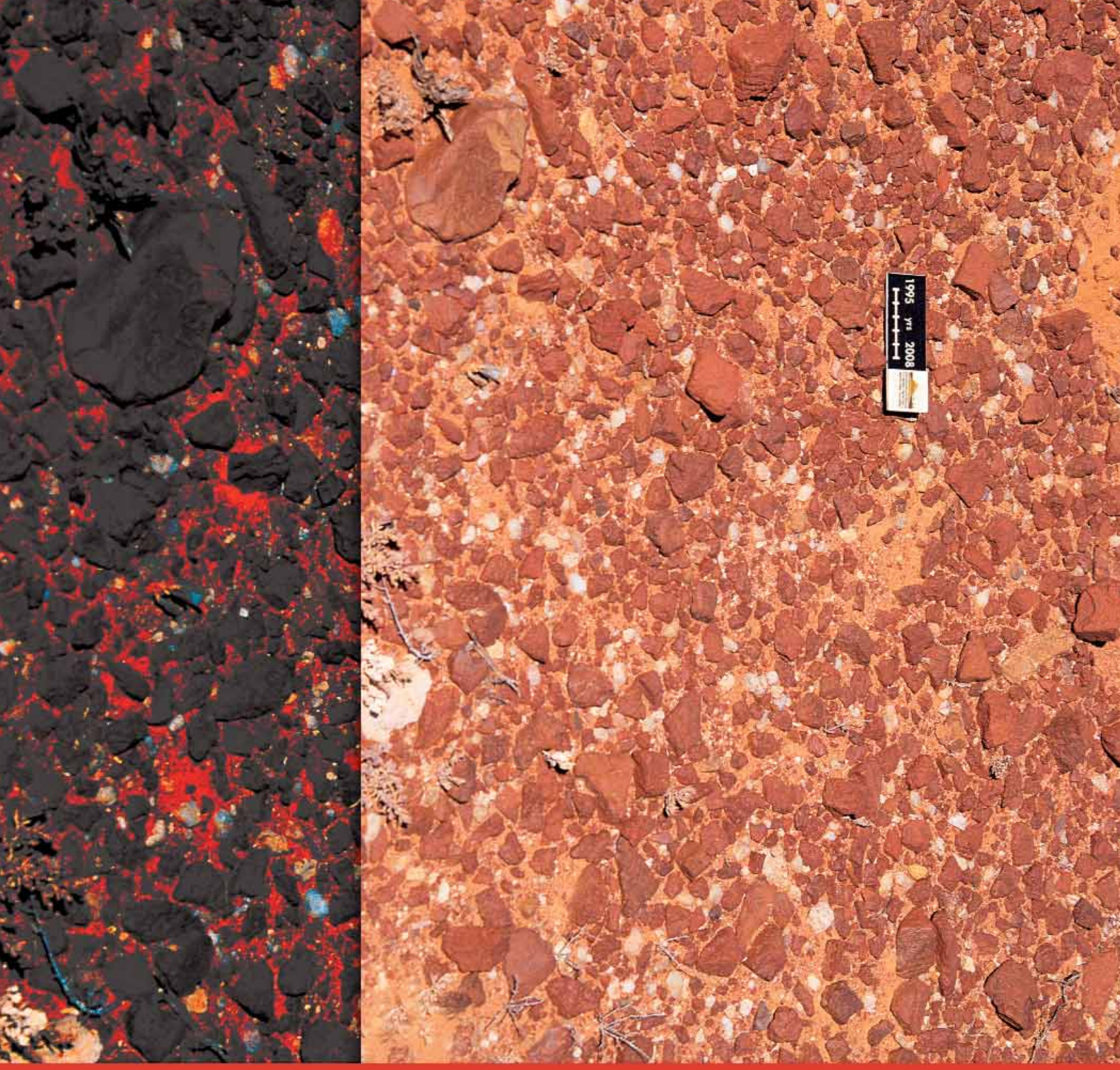

CRCLEME

Cooperative Research Centre for
Landscape Environments
and Mineral Exploration

CRCLEME FINAL ANNUAL REPORT

2007–08

CRC
AUSTRALIA

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.



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 multidisciplinary 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.

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

Executive Summary

Mr George Savell

Chairman's Report 2008

This Annual Report is the last that Cooperative Research Centre – Landscape Environment and Mineral Exploration (CRC LEME) will publish.

It provides a vehicle to not only talk about immediate matters such as legacy products, but an opportunity to cast a long look back over the road we have travelled to reach this point. In that respect I draw your attention to the messages provided by Dr Ross Fardon, Dr Ray Smith and Dr Dennis Gee, all of whom have contributed very creditably to the life and times of both incarnations of these Regolith CRCs. They can be found in the section titled "Reflections".

There is no doubt that CRC LEME has been a very successful CRC. The project outcomes, legacy products and open research paths illustrate this fact more clearly than the spoken word. The students, researchers and research managers can be justly proud of their achievements. The road has been long, and sometimes rocky, but never boring. This feature of the organisation has made the tasks set for us very interesting.

We pass the regolith baton to the new generation and trust they will seize it and forge on to the ultimate victory, the holy grail of complete understanding of the mysterious processes which form the complete regolith. We can only hope as we enter the final few months of the CRC LEME's existence.

The past year has been exceptionally busy for administrators, researchers and, indeed, the CRC's Governing Board.

The CRCs' support staff were fully occupied with not just routine work but wind-up strategies, run-out budgeting to ensure funds would last until termination date, and the full and final reimbursements to research providers for each project which was not transferred to another party for ongoing work. The whole exercise was akin to a master juggler's premier performance. Indeed, long time Business Manager, Gary Kong, met every challenge and in a timely and professional way; kept the process on track and on budget throughout.

The Program Leaders delivered outcomes from a multitude of concluding projects. The Board's congratulations are recorded to one and all for a job well done.

When CRC LEME received its grant and thus acceptance as a second round continuation of the original organisation I was there and recall the incredulous looks and exclamations by the Funding Committee Members when Ray Smith told them the plan to achieve an outturn of 60 Postgraduate students and 60 Honours students during the life of the organisation.

Well, despite a major mining boom and the fact that a number of Postgraduate students deferred to take jobs in the industry, we expect to have delivered 54 Postgraduate students and 117 Honours students before we fold our tent for the last time on 31st December, 2008.

But what else has the CRC achieved?

Perhaps the most notable thing is that during the past several years many agricultural disciplines as well as a good many mineral explorers have come to understand the importance of regolith research.

In agriculture, and in the question of dry land salt particularly, our scientists have demonstrated time and again that the only cure worth having is one which defines and treats the cause not the effect. By unlocking the mechanics of the Regolith and its systems, long-term solutions to many problems become possible.

Clearly we have not reached total understanding yet and there is a long way to go, particularly in mineral exploration systems but a good start has been made.

It is my personal view that a monumental mistake was made in not seeking to turn the CRC LEME into a Research Institute to continue the Regolith work it started into an on-going specialist science. It is not hard to demonstrate a community benefit far beyond its current work. What is needed is a co-ordinated group capable of supplying expert guidance to Governments and industry alike in all areas where Regolith matters are part of the scientific equation.

It is also appropriate to comment on the CRC system generally and to look at the many obvious flaws which have emerged over the years.

One very pertinent area is political influence. I recall clearly the Howard Government's classic mistake in announcing that "commercial" CRC applications would be viewed more favourably than "public good" applications. It obviously never dawned on them that this was a clear distortion of research needs and they were trying to pick winners, which no Government is ever very good at doing. Now, of course, all is forgiven and more normal times have returned "public good" is no longer bad.

To co-ordinate a programme of real worth, however, what is needed is a council of senior scientists who review all the applications made to establish what research is vital to Australia's future, free of politics and short-term considerations. This would kill two birds with one stone by containing the effort to producing needed answers and focussing available funds more effectively.

Lastly, I wish to thank loyal Head Office staff members and most especially the students and staff who made the CRC success possible. I also thank my fellow Board Members for their dedicated service to the CRC. It has been a pleasure working with you on such worthwhile issues.

Farewell and good luck in your future endeavours.

George A. Savell

Chief Executive Officer's Report

Ms Lisa Worrall

Dr Steve Rogers

This final Chief Executive Officer's report is jointly authored by Steve Rogers and Lisa Worrall – reflecting the transition from Steve to Lisa during CRC LEME's wind up period.

LEME DELIVERY

It is with great pleasure that we can report that CRC LEME has met all of its objectives.

CRC LEME has '*provided the minerals industry with world-leading capabilities leading to breakthroughs in exploration in Australia's extensive areas of cover.*' For example, CRC LEME research was instrumental in identifying new exploration targets for heavy minerals sands explorers on the South Australian margin of the Eucla Basin, and in opening up a new mineral province (see Case Study A).

The Centre has also led the way in the development of cost-effective, reliable and practical exploration techniques in the areas of biogeochemistry and hydrogeochemistry. CRC LEME researchers used river red gums to make a major mineral discovery near the Pinnacles, west of Broken Hill. Leaves from these trees, containing over 400 ppm lead and zinc and elevated silver, cadmium and gold, pointed to the buried Perseverance Lode: a resource with an estimated 6-12 million tonnes of ore. These trees are widespread across much of Australia and the technique has considerable potential.

Biogeochemical sampling programs have minimal environmental impact, especially when compared to other techniques, such as drilling. Surveys can be conducted on foot or from small vehicles, and only require the collection of a small bag of plant material. As a result, they can provide minimal impact access to sites that are otherwise environmentally and culturally sensitive. It is anticipated that sampling programs will ultimately benefit from the understanding that local indigenous communities have of plant and landscape associations, and that biogeochemical exploration could provide business opportunities for these groups.

Case Study A: Eucla Basin

Background

The palaeo-shorelines of the Eucla Basin provide information critical to understanding the landscape evolution and Cainozoic marine flooding events in south-western Australia. The shoreline sediments are also highly prospective for zircon and other heavy minerals. CRC LEME established a correlation between offshore marine sediments and their poorly-constrained onshore equivalents, providing new insight into the extent and timing of major sea level fluctuations over the period 38 to 10 Million years ago.

This knowledge was applied to:

- constructing models for heavy mineral accumulation in fossil beach deposits along the Eucla Basin margin,
- refining techniques to map onshore sediments resulting in a 1:2,000,000 scale map of Palaeodrainage and Tertiary Coastal Barriers of South Australia.

Impact

Models published by LEME researchers in late 2003 identifying various styles and potential sites for heavy mineral placer deposits on the eastern margin of the Eucla Basin helped to reinvigorate exploration in the region. Since November 2004, ten new 'greenfield' heavy mineral discoveries have been made with a total in-ground value of resources in excess of A$4 billion, at current zircon prices. The zircon-rich Jacinth-Ambrosia deposits have been approved for fast-track development by Iluka Resources.

Release of the SA Palaeodrainage and Tertiary Coastal Barriers Map in May 2007 was followed, from May to September 2007, by 78 new exploration tenement applications over palaeodrainage channels and associated sediments.

Our minerals industry end-users state:

"Work by CRC LEME to reconstruct Tertiary shoreline evolution in the Eucla Basin has been very valuable to Iluka for HM exploration. Using the palaeochannel map and shoreline interpretations have helped us build a successful geological model to drive exploration."

Ian Warland, Manager Geology Eucla Basin, Iluka Resources Ltd

"Revised stratigraphy and HM models published in 2003 by Hou and his team at CRC LEME were a critical ingredient in accelerating exploration activity in the Eucla Basin, while the associated work on Tertiary palaeochannels in South Australia has been no less significant in industries uranium exploration effort."

Chris Drown, Managing Director, Adelaide Resources Ltd

CRC LEME has provided '*essential multi-disciplinary knowledge of Australia's regolith environments, delivered this knowledge in readily useable forms, and ensured that it is transferred into practice in the minerals industry and environmental management.*' For example, CRC LEME research on acid sulfate soils (ASS) has had a significant impact on the development of effective environmental management strategies in the Murray Basin (see Case Study B).

CRC LEME has also applied regolith geoscience to salinity risk assessment, and protection of ground and surface water resources from salinisation. Specifically CRC LEME research on the calibration and validation of AEM data and development of appropriate information products has contributed to the design of salt interception schemes, the location of water storage facilities, the development of saline groundwater disposal options, informing irrigation re-zoning, mapping and predicting salinity risk in floodplain environments, mapping salt water intrusion, and underpinning strategies to target environmental water flows for sustaining floodplain biodiversity.

Case Study B: Management of acid sulfate soils (ASS) in the Lower Murray River

Background

The importance of ASS in environmental risk management strategies was overlooked by the community and government in the early part of this decade, largely because of the publicity being given to salinity problems. Nevertheless CRC LEME maintained research activity on this topic, believing, correctly as it turned out, that the problem of ASS would eventually be too big to be ignored.

Issue

The current drought in south eastern Australia is officially the worst on record, with minimal inflows to the River Murray. The main impact is clearly on water shortages, but management strategies have also focussed on ecosystem stress and salinity issues. Large parts of the River Murray system (including the Lower Lakes: Albert and Alexandrina) has begun to dry up, uncovering extensive areas of ASS, which are much more abundant than previously assumed. The discovery of ASS initially led to a perceived 'knowledge gap' in assessing management options which did not include the risks associated with ASS i.e. acidification, metal mobilisation, de-oxygenation, noxious gas release.

Impact

The CRC LEME research focus on rapid mapping, risk assessment and characterisation of ASS meant that many of the protocols for assessing the extent and character of ASS in the Basin are in place. This allowed very rapid assessments to be completed and effective management decisions to be made; maximising water allocation options in an area already overstressed for water availability. CRC LEME researchers are now involved in projects across the Basin, in partnership with State (SA Department of Environment and Heritage, SA Murray Darling NRM Board, Department of Water, Land and Biodiversity Conservation, Rural Solutions SA) and Federal agencies (Department of Water, Environment, Heritage and Arts) and the Murray Darling Basin Commission.

Management Outcomes

- determining which wetlands to close off from the river and which should be maintained due to high ASS risk;
- using risk ranking to select wetlands to be refilled when environmental water is available;
- building a bund between the Lower Lakes and pumping at a rate of 10 ML/day from Lake Alexandrina into Lake Albert to minimise impacts of ASS.

One of our key end users states:

"In response to extreme drought conditions across the Murray-Darling Basin, a project was initiated by the South Australian Government in late 2006 to investigate the potential to disconnect sites from the river channel to achieve evaporative water savings. During the preliminary investigations, acid sulfate soils were identified as a potential risk. As a result, an approach was made to Rob Fitzpatrick, Paul Shand and team from CSIRO to provide urgent advice on how to proceed. The response was overwhelming – rapid, comprehensive and highly professional. Working to timelines that would have been prohibitive to most individuals and organisations, a work program and schedule was developed and on-ground sampling commenced almost immediately.

As the project progressed, it was clear that we were facing a major and potentially catastrophic problem. As the drought continued, the sampling effort intensified and the program was expanded to include investigations in water bodies below Lock 1 that had become disconnected from the river and in Lakes Albert and Alexandrina as Lakes levels continued to fall, exposing large areas of previously subaqueous soils.

The data that has been gathered throughout this project and associated advances in knowledge has been, and continues to be, invaluable to our understanding about acid sulfate soils and their management. The knowledge that has been generated is so profound as to cause a complete rethink about the management of these inland water bodies and Lakes particularly from an ecological perspective, although there are also obvious significant implications from a social and economic perspective.

I applaud the efforts of CSIRO Land and Water and of the CRC LEME. Without this vitally important work, acid sulfate soils in Murray-darling Basin wetlands and Lakes would continue to be a 'sleeping giant' and the lessons from this drought would be of far less application and consequence"

Judy Goode,
South Australia River Murray Environmental Manager,
South Australia Murray Darling Basin Natural Resource Management Board

CRC LEME has provided '*high quality, geoscience-based education for those entering the minerals industry, land-care and environmental realms and provided continuing education for those already involved*'.

CRC LEME has supported 90 postgraduate and 118 honours students over the past seven years. This support reflects a substantial investment in the education and training of geoscientists at a time when the employment prospects for geoscientists were poor and enrolments in geology courses were low. The upturn in the minerals sector late in the life of LEME has created a demand for geoscientists and LEME students have been able to answer this demand, sometimes delaying or deferring the completion of their degrees as a consequence. These students, trained in regolith geoscience, take the CRC's research outputs, learning and expertise into their new workplaces, thereby promoting technology transfer and the adoption of LEME science (see Case Study C).

Case Study C: A LEME PhD Student

Mike Whitbread completed a PhD degree within CRC LEME with support from Pasminco. His study focused on detecting and quantifying the degree of mineral alteration in and around major ore systems at Elura and Century. Using a lithogeochemical approach Mike was able to show that these ore deposits had a large but cryptic geochemical halo that persisted into the regolith profile and he demonstrated that this pattern could be recognised and used for target vectoring during mineral exploration. Through the CRC and his industry contacts Mike was able to gain valuable experience and knowledge of other aspects of the regolith, particularly the importance of specific mineral hosts for dispersed elements.

In 2004, Mike joined ioGlobal, a group of geochemical consultants based in Australia, but working on projects around the world with varying commodity targets and for many different clients including; Oxiana, BHP, Anvil, Portmans, Goldfields, Minara, Teck Cominco, Vital Metals, and Newcrest.

Part of ioGlobal's 'brief' is to raise the overall level of geochemical expertise in the mining industry, and to assist in the establishment of good geochemical practice in the exploration sector. This was especially important given the poor view of geochemistry held by many industry insiders following the failure of poorly planned and implemented partial leach surveys in areas of significant cover.

Mike's detailed understanding of mineral hosts and geochemical dispersion mechanisms proved invaluable in assisting industry to apply appropriate sampling and analytical methods. In addition to the regular consulting work, Mike has assisted ioGlobal in conducting a series of in-house geochemical training workshops that incorporate key aspects of regolith geochemistry amongst other geochemical topics. These workshops have been carried out for Avocet, Vedanta, Oxiana, Newcrest, and Teck Cominco to name but a few companies. These workshops are the key to raising industry awareness of sampling, analysis and interpretation of geochemical data when exploring or mining.

It is clear that CRC LEME has '*informed and guided decision-makers in the Federal and State policy arenas about the relevance and contribution of the Centre's research to Australia's future.*'

For example, salt interception schemes (SIS) are the most economically viable engineering mechanism that can adequately meet salinity reduction targets. Nevertheless, capital cost is expensive – estimates range from $42m and $162m along stretches of the Riverland. By identifying the salinity 'hotspots' along the Murray River bank using both a floating (towed array) EM system, and by using information on the variability of the Loxton-Parilla Sands aquifer obtained from the airborne EM data, CRC LEME was able to advise on the development of these schemes, which are being developed collaboratively by CSIRO Land & Water, Department of Water Land and Biodiversity Conservation and SA Water, ensuing the effect of site-interception bores was maximised and the cost minimised. Long-term potential benefits in NPV terms may be of the order of $300-400 million.

2007 – 2008 HIGHLIGHTS

CRC LEME was a major presence at a number of key national and international conferences, and industry focussed symposia during 2007-2008. There were 7 invited LEME presentations, including a keynote presentation by Ravi Anand, at the Kalgoorlie 07 Conference: Old Ground New Knowledge in September 2007. There were 29 LEME presentations, including a keynote presentation by Lisa Worrall, at the 19th International Geophysical Conference in November 2007. There were 40 LEME presentations including a keynote presentation by Ken Lawrie, at the 2nd International Salinity Forum in April 2008. LEME also organised two conference workshops on Airborne EM and Catchment Characterisation. There were 25 LEME presentations, including four keynote presentations by David Gray, Brad Pillans, Steve Rogers and Ken Lawrie, at the Australian Earth Sciences Forum in July 2008. In addition, one day industry focussed CRC LEME Mineral Exploration Symposia were held in Perth, Canberra and Adelaide and attracted over 300 industry participants.

Three stories related to CRC LEME research went to air on the ABC TV Catalyst program during the 2008 season. '*Natures Little Diggers*' featuring Steve Hill and Ravi Anand, highlighting our work on biogeochemical exploration techniques went to air in March, and the gold mineralogy and micromorphology work of Rob Hough '*Gold Nuggets*' was aired in April. A further story '*Acid Mud*' highlighting the environmental issues in the lower Murray resulting from the prolonged drought and featuring the acid sulfate sediments work of Rob Fitzpatrick and Paul Shand was aired in May. Transcripts of all three stories can be found on the ABC web site at http://www.abc.net.au/catalyst/stories. It was a great privilege for the CRC to have such a keen interest shown in our work by the national broadcaster flagship science program, and a great credit to the individual researchers involved in the filming.

This year also saw a significant number of prizes and recognitions awarded to CRC LEME researchers and students.

- Lisa Worrall was awarded the Australian Society of Exploration Geophysics award for the *best environmental geophysics presentation* at the International Geophysical Conference in Perth 2007.
- Rob Hough, Charles Butt, Steve Reddy and Mike Verrall received the A.B. Edwards Medal for the best publication in economic geology in 2007 by the Geological Society of Australia.
- Kristy Beckett, was awarded the prize for the *best poster* at the International Geophysical Conference in Perth 2007.
- Vanessa Wong and her co-authors were awarded *Best Paper – Earths Environments Theme*, at the 2008 Australian Earth Sciences Convention, Perth, WA
- The Geoscience Australia Salinity Dynamics team led by Ken Lawrie were presented with the *Highly Commended in the Influence Category* award at the 2007 Geoscience Australia Annual General Meeting.
- Ross Brodie was awarded the *2008 Australia Day Achievement Medallion*, by Geoscience Australia.
- Lisa Worrall and John Wilford were recognised as *Distinguished Geoscience Australia Lecturers* and will receive *Harold Raggatt Awards* from Geoscience Australia.
- The PIRSA-LEME team led by Baohong Hou were presented with the *2007 PIRSA Directors Award* for an outstanding geoscience publication with instant impact on the exploration industry for the SA palaeochannel map.
- Lindsay Collins and Alexandra Stevens were given the *WA Coastal Award for Excellence for Outstanding Partnership in coastal planning*.
- Charles Butt was awarded a *CSIRO Fellowship* by the Office of the Chief Executive Science Team, CSIRO
- Brad Pillans was elected *Honorary Fellow* of the Royal Society of New Zealand.

During the year Dr Nigel Radford of Newmont Mining Corporation, was awarded the 2008 CSIRO/CRC LEME *Butt-Smith Medal* by Dr Steve Rogers and Dr Mike McWilliams, Chief CSIRO Exploration and Mining, for his outstanding and sustained contribution linking regolith science to exploration in Australia.

Congratulations to all.

THE LEME LEGACY

A summary of the Centre's resource allocation during 2007-08 shows $1.28 million on salaries, $0.03 million on student scholarships via the E&T Program, and $2.22 million on research. External income tied to projects was $542 million. Our forward cash flow forecast shows administrative activities and salaries can be resourced to ensure wind-up objectives are met up to the cessation of the 'wind-up' period on December 31st 2008. The CRC LEME Winding-Up Deed was endorsed by the Board that provides a legal agreement between the Core participants, during the July 1st to December 31st 2008 period. As mentioned in our Chairman's report, a number of projects that continue beyond the life of LEME were contractually transferred to Core Participants; these include the Loxton SkyTEM Project, and two Western Australian Acid Drainage Geochemistry projects.

The research and technology transfer legacy that CRC LEME leaves behind is considerable. All our outputs will be available in digital form from our web site, which will remain live for the next 5 years. Nearly 250 'Open File' technical reports can be downloaded, covering the outputs from both CRC funded research and industry/AMIRA sponsored projects that have now come out of their confidentiality. The web site also hosts a searchable digital compendium of 160 CRC LEME regolith maps employing an interactive *Microsoft Virtual Earth* display to select maps and geographically-associated Open File Reports for download.

