GRM: Gamma Radiometrics Methods

GSWA: Geological Survey of Western Australia

HEM: Helicopter Frequency Domain Electromagnetic

HGU: Hydrogeomorphic Units

HRU: Hydrogeomorphic Response Unit

ICPMS: Inductively Coupled Plasma Mass Spectrometry

IGPC: International Geological Correlation Program

IGU: International Geographical Union

INAA: Instrumental Neutron Activation Analysis

IP: Induced Polarisation

IP: Intellectual Property

IPRS: International Postgraduate Research Scholarship

IUGG: International Union of Geodesy and Geophysics

IUGS: International Union of Geological Sciences

Glossary and Acronyms

IUSS: International Union of Soil Sciences

LA: Laser Ablation

LAICPMS: Laser Ablation Inductively Coupled Mass Spectrometry

LEME: Cooperative Research Centre for Landscape Environments and Mineral Exploration

MCA: Minerals Council of Australia

MDBC: Murray-Darling Basin Commission

MERIWA: Minerals and Energy Research Institute of WA

MGA: Map Grid of Australia

MINEX: Minerals Exploration

MMI-I: Mobile Metal Ion

MTEC: Minerals Tertiary Education Council

NanoTEM: A ground based TEM system

NAPSWQ: National Action Plan (for Salinity and Water Quality)

NatCASS: National Committee for Acid Sulfate Soils

NGTN: National Geoscience Teaching Network

NHT: National Heritage Trust

NITON XRF: Portable X-Ray Fluorescence technology

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

NLWRA: National Land and Water Resources Audit

NMR: Nuclear Magnetic Resonance

NRM: Natural Resource Management

NTGS: Northern Territory Geological Survey

OSL: Optically Stimulated Luminescence dating method

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

PCR: Polymerase Chain Reaction

PIRSA: Primary Industries and Resources South Australia

pmd*CRC: CRC for Predictive Mineral Discovery

PDF: Portable Document Format

PHREEQC: A computer program for speciation, batch-reaction, one-dimensional transport and inverse geochemical calculations

PIMA: Portable Infrared Minerals Identifier

ppb: Parts per billion

ppm: Parts per million

ppt: Parts per thousand

PURSL: Productive Use and Rehabilitation of Saline Lands

RCAs: Regional Carbonate Accumulations

REE: Rare Earth Elements

RESOLVE: A kind of helicopter frequency domain AEM system

RIRDC: Rural Industries Research and Development Corporation

RNA: Ribonucleic acid

RTMAP: Regolith Terrain Mapping

SAM: Sub Audio Magnetics

SDP: Soil Gas Geochemistry

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

SIF3: Salinity Investment Framework III model

SIS: Salt Interception Scheme

SMMSP: Salinity Mapping and Management Support Project

SXRF: Synchrotron X-Ray Fluorescence

TSA: The Spectral Assistant (computer software)

TSG: The Spectral Geologist (computer software)

TEM: Time Domain Electromagnetics

TEM: Transmission Electron Microscopy/Microscope

TIMS: Thermal Ionisation Mass Spectrometry

UC: University of Canberra

U of A: The University of Adelaide

UNSW: University of New South Wales

UWA: The University of Western Australia

VHMS: Volcanic Hosted Massive Sulfide (deposit)

VSWIR: Visual to Shortwave Infra red

UV-VS: Ultra-Violet Visible Spectrophotometry

WRI: Water-Rock Interaction

XRD: X-Ray Diffraction

XRF: X-Ray Fluorescence

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