CRC LEME Guides to Mineral Exploration through the Regolith in the Thomson, Cobar, Curnamona, Central Gawler, Tanami and Yilgarn regions have been produced and will be available on the LEME Website. These Guides outline mineral exploration strategies and procedures in regolith-dominated terrains, based on state of the art knowledge gained from 13 years of CRC LEME 1 and 2 multidisciplinary research activities. The Guides provide a user-friendly introduction to the regolith, models of regional regolith landscape evolution, palaeo and contemporary dispersion processes and information on the most suitable geochemical sampling media and preferred laboratory techniques for identifying anomalies. In addition, a number of complementary products have also been produced, namely the CRC LEME Guides to Describing Regolith and Landforms, Regolith Dating Methods, Biogeochemical and Hydrogeochemical Exploration.

A reference book "Regolith Geoscience" was published during the reporting period and is available from CSIRO Publishing. This volume consists of 14 Chapters that have been authored by LEME researchers. Our special thanks and appreciation go to Keith Scott and Colin Pain who took on the monumental task of editing the volume. The book will be a valuable resource for researchers, postgraduate students and exploration industry/natural resource management geoscience professionals.

More important than the books, reports and guides, is the legacy of people and skills that CRC LEME has developed and nurtured. All of our students take the CRC's research outputs, learning and expertise into their new workplaces, whether they be mineral exploration/mining companies, the commercial environmental management companies, government geoscience and NRM departments or other research institutions. Having over 200 young and enthusiastic regolith geoscientists entering the workforce is an excellent way to ensure the technology transfer and adoption of LEME science. In addition, as a result of LEME investment, Australia now has two dedicated regolith geoscience lecturers, at Curtin and Adelaide Universities.

THE FUTURE OF REGOLITH RESEARCH

With the closure of CRC LEME there will no longer be a single dedicated regolith geoscience research organisation in Australia. However, there are a number of proposals to establish new research groups that will encompass regolith research. A new CRC bid *Deep Targeting Technologies* is currently being prepared by a consortium led by AMIRA International. The mission of the proposed CRC is *Deep ore discovery by opening up both the greenfields and brownfields search space, through quicker, more effective exploration at depth and through cover*. The proposed CRC will build on many of the research advances from CRC LEME, and is currently supported by a number of major multinational mining companies. PIRSA and the University of Adelaide are having discussions about establishing a Centre of Excellence at the University of Adelaide, and regolith research will also continue under the *Discovering Australia's Minerals Resources* theme of CSIRO's new *Minerals Down Under Flagship*.

THANKS

Finally, and we are sure we also speak for the previous CEOs Ray Smith and Dennis Gee, it remains for us to say a heartfelt thanks and farewell to the students, researchers, administrators, Program Leaders, members of the Executive, the Centre's Advisory Councils, the Centre Visitor, the Board of Management, and our external industry and government agency collaborators. It has been a great pleasure to work with such a dedicated and professional group of people. We wish you well in your future endeavours.

Lisa Worrall and Steve Rogers

The CEOs of LEME: *left to right*, Lisa Worrall, Steve Rogers, Dennis Gee and Ray Smith

Photograph by Steven Hill

LEME Board honours and thanks staff and students

At the end of June 2008, three Presentation dinners were held in Canberra, Adelaide and Perth. LEME personnel received engraved plaques, trophies and framed certificates, along with accolades from their peers, in recognition of their significant contributions to LEME over the past seven years. These awards were presented by George Savell and Steve Rogers.

LEME Honorary Fellowships

For Outstanding Contributions to the Development and Promotion of Regolith Science:

- Charles Butt – CSIRO
- Steve Hill – UA
- John Keeling – PIRSA
- Ken Lawrie – GA
- Ken McQueen – ANU
- Colin Pain – GA
- Steve Rogers – CSIRO
- Keith Scott – CSIRO Visiting Fellow
- Lisa Worrall – GA
- George Savell

This group of extraordinary scientists join LEME Fellows Tony Eggleton, Ross Fardon, Graham Taylor, Gerry Govett, Ray Smith, Dennis Gee and David Garnett.

Award for Outstanding Scientific Management and Delivery

- Ravi Anand – Leader Program 2: Mineral Exploration in areas of cover
- Ian Roach – Leader Program 5: Education and Training
- Paul Shand – Leader Program 3: Environmental Applications of Regolith Geoscience (from May 2006)
- Steve Rogers – Leader Program 3: Environmental Applications of Regolith Geoscience (to April 2006)
- Ian Robertson – Initiator (in 1996) and continuing Champion of the CRC LEME Open File Report Series

Team Awards for Outstanding Scientific Achievements

- Large Scale Regolith Mapping in Northern Territory and Queensland (Team – Mike Craig (Leader), Ian Robertson and Matilda Thomas)
- River Murray Corridor Airborne Electromagnetics Project (Team: Ken Lawrie(Leader), Colin Pain, Ross Brodie, Heike Apps, Jon Clarke, Kokpiang Tan, Vanessa Wong, Janine Luckman, David Gibson, Larysa Halas, Kristen Collen, Adore Makui)
- Palaeodrainage and Tertiary Coastal Barriers of South Australia (Team: Bahong Hou (Leader), Wenlong Zang, Adrian Fabris, John Keeling, Liliana Stoian)
- WA Acid Drainage Geochemistry Risk Assessment (Team: Paul Shand (Leader), Rob Fitzpatrick, David Gray, Ryan Noble, Margaret Smith, Adam Lillicrap, Grant Douglas, Brad Degens, Richard George, Steve Rogers)
- Yilgarn Laterite Atlas (Team: Matthias Cornelius (Leader), Ian Robertson, Amanda Cornelius, Paul Morris)
- AMIRA Project 778: Predictive Geochemistry in Areas of Transported Overburden (Team: Ravi Anand (Leader), Mel Lintern, Steve Wakelin, Rob Hough, Craig McFarlane, Brian Townley, Cajetan Phang, Ryan Noble, David Gray, Graham Carr, Mehrooz Aspandiar, Steve Hill, Siriporn Soongpankhao, Nathan Reid, Tenten Pinchand)

Butt Smith Medal

The 2008 Butt Smith Medal for Outstanding and Sustained Research Excellence in Geoscience was awarded to Dr Nigel Radford of Newmont Mining Corporation in a special presentation at the Australian Earth Science Congress in Perth. The Award was presented by Dr Steve Rogers, CEO CRC LEME and Dr Mike McWilliams, Chief of CSIRO Exploration & Mining.

Dr Radford, a Consulting Geochemist at Newmont, is widely known throughout the Australian and the international exploration geochemistry community through his personal research in application and testing of innovative ideas in regolith geochemistry. He has a world-class reputation in the mineral exploration community, and he is a committed teacher and mentor of younger staff members.

Dr Radford has a strong association with CRC LEME and helped develop and present the bid for CRC LEME 1 and served on the Mineral Advisory Council for both CRC LEME 1 and 2

The Butt Smith Medal honours eminent geoscientists Dr Charles Butt and Dr Ray Smith of the CSIRO Division of Exploration and Mining, who made invaluable contributions to mineral exploration, regolith geochemistry and ore deposit research over the past 37 years. The Medal is jointly awarded by CRC LEME and CSIRO Exploration & Mining every two years.

Nigel Radford, Charles Butt and Ray Smith at the Australian Earth Science Congress in Perth

Professional memberships, Awards and Invitations

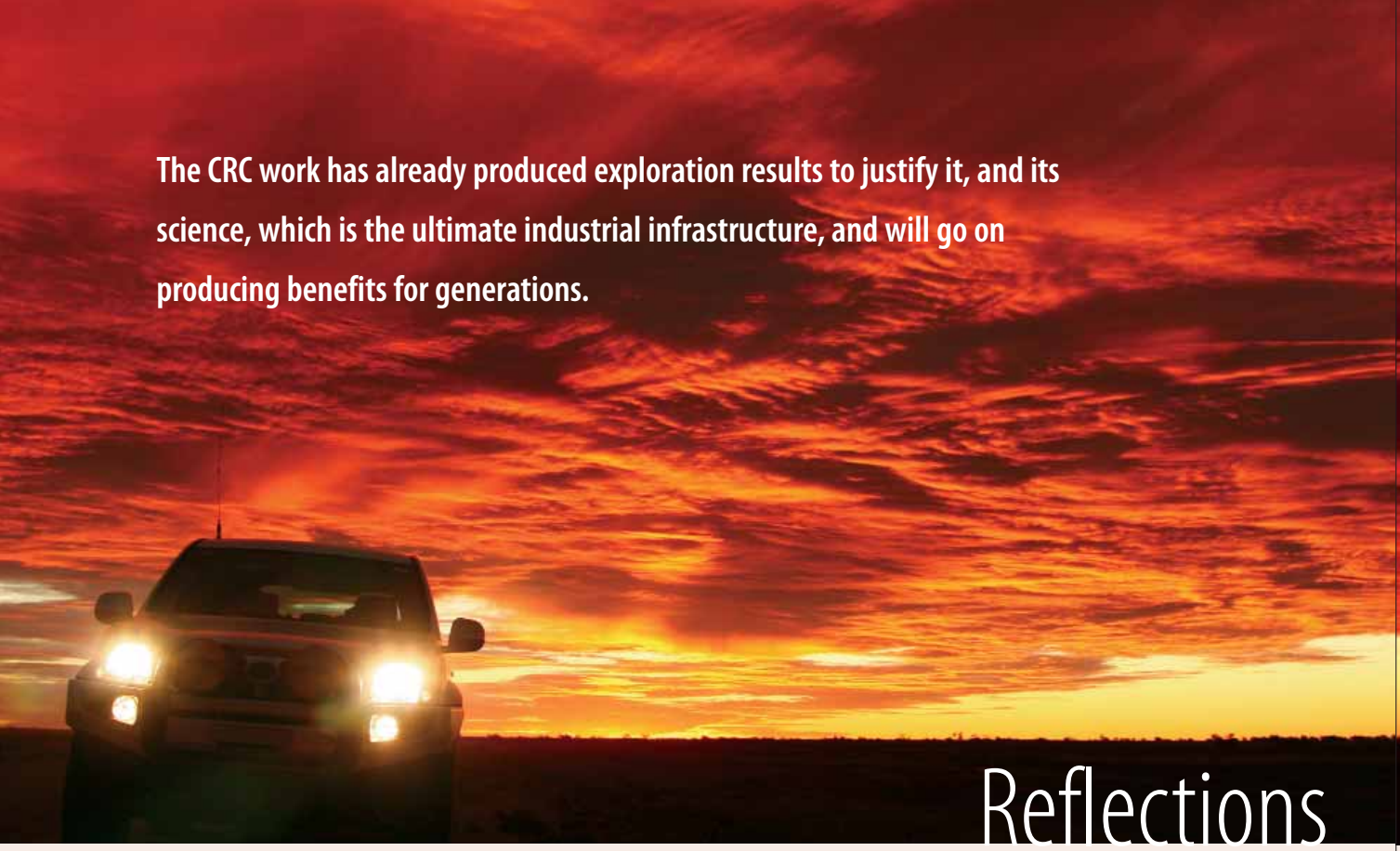
These tables illustrate the high regard in which LEME researchers and students are held.

Name	Core Party	International and National Committee Membership	Date
Charles Butt	CSIRO	Liaison Committee – Regional Geoscience Mapping and Mineral Resources, Geological Survey of Western Australia	1996 onwards
Charles Butt	CSIRO	Deputy Chairman – Minerals Research Advisory Committee, Minerals and Energy Research Institute, Western Australia.	1997 onwards (Deputy Chair from 2006 onwards)
Charles Butt	CSIRO	Board Member, Executive Member and Secretary – Earth Sciences WA	2005 onwards
Charles Butt	CSIRO	Convenor, Awards Sub-Committee, Geological Society of Australia (WA Branch)	2006 onwards
Richard Cresswell	CSIRO	Member – National Coordinating Committee for Salinity	2006 onwards
Rob Fitzpatrick	CSIRO	Working Group Member – International Geohazards	2005-07
Kathryn Fitzsimmons	ANU	Australasian Quaternary Association Executive Committee Member	2007 onwards
Graham Heinson	UA	Chair of Earth imaging sub-committee – Auscope NCRIS Facility 5.13 Structure and Evolution of the Australian Continent	2006 onwards
John Keeling	PIRSA	President, Australian Clay Minerals Society Inc.	2007-09
Ken Lawrie	GA	Chair, Geological Society of Australia's Environment, Engineering and Hydrogeology Specialist Group	2005 onwards
Ken Lawrie	GA	Member of International management Committee of IUGS Working group on Communicating Environmental Geoscience	2005 onwards
Ken Lawrie	GA	Member Steering and Technical Organising Committees – International Salinity Forum 08	2006 – 2008
Colin Pain	GA	Member – National Committee on Soils and Terrain	2002 onwards
Colin Pain	GA	Australian Representative – International Association of Geomorphology Working Group on Applied Geomorphic Mapping	2006 onwards
Brad Pillans	ANU	President – Stratigraphy and Chronology Commission, International Union for Quaternary Research (INQUA)	2003 onwards
Brad Pillans	ANU	Member of Sub-commission of Quaternary Research, International Commission on Stratigraphy	2004 onwards
Paul Shand	CSIRO	Member – UNESCO IHP Committee on Climate Variability and Impact on Low and High Flows	2006 onwards

Name	Core Party	Editorships and Invited papers	Publisher	Date
Charles Butt	CSIRO	Associate Editor – Geochemistry: Exploration, Environment, Analysis	Geological Society of London & Association of Applied Geochemists	2000 onwards
Barry Cooper and John Keeling	PIRSA	Editors – Abstract Volume 87, Sprigg Symposium, Adelaide	Geological Society of Australia	2007
Patrice de Caritat	GA	Editorial Board – Geochemistry: Exploration, Environment Analysis	Geological Society of London and Association of Applied Geochemists	2005 onwards
Jon Clarke and Colin Pain	GA	Editors of a Special Issue of the Australian Journal of Earth Sciences on Australian Cainozoic Sediments and Landscapes	Geological Society of Australia	2006 – 2008
Kathryn Fitzsimmons	ANU	Editor – Quaternary Australasia	Australasian Quaternary Association	2007 onwards
Graham Heinson	UA	Sub editor – Pure and Applied Geophysics	Springer	2002 onwards
Steven Hill	AU	Associate Editor – Australian Journal of Earth Sciences	Geological Society of Australia	2006 – 2008

Name	Core Party	Editorships and Invited papers	Publisher	Date
John Keeling	PIRSA	Editorial Board, Applied Clay Science	Elsevier	April 2008
Colin Pain	GA	Guest Editor, International Journal of Remote Sensing	Taylor & Francis	2007 onwards
Colin Pain	GA	Editor of a Special Issue of the International Journal of Remote Sensing on the application of Digital Elevation Models for landscape mapping	Taylor & Francis	2006 – 2008
Brad Pillans	ANU	Editorial Board – Quaternary Science Reviews	Elsevier	1996 onwards

Name	Core Party	Award, Appointment or Promotion	From	Date
Kristy Beckett	CUT	Best poster, 19th International Geophysical Conference, Perth	Australian Society of Exploration Geophysics	Nov 2007
Charles Butt	CSIRO	CSIRO Fellow	CSIRO	Nov 2007
Ross Brodie	GA	2008 Australia Day Achievement Medallion	Geoscience Australia	Jan 2008
Lindsay Collins and Alexandra Stevens	CUT	Excellence for Outstanding Partnership in coastal planning and/or Management	Western Australian Coastal Awards	2007
Geoscience Australia Salinity Dynamics team led by Ken Lawrie	GA	Highly Commended in the Influence Category	Geoscience Australia	Dec 2007
Baohong Hou, John Keeling, Adrian Fabris, Wen-long Zang, Liliana Stoian, Martin Fairclough	PIRSA	Minerals Resources Director's Award, PIRSA, South Australia: Outstanding geoscience publication with instant impact on the exploration industry – The SA Palaeochannel Map.	Minerals Group, PIRSA	Dec 2007
Rob Hough, Charles Butt, Steve Reddy and Mike Verrall	CSIRO	A.B. Edwards medal for the best publication in Economic Geology in 2007	Geological Society of Australia	2007
Brad Pillans	ANU	Honorary Fellow of the Royal Society of New Zealand	Royal Society of New Zealand	2007
Vanessa Wong and co-authors	GA	Best Paper - Earths Environments Theme, Australian Earth Sciences Convention, Perth	Geological Society of Australia	July 2008
John Wilford	GA	Distinguished Geoscience Australia Lecturer	Geoscience Australian	Dec 2007
Lisa Worrall	GA	Best environmental geophysics presentation, 19th International Geophysical Conference, Perth	ASEG	Nov 2007
Lisa Worrall	GA	Distinguished Geoscience Australia Lecturer	Geoscience Australian	Dec 2007
Keith Scott	CSIRO	Honorary Fellow	CSIRO Exploration & Mining	Jan – Dec 2007
Keith Scott	ANU	Visiting Fellow	ANU	Mar 07 – Feb 08



The CRC work has already produced exploration results to justify it, and its science, which is the ultimate industrial infrastructure, and will go on producing benefits for generations.

Reflections

DR ROSS FARDON BOARD CHAIR CRC LEME 1 1995 – 2001 & CRC LEME 2 2001 – 2003

The Significance of CRC LEME

The proposal by Ray Smith in 1994 to create CRC LEME set off one of the more important geological research programs in the world. I have been a laterite man since 1961, and to be associated with CRC LEME has been a privilege as much as any other, seeing this field at last achieve, not an understanding of everything, no "42", but maturity after a frustrating 200 years.

By 1994 the chemical stability relations of the iron and aluminium oxides, silica, the clay minerals and carbonates were well-enough known, but the field and microscopic documentation of what happened in the super-complex regolith was still in its infancy.

This was not surprising despite the two centuries of observation starting with English, French and Dutch colonists, of laterite and related rocks, and familiarity by the world's geologists with weathering. Soils were very hard to study compared with basalt or sandstone units that formed in single relatively simple episodes. The main reasons were their very fine grain, and that every soil is an evolved product of its long geological history as varied climate, weathering, deposition, erosion and organic processes work their way down from the surface.

The name of the CRC was crucial – Landscape Evolution.

From the mineral exploration side, we also could not even talk sensibly about the regolith because the names, terms and theories were vague. I vividly remember many exploration discussions where we were confounded by trying to understand what the others were saying, let alone understanding the duricrust in front of us. Dennis Gee, later to lead the CRC, once hauled off and delivered a lecture to a field exploration party about the need for rigour in how we described and understood laterite formation. Eastern Australians with our comparatively simple laterites and weathering history were stumped by the Western Australian hardpans and duricrust that had fascinated Messrs Smith, Butt and Anand.

The understanding of chemical dispersion of the economic metals in soils still leaves much to be desired, and exploration geochemistry in the mineral industry is still a fine geological art in itself. But CRC LEME transformed it.

What a difference thirteen years made. Many CRC LEME field studies were pointillist, building up a picture for Australia from countless small studies. But they were informed and formalised by the great glossary and text-book of regolith, and so many regional maps and atlases made with the help of CSIRO, Geoscience Australia and the state Geological Surveys. Microscopic techniques and colour printing had reached the precision required to study and classify soils. So CRC LEME produced works of great beauty as well as clarity in a murky field.

The great foundations of the CRC were its Australia-wide and world-wide reach, the cooperative ethos, the wide involvement of companies, universities and government organisations, and the sheer volume of work made possible by the extra coordinated funding. My only regrets are that we were late to give organic processes due importance, and that we did not produce a large beautiful scientific volume on the landscape evolution of Australia. Perhaps it can still be done when the dust of feverish activity settles.

The CRC work has already produced exploration results to justify it, and its science, which is the ultimate industrial infrastructure, and will go on producing benefits for generations.

I can only pay tribute to the boards of wise and committed people, the executives, and especially to the hundreds of researchers, both students and industry and academic workers. The education of hundreds of specialists who carry the new culture and science of regolith to the world will be the most lasting creation of a wonderful CRC.

Clearly, the harvest years of CRC LEME have been bountiful. It is particularly satisfying that the legacy arrangements will ensure the benefits, spanning widely across regolith science, will continue well into the future. Equally importantly, we see new groupings of researchers emerging to tackle expanding frontiers.

DR RAY SMITH CEO CRC LEME 1 1995 – 2001 & CRC LEME 2 2001 – 2002

CRC LEME 1 – CRC for Landscape Evolution & Mineral Exploration

Critical to formation of CRC LEME 1 was a belief that enhanced collaboration across the country in regolith research would have a profound impact on understanding, thinking, education and knowledge of regolith and landscape evolution, particularly applied to mineral exploration. This was 1994. A concerted effort over the relatively short period of six weeks by Colin Pain (AGSO), Tony Eggleton (ANU), Graham Taylor (University of Canberra), Charles Butt, and myself (the latter two from CSIRO), together with respective teams, converted this belief into the successful CRC proposal. A key ingredient was sound financial backing from the mineral industry and state government organisations. CRC LEME 1 formally started 1st July, 1995. The core parties were the Australian National University, University of Canberra, Australian Geological Survey Organisation (later called Geoscience Australia) and CSIRO.

Centre activities thrived through these core parties and through a growing network of state geological organisations, universities and exploration/mining companies. Clearly, the new Commonwealth monies provided both the "glue" to bind the parties together, as well as the catalyst that enabled expanded activities across the country to become "greater than the sum of the parts". Important were projects that would not otherwise be possible. Regolith dating is such an example. This was a project we realised would require many years of research to provide sufficient data to enable meaningful synthesis.

The importance of regolith-landform understandings to mineral exploration was demonstrated through case studies and syntheses in areas and regions previously lacking in such studies, as well as expanding frontiers in the relatively well-studied Yilgarn Craton of Western Australia. Gradually, far more meaningful understandings arose than previously possible. Concurrent with the expansion of knowledge, geochemical exploration methods were adapted to new terrains. The transference of calcrete geochemistry from Western Australia to the Gawler Craton was a dramatic example, resulting in frenzied exploration and discovery of the important Challenger gold deposit as well as numerous gold prospects.

Education and training activities brought across the importance of regolith, landform and landscape concepts to increasing numbers of both undergraduate and postgraduate students, not only with core party universities, but with a widening network of collaborating universities, and through field and laboratory workshops in the mineral industry, including support from the Minerals Council of Australia.

As LEME 1 moved into its mature years, dryland salinity was emerging as a national problem of major significance. We could see that growth in regolith knowledge together with recent developments in airborne electrical geophysical survey techniques had important implications in understanding and management of salt affected lands. Broadening our strategies into the environmental arena thus became part of the successful LEME 2 bid which was submitted in the 2000 CRC round. Greater collaboration at all levels lead to broadening participation by way of increasing core parties to include two additional universities, two state geological surveys and the Minerals Council of Australia.

CRC LEME 2, CRC for Landscape Environments & Mineral Exploration

From the start, the approach of LEME 2 was based on a program structure in which fundamental research into regolith-landform dynamics and processes would feed, firstly, into mineral exploration particularly in areas of extensive cover and, secondly, into the environmental realm, particularly salinity mapping, land care, understanding the extent of inland acid sulfate soils, and seismic hazard assessment. There was also an increased emphasis on education, with the bold target of 60 postgraduate completions.

My custodianship of LEME 2 ran to the end of its Year 1, with the setting up of the program structure and its initial projects. After that, I continued as a researcher until 2004, thereafter as an emeritus researcher until closure. From this position, it has been very pleasing to see the full span of LEME's activities come to fruition, some from foundations I was familiar with, others arising from new initiatives. The monograph "Regolith expression of Australian ore systems" contains a wealth of experience that is highly valued by the mineral industry. Likewise, the underlying science of regolith-landform dynamics has moved ahead rapidly, summarised in the monograph "Regolith Landscape Evolution Across Australia". Besides publication in scientific journals referred to by researchers around the world, practitioners in industry



welcome the explorers' field guides and regolith atlases that now cover key regions in Australia, including whole states. In terms of heavy mineral sands, the sedimentological synthesis research of the Centre's teams in Adelaide greatly contributed to the important discoveries in the Eucla Basin. That these concepts can be applied westwards into the Eucla Basin of Western Australia adds to the excitement.

The involvement of biota in geochemical dispersion in areas of cover has led to exciting application trials in mineral exploration. New science of how bacteria can bring about mobilisation and precipitation of Au was well received in the scientific literature.

In regard to ground water salinity, LEME's researchers knew that mounting a regolith-landform approach directed at understanding salinity would likely provide essential insights and sound ways to tackle the associated land-care issues. Accordingly, this prospect aroused considerable enthusiasm. Yet, in its initial stages, the salinity program was characterised by challenging cooperative arrangements. I found it particularly pleasing, therefore, to see the challenges overcome and a series of multidisciplinary projects undertaken and successfully completed in several key regions. These projects have demonstrated new approaches to salinity mapping, understanding salt stores in the environment, the geological background to river recharge, and have provided new insights into salinity modelling, prediction and remediation. The activities focused on acidity formed during deep drainage of salt-affected areas will continue beyond the life of LEME.

Also in the environmental realm, it was particularly pleasing to see how research on acid sulfate soils has progressed. That there were major inland environmental issues was known by key researchers yet the implications were perhaps less generally known, particularly the environmental risks of the drying of saline wetlands. Such environmental issues have come to the fore in the Murray-Darling Basin, for example. The Centre's research has led to a framework to develop an understanding of inland acid sulfate soils on a national scale.

Clearly, the harvest years of CRC LEME have been bountiful. It is particularly satisfying that the legacy arrangements will ensure the benefits, spanning widely across regolith science, will continue well into the future. Equally importantly, we see new groupings of researchers emerging to tackle expanding frontiers.

Real advances were made in understanding regolith architecture, regolith dynamics, biotic roles in metal mobility, groundwater flow modeling, and salt mobilization. This clearly laid the platform for the Board directive to take LEME to a productive conclusion.

DR DENNIS GEE CEO CRC LEME 2002 – 2005

These reflections are set in the time of the early half of the second round of LEME. On re-reading my three CEO annual reports, I am reminded what a critical period it was. LEME was facing some seemingly intractable problems and demanding scientific challenges. Chairman Ross Fardon, who I consider one of my career mentors, gave me his riding instructions – bring the total intellect and enterprise of the 120 odd (metaphorically speaking) researchers in LEME to focus on a grand project that would shake the scientific world. I was familiar with the 'Manhattan Project' approach of Ross.

On joining LEME, I thought I knew all about unincorporated joint ventures. But this one involved a varying number of disparate academic, government and research agencies essentially pursuing their own interests. It was indeed a strange animal. It was a bit like rugby – if it did not already exist, it would be impossible to invent it. Each contributing participant had different aspirations, and was intently watching its return on equity.

In this, the second year we were still feeling the aftermath of the withdrawal of BRS, who was to be a major financial and scientific contributor to the natural resource management (NRM) programs. This required a Deed of Variation to re-align us with the Commonwealth Agreement. Before the deed could be consummated, we were shaken by the unilateral withdrawal of University of Canberra from the CRC. This problem was resolved by the assumption of their rights and obligations by ANU who effectively took up a double dose of LEME. This turned out to be a bountiful step, as it enhanced the pool of expertise in LEME. A further re-drafting of the draft deed of variation was required when NSW, a long-time generous partner to LEME, announced a substantial reduction in their future contributions. Again this simply reflected the delicacies of an unincorporated joint venture.

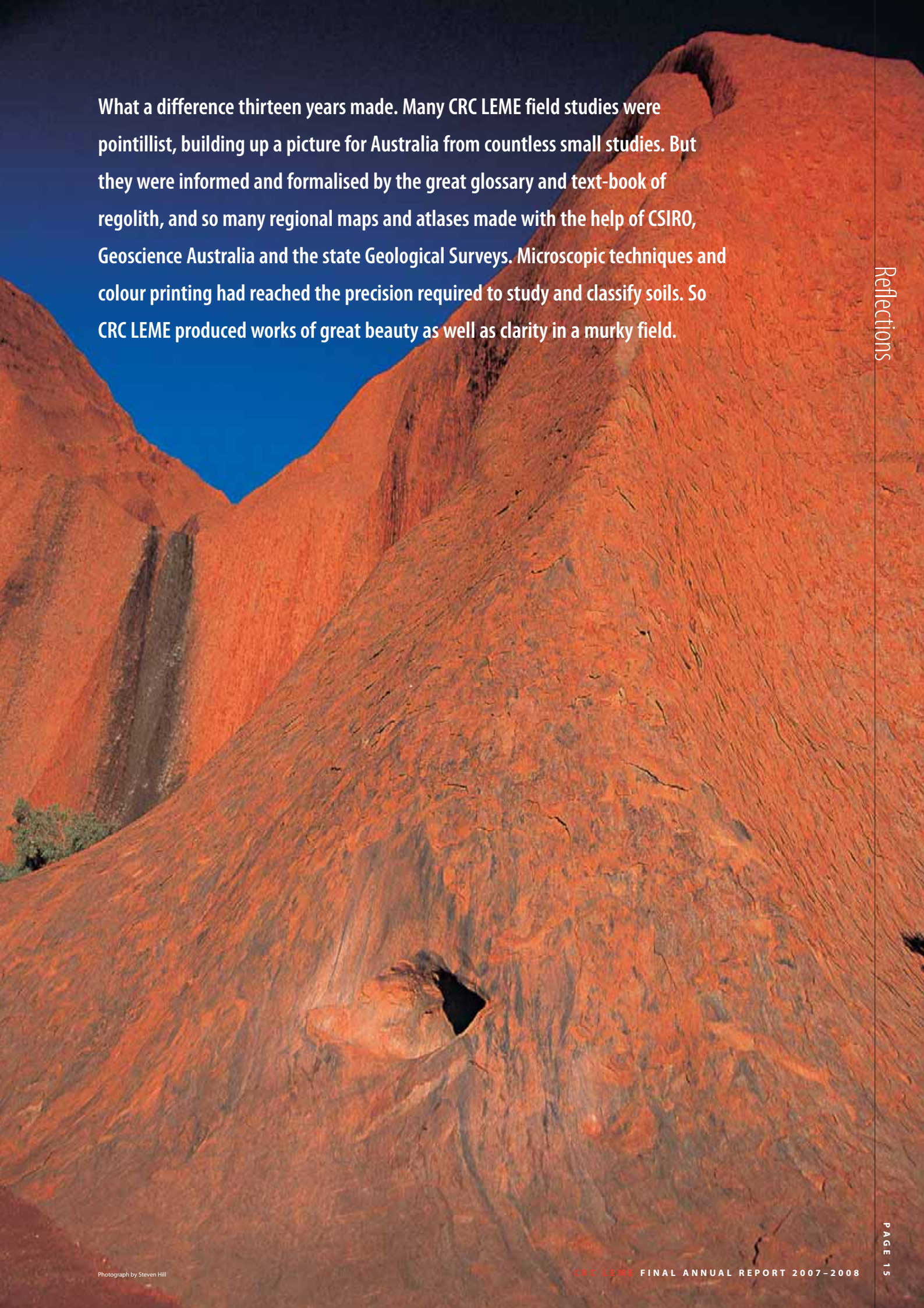
One of my first tasks was to formally review the projects around the three nodes, with a view to culling and refocusing projects. This was to be done using a costed work-program approach – that is control by the purse strings – a perfectly normal management process. But even this process was difficult. We had a diffuse spread of four types of projects, reporting and communication, site or region studies, generic process studies, and technology development. It was just not possible to reduce the number of projects, and still preserve participant's expectations. We managed to substantially reduce the number of projects by creating multi-disciplinary, cross-party mega-projects from the constituent parts. I think the Board was not fully convinced about this re-focus.

All this was happening at a time of dwindling funds for mineral exploration (MINEX) research because of the so-called "rationalization" of the Australian mining industry. Similarly the flow of NRM funds became clogged and prescriptive after the unexpected devolution of management responsibility from the Commonwealth to the States. Clearly we were not able to fit the funding to the desired projects, but we had to shape the projects to fit the funding sources. The 'Manhattan concept' could not work.

But in consequence we did receive considerable funding from geological surveys for regional studies in Programs 1 and 2, and NRM funds for contracts of work in Program 4. This attracted some comment that it was not strategic research. But I stoutly defended this approach, because it was a successful launching pad for our fledgling salinity projects – which turned out to be highly successful.

The twin streams of MINEX and NRM, with totally different stakeholders, was always going to be difficult to manage, and perhaps impossible to bring together into a single-focus research entity. It was therefore not surprising that the core participants in this strange unincorporated joint venture decided not to pursue a re-bid as a CRC, but to direct the Executive to focus on full delivery of scientific programs and maximum uptake of regolith knowledge by stakeholders.

It is inevitable in these reflections I should dwell more on corporate and managerial aspects, rather than scientific outcomes, because that is what consumed my adrenalin. Despite all the challenges, we did manage to re-ignite the research projects. Real advances were made in understanding regolith architecture, regolith dynamics, biotic roles in metal mobility, groundwater flow modeling, and salt mobilization. This clearly laid the platform for the Board directive to take LEME to a productive conclusion. In my third and final CEO annual report I was able to state that "managerial stability was reflected in the eventual execution of the Deed of Variation of the Commonwealth Agreement".



What a difference thirteen years made. Many CRC LEME field studies were pointillist, building up a picture for Australia from countless small studies. But they were informed and formalised by the great glossary and text-book of regolith, and so many regional maps and atlases made with the help of CSIRO, Geoscience Australia and the state Geological Surveys. Microscopic techniques and colour printing had reached the precision required to study and classify soils. So CRC LEME produced works of great beauty as well as clarity in a murky field.

Photograph by Steven Hill

The seemingly simple request to reflect on and summarize the science highlights of the CRC presents a considerable challenge, given the quantity and high quality of the research that has been conducted during its 13 years. This research was conducted not only by the staff of the core institutions and their collaborators, but also by the many Honours and Postgraduate students who worked with them.

CRC LEME KEY RESEARCHER: DR CHARLES BUTT

The seemingly simple request to reflect on and summarize the science highlights of the CRC presents a considerable challenge, given the quantity and high quality of the research that has been conducted during its 13 years. This research was conducted not only by the staff of the core institutions and their collaborators, but also by the many Honours and Postgraduate students who worked with them. The selection presented here is a personal view, and must of necessity omit many worthy achievements.

CRC LEME set out to determine the influence of the formation and evolution of the regolith and landforms in Australia on the practice of mineral exploration, subsequently extending to their significance in a range of environmental issues, most importantly those related to dryland salinity. In terms of the more fundamental issues of regolith geoscience, considerably improved models of regolith evolution have been developed for key sites across Australia. These models can now be constrained by more robust estimates of the ages of weathering, based mainly on palaeomagnetic data. Some results from NSW and WA have extended the age of the regolith in those regions back to the Carboniferous, more than confirming the antiquity of the landsurface. Conversely, other events, based on thermo-luminescence and optically stimulated luminescence (OSL), are dated to the last few thousand to 1 million years. The information contained within these generic models of landscape evolution is largely derived from regolith-landform mapping in two and three dimensions. 2D mapping has advanced from a reliance on aerial photography and Landsat-1 imagery; LEME scientists have been at the forefront of the routine application of digital elevation data and radiometric, radar, hyperspectral, magnetic and electromagnetic surveys to regolith mapping at all scales, supported by rigorous "ground-truthing". Of particular significance have been the State-wide regolith maps and materials atlases of Queensland and the Northern Territory, complementing the more conventional local to district-scale mapping used for mineral exploration and land-use planning. Mapping of the distribution and characteristics of major palaeochannels and Tertiary coastal features in South Australia provided an immediate boost to exploration for heavy minerals. 3D regolith landform mapping has also progressed. In 1998-2000, the pioneering Yandal project in Western Australia produced the first 3D model of a whole mineral district, with depth and logging data based mainly on drilling, whereas the Gilmore project in NSW also utilized airborne electro-magnetic (AEM) surveys, demonstrating the value of this technique in mapping subsurface features including, importantly, the location of saline groundwater. CRC LEME research has continued to test, evaluate and develop a range of AEM instruments, and these, coupled with other ground and down-hole geophysical techniques such as shallow seismics and active gamma and neutron-logging, can readily map salt storages, saline discharge into rivers, palaeochannels and other sub-surface features important for the management of salt-affected land.

Descriptive logging of regolith materials has long been recognized as complex and highly subjective, and CRC LEME has been actively developing routine, rapid mineral logging protocols based around the CSIRO Hy-Logger instrument. At a more detailed level, advances in the precise location of elements within regolith materials, minerals and plants have been made by the application of a range of analytical techniques such as electron microprobe, laser ablation-ICMS, proton microprobe and synchrotron. The latter, for example, has been able to establish the distribution and oxidation state of arsenic within ferruginous pisoliths, and the location of heavy metals in plant tissues. Both of these are used as mineral exploration sample media and such information can assist both in application and data interpretation. Novel experimentation on the role of bacteria in weathering demonstrated their potential role in mobilizing and precipitating gold. However, using much larger specimens, convincing chemical and crystallographic evidence shows that gold nuggets are hypogene – that is formed at high temperatures and pressures deep in the Earth's crust – and not products of weathering at the surface, settling the 150 year long debate in Australia about their origin.

An initial objective when CRC LEME was established was to extend the application of regolith landform based concepts in mineral exploration from the Yilgarn Craton, where they had been developed through a series of AMIRA-sponsored projects, to other regolith-dominated terrains elsewhere in the country. A series of projects was established in key mineral provinces, including the Mt Isa and Drummond Basin in Queensland, Lachlan Fold Belt, NSW, Broken Hill and Curnamona Province (NSW and SA), Gawler Craton (SA) and Tanami (NT). These areas remained a focus of research throughout the life of the CRC. Many of the results are included in the thematic volume "Regolith expression of Australian ore systems" and the regional exploration guides, which describe the geochemical footprint of mineralization in different landscape environments as a basis for selecting the most appropriate exploration procedures. Effective exploration in areas of transported overburden has been a key issue for the mineral industry. It is perhaps a particular problem for gold, which is present in low abundance even in rich deposits; in places, as little as 2 m of barren cover can effectively conceal sub-cropping ore. However, following the successful application of pedogenic carbonate (calcrete) sampling in the southern Yilgarn and the Gawler Cratons, extensive investigations have shown that calcrete can be used to 'see' through between 5 and 10 m of cover. OSL dating has indicated that the concentration of gold into the carbonates is recent and probably still active, mediated by

vegetation. Direct sampling of plants themselves has also proved successful; biogeochemistry has undergone a resurgence following the successful detection of mineralization by LEME research using river red gums (NSW), spinifex (Tanami NT) and Acacia (northern Yilgarn, WA). This success has been aided by improved analytical procedures and has contributed to a significant increase in demand for vegetation analyses received by commercial laboratories. Less successful have been attempts to use partial or selective analyses to detect labile metals, derived from underlying mineralization, in soil on transported overburden. Such procedures have been widely promoted, but have not been demonstrated to be successful even where a base metal deposit provides a rich source. CRC LEME research has, however, demonstrated that red wine and commercial soft drinks are just as effective as more conventional reagents!

CRC LEME recognized that regional geochemistry is a major omission from the pre-competitive data available for explorers and other users in Australia. This has been largely due to the lack of a single sample medium suitable for all environments. Regional stream sediment surveys, used in most developed and many developing countries, are unsuitable over much of Australia. Following several years of research, including the CRC's major diamond exploration project funded by Astro Mining Ltd, CRC LEME contributed to a geochemical atlas of 250000 km^2 of the western Yilgarn Craton, based on sampling lateritic pisoliths on a 9 km triangular grid. This is the largest single geochemical survey of any region in Australia. Publication of the atlas led to a surge of applications for mineral tenements, although whether any significant discoveries will be made as a result is yet to be established. Similarly, the ongoing hydrogeochemical survey of the northern Yilgarn was initiated in the last years of the CRC, following many years of research in the Yilgarn and Gawler Cratons. The CRC also contributed to the pilot studies of low density overbank sampling, which is being used for the first geochemical map of the whole country. Although the latter will have some exploration implications, its main thrust will be to establish geochemical backgrounds for environmental application.

In environmental issues, LEME scientist have been prominent in highlighting the threats posed by acid sulfate soils (ASS). These are formed when water-tables are lowered by drainage or drought, causing oxidation of sulphides and release of potentially toxic metals into the broader environment. The problem is widespread, with the Murray-Darling Basin and the WA wheatbelt being the main focus of LEME research. Mineralogical, chemical and microbiological studies have been used to develop new models of ASS formation at scales ranging from nano to landscape. These have been used to derive a 'user-friendly' key for the early identification of ASS, and the research has contributed to the management strategies for the control of their formation and the amelioration of affected land and water.

Using the geophysical approaches discussed above, considerable advances have been made in salinity management and hazard assessment in a range of environments, from the Kimberley, WA, to Central Victoria. CRC LEME has worked closely with a range of agencies to establish 4D landscape models as a platform for interpreting the hydrogeology of each of the study areas. These have been influential planning and management tools for the exploration of freshwater in mainly saline areas, mapping the intrusion of saline waters in sediments, locating sites of aquifer discharge and recharge in rivers, and for deciding appropriate (and inappropriate) sites for irrigation, salt interception and salt disposal.

Overall, the CRC has helped to provide the mineral exploration and land resource management industries with world-leading capabilities in tackling regolith-dominated terrains, whether in Australia or other countries in which they occur. This has been achieved not only through the research itself, but also in the manner it has been delivered to the end-users, through scientific papers, reviews, reports, manuals, workshops and collaborative activities. In addition, numerous graduates and post-graduates have been introduced to regolith geoscience during their course work and through their own research, and have taken that experience with them into the workforce.

A significant achievement of CRC LEME has been to raise the profile of regolith geoscience from the pursuit of a few eccentrics ("real geologists don't look at weathered rocks") to a position in which it is recognized as an important facet of the earth sciences, in academic geology and applied in mineral exploration and environmental science. A test of CRC LEME's success will be whether regolith geoscience maintains this position.

Charles Butt is a CRC LEME Key Researcher, a CSIRO Fellow, and a Chief Research Scientist with CSIRO Exploration and Mining. He was a member of the teams that assembled the bids for both CRC LEME 1 and CRC LEME 2, and was Deputy Director and Program Leader in CRC LEME 1.

CRC LEME KEY RESEARCHER: DR COLIN PAIN

It is worth remembering that CRC LEME grew out of earlier groupings of regolith scientists – first CARS, the Centre for Australian Regolith Studies, combined interested staff and students from ANU and University of Canberra, and in the early 1990s, also from BMR/AGSO/Geoscience Australia. This led to the very first conference devoted to regolith in Australia, at Broken Hill in 1994. All those who were to become members of the LEME 1 Executive were at that meeting. The second grouping was CRC AMET, with CSIRO Exploration and Mining and BMR/AGSO as core parties. Again, a number of those who were to become part of the LEME leadership were involved. So LEME was a natural development from earlier moves to bring the regolith community of Australia together.

LEME 1 was successful in assembling a group of people from four very different organisations to work on the general theme of enhancing the use of regolith information in mineral exploration. I learnt a lot about mineral exploration, regolith geochemistry, and about the Yilgarn. I hope others in LEME 1 learnt a lot about geomorphology, regolith mapping, and the rest of Australia. The Education Program was a very real success, with former LEME students now in senior positions in mineral exploration, and also well placed in government and research agencies.

LEME 2 expanded on the LEME 1 foundation, both in the number of core parties, and in taking on environmental aspects of regolith science. This enhanced LEME built on the work of LEME 1, and applied it to additional issues. The highly successful Education Program continued; the fact that LEME students had instant access to practitioners outside the university system was a major factor in the success of the program.

The scientific achievements of CRC LEME are typified by the contents of “Regolith Science”, the LEME book published by CSIRO Publishing. Among them I would list the increasing realisation that biological activity is a fundamental part of regolith character and evolution, the use of a growing range of geophysical and geochemical techniques in the search to understand the regolith, and the better understanding of the age and evolution of the Australian regolith and its relationship to the Australian landscape.

One measure of the success of LEME is that mineral explorers are now comfortable working with regolith, and as a consequence probably don’t need the same level of research support that was required at the beginning of LEME 1. Another measure is the fact that natural resource managers now recognise the need for regolith information, although they are not yet in a position to provide it for themselves, or buy it from consulting companies. In both cases the industries have moved from a position of ignorance – not knowing about regolith so ignoring it – to a position where they recognise and understand the fundamental role that regolith can play in their work. Finally, as word has got out, Australia is now internationally recognised as world-leading in regolith research. However, it must be said that the term “regolith” is still dominantly used for surface materials on other solar system bodies. A quick search for “regolith” on Amazon.com finds 9 books about terrestrial regolith, of which 5 have LEME authors. In 2001 the ratio was 3 out of 5.

Personally, I have met wonderful people and seen great places. I have attended all the LEME Symposia, and count them a major success in bringing together, both formally and informally, a very diverse group of scientists. LEME research has opened my eyes in some areas, and reinforced my prejudices in others! For me, LEME has been fun.

Colin Pain is a CRC LEME Key Researcher, a CRC LEME Honorary Fellow and a senior geoscientist at Geoscience Australia. He was a member of the teams that assembled the bids for both CRC LEME 1 and CRC LEME 2, was Assistant Director in CRC LEME 1, and Program Leader in both CRC LEME1 and CRC LEME 2.

CRC LEME KEY RESEARCHER: DR BEAR McPHAIL

There have been many highlights of research in CRC LEME, from its inception some 13 years ago to its end in 2008. I focus more on some of the ones from recent years in this short description, recognising that this list is by no means complete and does not give important recognition of LEME's achievements in previous years. There are many other highlights recognised in the comments from my fellow Key Researchers and LEME executives in this final report.

Perhaps the most important achievement of LEME is the training of new scientists in regolith-related research. 117 Honours students have graduated during the last 7 years and, although based at the 3 participating universities, many of the Honours projects have been in collaboration with other LEME core parties. During the same time, 47 postgraduate students have also completed, and there are a dozen or more that are in the throes of finishing their studies. Many of these students have contributed enormously to broader LEME projects amongst all the core parties of LEME. The individual and combined outcomes of these new scientists is probably the most important legacy of LEME, as they will continue to contribute to and build Australia's and the world's knowledge of regolith, from landscape evolution, environmental science, geophysics, mineral exploration, geochronology, acid sulfate soils and much more.

The research highlights include advances in air, surface, shallow and remote sensing geophysics, geochronology and geomicrobiology.

LEME has led the way in the geophysical measurement and interpretation of regolith-dominated terrains. This includes airborne electromagnetic methods, especially targeting salinity-related problems in many key areas of the country, hyperspectral, radiometric and other imaging of landscapes, and innovative new applications of shallow electrical and physical methods, as well as core and chip logging techniques using objective methods for detecting mineralogy and geochemistry.

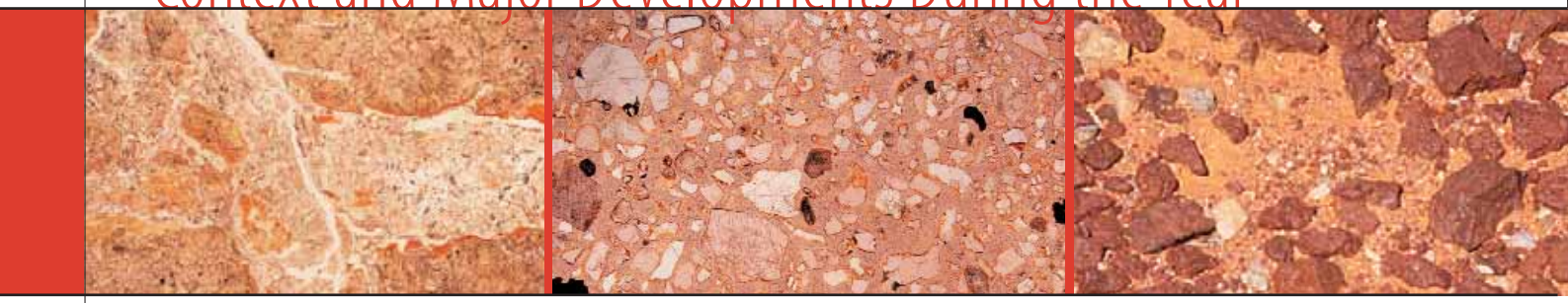
Geochronology has been developed in LEME, through palaeomagnetic, optically stimulated luminescence (OSL) and isotopic methods. Palaeomagnetic methods have allowed us to understand more of the breadth and depth of regolith evolution in Australia, especially the periods of deep weathering at approximately 60 Ma, and more recently at approximately 15 Ma. OSL methods have allowed us to understand the development and transport of dune systems, which helps us to understand the history of aridity in Australia, an important piece of the climate change puzzle. Cosmogenic isotopes, for instance chlorine-36, have allowed us to understand weathering rates and the dynamics of groundwater.

Applications of molecular microbiology have been instrumental in understanding metal mobility in the regolith, in particular gold, as well as the development of acid sulfate soil environments and their subsequent weathering. This is a perfect example of scientists and organisations from different fields contributing their knowledge and enthusiasm to confront some of the major questions we face in regolith science, such as which biological, physical and chemical processes have shaped the surface of our continent and the globe.

In summary, I think we have really just "scratched the surface" of regolith research and understanding, and hope that all of us who have been involved with CRC LEME will continue to build on our present knowledge and further it for the benefit of Australia and elsewhere – be it for mineral exploration, environmental science or other applications.

Bear McPhail is a CRC LEME Key Researcher and a Senior Lecturer in the Research School of Earth Sciences, Australian National University

Context and Major Developments During the Year



To deliver on its objectives, LEME operated within two industry contexts – mineral exploration (MINEX) and natural resource management (NRM).

Mineral Exploration Industry Context

LEME research outputs from Programs 1 and 2 have been focussed on applying regolith geoscience to the challenges facing the Australian mineral exploration industry. Whilst large multi-national corporations are active explorers, exploration in Australia is predominantly carried out by junior or medium sized companies, creating a large and diverse end-user market that in itself presents unique challenges to technology transfer.

During 2007-08 'boom time' conditions continued to prevail in the resources sector. According to the Australian Bureau of Statistics, minerals exploration expenditure increased by 41.8 % from $1407m in 2006-7 to $1995m in 2007-08.

The increased expenditure on minerals exploration came at a time when CRC LEME activities were winding down. Interest in the outcomes of CRC LEME research, as expressed by requests for advice and information and demand for CRC LEME products, is at an all time high. The regolith is still seen as the greatest challenge facing Australia's mineral explorers, and a number of company personnel have voiced their concern about the demise of LEME's collaborative research programs into exploration through and within the regolith.

This concern has led in part to the development of an industry led bid for a new (Round 11) CRC; the CRC for Deep Exploration Technologies. The proposed Deep Targeting Geochemical Methods Program in this CRC will be drawing on the outcomes of CRC LEME research, and LEME staff members are involved in drafting the CRC proposal.

The Australian Natural Resource Management Context

Research outputs from Programs 3 and 4 have been focussed on applying regolith geoscience to environmental issues facing Australia such as salinity risk assessment, protection of ground and surface water resources from acidification and salinisation, and the many risks associated with acid sulfate soil (ASS) disturbance. Within this context, the natural resource management (NRM) sector comprises a diverse group of end users and decision makers such as Commonwealth and State Government agencies, Local Government, Catchment Management Authorities (CMAs) and Landcare Groups. This diverse and complex stakeholder group required a multi-layered, targeted approach to the delivery of research outputs to ensure adoption.

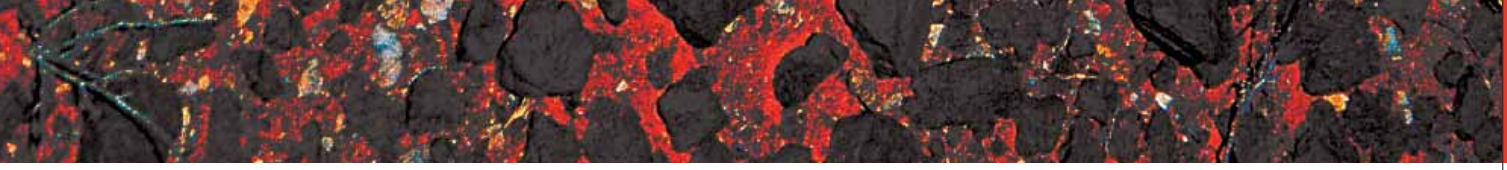
Procurement and sustainable use of water resources remained high on the political and public agenda in Australia in 2007 – 2008. Continuing drought in many parts of the country focussed policy and research effort on strategies to ensure the future supply and quality of scarce water resources.

Key staff appointments

Lisa Worrall (Program 1 Leader, CRC LEME) was appointed Chief Executive Officer of CRC LEME on August 18 2008, following the departure of Dr Steve Rogers who resigned to accept the position of CEO of the Parker Cooperative Research Centre for Integrated Hydrometallurgy Solutions.

Lisa concurrently maintains her position as Program 1 Leader during the wind up period of CRC LEME.

Dr Sara Beavis, (Research Fellow, Centre for Resource and Environmental Studies ANU) was appointed Leader of the Education and Training Program (Program 5) in May 2008 following the departure of Dr Ian Roach, whose employment contract with ANU expired in April 2008.



National Research Priorities

As LEME's two research streams are focussed on mineral exploration and natural resource management, the Centre's research outcomes relate to two of the Australian Government's broader 'whole-of-government' national research priorities:

- An Environmentally Sustainable Australia
- Frontier Technologies for Building and Transforming Australian Industries.

AN ENVIRONMENTALLY SUSTAINABLE AUSTRALIA

Water – a critical resource

The outcomes and outputs of CRC LEME Programs 3 and 4 research activities are directly relevant to developing national strategies to manage the continuing water shortage and worsening water quality in Australia.

The ongoing drought in south east Australia has placed considerable strain on water resources in the Murray Darling Basin, with consistently low inflows over several winters. In addition, the drought has impacted on water quality, with algal blooms becoming more common during the summer months. Management strategies must also take account of the "hidden" problems stemming from the long term impact of extended drought conditions, some of which may only become apparent after the drought has broken and flows in the system begin to increase. Problems that may arise include the build up of salinity on floodplains, and the release of heavy metals from acid sulfate soils.

During the final year of CRC LEME, state and federal agencies began to appreciate the importance of ASS. Large parts of the River Murray system (including the Lower Lakes: Albert and Alexandrina) were impacted by acidification due to the exposure of extensive areas of ASS, which are much more abundant than previously assumed. CRC LEME (Program 3) research has focused on rapid mapping, risk assessment and characterisation of ASS, and many of the protocols for assessing the extent and character of ASS in the Murray Basin are now in place. This has allowed very rapid assessments to be completed and rapid effective management decisions to be made; maximising water allocation options in an area already overstressed for water availability. This work will continue during rewetting phases, and monitoring protocols are being agreed between LEME scientists and state and federal agencies.

CRC LEME (Program 4) has expanded the knowledge and understanding of groundwater salinity processes in river catchments, such as the Murray-Darling Basin, aided by the use of cutting-edge geophysical technological equipment and data to map saline groundwater and areas which are at risk of salinity.

Transforming existing industries

One of the Centre's primary objectives is:

To develop breakthroughs in mineral exploration of covered areas which will attract exploration investment in Australia and increase discovery of ore deposits, the development of which will ultimately lead to creation of national wealth.

CRC LEME (Programs 1 and 2) has achieved significant scientific breakthroughs that have impacted on Australia's resource-based industries, more specifically on the minerals exploration industry. Centre research outcomes have enabled the mineral exploration industry to operate more effectively in regolith-dominated terrains because of an improved understanding of the biological, chemical and physical controls on regolith processes. This research has culminated in the production of CRC LEME Guides to Mineral Exploration through the Regolith in the Thomson, Cobar, Curnamona, Central Gawler, Tanami and Yilgarn regions.

The Centre has led the way in the development of cost-effective, reliable and practical exploration techniques in the areas of biogeochemistry and hydrogeochemistry. This work has culminated in the production of CRC LEME Guides to biogeochemical and hydrogeochemical exploration.

Overcoming soil loss, salinity and acidity

CRC LEME (Programs 3 and 4) research has specifically addressed the environmental issues of salinity and acidity spread.

Soil acidification is now accepted as a major risk to soil fertility, much more so than salinity. Australian soils are generally very old and strongly weathered, and they are often acidic and nutrient poor. Where soil acidification and salinity occur together the problems, and hence solutions, can be extremely complex. CRC LEME (Program 3) has been particularly involved in assessing the geochemical impacts of deep drains in the WA Wheatbelt. Over much of this area the shallow groundwaters are saline and acidic (often with pH as low as pH 2) hence, the drainage of waters high in trace elements needs to be carefully managed. CRC LEME projects have characterised the risks and extent of the problem over large parts of the Wheatbelt to help develop guidelines for drain management. As well as assessing the geochemical risks, ongoing projects are also assessing low cost treatment options, which can be used to ameliorate acidity and metal transport through the drains.

CRC LEME's (Program 4) research activities have been concerned with developing new geoscientific methods to map saline environments and define areas at risk of salinity. To achieve these goals CRC LEME undertook case studies using airborne and ground geophysics techniques as part of a systems approach to mapping and assessing salinity in landscapes throughout Australia. Data and interpretation products from these studies are



being used to underpin new salinity management strategies in the Murray floodplain, and in irrigation districts in Victoria, South Australia, Western Australia and Queensland. Ground and airborne geophysical methods have also been used to map and assess the risk of salt water intrusion in coastal landscapes. New methodologies for mapping salinity in erosional landscapes in Eastern Australia have been developed, and are being used to formulate new management strategies to prevent salt export from upland landscapes and assist with in-valley salinity management. Ground-based geophysical techniques have been applied to underpin desalinisation strategies in Western Australian rural towns.

Developing deep earth resources

In addition to developing improved strategies for exploring in regolith dominated terrains, CRC LEME has developed a rapid and practical interpretation tool, based on measurements of the visible and near infrared spectra, for the logging and categorisation of regolith materials collected as core, drill chips, or pulps. This technology is already assisting exploration and mining geologists by providing meaningful, objective mineralogical data to assist in geological interpretation of buried mineral systems based on their spectral properties.

In CRC LEME's final year, emphasis was placed on documenting spectral logging procedures and protocols relevant to regolith materials/settings, the implementation of regolith logging methods and algorithms into appropriate software such as TSG Core, and promoting the benefits of using spectroscopic mineralogy as a mineral exploration tool to the wider mining and exploration community.

Responding to climate change and variability

An effective response to climate change and variability depends in large part on the understanding on how natural systems have responded to climate change through time. Climate changes affect regolith forming processes and are recorded in the regolith. CRC LEME (Program 1) researchers have systematically studied the Cainozoic climate history of Australia.

Their work has led to an improved understanding of the effects of various factors including orbital forcing, palaeolatitudes, and ocean currents on Australia's climate and hydrology, as well as the response rates of regolith processes including soil formation, erosion, and transport of regolith materials. This understanding not only gives the climate change debate historical context, but will improve the predictive analysis of the impact of climate change on Australia.

Climate variability and change are important considerations for the sustainable management of Australia's water resources. The present drought has resulted in water restrictions in most major population centres, as well as on the environment, where many ecosystems are under considerable stress. The River Murray is a good example of a system which is not only highly stressed but has been highly managed for many years. The introduction of locks and weirs in the early part of the 20th Century resulted in extensive agricultural development. However, the permanent inundation of the wetland systems had a significant impact on the surrounding wetlands, with a loss of the natural wetting-drying cycles so important to biodiversity and wetland functioning. This change has promoted the build-up of sulfide minerals and acid sulfate soils which, as the climate changes, is causing problems with the development of acid soils and potential metal release. The outcomes of CRC LEME (Program 3) research are being applied at a range of scales to underpin the development of management and treatment options in the Murray Darling Basin which are cognisant of the ramifications of climate change.

FRONTIER TECHNOLOGIES FOR BUILDING AND TRANSFORMING AUSTRALIAN INDUSTRIES

Frontier Technologies

LEME has undertaken research through the Australian Synchrotron Research Program as part of developing applications for the Australian Synchrotron in Melbourne. Once fully online, the new synchrotron will undertake rapid analysis at high resolution, this will allow for the spatial distribution of certain elements in a given sample of regolith materials to be quickly and accurately determined.

LEME, through its Core Participants, is pioneering the development of innovative geophysical techniques through Centre-funded PhD research. These techniques have potential applications in both mineral exploration and natural resource management.

These techniques include:

- Audio-Magnetotellic (AMT) – a ground-based method that uses reflected natural electromagnetic energy to measure the three-dimensional electrical structure of the Earth.
- Electrokinetic seismic (EKS) – a groundwater mapping system that works by measuring weak electrical impulses given off by an aquifer when in contact with seismic waves.

LEME has also undertaken research to develop signal processing algorithms to improve the quality of seismic data generated in areas of high electrical noise.

National Research Priorities and CRC Research

NATIONAL RESEARCH PRIORITIES	CRC RESEARCH (%)
AN ENVIRONMENTALLY SUSTAINABLE AUSTRALIA – *Transforming the way we use our land, water, mineral and energy resources through a better understanding of environmental systems and using new technologies*	
Water – a critical resource	15
Transforming existing industries	40
Overcoming Soil Loss, Salinity and Acidity	30
Developing deep earth resources	5
Responding to climate change and variability	10
FRONTIER TECHNOLOGIES FOR BUILDING AND TRANSFORMING AUSTRALIAN INDUSTRIES – *Stimulating the growth of world-class Australian industries using innovative technologies developed from cutting-edge research*	
Frontier technologies	10

Photograph by Matilda Thomas

Governance and Management

Photo taken at the final face to face CRC LEME Board meeting Perth on the 23rd of October 2008. *Left to right,* David Garnett (Deputy Chair and Chair MAC), John Watkins (NSW DPI), Bear McPhail (ANU), George Savell (Chair), Tim Brown (Independent), Gerry Govett (Centre Visitor), Lisa Worrall (CEO), Adrian Larking (Independent), Ian Lambert (GA), Graham Carr (CSIRO), Charlie Thorn (CUT), Gary Kong (Business Manager and Board Secretary), Paul Heithersay (PIRSA)

Core Participants

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

- The Australian National University (ANU)
- CSIRO (Division of Exploration and Mining and Division of 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 (UA)

Board of Management

The Governing Board is responsible for policy and strategy. It comprises representatives of Core Participants, Advisory Council Chairs, and Independent members. Mr George Savell is the Independent Chair. Members during 2007-08 were:

Name	Position / Organisation	CRC Position / Role
Professor Tim Brown	Independent	Board member, Audit sub-committee member, Remuneration review committee member Jun 08 – Dec 08
Professor Tim Brown	Dean, College of Science, The Australian National University	Board member, Audit sub-committee member, Remuneration review committee member Jul 07 – May 08
Professor David Ellis	The Australian National University	Board member Jun 08 – Dec 08
Dr David Garnett	Independent	Board member, Deputy Board Chair, Remuneration review committee member, Minerals Advisory Council Chair
Dr Richard George	Independent	Board member, Land Use Advisory Council Chair Jul 07 –Jun 08
Mr Lindsay Gilligan	Director, Geological Survey NSW, NSW Department of Primary Industries and Resources	Board member
Professor Richard Hillis	Head of the Australian School of Petroleum, The University of Adelaide	Board member, Remuneration review committee member
Dr Steve Harvey	Deputy Chief, CSIRO Exploration and Mining	Board member, Remuneration review committee member
Dr Paul Heithersay	Executive Director, Department of Minerals and Energy, Primary Industries and Resources, South Australia	Board member
Gary Kong	Business Manager, CRC LEME	Board Secretary, Audit sub-committee member, Remuneration review committee member
Mr Adrian Larking	Independent, Minerals Industry	Board member
Dr Ian Lambert	Group Leader, Minerals Division, Geoscience Australia	Board member
Dr Steve Rogers	Chief Executive Officer, CRC LEME	Board member, Audit sub-committee member, Remuneration review committee member Jul 07 – Aug 08
Mr George Savell	**Independent**	**Board Chair, Audit sub-committee member, Remuneration review committee member**
Mr Charlie Thorn	Associate Director, Research and Development, Curtin University of Technology	Board member
Dr Kevin Tuckwell	Executive Director, Minerals Tertiary Education Council, Minerals Council of Australia	Board member
Ms Lisa Worrall	Chief Executive Officer, CRC LEME	Board member, Audit sub-committee member, Renumeration review committee member Aug 08 – Dec 08

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

The Board met on the following occasions:

- Thursday September 6, 2007
- Thursday December 6, 2007
- Thursday March 20, 2008
- Tuesday July 1, 2008
- Thursday October 23, 2008

These meetings were supplemented by out of session endorsement of corporate governance matters.

In view of its corporate governance obligations, the Board officially approved the term extension of the CRC LEME Governing Board to 31st December 2008, as per Clause 2.4 of the CRC LEME Winding Up Deed, to duly ensure all actions required by the Board to wind up CRC LEME have been satisfactorily completed. Board membership from 1st July 2008 largely remains unchanged apart from the following movements:

- resignation of Dr Richard George (effective 1st July 2008)
- resignation of Dr Steve Rogers as CEO (effective 1st September 2008)
- appointment of Ms Lisa Worrall as CEO (effective 18th August 2008)

Advisory Councils

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

Members during 2007-08 were:

Name	Organisation	CRC Position / Role
Mr Paul Agnew	Rio Tinto Exploration Pty Ltd	Member
Prof Bob Gilkes	University of Western Australia	Member
Dr David Garnett	Independent	Chair
Dr Jon Hronsky	Encounter Resources	Member
Dr Richard Mazzucchelli	Searchtech Pty Ltd	Member
Mr Christopher Oates	Anglo American PLC, London	Member
Mr Bill Peters	Southern Geoscience Consultants	Member
Dr Paul Polito	Anglo American Exploration (Aust) PL	Member
Dr Bryan Smith	Bryan Smith Geosciences	Member
Dr Nigel Radford	Newmont Mining Corporation	Member
Prof Peter Williams	University of Western Sydney	Member
Dr Wally Witt	Geological Consulting	Member

The CEO and Board Chair are *ex-officio* members of Minerals Advisory Council

The Land Use Advisory Council provides comments 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, Dr Richard George.

Members during 2007-08 were:

Name	Organisation	CRC Position / Role
Mr Murray Chapman	Rural Plan Pty Ltd	Member
Dr Richard George	Independent	Chair
Mr Mike Grundy	Dept Natural Resource & Mines Qld	Member
Mr Gavin Hanlon	North Central Catchment Management Authority	Member
Dr Mike McLaughlin	CSIRO Land and Water	Member
Dr Bruce Munday	CRC Plant Based Management of Dryland Salinity	Member
Mr Bob Newman	Consultant Catchment Management	Member
Mr Colin Simpson	Consultant	Member
Mr Ross Williams	Water Landscape Sciences, NSW	Member
Mr Blair Wood	Land and Water Australia	Member
Mr Ryan Vogwill	Department of Environment and Conservation WA	Member

The CEO and Board Chair are *ex-officio* members of Land Use Advisory Council and the Centre Visitor attends by invitation.

Both Advisory Councils were consulted at an early planning stage of the 2007-08 Research 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 2007 to receive presentations from Program Leaders and to discuss the year's research program and forward planning to the end of June 2008. Input from both Councils were assimilated prior to finalisation of the operating budget.

Executive Committee

The Executive Committee is responsible for the overall management of research programs, including the annual assembly of research project portfolios and budgets 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.

Members during 2007-08 were:

Name	Organisation	CRC Position / Role
Dr Steve Rogers	CRC LEME	CEO, Chair of Executive Committee
Ms Lisa Worrall	Geoscience Australia	Program 1 Leader
Dr Ravi Anand	CSIRO Division of Exploration and Mining	Program 2 Leader
Dr Paul Shand	CSIRO Division of Land and Water	Program 3 Leader
Dr Ken Lawrie	Onshore Energy and Minerals Division, Geoscience Australia	Program 4 Leader
Dr Ian Roach	Department of Earth and Marine Sciences, The Australian National University	Program 5 Leader Jul 07 – Apr 08
Dr Sara Beavis	Research Fellow, Centre for Resource and Environmental Studies, The Australian National University	Program 5 Leader May 08 – Jun 08
Assoc Prof Lindsay Collins	Curtin University of Technology	Assistant Director, Perth
Dr Stephen Hill	School of Earth and Environmental Sciences, The University of Adelaide	*ad hoc* UA Member
Mr John Keeling	Department of Minerals and Energy, Primary Industries and Resources, South Australia	Assistant Director, Adelaide
Mr Gary Kong	CRC LEME	Business Manager and Board Secretary
Assoc Prof Ken McQueen	Department of Earth and Marine Sciences, The Australian National University	Assistant Director Canberra
Dr Bear McPhail	Department of Earth and Marine Sciences, The Australian National University	*ad hoc* ANU Member
Mr John Watkins	Geological Survey NSW, NSW Department of Primary Industries and Resources	*ad hoc* NSW DPI Member

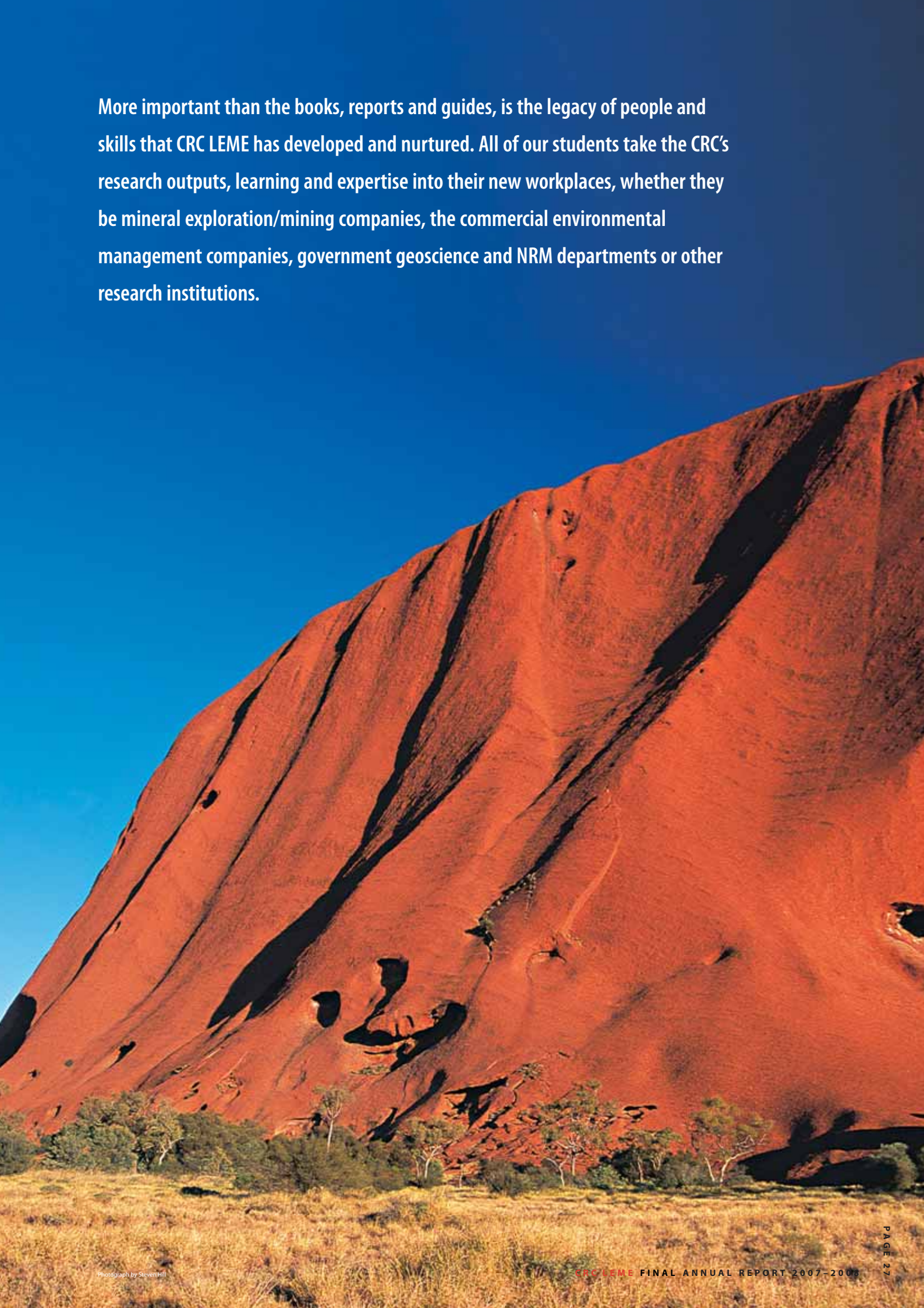
The Executive Committee met several times via teleconference during the year, more frequently when setting the 2007-08 Research Portfolio and Operating Budget. The CEO took the opportunity to meet with Executive Committee members individually when travelling, and there was continuous email liaison amongst Executive Committee members.

Gerry Govett

CRC Visitor

Since its inception, LEME has received valuable counsel from its longstanding Visitor – Emeritus Professor Gerry Govett. The Board endorsed his continuation in this role during the reporting period. Professor Govett is a mentor and independent advisor to all LEME personnel – 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.

More important than the books, reports and guides, is the legacy of people and skills that CRC LEME has developed and nurtured. All of our students take the CRC's research outputs, learning and expertise into their new workplaces, whether they be mineral exploration/mining companies, the commercial environmental management companies, government geoscience and NRM departments or other research institutions.



Photograph by Steven Hill

Research Programs

RESEARCH ACTIVITIES AND ACHIEVEMENTS

Program Structure

Research is reported under the four CRC 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

Program Milestones

Each Program report concludes with a table that marks research progress against the amended program milestones stated in the 2004 – 2005 Annual Report. All of the milestones stated relate to the original objectives, as set out in the Commonwealth Agreement.

Program 1: Regolith Geoscience

Program Leader: Lisa Worrall (Geoscience Australia)

Highlights 2007 2008

- Production of CRC LEME Guides to Mineral Exploration through the Regolith in the Thomson, Cobar, Curnamona, Central Gawler and Tanami regions.
- Production of CRC LEME Guide to Describing Regolith and Landforms
- Production of CRC LEME Guide to Dating Regolith Materials
- Production of CRC LEME Guide to Biogeochemical Exploration.
- Production of the Queensland Regolith Map and Atlas (OFR 242)
- Publication of the results of the Thomson Region Geochemical Survey (OFR 145)
- Publication of the results of the Weipa Project as 6 papers in a thematic issue of the Australian Journal of Earth Sciences.
- Digital Compilation of 160 CRC LEME regolith maps now available on the LEME website
- Physiographic Region Project outputs adopted by a soil monitoring protocol project being developed by the Department of Agriculture Fisheries and Forestry, and incorporated into the revised Australian Soil and Land Survey Field Handbook.
- The PIRSA-LEME team led by Baohong Hou presented with the *2007 PIRSA Directors Award* for an outstanding geoscience publication with instant impact on the exploration industry for the SA palaeochannel map.
- Lindsay Collins and Alexandra Stevens given the *WA Coastal Award for Excellence for Outstanding Partnership in coastal planning.*

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, Generic Process and Commercial projects.

REGIONAL FOCUS PROJECTS

Thomson Orogen

John Greenfield, Bill Reid, Kingsley Mills, Dick Glen, Steve Trigg, Gary Burton, Steve Hill, Karen Hulme, Robert Dart, Jess Davey, Lisa Worrall, Patrice de Caritat, Megan Lech, Andrew McPherson, Ken McQueen, Ian Roach, Richard Greene, Tony Eggleton

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 established the Thomson Orogen Project with the primary objective of improving regional prospectivity by developing an effective means of exploring through the 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 were analysed using a number of techniques (e.g. NITON, MMI partial leach, XRF, ICPMS).

- 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 are being released as a GIS DVD package along with an interpretative analysis and an explorers' guide.

There were three major highlights of 2007-2008:

The completion of Open File Report 145, *Thomson Region Geochemical Survey* authored by the Geoscience Australia team of Patrice de Caritat and Megan Lech. This is a significant volume of work at nearly 500 pages of atlas-style geochemical maps and discussion. It represents a major contribution to the understanding of the geochemistry of the Thomson Orogen. The survey was able to detect areas of elevated base metals from catchments containing known mineralisation, and was able to highlight areas for future exploration.

The completion of the *Guide for mineral exploration through and within the regolith in the southwestern Thomson Orogen, NSW*, by Steve Hill (University of Adelaide), John Greenfield, Phil Gilmore and Bill Reid (NSW DPI). This explorer's guide is another significant piece of work to come out of the NSW Thomson Orogen Project. It represents a concise summary of the results of over ten years of research in northwestern NSW by Steve Hill as well as collaborative scientists and students, mainly from the University of Adelaide.

A research manuscript by Ken McQueen entitled: *A thirsty and confusing diggings: the Albert Goldfield, Milparinka-Tibooburra, north-western NSW*, published in the Journal of Australasian Mining History. This paper represents extensive investigative research by Ken into the history of the gold rush in the Tibooburra area, southwestern Thomson Orogen. It has thrown light on the areas targeted by the early prospectors, and the particular horizons that were prospective.

All of these products were immediately in demand by mineral explorers and other researchers in the Thomson region and this is testament to the quality of the research and the reputation of the researchers that has been garnered through continuous contact with clients over the course of the Project.

The NSW Thomson Orogen Project as a whole has resulted in a great leap forward in the understanding of the landscape evolution and geochemical expression of the Thomson Orogen. This new knowledge is one of the key drivers for an exploration boom that has developed in the Thomson Orogen since the early stages of the Project.

Central Gawler Landscapes

John Keeling, Malcolm Sheard, Baohong Hou, Wenlong Zang, , Barry Cooper, Liliana Stoian, George Gouthas, Steven Hill

The *Palaeodrainage and Tertiary Coastal Barriers of South Australia Map and GIS* (2007) proved to be a popular product and resulted in additional uptake of exploration tenements with potential for heavy mineral sands in the Eucla Basin as well as for sandstone-hosted uranium on the central Gawler Craton. The PIRSA-LEME team led by Baohong Hou responsible for Map and GIS were presented with the *2007 PIRSA Directors Award* for an outstanding geoscience publication with instant impact on the exploration industry.

A review paper entitled *The Cenozoic Eucla basin and associated palaeovalleys, southern Australia – Climatic and tectonic influences on landscape evolution, sedimentation and heavy mineral accumulation* by Baohong Hou, Larry Frakes, Mike Sandiford, Lisa Worrall, John Keeling, and Neville Alley was published in Sedimentary Geology (2008).

Since late 2004, ten significant heavy mineral deposits and prospects have been discovered by company exploration of palaeo-barrier sands on the eastern and northern margins of the Eucla Basin. In May 2008, Iluka Resources announced their decision to develop deposits at Jacinth-Ambrosia containing probable reserves of 6 Mt heavy minerals, including 2.9 Mt of zircon. Selected outcomes of CRC LEME investigations in the region since before 2004 were summarised in a 2008 MESA Journal article by Baohong Hou and John Keeling entitled *Eucla Basin – emerging as a new Heavy Mineral Province of Global Significance*, and are included in presentations at the International Workshop on Fluvial and Marine Processes and Placer Deposits held in Goa in India in November 2007, the Australian Earth Sciences Convention in Perth in July 2008, and the International Geological Congress in Oslo in August 2008.

Regolith mapping and characterisation of regolith materials for the Wudinna North area were detailed in LEME Open File Report 232. The area includes the Barns, Baggy Green and White Tank gold prospects discovered by Adelaide Resources using calcrete sampling. A *Regolith benchmark atlas for the Gawler Craton, South Australia* has also been published as LEME Open File Report 210 and is included as an appendix to the *Guide for Mineral Exploration through the Regolith of the Central Gawler Craton, South Australia*. An overview of the structure and content of the benchmark atlas was presented at the Sprigg Symposium held in Adelaide in November, 2007. The Explorer's Guide was pre-released at the South Australian Resources and Energy Investment Conference held in Adelaide in May 2008.

Electro-geochemical (CHIM) surveys, under the direction of Professor Luo of Guilin University, China, were conducted over

the Challenger gold mine and Tunkillia gold deposit. This work follows on from earlier surveys described in LEME Open File Report 117, released in 2007. A workshop and lectures on geochemical methods and sediment-hosted mineralisation were presented by LEME at Guilin University of Technology. This incorporated a field visit to antimony mines in Yunnan Province where CHIM has been used successfully to locate blind deposits of antimony sulphide. The opportunity was taken to visit Dr Lee at the Beijing Research Institute of Uranium Geology to discuss models for sandstone-hosted and unconformity-style uranium mineralisation applicable in China and Australia.

Key outcomes of CRC LEME research in the central Gawler Craton have been the refinement and widespread adoption of calcrete as a geochemical sample medium for gold mineralisation, a better understanding of the role of vegetation in mobilisation of Au through sand dune cover, an improved understanding of landscape evolution, timing and controls on sedimentation that affect heavy mineral deposition, and techniques to map palaeodrainage sediments that may host uranium. LEME investigations in the region have promoted the use of regolith mapping in planning exploration and interpreting geochemical data, introduced various techniques including electro-geochemical prospecting, partial leach geochemistry and spectral mapping of mineral alteration systems, and trialled biogeochemical and hydrogeochemical sampling as exploration techniques. These investigations underpin the development of new approaches to detect mineralisation in the weathered zone and beneath cover in the Gawler Craton.

Curnaminex

Adrian Fabris, John Keeling, Baohong Hou, George Gouthas, Steve Hore, Liliana Stoian, Mark McGeough, Roger Fiddler, Malcolm Sheard, John Joseph, Joel Brugger, Pierre-Allain Wulser, Steve Hill, Karen Hulme, Jessie Davey, Michael Neimanis, Dirk Kirste, Sue Welch, Bear McPhail

The Curnaminex Project was established in 2005 to develop comprehensive geochemical and geophysical exploration strategies targeting specific mineral deposit types, primarily copper-gold, lead-zinc-silver and uranium, in areas of regolith cover. The thickness and complex nature of transported cover in large areas of the region provide significant challenges to mineral explorers.

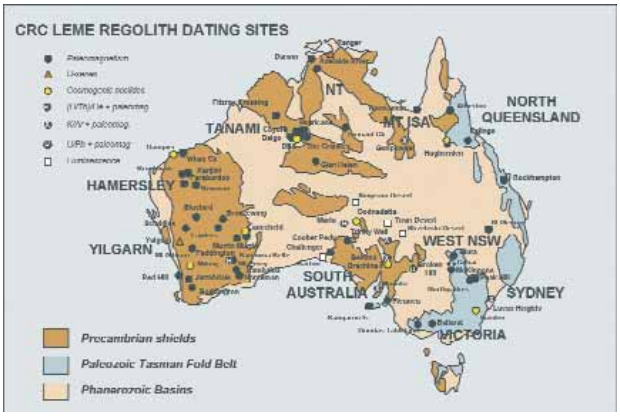
Four prospects were researched during this Project: Polygonum (multi-element), Kalkaroo (copper-gold-molybdenum), Goulds Dam (uranium) and Christmas Ball (copper-gold). Combinations of traditional and novel geochemical techniques have been trialled at most prospects. These include soil sampling from two depth intervals, the use of a variety of partial leaches, hydrogeochemical samples and the electro-geochemical CHIM method.

Partial leach soil geochemistry appears to be mapping changes in underlying bedrock, even through more than 100 m of transported cover. Double-peak anomalies for molybdenum and to a lesser extent uranium, gold and conductivity were the most useful for detecting deeply buried Cu-Au-Mo mineralisation. Relatively high silver concentrations were gained from soils over Pb-Zn-Ag mineralisation at the Polygonum Prospect. Stream sediment sampling to investigate the surface geochemistry of the Polygonum region indicated that modern drainage is not the cause of high trace element concentrations. A weak cyanide leach was generally preferred in all surveys. The three survey lines with electrochemical CHIM results showed mainly high contrast, one point anomalies over mineralisation. These results have been published in Geochemistry: Exploration Environment Analysis (2008) in a paper by Adrian Fabris, John Keeling and Roger Fidler entitled *Surface geochemical expression of bedrock beneath thick sediment cover, Curnamona Province, South Australia.*

Approximately 12 line kilometres of TEM data were acquired over the Kalkaroo Deposit (7 km using a 100 m transmitter loop, 4 km using a 20 m transmitter loop, ~1 km using a 40 m and 10 m transmitter loop). The surveys have highlighted the high conductivity of cover sediments in the region. General differentiation of cover sediments has been achieved including quantification of thickness. The basement-cover interface was defined using a 100 m-loop configuration. A 3D model of the resistive properties of the regolith over the Kalkaroo Deposit was generated.

The Project outcomes are summarised in a comprehensive *Guide for Mineral Exploration through the Regolith in the Curnamona Province, South Australia.* There are a number of digital appendices to this guide, including one appendix which contains pdfs of all of the available regolith maps. This appendix includes a number of maps that were completed this year*; A regolith map of the 1:100 000 Mingary map sheet*, and also prospect scale regolith maps over Kalkaroo and Christmas Ball. Significant variations in regolith and landform settings became evident during the mapping. An understanding of these variations is important to effective planning and interpretation of drilling and geochemical survey results.

LEME/UA PhD students, Michael Neimanis and Jessie Davey, are studying the biogeochemical expression of uranium mineralisation, and the landscape evolution of the northern Flinders respectively. The uptake of uranium and thorium in a variety of native plant species has been demonstrated over a number of known uranium deposits in the Northern Flinders,



CRC LEME Regolith dating sites

indicating that biogeochemistry is a viable method for uranium exploration. Future work will use vegetation to detect secondary uranium mineralisation in palaeodrainage systems.

Tanami

Lisa Worrall, Tony Eggleton, Steven Hill, John Joseph, Dirk Kirste, Anna Petts, Brad Pillans, Nathan Reid, Martin Smith

The Tanami Collaborative Regolith Research Project was established in 2005 to develop an effective means of exploring through cover in the region. The collaborative partners are LEME, GA, Northern Territory Geological Survey, Geological Survey of Western Australia, Newmont, Tanami Gold and Anglo American.

Studies demonstrate that regional weathering history in the area extends as far back as the late Carboniferous and long-term erosion rates are of the order of one to four metres per million years. Geophysical investigations have shown that deep weathering (greater than 300 m) has enhanced the electrical conductivity contrast between rock and regolith. It has also been shown that the combination of electromagnetic and magnetic techniques are highly effective at mapping out key elements of the primary mineral system, as well as identifying key interfaces within the regolith. Downhole geochemical sampling is most effective if key interfaces are targeted.

The results of geochemical analyses of termitaria and plant samples are highly correlated – both detecting anomalies over areas of known mineralisation. These results are discussed in two papers in Geochemistry, Exploration, Environment and Analysis (2008); one by Anna Petts, Steve Hill and Lisa Worrall entitled *Termite species variations and significance for termitaria biogeochemistry: towards a robust approach for mineral exploration*, and one by Nathan Reid, Steve Hill and David Lewis entitled *Vegetation biogeochemical expression of buried Au-mineralisation in semi-arid northern Australia: penetration of transported cover at the Titania Gold Prospect, Tanami Desert Australia.* A third paper by Nathan Reid, Steve Hill and David Lewis entitled *Spinifex biogeochemical expressions of buried gold mineralisation: the great mineral exploration penetrator of transported regolith* was published in Applied Geochemistry (2008). Spinifex chemistry mirrors groundwater chemistry suggesting that spinifex roots tap groundwater at depths of over 20 metres. Proximity to gold mineralisation can thus be identified in the groundwater chemistry in areas of thick cover.

The Project outcomes are summarised in a comprehensive *Guide for Mineral Exploration through the Regolith in the Tanami Desert Region, North Australia.* Project results have also been featured in the popular press, including one article in Cosmos magazine, and interviews with Project staff have been broadcast on ABC TV and Channel 10.

GENERIC PROCESS PROJECTS

Geochronology and Quantitative Models of Landscape Evolution

Brad Pillans, Ed Rhodes, David Ellis, Jim Dunlap, Ian Williams, Rainer Grun, Steve Eggins, David Edwards, Andrew Christy, Martin Smith, Kat Fitzsimons, James Hughes

The current LEME Geochronology Project grew out of the Palaeomagnetic Dating Project that began in LEME 1 in 1995. The LEME 1 and LEME 2 Projects were responsible for a ten fold increase in the number of regolith dating sites in Australia, the publication of a number of important papers in national and international journals as well as monographs including, during 2007 – 2008, *Regolith Dating Methods: A Guide To Numerical Dating Techniques In Australia.*

While palaeomagnetic dating always remained at the forefront of the Project it was, however, progressively supplemented by other dating methods including K/Ar and Ar/Ar, cosmogenic isotopes, luminescence, (U-Th)/He, U/Pb and U-series. Of these, the latter three methods have yet to reach maturity and further work is required to fully test their applications to regolith materials; the other methods may be considered to be "well established".

Initially, the Project's focus was on palaeomagnetic dating of deeply oxidized regolith in the Lachlan Fold Belt and the Yilgarn Craton, where ages as old as 320 Ma were forthcoming. In both regions, the palaeomagnetic ages fitted well with denudation histories derived independently by apatite fission track thermochronology, and confirming the scenario of kilometre-scale episodes of burial and exhumation over the last 320 Ma. A similar pattern of deep oxidation ages was subsequently determined from palaeomagnetic dating in the Tanami region.

In 2001, Brad Pillans was asked to assist in determining the timing of the last movement of two faults on the site of the replacement research reactor (RRR) at Lucas Heights in Sydney. Two steeply dipping faults could be traced for more than 100m across the RRR excavation. However, a prominent unfaulted iron oxide layer yielded a paleomagnetic age of >5 Ma, indicating a lack of fault movement in the last 5 Ma. This was considered sufficiently long ago for the risk of future fault movement to be negligible, and for approval to be given to proceed with construction. The RRR was commissioned in early 2007.

At two sites in South Australia (Beltana and Trinity Well), Jim Dunlap made a series of K/Ar age measurements on supergene Mn oxides, yielding Paleozoic ages. Another site (Moonta copper mine) yielded Late Pliocene-Early Pleistocene ages for alunite veins. In 2007, Jim also demonstrated the feasibility of K/Ar dating of beudantite with a preliminary Miocene age from Elura mine in NSW. Mark Paine also demonstrated the feasibility of (U-Th)/He

Honours student, James Hughes, and Prof Keith Fifield (ANU) contemplate a 3m deep exposure of parna (wind blown dust) near Harden, NSW, prior to sampling for cosmogenic nuclide measurements

Rio Tinto geologists Mawson Croaker, Greg Hartshorne and Zoe Kyriazis with Graham Taylor (sitting) on Weipa bauxite

dating of pisolites from the Paddington mine near Kalgoorlie, WA, while Juan Pablo Bernal completed a PhD thesis on U-series dating of pisolites at Ranger uranium mine in the Northern Territory.

In 2007-2008, palaeomagnetic samples from various parts of Queensland, which were collected by Mike Craig for the Queensland Regolith Project, were analysed to complete a continent-wide coverage of palaeomagnetic dating sites. Results from these sites consolidate the hypothesis (as summarised in previous annual reports) that major continent-wide episodes of deep regolith oxidation occurred during Neogene (0-20 Ma), Early Palaeogene-Late Cretaceous (50-80 Ma), and Early Permian-Late Carboniferous (290-320 Ma).

Cosmogenic nuclide measurements were undertaken in several areas in collaboration with Prof Keith Fifield (ANU) to determine long term rock erosion rates. For example, James Hughes completed an honours project at ANU, investigating regolith/landform evolution in Jugiong Creek catchment, near Harden in the Murray Darling Basin, NSW. James used cosmogenic nuclide analyses to estimate long-term erosion rates and determine their implications for the distribution of dryland salinity.

Cosmogenic nuclide data also played an important role in a pilot project, funded by Woodside Energy Ltd, to investigate the nature, age and weathering history of rock surfaces associated with petroglyphs (Aboriginal rock carvings) at Burrup Peninsula, WA. The data indicate that long-term erosion rates on rock surfaces associated with the rock art are among the lowest measured anywhere in Australia.

Macro and micro biotic influences on the solubility of alumina and the formation of bauxite at Weipa

Tony Eggleton, Graham Taylor

Weipa is the world's largest Bauxite mine. It is situated on Cape York Peninsula, Northern Australia, and is in many ways unique, notably in that it is composed entirely of pisolithic ore. There are some 35 cubic kilometres of bauxitic regolith spread across a huge plateau along the western margin of the Cape. The origin of the deposit, the nature and origin of the pisoliths, the effects of biotic components in its evolution, and of bushfires on its formation have been investigated over the past 15 years. Dave Andrews and many others from Rio Tinto Exploration and Rio Tinto Aluminium are thanked for their unstinting support over this time period.

The Project results show clearly that the deposit is sedimentary. This origin is reflected in the overall nature of the deposit, the internal structure of its pisoliths, and their distribution across the various bedrocks of the plateau. This is a revolutionary concept which has significant implications for exploration as it was theorised previously that the deposit was the result of *in situ* weathering.

The bauxite has been forming for some time, probably since the Late Cretaceous, and it is clear that it is still forming and changing today. Sedimentary processes continue, biological processes renew the bauxite by disturbing the weathering profile and by bringing kaolin up to the surface, and fire impacts heavily on the mineralogy of the bauxite. These are all new concepts for a deposit of this size.

Our results are contained in six papers which have been published in a special issue of the Australian Journal of Earth Sciences (2008), titled:

Weipa Bauxite, Northern Australia:

Part 1. The landscapes and regolith of Weipa
Part 2. Regolith profile, mineralogy and geochemistry
Part 3. The nature of the Bauxite
Part 4. The effects of some macrobiota on the Weipa Bauxite
Part 5. The impact of fire on the bauxite.
Part 6. The genesis of pisoliths and of the Weipa Bauxite deposit.

This study has generated novel science explaining many hitherto unimagined aspects of the origin of the Weipa bauxite, as well as providing new insights to many regolith processes. These processes are very much more widespread than the Weipa plateau and the findings of the Weipa Project are relevant to many regolith studies across a wide range of terrains.

COMMERCIAL PROJECTS

Queensland Regolith Map and Atlas

Mike Craig, Matilda Thomas, Ian Robertson in collaboration with Mal Jones and Joanne Morrison (Geological Survey of Queensland) and Tessa Chamberlain, and Ben Harms (Queensland Department of Natural Resources and Water).

LEME has successfully completed its second major commercial regolith mapping and atlas generation project. The first project of this scale concluded in June 2006 and involved a study of the Northern Territory leading to the production of a Regolith Map of the Northern Territory and an Atlas of Northern Territory Regolith Materials.

The second major Project concluded in June 2008 and involved the production of a *Regolith Map of Queensland* (seamlessly connected to the NT map) and an *Atlas of Queensland Regolith Materials*. The Project involved the Queensland Geological Survey

Examining a clast population in alluvial deposits in central QLD. Right to left: Ian Robertson, Tessa Chamberlain, Joanne Morrison and Matilda Thomas

A view from Tick Hill mine site across the vast plains of Central QLD. Left to right: Tessa Chamberlain, Ben Harms, Mal Jones, Mike Craig and Joanne Morrison

(GSQ), the Queensland Department of Natural Resources and Water (QLD NRW) and Geoscience Australia (GA). GSQ funded the Project as part of its $20 million Smart Exploration Initiative.

The first major Project milestone, which was completed in late 2006, was a 7,500 km Queensland regolith traverse. The purpose of the traverse was to assess and gather information about the major variations in regolith terrains and landscapes across the state. The traverse findings were used to devise a strategy for gathering the vast amount of information needed about regolith materials, their distribution and associated landscapes across the state so that a reliable and accurate QLD Regolith Map and Atlas of Queensland Regolith Materials could be constructed. This strategy was implemented in the second phase of the Project.

The second major Project milestone was the completion of fieldwork in September 2007. The work involved approximately 42,000 km of traversing throughout Queensland, and approximately 6,000 site-specific descriptions of regolith materials and landforms. Approximately 300 major regolith material types were characterised for inclusion in the Atlas of Queensland Regolith Materials. The palaeomagnetic characteristics of regolith samples collected from both surface and mine exposures were determined, and the results used to provide a broad, but simple, chronology for oxidized materials preserved across the state. The results also assisted with the ongoing construction of a wider chronology for oxidised materials across Australia.

Much of the new regolith information about Queensland is presented in the maps and the Atlas. However, additional detail about the regolith is contained in the supporting Project GIS, and the stand-alone databases included with the Atlas. Each sample description in the databases is linked to the Google™ Maps service to allow its location in Queensland to be easily identified.

The successful completion of large area regolith assessments such as was carried out in the Queensland and the Northern Territory Projects relies on detailed planning, good logistics and teamwork. The development of new regolith digital data collection technologies during these Projects contributed significantly to their success.

The new Regolith Map and Atlas of Queensland adds momentum to the call, made after the release of the NT Regolith Map And Atlas, for consistent and comprehensive datasets of spatially located regolith information to be compiled for all the States and Territories of Australia.

Physiographic Regions

Colin Pain

Much of 2007-2008 was spent waiting for state and territory contributions to the final map of physiographic regions. As of June 2008 WA and QLD were still outstanding. Meanwhile, the lessons learned during compilation of the map were transferred to regolith landform mapping concepts with the development of a framework for mapping of regolith in Australia (Table 1).

Table 1. Regolith-landform mapping hierarchy

Level	Regolith hierarchy	Characteristic dimension	Descriptive or defining attributes	Appropriate map scale	ASRIS order
0		100 km	Very broad geology – only 3 units for Australia		
1		30 km	Broad physiography (slope and relief) and geology	1:10 million	Division
2	Physiographic Region	10 km	Physiography, geology	1: 2.5 million	Province
			Mapping hiatus		
3	Regolith-landform province	3 km	Broad landforms and regolith materials	1:1 million	Zone
4	Regolith-landform association	1 km	Groupings of local landforms and associated regolith related in toposequences	1:250 000	District
5	Regolith-landform unit	300 m 100 m	Local landforms and associated regolith	1:100 000 1:25 000	System
6	Regolith-landform facet	30 m 10 m 3 m	Slope, aspect, regolith class	1:10 000 1:2500 1:1000	Facet
7	Site	10 m	Regolith properties, surface condition, microrelief	N/A	Site

Note: Physiographic regions fit in at level 2.

In addition to compilation of national scale landform and regolith information, this Project has provided standard lists of landforms, regolith and parent material lithology for inclusion in an updated version of the Australian Soil and Land Survey Field Handbook that will appear in 2008. The results of the Project have also been picked up by a CSIRO Project for DAFF that is defining a monitoring protocol for soil condition in Australia. This Project will use the physiographic regions as part of stratification for Monitoring Regions and Monitoring Units, regions which have more or less similar parent material (regolith), geomorphic processes and climate.

Work on this Project will continue after the end of CRC LEME support.

Northern Agricultural Catchment Council (NACC) Coastal Project

Lindsay Collins, Alexandra Stevens

This Project had two distinct components: the development of coastal Geographic Information System (GIS) datasets for the coastal zone of the Northern Agricultural Region (NAR) of Western Australia, which includes more than 400 km of coastline, and the development of a genetic model for mineral-sand accumulation for the coastline in the Hutt River Region in the Midwest of WA.

All of the six GIS stages and a final GIS Project joining all the stages together into one seamless set of GIS datasets were delivered to the sponsors; the Northern Agricultural Catchments Council (NACC) and the WA Department of Environment and Conservation. The GIS has provided NACC, DEC, Local Government and community groups with a dynamic database into which on-ground works and coastal remediation could be incorporated and monitored.

The most important findings of the Project are that the NAR coast is under increasing pressure from development and anthropogenic damage as the coastal population expands, placing pressure on current nodes and opening up new nodes along the coast. The unregulated four wheel drive track system along the coast is a major issue for the NAR, and significantly contributes to damage and degradation along the coast in the form of devegetation, multiple tracks and blowouts. Climate change and its impact on the coast is a future management issue that will need to be considered in planning and management along the coast.

Mine mapping at Hutt River has established the processes and pattern of mineral sand accumulation within a Holocene highstand barrier complex, and the genetic model being developed will assist mine development and further exploration.

In partnership with Department of Environment and Conservation the Project won the *award for Outstanding Partnership in Coastal Planning and/or Management* at the 2007 Western Australian Coastal Awards.

Summary

In 2007 – 2008 Program 1 staff delivered five CRC LEME *Explorer's Guides*. These Guides outline mineral exploration strategies and procedures in regolith-dominated terrains, based on state of the art knowledge gained from 13 years of CRC LEME 1 and 2 multidisciplinary research activities. The Guides provide a user-friendly introduction to the regolith, models of regional regolith landscape evolution, palaeo and contemporary dispersion processes and information on the most suitable geochemical sampling media and preferred laboratory techniques for identifying anomalies. The Guides are available as .PDF files for free download from the CRC LEME web site.

In addition, a number of complementary products were developed, namely the CRC LEME *Guide to Describing Regolith and Landforms*, and a *Guide to Biogeochemical Exploration*.

Regolith geologists in Australia are handicapped by lack of fundamental data on the distribution of regolith materials in 2D and 3D, and at regional and local scales. CRC LEME has moved to redress this situation by engaging in a systematic program of regolith mapping. 160 maps have been compiled digitally and are now available for download from the CRC LEME website. Program 1 staff have also been responsible for generating two state/territory wide regolith maps, each of which have been released with a regolith atlas. These products, which are available through the Northern Territory Geological Survey and the Queensland Geological Survey, are very popular, and other states are now interested carrying out regolith mapping at a similar scale.

Program 1 has also engaged in a systematic program of dating regolith materials in order to develop a better understanding of the nature and rates of regolith forming processes. The program has led to a ten fold increase in the number of dating sites, the publication of a number of important papers in national and international journals as well as monographs including, during 2007 -2008, the CRC LEME *Guide to Regolith Dating Methods.*

Program 1 staff would like to gratefully acknowledge the support of the many mining and exploration companies as well as local, State and Federal Government agencies that have contributed to Program research and enabled delivery of Program outputs. The Program Leader would like thank Program staff and students for their enthusiasm and determination to deliver on the Program 1 objectives.

Program One: Regolith Geoscience Research Milestones and/or Outputs Table

Milestone and/ or output	Milestone descriptions and/or outputs incl past milestones which have not been meet	Achieved (yes/no)	If achieved, progress during 07-08
Publication	1. Publish monographs on Regolith Geology of the Yilgarn Craton and Calcrete Manual	Yes (see 2004-05 Annual Report)	
Publication	2. Regolith-landscape case histories across Australia – all modules released on LEME website in 2004-05	Yes	
Collaborative Project development	3. Develop multi-disciplinary research teams involving staff from several Core Participants by end of Year 2	Yes (see 2004-05 Annual Report)	
Regolith model development	4. Develop quantitative regolith-landscape models for key mineral areas in western New South Wales,	Yes (see 2004-05 Annual Report)	Thomson (north western NSW), Curnamona (western NSW and eastern Gawler Craton, Curnamona and Cobar mineral regions SA), Gawler and Cobar Explorers Guides published or prepared for publication
Complete integrated study	5. Complete initial studies in integrating three-dimensional geochemical and airborne electromagnetic modelling in Year 2	Yes (see 2004-05 Annual Report)	
Initiate study	6. Initiate studies on dynamics, distribution and diagenesis of transported regolith in selected regions by Year 2	Yes (see 2004-05 Annual Report)	
Create product control references	7. Produce control reference sets for interpreting mineralogy from spectral signatures of regolith materials	Yes (see 2004-05 Annual Report)	
Extend regolith models into specified regions	8. Extend quantitative regolith-landscape models into Lachlan Fold Belt and Northern Territory	Yes	NT Regolith Map and Atlas delivered. Cobar (Lachlan Fold Belt) Explorer's Guide published
3D regolith model development	9. Develop exemplar integrated 3D models of basinal areas of transported regolith surrounding key mineral provinces by July 2006	Yes	Thomson, Curnamona and Gawler Explorers Guides prepared for publication
Develop techniques for dating regolith	10. Develop techniques for dating regolith and land surfaces, and publish new edition of the handbook Regolith Dating Methods by June 2006	Yes	Revised edition of Regolith Dating Methods published
Develop quantitative framework	11. Synthesize quantitative framework for the history of aridity of Australia by June 2006	Yes	Results of the History of Aridity Project are being published in national and international journals
Develop petrophysical model	12. Predict the geophysical responses of transported regolith and weathered rock, based on modelling of petrophysical data of regolith	Yes	
Develop geophysical techniques for mapping regolith in 3D	13. Develop practical electrical and electromagnetic geophysical techniques for mapping regolith in three dimensions	Yes	

Program Two: Mineral Exploration in Areas of Cover

Program Leader: Ravi Anand (CSIRO EM)

Highlights 2007 – 2008

- Production of a guide for mineral exploration through the regolith in the Yilgarn Craton, Western Australia.
- Gold nuggets shown to form at high temperatures as primary gold and not by low temperature secondary growth.
- Nanoparticulate gold found in salty groundwater indicating that colloidal gold transport is a viable mechanism of gold mobilisation during weathering.
- Soft drinks and wines found to be suitable extraction solutions and in many cases perform better than some commercial techniques.
- Copper likely to be transported only mm to tens of mm per year, even in groundwater flow rates of 1 m/yr and acidic (pH 4) conditions.
- Minerals mapped at the surface appear to provide surrogates for subsurface geochemical trends and zonations linked to alteration. For example, variations in the crystallinity of illite at the surface appear to mirror muscovite-phengite trends found in drill hole data.
- The benefits of using spectroscopic mineralogy as a mineral exploration tool promoted to the mining and exploration community.
- Significant progress made towards understanding biotic and chemical metal dispersion processes in areas of transported cover. Important conclusions and outcomes from various study sites integrated and presented at AMIRA P778 Project meetings in Perth and Chile. This Project continues post LEME.

Overview

The objective of Program 2 was to provide new and improved tools for mineral exploration in areas of cover, based on understanding metal and mineral transport and transformation processes. New knowledge will provide guidelines to explorers to select the most suitable environments in the transported regolith in which metal dispersion is possible and what sample media or techniques are needed to detect this dispersion. The researchers applied analysis of various plant tissues, metal geochemistry in the zone of plant roots in relation to plant uptake, mass balance studies, in-house laboratory and greenhouse studies, groundwater geochemistry, microbial characterization and isotopic analysis to establish the source of metal in plants and soil. Soil desorption analyses were used to test gas migration possibilities. Activity this year was focussed on synthesis and delivery of final research outputs through Open File Reports, peer review publications, LEME Legacy products and conference presentations.

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

GENERIC PROCESS PROJECTS

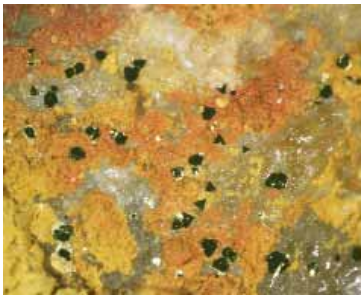
Metals Mobility

Bear McPhail, Steve Eggins, Susan Welch, Andy Christy, David Ellis, Ken McQueen, Joel Brugger, Marc Norman, Alistair Usher, Chris Gunton, John McDonald

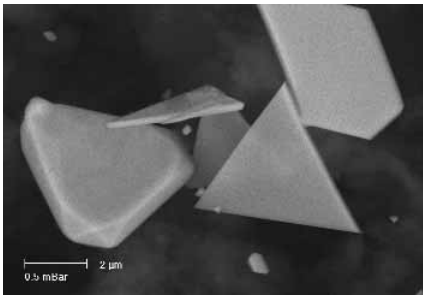
(i) Gold geochemistry in saline waters and brines

UV-Vis spectrophotometry was used to identify gold chloride, bromide and hydroxide mixed complexes of oxidised gold. This is the first documented investigation for mixed chloride-bromide complexes. Thermodynamic modelling predicts Au(III) halide-hydroxide complexes are important under acidic (e.g., pH < 4) and oxidising (atmospheric) conditions. Chloride-bromide and bromide complexes are predicted to be important in transporting gold in brines with high bromide to chloride ratios, such as the Smackover Formation brines in Nevada. The solubility of native gold is likely to be increased by the mixed chloride-bromide complexes for oxidised and reduced gold. The results of this study improve our understanding of gold transport in groundwater and could lead to improved methods for mineral exploration (hydrogeochemistry for gold deposits) and hydrometallurgical processing of gold ore using bromide-bearing lixiviants.

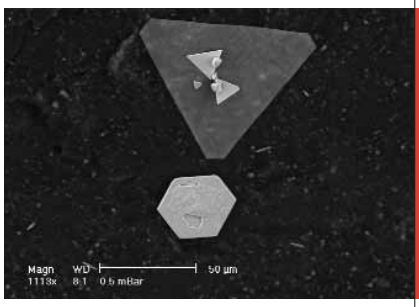
Optical microscope image of a surface coated by iron oxides and clays together with supergene gold crystals



Scanning electron microscope image of triangular single crystal gold particles



Gold crystals showing contrast variation based on changes in nanoplate thickness



A manuscript describing this work and study entitled *A spectrophotometric study of aqueous Au(III) halide-hydroxide complexes at 25-80°C* by Alistair Usher, Bear McPhail and Joel Brugger was submitted to Geochimica et Cosmochimica in June 2008.

(ii) Microbial interactions with gold

The possibility of developing new and improved methods of processing gold ore using microbes was investigated in this Project. Bacteria can dissolve gold in microcosm experiments with live bacterial communities, possibly by producing strong amino acid, cyanide or thiosulfate (strong ligands that can leach gold). Other bacteria, such as Ralstonia Metallidurans, are capable of accumulating gold from solution.

A paper entitled *Potential for the utilisation of micro-organisms in gold processing* by Frank Reith, Rogers, Bear McPhail and Joel Brugger was published in the proceedings of the World Gold 2007 conference in October 2007.

(iii) Transport of copper through iron-rich regolith

New reactive transport experiments by Honours student John McDonald show that reduced copper (Cu(I)) is transported in groundwater more readily than oxidised copper (Cu(II)) through goethite-rich regolith, even though some Cu(I) is oxidised by reactions with goethite and subsequently attenuated. Flushing experiments indicate that initial rates of desorption (leaching) of copper are similar to rates of adsorption, although copper is retained in columns even after long periods of flushing. The presence of kaolinite affects the transport of copper, probably because of outer-sphere cation exchange, and results in attenuation of copper even at pH<4. These new results suggest that copper is likely to be transported only mm to tens of mm per year, even in groundwater flow rates of 1 m/yr and acidic conditions (pH 4).

Detailed experiments measuring the adsorption of Cu on goethite show that NaCl increases sorption at pH <4.5, whereas Na-sulfate and Na-nitrate decrease sorption. The enhanced sorption will decrease copper transport in NaCl-rich waters, common in many Australian regolith environments, resulting in smaller haloes of copper associated with copper mineralisation.

Tracing, Timing and Mechanisms of Metal Migration (Trimm)

Rob Hough, Ray Smith, Ryan Noble, Mel Lintern, David Gray, Ravi Anand, John Keeling, Ken McQueen, Charles Butt, Andy Christy

Hough *et al* published a paper in the Australian Journal of Earth Sciences (2007) entitled *Gold nuggets; Supergene or hypogene?* on gold nuggets that has shown how they were formed at high temperatures as primary gold and not by low temperature secondary growth. This paper has changed some widely held views on the formation of gold nuggets and has implications for exploration in that gold nuggets are now recognized as detritus from eroded gold bearing lodes. The paper received the A.B. Edwards medal for the best publication in Economic Geology in 2007 by the Geological Society of Australia.

Gold nanoplates and nanoparticles are highly topical advanced materials being developed for applications in the nanotechnology industry. They exploit unique physical, chemical and biological properties. The objective is to manufacture, in large numbers, particles that display controlled growth of size and shape. The Mineral Hosts Project team published a paper entitled *Naturally occurring gold nanoparticles and nanoplates* in Geology (2008) reporting on a natural occurrence of these single crystalline gold nanoplates and gold nanoparticles with well-defined crystal shapes and signs of self-assembly that are identical to their manufactured counterparts. The gold nanoplates are so thin (<20 nm) that they are transparent to the electron beam. The crystals occur where a gold deposit is actively weathering, where groundwaters are saline (as in southern WA), and where gold occurs in solution as gold chloride. The nanoparticles are thought to occur in the groundwater as colloids, together with similar-sized halloysite nanoparticles. Reduction of this solution by evaporation precipitates gold nanoplates and nanoparticles. This is supported by their close association with evaporite minerals. This is not only the first direct observation of such nanoparticulate gold in nature but also the first to prove colloidal gold transport is a viable mechanism of gold mobility during weathering. The article has attracted widespread media attention and the lead author (Hough) has provided interviews for national radio, science magazines and a wide variety of print and internet publications.

The gold studies took on a historical angle this year when Dr Charles Butt and Dr Rob Hough obtained the original Liversidge gold samples on loan from the Natural History Museum in London. The samples include nuggets from Australia and PNG that were sliced and etched by Archibald Liversidge in the 1890's. He came to the conclusion that all the gold nuggets he studied were primary detritus from gold veins reaching the same

AMIRA P778 field trip to
Inca de Oro, Chile

conclusion reached by Hough *et al* (2007) using modern analytical methods.

Investigations continue into gold in calcrete by Mel Lintern, a PhD student at CUT. Efforts to find gold by SEM in calcrete have failed, despite many hours of searching, implying that gold is very fine. Other methods are required to identify and locate gold in hand specimens. Research focussed on the soil profile at Bounty Gold Deposit, south of Southern Cross (Western Australia), where there is a strong correlation between gold and calcium and high gold concentrations. Soil particles were separated from bulk samples and analysed by laser ablation ICPMS. Spiky data indicated particulate gold in some soil particles, surrounded by elevated gold concentrations. However, laser ablation ICPMS is a rather blunt instrument to determine precisely where gold is located in the samples. Any gold identified by laser ablation ICPMS has, of course, been destroyed. The same soil samples examined by synchrotron XRF (in Chicago) were mapped for gold to show how and where gold was located. Work is continuing and will be the topic of a paper to be submitted shortly.

The Project has also provided methods for statistical comparison of accuracy and contrast in geochemical orientation surveys using minimum probabilities, and investigated 'alternate' partial extractions (digestible digests). Soft drinks and wines were found to be suitable extraction agents and, in many cases, performed better than some commercial techniques. Three papers entitled *Optimizing geochemical threshold selection evaluating exploration techniques using a minimum hypergeometric probability method* (Stanley and Noble, 2007); *Quantitative assessment of the success of geochemical exploration techniques using minimum probability methods* (Stanley and Noble, 2008) and *Traditional and novel geochemical extractions applied precision* (Noble & Stanley, in press) have been, or are being, published in Geochemistry: Exploration, Environment and Analysis, along with many other reports in print and broadcast media.

Arsenic distribution around the Stawell Gold Mine forms a large halo around the mineralisation and is from natural resources. The highly mobile and more toxic forms of As (anthropogenic sources) were low. One paper is presently in review (Noble *et al*., Journal of Environmental Geochemistry and Health).

Predictive Geochemistry in Areas of Transported Overburden

AMIRA P778 – Ravi Anand, Mel Lintern, Steve Wakelin, Rob Hough, Craig Macfarlane, Brian Townley, Cajetan Phang, Ryan Noble, David Gray, Graham Carr, Michael Korsch, Mehrooz Aspandiar, Steve Hill, Steve Rogers, Siriporn Soongpankhao, Nathan Reid, Tenten Pinchand

AMIRA P778 aims to determine the mechanisms responsible for formation of geochemical anomalies in transported overburden and, based on those mechanisms, to develop effective and robust geochemical exploration techniques. The Project team is systematically studying the role of various chemical and biological mechanisms that form geochemical anomalies in areas of transported overburden in Australia and Chile. Sixteen mining companies sponsor the Project.

Mechanistic work is focused at four major sites representing four commodities (Jaguar, VMS; Barns, Au; Miitel North, Ni; Inca de Oro, Cu). In addition to these four major sites, work is being done at secondary sites including Moolart Well (Au), Rose Dam (Au) and Gnaweeda (Au).

Significant progress has been made in understanding biotic and chemical metal dispersion processes in areas of transported cover. Important conclusions and outcomes from various study sites were integrated and presented at the Sponsors' Meetings in Dec 2007 and June, 2008 in Perth. The review meetings in Perth and Chile were followed by field trips to the Eastern Goldfields of the Yilgarn Craton and Inca de Oro in Chile. Field and experimental work was complied into several confidential investigation reports.

The AMIRA P778 Project will continue generic process-oriented research into understanding metal dispersion beyond the life of CRC LEME.

REGIONAL FOCUS PROJECTS

Yilgarn Laterite Atlas

Ian Robertson, Matthias Cornelius, Amanda Cornelius, Paul Morris

This Project has established that multi-element data produced from the analysis of ferruginous nodules and pisoliths from lateritic residuum, derived lag and ferruginous gravel are valuable for both exploration and environmental purposes. More than 3100 samples were analysed for 53 elements by XRF, ICP-AES and ICP-MS, with selected samples also analysed for PGE. Elevated Au abundances in the NE of the survey area not only cluster around known gold deposits but extend beyond them, indicating the

Tropicana gold deposit

Soil, vegetation and regolith sampling at Tropicana gold deposit

likelihood of more widespread mineralisation in these areas. A chalcophile element index illustrates potential for Au and base metal mineralisation in the westernmost part of the Yilgarn Craton, whereas a pegmatophile index shows a regional NW trend parallel to regional structures. Abundant chromium in granite-dominated areas might indicate mafic-ultramafic remnants (some with anomalous Au) beyond known greenstone belts. A newly discovered regional Hg anomaly trends NW for more than 500 km. Anomalous As, Bi, Mo and Sb along the southern margin of the Craton may be related to Au mineralisation.

The final output from this Project is a paper entitled *Geochemical mapping of the deeply weathered western Yilgarn Craton of Western Australia, using laterite geochemistry* which was published in Geochemistry, Exploration, Environment and Analysis.

Hydrogeochemistry for Mineral Exploration

David Gray, Bear McPhail, Patrice de Caritat, Ryan Noble, Grant Douglas

This collaborative Project, which includes 30 companies, the Geological Survey, Department of Water, the Minerals and Energy Research Institute of Western Australia, and Geoscience Australia, is using groundwater to locate Au, Ni, Cu, Zn and other high value resources over a vast area of the northern Yilgarn Craton in Western Australia. Collection of water samples in the field is progressing well. Approximately 1050 groundwater samples have been collected from the central and eastern region, including the Duketon, Yandal and Agnew-Wiluna greenstone belts and many of the secondary uranium occurrences at Yeelirrie and elsewhere. Our examination of early data has strongly indicated occurrences of regional patterns and has already been utilised to further develop process models. Most waters are fresh, neutral and moderately oxidizing. Nitrate concentrations are much greater than in other groundwaters in Western Australia and sulfate concentrations are varied. These results are consistent with the weathering model and the evolution of groundwater chemical signatures around sulphides.

WA Wheatbelt Uranium

Grant Douglas, Steve Rogers, David Gray, Ryan Noble

The application of hydrogeochemistry as an exploration tool in the southern Yilgarn is difficult, as the groundwater is saline, acidic and has naturally high concentrations of pathfinder metals. This Project was developed with the industry sponsor Mindax to investigate the high concentrations of U in the wheat belt area of Western Australia. Two hundred and twenty eight water samples were collected, analysed and combined with other data sets from CRC LEME, CSIRO and DEC. The results show high U occurrences. Geochemical modelling demonstrated that wheat belt samples can both dissolve and/or precipitate various U minerals, depending on local conditions, with implications for the potential formation of secondary uranium deposits. A restricted CRC LEME report has been produced and provided to the sponsor following Project completion.

TECHNOLOGY DEVELOPMENT PROJECTS

Objective Regolith Logging

Tim Munday, Cajetan Phang, Alan Mauger, Amanda Cornelius, David Gray

This Project has been concerned with the development of spectroscopic logging technologies for the purpose of characterising regolith materials in an objective manner through the application of CSIRO-developed HyChips automated spectroscopic logging technology. Its primary objective has been to promote the use of spectral techniques for the rapid mineral characterisation of regolith samples from drill chips and core.

The Project's medium-term goal has been to build a regolith version of The Spectral Assistant, a TSG Software Package used by the minerals industry for spectroscopic analysis. Whilst progress towards defining a pathway for using a mixture-model algorithm that can be incorporated into the software has been made, the implementation of this awaits further resourcing and now is most likely to be developed under the CSIRO-led Minerals Down Under Flagship Program. The efforts of CRC LEME have ensured that we are significantly closer to delivering an automated approach that determines mineral abundances of regolith materials. This fundamental work is being complemented by collaborative research with AusSpec International aimed at developing a Regolith Geological Environment Specific Spectral Library (Regolith GESSL) and a Spectral Expert File (SEF) that characterises regolith material spectral responses as a market-ready AusSpec product for the mineral exploration industry.

During 2007-08, LEME worked with CSIRO Exploration and Mining in a significant upgrade of its HyChips technology, commissioning a new HyChips logging system which has since been deployed into the Eastern Goldfields of WA. This system is now seeing use by several Au and Ni explorers and miners, to support predominantly brown field activities. The system is also helping promote the benefits of spectroscopic mineralogy as a routine tool in better understanding mineral systems of the Yilgarn Craton.

Mineral Mapping SA

Alan Mauger, John Keeling

Mineral Mapping SA used hyperspectral techniques to map both surface and drill hole mineralogy to aid mineral exploration through, and within, the regolith of South Australia. HyMap, developed and operated by HyVista, provided the data for surface mapping from an aircraft. HyLogger, developed and operated by CSIRO, provided much of the subsurface, drill hole information. Handheld devices including PIMA (from Integrated Spectronics), and ASD Field Spec Pro (from Analytical Spectral Devices in the USA), enabled analysis of surface samples to link the airborne and subsurface data sets.

When comparing instruments it was found that, although the spectra differed in resolution and amplitude, the major mineral boundaries could be identified in all datasets. In addition, each dataset informed the other. For example, surface and airborne data assisted the interpretation of drill hole spectra. In all studies, four mineral suites comprised the bulk of information. Al(OH), (kaolin and white mica), Mg(OH) (Fe-, Mg- and intermediate-chlorite), CO_3 (carbonates) and Fe Oxides (hematite and goethite). Minerals mapped at the surface provide surrogates for subsurface geochemical trends and alteration zones. For example, variations in the crystallinity of illite at the surface appear to mirror muscovite-phengite trends found in drill hole data. Using subsurface drill hole data it has proved possible to map regional alteration trends, inferring regional Eh-pH conditions below the regolith.

Sites in South Australia that were the focus of spectral studies included carbonate mineralogy at Screechowl Creek (Willouran Ranges), Mount Hutton (northern Flinders Ranges) and Beltana (zinc silicate in carbonate). Lithologies, alteration and mineralisation were examined at Mount Painter (northern Flinders Ranges); weathered kimberlite at Pine Creek (near Burra); regolith mapping at White Dam (near Olary), white mica and chlorite alteration associated with Au mineralisation at Tarcoola and Barns (Gawler Craton). The results of these Projects are summarised in a CRC LEME Open File Report entitled *Hyperspectral analysis as applied to regolith and mineral mapping in South Australia.*

Summary

Much of the continuing Program 2 research will form part of the CSIRO Mineral Down Under (MDU) flagship which aims to deliver technologies and capabilities that will enable Australian mineral explorers to understand the evolution of the continent and to target their exploration efforts with greater effect.



Program Two: Mineral Exploration in Areas of Cover Research Milestones and/or Outputs Table

Milestone and/ or output	Milestone descriptions and/or outputs incl past milestones which have not been meet	Achieved (yes/no)	If achieved, progress during 07-08
Publish report	1) Compile case histories of Regolith Expression of Australian Ore Systems	Yes	Publication released as hard copy and on Internet in 2005
Compile and publish report	2) Deliver first results from integrated regolith projects in the Gawler and Cobar regions during Year 2	Yes	Reports completed. See 2004-05 Annual Report
Develop and undertake research project	3) Develop major interdisciplinary projects involving staff from several core participants in the Curnamona, Gawler, Lachlan and Yilgarn exploration regions	Yes	Projects complete and products delivered. See 2004-05 Annual Report
Undertake research project	4) Demonstrate the use of acid sulfate soils and saline discharges in mineral exploration	No	Project transferred to Program 3 See 2004-2005 Annual Report for further details
Undertake research project	5) Complete the Base Metals Exploration Project	Yes	Project completed in 2002-03
Undertake research project	6) Complete multi-client project in Pb isotope geochemistry in selective extraction analysis	Yes	
Undertake research project	7) Assess all possible chemical, mechanical and biological processes leading to the formation of geochemical anomalies in regolith by June 2007	Yes	Report completed June 2005
Undertake research project	8) Identify dispersal mechanism of metals through transported regolith and develop practical deep-sensing geochemical exploration methods – promising breakthroughs using vegetation achieved by June 2006 – practical techniques by June 2008	No	Subject of ongoing research in AMIRA Project P778
Undertake research project	9) Quantify the role and kinetics of biological processes in rock weathering – by June 2006 Publication submitted	Yes	
Undertake research project	10) Determine the physical, chemical and biological processes in the mobilisation and fixation of gold and other trace element in calcrete – by June 2008	Yes	
Undertake research project	11) Demonstrate practical base-metal exploration methods in hydro geochemistry, including now extended to nickel by June 2007	Yes	Report completed and delivered. Significant breakthroughs made. Isotope geochemistry – achieved for isotopes in June 2005
Undertake research project	12) Establish regional laterite geochemical patterns, and develop geochemical tracing methods using particles of residual regolith in eroding and buried regolith terrains by July 2006	Yes	Report complete and product delivered in June 2007
Develop regolith product	13) Develop prototype mineral maps of regolith, using remotely sensed spectra by June 2006	Yes	Kalgoorlie test area completed June 2005 Report completed
Developed regolith logging mineral technology	14) Develop a production oriented, automatic regolith mineral logging technology based on spectral characteristics by June 2006	Yes	Prototype successfully field tested in Kalgoorlie and Commercial analytical lab

Program Three: Environmental Applications of Regolith Geoscience

Program Leader: Dr Paul Shand (CSIRO LW)

Highlights 2007 – 2008

- Delivery and uptake of acid sulfate soil (ASS) research has proved critical to management decisions in the Murray Basin during the current drought
- Delivery of ASS research through forums, brochures, training courses and talks
- Treatment techniques applied to acid drains in the WA Wheatbelt
- Relationships between vegetation, calcrete formation and acid groundwaters helping to provide better conceptual models of acid groundwater development in the WA Wheatbelt
- Uptake of low density geochemical surveys at National Scale

Overview

Program 3 applies regolith science to environmental problems, with an emphasis on geochemistry and environmental hazards. The multi-disciplinary skills of the LEME Core Participants were used to provide robust scientific information to land managers. Key areas of research include regolith characterisation, acid sulfate soil characterisation, process understanding, biogeochemical controls of acidity and metal mobility, and the development of geochemical risk assessment strategies. The projects were typically multi-disciplinary in nature and involved active collaboration with external research groups, agencies and other end-users.

Inland Acid Sulfate Soils (ASS)

Rob Fitzpatrick, Paul Shand, Warren Hicks, Mark Raven, Mark Thomas, Richard Merry

The focus of work on inland acid sulfate soils (ASS) during this final year of the CRC has been on delivery and uptake of the science generated in LEME. During the current drought, the potential risks and impacts posed by ASS during the drying of lakes and wetlands containing potential ASS have moved to the forefront of management decisions, especially in the Murray Darling Basin. LEME scientists have been working very closely with State and Commonwealth agencies to minimise impacts to a number of key environments along the reaches of the Lower Murray. The Lower Lakes and floodplains in the lower reaches of the River Murray are undergoing their first major drying phase since the introduction of barrages more than 50 years ago. A wide range of new potential ASS types have been identified and their risks assessed at both local and regional levels.

A series of AAS forums were held in the Northern Territory, New South Wales and Victoria with national and local collaborators to inform stakeholders about the issues and potential impacts that ASS can have on the environment, infrastructure and industry. The forums provided examples of how other States have dealt with ASS, including presentations on policy, research and remediation.

Science transfer and uptake have not only been a major focus of delivery to managers and policy makers, but also to local communities in South Australia. For example, presentations have been made to local groups around the Lower Lakes at the mouth of the Murray River which have been impacted severely by low water levels as well as the exposure of *ASS. Brochures* and *ASS Information booklets* have been produced for landholders and the general public to help describe and recognise ASS in the field. Training courses have also been designed to enhance the capacity of on-ground NRM staff to identify and assess sites with ASS potential for further investigation and management.

Detailed mapping of ASS sub-types has been completed on the Lower Lakes and River Murray below Lock 1 (Blanchetown) and uploaded on the CSIRO Land and Water ASS website with explanatory notes. Conceptual process models have been developed for State Agencies, which are being used to help: (i) explain the sequential formation and transformation of sulfidic material to sulfuric material in various sub-types of ASS, (ii)

predict the impacts of further drought on water quality and ASS formation and (iii) develop remediation and management options for specific ASS environments. Further progress has also been made using synchrotron techniques on ASS, with the application of X-ray diffraction techniques to explain the rapid transformations of ASS minerals by heat and water application, especially the oxide and hydroxy-sulfate minerals formed as result of oxidation processes.

Acid Drainage In The Western Australian Wheatbelt

Recent studies have built on earlier LEME studies of acid groundwater and surface drains in the Avon catchment of the WA Wheatbelt, and have focussed on extending the geographical coverage and determining geochemical processes during remedial activities.

(i) Acid Drainage – EEI Phase II Wheatbelt Geochemistry Risk Assessment

Brad Degens, Paul Shand, Rob Fitzpatrick, Grant Douglas, Warren Hicks, David Gray, Ryan Noble, Richard George, Adam Lillicrap, Michael Smith

This Project expands upon earlier LEME investigations in the Avon Catchment to assess geochemical risks associated with deep drainage in the WA Wheatbelt. Three new regions in WA were targeted for further detailed study; the Yarra Yarra, Blackwood and South Coast catchments.

All regional surveys of the hydrochemistry in groundwater, drains, receiving lakes and reference lakes in the Yarra Yarra, Blackwood and key catchments on the South Coast were completed. Acidic groundwaters were found in all basins, and these contained a similar range of pH, acidity and trace elements as identified in earlier surveys in the Avon basin. The survey has also confirmed that acidic groundwaters occur throughout most of the eastern agricultural zone of WA, covering an area of over 90 000 km^2. Sampling has identified a significant threat posed by acidic waters to coastal estuaries on the eastern South Coast. Acidic surface waters have been found in the upper reaches of main channels during flow events in volumes that have not been found elsewhere in the state. This acidity is not due to discharge from deep drains.

Soil and sediment samples for detailed mineralogical studies were collected from drain profiles and selected receiving environments. Secondary surface evaporite precipitates and efflorescences, which provide insight into the active evaporation and hydrogeochemical processes, were sampled to assess the variety of evaporite minerals. Sulfidic sediments were well developed in many of the alkaline-saline playa lakes, as well as in deep acid drainage channels. Detailed mineralogical and geochemical analyses of the sediments at each site will be completed and linked in with the regular water quality monitoring.

Spatial analysis of the regional distribution of acidic groundwater has identified strong associations with York Gum and Salmon Gum woodland vegetation communities and to a lesser extent dominant geology and regolith landform type. Strong relationships have also been identified between the frequency of acidic groundwater (at regional level) and the occurrence of soils with carbonate rich subsoils (either as carbonate nodules or calcrete layers). These data are currently being studied beyond the lifetime of LEME to develop regional conceptual models for Wheatbelt acidification.

Bench-top investigations have been completed to provide calibration points for refinement of numerical prediction of acidic drain and alkaline surface water mixing using the PHREEQC geochemical code. The investigations consisted of mixing samples of representative acidic drainage waters with alkaline lake waters in a range of ratios and determining the equilibrium concentrations of major and trace elements. WinPEST is currently being used to fit modelled data to the empirical data derived from the bench-top studies. Development of the model is being carried out to provide a robust, desk-top decision support aid to WA agencies involved in evaluating and managing the risks posed by acidic drainage waters to surface water environments.

(ii) Evaluation of Acid Drainage Treatment Technologies AG 3

Brad Degens, Warren Hicks, Paul Shand, Richard George

This Project forms part of the Avon Catchment Council (ACC) investment in Salinity Management Project and continues post-LEME. The Project aims to:

- Review and report on available treatment methods for acidic-drainage waters
- Identify feasible treatment methodologies and sites for method evaluation
- Construct and evaluate practical options for treatment of acidic-saline drainage waters, focussing on the discharge point of drains
- Evaluate simple, low cost options for treatment of acidic-saline drainage waters in drains
- Identify, evaluate and demonstrate practical options for treatment of acidic-saline drainage waters by mixing with alkaline surface waters
- Develop a set of best-management practice guidelines for such drainage treatments in the Avon Catchment
- Promote evaluation trials and best management guidelines to the broader Avon River Basin Community
- Contribute to 2006-08 salinity management investment planning for the Avon Region.

Monitoring of six on-ground pilot treatment systems established by the WA Department of Water in 2006-07 indicated that simple engineering structures using either calcite (calcium carbonate) neutralisation or sulfate reduction systems initially performed well in treating saline acidic drainage waters. The on-going performance of the calcite neutralisation treatments was limited by either burial of the materials or armouring by iron-oxides and hydroxysulfate minerals. This could be minimised using calcite in pulsed flow treatment systems (where water actively treated by pumping through a tank reactor), or by use of more reactive neutralising materials, such as hydrated lime (calcium hydroxide). The latter required pH controlled dosing systems, and is probably only suited to treatment of drains with high acid loads. Passive treatment of acidic waters using calcite lining of a simple basin structure proved effective, though slow.

Sulfate reduction systems using locally available carbon sources were effective in removing a wide range of trace elements from the acidic drainage waters, although the rates of treatment were slow and decreased with time. Initial treatment rates exceeded those reported for similar systems elsewhere in the world (mostly northern hemisphere) possibly assisted by higher ambient temperatures. Minimal maintenance was required for such treatment systems over the 12 month evaluation period offering some considerable advantages over active treatment by calcite or hydrated lime neutralisation. Results indicate that the use of sulfate reduction systems will be dependent upon concentration of drainage water acidity and quality of carbon substrates available to construct the treatment systems. The outcomes of these evaluations are currently being incorporated into *Best Practice Guidelines for Treatment of Saline Acidic Drainage Waters in the WA Wheatbelt*.

Loveday Basin Floodplain Sulfidic Sediments

Studies of the Loveday Basin in the Riverland Region of the Murray Basin have been a focus of LEME ASS research for a number of years. Originally an ephemeral wetland, the site was subsequently used as a disposal basin between 1970 and 2000. This work, in collaboration with the SA Department of Water, Land and Biodiversity Conservation (DWLBC), provides regolith biogeochemical and hydrogeochemical inputs into the site's rehabilitation. The Loveday Basin was chosen as a test case to assess the impact of re-flooding wetlands with the aim of restoring the basin to an ephemeral, river red gum-dominated wetland.

(i) Drawdown Geochemistry

Sebastien Lamontagne, Warren Hicks

The Loveday Disposal Basin flooding experiment was completed in March 2007. Water quality monitoring in the basin, which began prior to the re-flooding event, was undertaken for almost a year. The experiment was a partial success from a management point of view, as flooding of the basin did curtail noxious smell emissions during the summer of 2006-07. However, due to drought conditions in the Murray-Darling Basin, the delivery of water from the river to Loveday was stopped earlier than anticipated by management agencies. As a consequence, salinity was only temporarily lowered and saline conditions returned by March 2007. The drought is ongoing and most regulated wetlands along the lower reaches of the river have dried or drying, in some cases exposing sulfidic sediments.

The two main objectives for 2007-08 were to: 1) disseminate the findings of the study to managers and other researchers across the Murray-Darling Basin, 2) complete a final report, and 3) to draft a journal paper. The following communication events were held in 2007-08:

- A presentation to the Loveday Disposal Basin Management Committee (10 Oct 07);
- A meeting and site visit to Riverland floodplains with the NSW Murray Wetlands Working Group (15/16 Nov 07);
- An invited presentation about the Loveday Disposal Basin Project for the South Australian Wetland Technical Working Group (30 Nov 07).

In addition, a workshop was organised in Adelaide on 9 November 07 to review the state of research on inland sulfidic materials. The workshop included over 15 participants from the CRC LEME, CSIRO and universities. The key findings from the workshop were:

- Work is still required to define a proper taxonomy for inland acid sulfate soils;
- Inland sulfidic materials have become a key environmental management issue during the life of the CRC LEME;
- Research to understand the environmental impacts of exposing inland sulfidic materials is in its infancy.

The analysis of the water and salt budget at Loveday Disposal Basin during the flooding experiment is ongoing. Findings to date suggest that a large increase in evaporation losses following flooding was the key re-salinisation mechanism. Because Murray wetlands are shaped like dinner plates, small increases in depth result in large increases in surface area and hence evaporation. However, a drop in the regional water table probably fostered by the ongoing drought also contributed to Loveday receding to its pre-flooding size within five months. It is clear that the management of Murray wetlands must taken into account surface water as well as groundwater processes.

The results of the Projects are summarised in a CRC LEME Open File Report entitled *Water quality monitoring at Loveday Disposal Basin during a wetting and drying cycle.*



(ii) Geomicrobiology and Geochemistry of Acid Sulfate Soils

Sue Welch, Sara Beavis, Dirk Kirste, Luke Wallace and Sarah Tynan

This Project explored the biophysical and geochemical controls on sulfur and salt cycling in the Loveday Basin, South Australia during a period of fluctuating water levels. Water levels changed in response to prolonged drought and controlled influxes as a part of rehabilitation strategies.

Site characterisation in terms of clay mineralogy and content, bulk sediment mineralogy, fabric and hydrological response, water chemistry and geomicrobiology indicates that this is a highly heterogeneous system from micro to macro scales.

Sediment sampling has shown that wetting and drying of sulfidic sediments has partially separated carbonate from sulfides in the Loveday basin. Wetting and drying over a period of 5 years has removed the majority of pyrite from sulfidic sediments without large scale acidification. The separation of carbonate from the remaining pyrite is a result of decreased pH, due to pyrite oxidation and vertical diffusion driven by high evaporation rates. The combination of these processes in sediments undergoing wetting and drying has produced a sediment horizon (5-20 cm depth) with net acid generation potential. Carbonate, along with sulfur, largely remains within the sediment profile but is redistributed to the sediment surface and concentrated in efflorescences (0-5 cm depth) due to high upward vertical diffusion and low horizontal diffusion. As the separation of carbonate from sulfides is only over relatively small distances the complete sulfidic profile (0-40 cm depth) has no net acid generation potential. This indicates the wetting and drying of well buffered inland sulfidic sediments is an effective way of removing pyrite from wetlands without large scale sediment acidification. However, in the small areas where carbonate has been completely removed from the sediment profile, small pockets of sediment have become acidified during pyrite oxidation. This indicates that increasing the flushing of carbonate from the profile by horizontal advection could increase the risk of larger scale sediment acidification.

Oxidation of sediments under both acidic and pH-neutral conditions in the field produces high amounts of sulfide oxidation suggesting an acceleration of pyrite oxidation under field pH-neutral conditions. Under oxidising field conditions pyrite framboids in pH-neutral sediments are distinct from acidic sediments where coatings and halos of iron oxides and bacteria form. Additionally, pH-neutral sediments develop characteristic jarosite 'honeycombs' within pyrite framboids not associated with iron oxide coatings. Iron oxide and bacterial coatings indicate that initial pyrite oxidation occurs in acidic nano-environments at the pyrite surface. Jarosite forms only at pH < 3. The discovery of jarosite 'honeycombs' demonstrates accelerated acid production between pyrite crystals resulting in acidic micro-environments. Bacterial halos and the absence of iron oxide coatings around these jarosite 'honeycombs' indicate an expanding acid front outward into the sediment matrix. These results characterise the formation and expansion of acidic micro-environments during pyrite framboid oxidation within pH-neutral sediments. These finding have been published in Chemical Geology (2008) in a paper entitled *Jarosite dissolution II – Reaction kinetics, stoichiometry and acid flux*.

(iii) Loveday Basin Rehabilitation

Sara Beavis, Andrew Higgins, David Ellis, Uli Troitzsch, Sue Welch

When the Loveday disposal basin was decommissioned the site was highly degraded with hypersaline sediments and waters. Re-flooding of the site with 2.4GL of water in 2006 was undertaken as a rehabilitation strategy to mitigate salinity, reduce the risk of acidification associated with oxidising conditions, and prevent gaseous emissions and associated noxious odours. In the longer term the principal aim of re-flooding was to restore the basin to its original status as an ephemeral wetland. The basin was only flooded once because of the high cost of water, and water scarcity due to the prolonged drought.

Initial responses to flooding included the growth of extensive algal blooms and the creation of anoxic conditions within the sediments. Progressive drying out due to evaporative and seepage losses resulted in the formation of decaying algal mats on the surface, oxidising conditions and precipitation of salts within the sediments. In 2008, due to the issue of noxious odours and potential health risks associated with the drying out of the basin, 750ML was allocated to the site as emergency water, and 250ML was applied in a three step process (March, April and May).

A total of 100 samples of water and sediments were collected in February 2008 and analysed for pH, EC and total alkalinity. The water samples were collected from standing water, shallow pits and auger holes up to a depth of 1.5m, and piezometers. Sediments were collected from key transects in the north and south basins up to a depth of 1.5m. Analyses for AVS and CRS are currently being undertaken, as well as sulfate reduction and oxidation experimental work. At the time of sampling the basin was nearly completely dry and the site had been extensively burnt by recent bushfire that had destroyed virtually all vegetation along the western perimeter of the basin as well as vegetation and woody debris on the basin floor.

The results from analyses are being used to determine the changes that have occurred since the collection of baseline data prior to 2006. Shallow groundwater is significantly less than before flooding (~36-51mS/cm in contrast to 72-113mS/cm), whilst deeper groundwater is more saline. EC results of the 1:5 extracts of basin floor sediments indicate significant spatial heterogeneity, both horizontally and vertically, which is evaporation controlled. Overall, salinity of the sediments has increased relative to previous conditions, with increasing salinity from the wet zone to the dry zone and, at a finer spatial scale, up profile and along exposed surfaces in the pedal structures due to capillary rise and evaporation. Although there is continued spatial variability of pH of waters and sediments, there is little change since before flooding. However, it was noted that, due to prolonged drought and associated oxidation of sulfidic materials, near surface sediments in Mussel Lagoon have a low pH (3.25). The EC results suggest that single pulses of freshwater provide conditions by which salts diffuse down profile and add to the groundwater salt load.

Ongoing analyses and experimental work will provide further data from which conclusions can be drawn about geochemical changes to the system, and the associated risks of acidification and salt mobility, in response to the rehabilitation strategy of flooding and subsequent drying.

Low-Density Geochemical Surveys

Patrice de Caritat, Megan Lech, Amy Kernich

Geochemical atlases for the Riverina, Gawler and Thomson regions were released in 2007/08. Each of these open-file reports describes in detail the methodology adopted for sample collection, preparation and analysis. Hundreds of regolith geochemical maps and statistical diagrams are presented in each report to provide the end-user with graphical tools to interpret the geochemical patterns and inform decisions that may pertain to mineral exploration or environmental management. Complete datasets, as well as full quality control information, ensure that these atlases provide the full picture for meaningful application.

As a result of these three pilot projects, as well as the forerunner Curnamona pilot project, a strategy was devised to deploy a geochemical survey at the national scale. This exciting new project, dubbed the National Geochemical Survey of Australia (www.ga.gov.au/ngsa), is currently underway as part of Geoscience Australia's Onshore Energy Security Program and is being carried out in collaboration with all States and the Northern Territory.

Summary

The main emphasis and direction of Program 3 during this final year was the delivery of LEME science, and in ensuring that avenues for science uptake are open. The current drought in Australia has created a large demand for the outputs and environmental science base developed during the lifetime of LEME.

This has particularly been the case for acid sulfate soils research, and LEME has worked extensively in developing materials and providing tools to help support management decisions at a range of scales, and for a wide range of end-users (farmers, NRM Boards, State and Federal Government). The relevance of low density geochemical surveys to regional scale exploration and environmental surveys is clear from uptake at a National level. Delivery for the Wheatbelt drainage and treatment projects will continue post-LEME.

The realisation at both State and National levels that an understanding of ASS and acid drainage are critical to effective management of river, wetland and lake systems will ensure that the Program Leader and project teams continue to provide expertise to end-users, and to provide a scientific basis for long term management strategies during and subsequent to the drought. The regional surveys are also now well established, and we look forward to positive results and new assessments of the regolith geochemistry.

The Program 3 leader is indebted to the support and collaborations developed within LEME and with the many State and Federal Agencies who have helped make Program 3 delivery a reality. CRC LEME is also grateful to the many landholders who have not only allowed access to key sites, but have shown great interest in the work and provided invaluable local information essential to any study of the natural environment.

Finally the Program Leader would like to thank the many researchers who have dedicated much time and effort to provide solutions and to make the outputs and outcomes (present and future) relevant to regolith science in Australia.

Program Three: Environmental Applications of Regolith Geoscience Research Milestones and/or Outputs Table

Milestone and/ or output	Milestone descriptions and/or outputs incl past milestones which have not been meet	Achieved (yes/no)	If achieved, progress during 07-08
Identify research opportunities	1) Discuss with NRM agencies and other CRCs collaborative research opportunities	Yes	
Identify research opportunities	2) Identify and pursue research problems critical to the success of the dryland salinity work being undertaken in Program 4	Yes	
Identify research opportunities	3) Identify and pursue environmental risks requiring regolith geoscience input	Yes	
Identify environmental potential of geoscientific data	4) Identify and assess geochemical datasets that can be used for baseline environmental geochemistry of selected regions	Yes	
Conduct geochemical surveys	5) Complete pilot low-density baseline geochemical surveys in diverse regions by Dec 2006	Yes	
Develop georisk methodologies	6) Develop and apply methodologies for geochemical risk management of soils and groundwater at the catchment scale by Jun 2005	Yes	
Conduct ASS research	7) Establish the distribution, hydrochemical and biogeochemical processes involved in the formation of inland acid-sulfate soils and alkaline soils by June 2007	Yes	
Conduct acid drainage research	8) Erect first model of acidity and metal toxicity in drainage water discharge in a Western Australian agricultural area, and participate in pilot engineering options for hazard remediation by June 2007	Yes	Ongoing for completion beyond CRC LEME transferred to CSIRO

Photograph by Steven Hill

Program Four: Salinity Mapping and Hazard Assessment

Program Leader: Dr Ken Lawrie (Geoscience Australia)

Highlights 2007 – 2008

- Involvement in organisation and sponsorship of the Second International Salinity Forum and the presentation of over 30 papers.
- AEM data used to provide information on salt accumulation in the Murray River floodplain, underpinning new groundwater and salinity models and assisting in the development of new salinity management strategies.
- Geophysical data enhanced the hydrodynamic understanding of the Stockyard Plains (South Australia) saline groundwater disposal basins.
- AEM shown to be an effective technology for "in stream" salinity surveys
- A new multi-scale method for mapping Groundwater Flow Systems (GFS) and 'hydrogeomorphic units' (HGUs) finalised and assessed.
- First national coverage of chloride accession to Australia.

Overview

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).

This year's focus has been 1) finalisation of the externally co-funded research program, 2) presentation of major Program and Project highlights at national and international conferences, and 3) completion of a suite of legacy products to support the knowledge transfer strategy.

EXTERNALLY CO-FUNDED AIRBORNE ELECTROMAGNETICS (AEM) PROJECTS

River Murray Corridor (RMC) Project

Ken Lawrie, Colin Pain, KP Tan, Jon Clarke, Heike Apps, Dave Gibson, Richard Lane, Vanessa Wong, Larysa Halas, Janine Luckman

In the River Murray Corridor (RMC) Project, a 4-D landscape analysis approach complemented more traditional hydrogeological analytical techniques. This approach incorporates an understanding of landscape evolution and scale, utilises modern investigative approaches to the conceptualisation of aquifer systems, and incorporates data on water, salinity and vegetation dynamics to provide key constraints on interpretation of both near-surface AEM responses and floodplain hydrostratigraphy.

Recently, this approach has been greatly facilitated by development of a holistic inversion method. Unlike conventional inversions in which each airborne sample in the survey is inverted independently, the holistic method inverts all of the airborne samples in one large inversion. This allows it to capitalise upon the spatial coherency in the data to produce a spatially continuous conductivity model defined by spline meshes. It also allows the inversion to account for systematic calibration errors that may not have been identified and removed during the data processing. The superior spatial continuity of the holistic model allows for the interpretation of more subtle features (eg palaeo strand line patterns) in the data than could be done from the conventional "sample by sample" stitched inversions, which were also used in the Project. This method also allows for more rapid-turn around in developing interpretation products.

The AEM-based products provide important new information on the spatial distribution of key elements of the hydrogeology, notably the extent and thickness of aquitards such as the Blanchetown Clay, as well as important data on the depth to the top of the Loxton Parilla Sands aquifer and the distribution of zones with higher hydraulic conductivity within this aquifer. Combined with new products, which show the spatial distribution of groundwater salinity and salt stores within the unsaturated zone, these datasets provide important new inputs to hydrogeological models and provide the spatial context to salinity impact modelling.

Integration of the AEM data with new surface geomorpological and surface salt mapping (using SPOT5, Landsat, and LIDAR datasets), new borehole hydrogeological data, and spatio-temporal analysis of vegetation health, has also facilitated development of a broader range of interpretation products. These include porosity-corrected maps of the thickness, and extent of

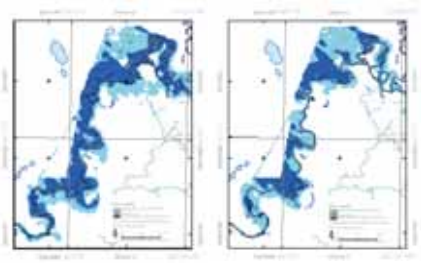


Figure 1. River flush zone maps for the Liparoo-Robinvale sub-area from different depth slices below the floodplain surface (A) 10 to -15 m and (b) -25 -30 m below floodplain surface). The flush zones (dark blue) in the shallower depth slices are within the Coonambidgal Fm and essentially follow the course of the main river channel, while the fresh groundwater in the deeper slices is more compartmentalised within the Parilla Sands.

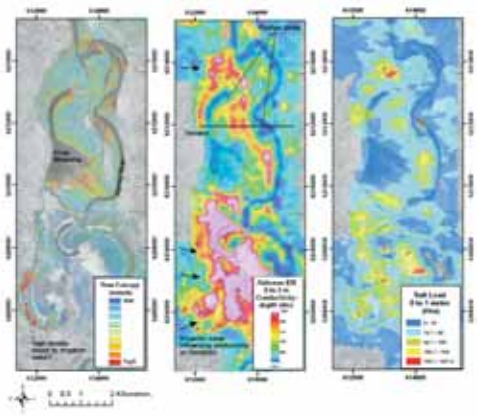


Figure 2: Salt loads calculated from AEM data, Sunraysia Project

individual formations, river flush zone maps (Figure 1), recharge maps, maps of near-surface salt stores, near-surface freshwater distribution, irrigation-related anomalies, maps of groundwater quality, and new salt store, salt load, and salinity hazard maps.

Angas Bremer

Andrew Fitzpatrick, Tim Munday, Kevin Cahill, Richard Cresswell

Concerns by irrigators over the sustainable use of very limited water resources in the Angas Bremer Plains of South Australia has driven a number of recent initiatives aimed at trying to understand the complex interaction between surface and ground water and, in particular, the effect this has on the quality of these resources and the potential for irrigation-induced salinisation of the region. Among these initiatives is the development of the Angas Bremer Integrated Systems Model (ABISM) which aims to better define strategies for a conjunctive approach to water management from the paddock to catchment scale. The key to the effectiveness of this model is the availability of good biophysical data to describe the spatial variability of salinity and water quality across the region, most particularly in the near surface (< 30m depth).

The use of constraints in the inversion of previously acquired AEM data over the Angas Bremer Irrigation District permitted the derivation of three biophysical products from these data. Specifically, they included a map of soil salinity, along with maps detailing the quality of water in the underlying Quaternary and Upper Tertiary aquifers. The incorporation of these data into the ABIS model provides information that can be used to directly inform land owners and catchment managers on how to effectively mitigate against salinity risk. Irrigators are benefiting through the provision of enhanced model constraints, which is helping to determine where groundwater pumping should be restricted in order to limit drawdown and salinisation of the Tertiary aquifer.

Stockyard Plains

Andrew Fitzpatrick, Tim Munday, Amanda Cornelius

Airborne geophysics, particularly airborne EM, has significant – though largely unrealised – potential to inform our understanding of disposal basin hydrodynamics; as has been suggested at limited local scale by ground geophysics. CRC LEME recently completed a collaborative study with the South Australian Department of Land, Water and Biodiversity Conservation which focuses on the interpretation of RESOLVE frequency domain HEM (FDHEM) data acquired over the Stockyard Plains natural saline water disposal basins located southwest of Waikerie, South Australia. The Project's intent was to determine the extent of saline plume migration around the extant basin at Stockyard, and to inform our current understanding of the hydrodynamics of saline groundwater disposal in the area. It also aimed to determine the potential for extending disposal options in the vicinity of the existing basin by identifying areas where aquitards (the Blanchetown Clay) were present or absent in the landscape.

The results of the study provided a spatial context for understanding information derived from available bore data, in particular that pertaining to how the existing disposal basin is behaving, and how groundwater salinity is being influenced by leakage from the basin. At this stage there is no evidence to suggest that regional groundwater gradients (which trend westerly) are significantly influencing the brine pulse emanating from the basin as identified in the HEM data. Regional airborne magnetic data also suggest that basement faults may significantly influence the integrity of the overlying sedimentary aquifers, and that their role on the hydrogeology might need to be considered.

Sunraysia and Gol Gol

Tim Munday, Andrew Fitzpatrick, KP Tan, Kevin Cahill

The Sunraysia/Gol Gol airborne geophysics Projects are approaching their conclusion with a strong focus on delivering outputs that can inform the Eastern Mallee 2 Model as part of the MDBC's Basin Salinity Management Strategy. To that end the study has defined groundwater conductivity variations in the saturated zone of the Murray Trench, along with estimates of salt loads. This information has also been used in models (WINDS) aimed at predicting the consequences of salinity on vegetation health around the Gol Gol Lake and Swamp areas.

A detailed study of the Kings Billabong area has demonstrated a strong correlation between the density and health of floodplain vegetation communities and the quantity of salt stored in the near surface as defined in the HEM data. In a sense vegetation is an excellent indicator of how salt has moved and concentrated in floodplain soils, and the HEM data confirms this relationship. The project also suggests that the considered inversion of the HEM data is required to accurately define the quantity of salt stored on the floodplain (Figure 2). Once completed, we believe that the derived data will usefully constrain models describing mechanisms of salt transport and accession on floodplain systems, and provide a realistic picture of total floodplain salt storage.

Loxton SIS Study using AEM data

Tim Munday, Andrew Fitzpatrick

An analysis of SkyTEM data was completed in order to determine if AEM could inform the development of Salt interception Schemes. New quasi 3D inversion methods (Spatially Constrained Inversion) defined the conductivity structure of deep aquifers and may also help to identify cross aquifer leakage.

SA Murray Floodplains Project

Tim Munday, Andrew Fitzpatrick, Kevin Cahill, Ian Overton, KP Tan

This Project has demonstrated the value of acquiring AEM data over the floodplains of the Murray, and has been instrumental in developing our understanding of how low power, high resolution AEM systems can perform in these settings. The Project recently completed a comparative study of the SkyTEM Time Domain and RESOLVE Frequency Domain EM systems and, working in collaboration with the University of Aarhus in Denmark, has evaluated fast approximate transforms of the data, along with a Spatially Constrained Inversion technique.

The Project also completed a study of recharge mechanisms along the Murray. Specifically a soil sampling program in an irrigated area in the Riverland of South Australia was carried out in order to determine if perched water tables were present, and to evaluate recharge/leakage processess/rates through near surface aquitards. It also aimed to determine whether areas of perching (or potential perching) can be mapped spatially from airborne EM. Estimates of below root zone drainage rates at the sites studied were compared with those defined using other methods and with estimates currently used in SIMPACT. Estimates of drainage from this work agree with values currently used in modelling salt load to the Murray. In areas that have been irrigated for decades and irrigation returns are high, and perching will take place if the Blanchetown Clay is present. In the areas studied in this report, only 2-6 % of the perched water leaks through the clay layer. The remaining therefore must move laterally until it finds a gap in the clay or disappears down drainage bores. Available Helicopter EM data proved effective in mapping a near surface clay aquitard, but the challenge remains in applying these technologies more widely, particularly in areas where significant infrastructure is present.

Elsewhere, on the floodplains of Chowilla in South Australia, the Project examined the value of using biophysical parameters derived from the helicopter electromagnetic (HEM) data, specifically groundwater conductivity for specific zones in the saturated and unsaturated parts of the floodplain, as a basis for making vegetation health assessments or predictions at any particular time. Along the floodplains of the Murray River in south eastern Australia, spatial variations in evapotranspiration develop due to the variable distribution and type of floodplain sediments, patterns of vegetation type, floodplain elevation and geometry. In places where the groundwater system is particularly close to the surface, evapotranspiration concentrates salt resulting in extensive salinisation, vegetation dieback or health decline. In many floodplain areas, ecologically important *Eucalyptus* woodlands and forests that inhabit the floodplain are dying from soil water salt concentrations that often exceed those of seawater.

To better manage this problem and to protect the ecology and biodiversity on the floodplains along the river, a range of management strategies are being employed. Modelling tools are integral to their development, but key to their effectiveness is the availability of detailed biophysical data. The Project examined the use of WINDS, a spatial model that examines soil water availability to show the possible effects of manipulating flow regimes and groundwater lowering options across the whole of the floodplain. The use of derived parameters on floodplain conductivity from the airborne geophysics resulted in an improved prediction of vegetation health across the floodplain against available information; the improvement rising from 60% to 72%. We expect that with further refinement, particularly with information on the depth to groundwater that might be extracted from inverted EM data, this predictive accuracy should improve further. We believe the procedures defined in this study have application to other areas of the Murray River Floodplain where HEM data have been acquired, and the approach developed here is now being applied in other reaches of the river.

MURRAY-DARLING BASIN COMMISSION CO-FUNDED PROJECTS

Comparison of AEM and In-Stream Survey Technologies

Tim Munday, Andrew Fitzpatrick, Kevin Cahill, Mike Hatch, KP Tan, Dave Allen (Geoimaging), Barry Porter (DWLBC), Andrew Telfer (AWE)

CRCLEME recently completed a comparative study of in-stream sampling or airborne survey techniques in a test of their relative suitability for characterising in stream salinisation and for determining which sections of river systems might be gaining or losing. This study addressed several key outcomes from the Melbourne NanoTEM technical workshop (held on November 22nd 2006).

Three of the techniques are geophysical and the other is the Run-of-River (ROR) survey method that has successfully been used for years to site nearly all of the current SIS projects along the river. The three geophysical techniques reviewed were the In-stream NanoTEM (a time domain EM system), an in-stream resistivity array technique (the Blue Eel), and a Helicopter frequency domain electromagnetics system (specifically the RESOLVE FDHEM).

The three geophysical techniques reviewed produced comparable results, in that they all defined “gaining” and “losing” stretches of the river and the conductivity structure of the river bed. The helicopter EM technique was most effective at seeing deeper variations in the subsurface conductivity structure. While information about the zone immediately under the river is of primary interest when attempting to locate sources of saline groundwater influx into the river, this is not the only information that can be garnered from the observed conductivity response. The observed patterns of in-stream conductivity are also strongly correlated with geology.

A new approach to the definition of Groundwater Flow Systems (GFS)

John Wilford, Larysa Halas

In this past year, advances have been made in finalising development and assessment of a new approach to the definition of Groundwater Flow Systems (GFS). The approach was based on an ability to take advantage of higher resolution topographic data, the development of a weathering index, and capacity to apply this analysis to large spatial areas via increased processing capability. The new body of work significantly enhances the value of the existing groundwater flow system (GFS) for managing salinity. A new framework, termed 'Hydrogeological-Landscapes' has been developed. The 'Hydrogeological' term highlights the important components of water and geology whereas 'Landscape' highlights the importance of landforms and regolith for hydrological processes.

A Hydrogeological-Landscape Unit (HLU) is a broad, all encompassing entity that accommodates all forms of water flow (surface, inter-flow and groundwater flow). The framework has the potential to be used for a range of NRM applications where decisions involve soil, regolith or hydrological properties. HLUs accordingly integrate information on lithology, bedrock structure, regolith (including soils), landforms and contained hydrologic systems. These components all influence to greater or lesser degree the rates and pathways of water movement. Other factors including climate and vegetation are also taken into account when describing the hydrological characteristics of a particular system, but are not used to define HLU boundary. A mix of old and new datasets (depending on availability of suitable data) and enhancement techniques (eg. automatic landform extraction; geochemical weathering indexes) are used to capture these components and build HL maps and associated descriptions.

HLUs have been placed in a hierarchical mapping system to address the importance of landscape scale, both from a hydrological and management perspective. The rational here is that both hydrologic and management components are intrinsically linked across different scales, e.g. most flow systems are nested within larger ones and most local land management strategies ideally need to be integrated into regional programs and goals.

Work was conducted with Victorian and NSW State agencies and consultants including Mark Hocking and Ray Evans, to assess these new GFS-style products. It was found that the new HLU products have higher levels of resolution than existing GFS products due to improved algorithms and the use of a weathering index that better correlates with salt store. HGU products also improve confidence in the salinity model and provide improved landscape resolution.

Landscape Analysis

Dave Gibson, Colin Pain, Jon Clarke

During the year work continued on combining existing maps such as the Physiographic Regions of Australia and various regional land system maps with up-to-date images such as digital elevation models and gamma-ray spectrometrics (radiometrics). This was used to develop a hierarchy of spatial units with information available at a range of scales, following the ASRIS model.

In the past 12 months this Project has finalised a legacy report (with database and GIS) that compiles all available K/Ar and Ar/Ar age dates and OSL age dates for the Cenozoic in Eastern Australia, produced a legacy report that sets out the methodologies, the scientific background, and example maps for landscape analysis in Eastern Australia and presented a series of papers on results to the Australia New Zealand Geomorphology Group meeting in February 2008. This Project links to the preparation of a special issue of the International Journal of Remote Sensing. Many of the papers are derived from work carried out in this Project.

The Project has demonstrated the value of hierarchical approaches to mapping natural attributes for such issues as controls on regolith distribution and variability within catchments in eastern Australia; sources of signals received by gamma ray instruments and presented on radiometric images (key to moving towards production of 3D soil and recharge maps); and significantly improved regional natural resource management tools – for example, the approach is now being incorporated into a plan for monitoring national soil condition.

Salinity Dynamics

Richard Cresswell, Dirk Kirste, KP Tan, Richard Greene

In the Salinity Dynamics Project, there were several highlights, including the Web-based delivery of salt accession maps of Australia. These products represent the first national coverage of chloride accession to Australia through the joint CSIRO-MDBC-CRC LEME rainfall collector network, in combination with the BRS MDB collection network. Comprehensive monthly data on major ion accession and stable isotope (O and H) composition is collected from 20 sites, and is now linked to US-based study investigating fluoride and other halide transport in the regolith (with Bridget Scanlon, Uni Texas at Austin).

Elsewhere, the Hodgson Creek surface water – groundwater interaction study has been incorporated into a NWC national project. This Project has found that seasonal and inter-annual variability of groundwater input to the surface water system can be documented and quantified using a combination of geochemical and isotopic modelling. Salt transport is sporadic and seasonal. Whist the catchment has a high salt export relative to input (O/I >4), this is almost entirely due to seasonal flushes of the creeks

during summer floods and hence predominately consists of surficial salts formed through evaporation of discharging groundwaters at the surface. Discharge is governed by the discontinuous flow characteristics of the regolith: layered basaltic flows on weathered sandstones, with variably weathered profiles that define the groundwater flow systems.

A study of the persistence of waterholes on the Moonie River has found that persistence is a function of waterhole size and SW-GW interaction, but high interaction may mean shorter persistence. The nature of the waterhole sediments and lining of the waterhole floor is an important constraint. Where groundwater can feed the surface system during periods of high water-tables, may also be where drainage of the waterhole is greatest when water-tables drop. Waterholes that are not affected by rising groundwaters develop an impermeable lining, and evaporation is the only water loss mechanism. Studies have also found that the near-surface is the critical zone when considering the chemical transformation of rainwater into soil and ultimately recharge water. Biogenic re-cycling of elements is of fundamental importance when considering the chemistry of recharge waters and consequently the input composition when considering groundwater evolution. The use of rainfall chemistry as an input to geochemical models is therefore not appropriate.

Water transport through the vadose zone can be realistically modelled using HYDRUS even in complex vertosols where shrink and swell clays prohibit the use of standard water transport equations. Using bromide as a tracer in lysimeter studies with QDRNW, we have successfully modelled break-through curves in soils that exhibit varying water transport capability due to strong shrink and swell capacity. Previously, the effect of the salinity of waters on the transfer capacity of these soils was demonstrated and imaged using gamma tomography.

In the past 12 months the Corangamite study has also been completed. This Project found that linkages between eco-hydrology, climate and regolith architecture determine the fate of the lakes in the Corangamite region of western Victoria.

Summary

The wrap-up of the externally co-funded projects on the application of AEM to salinity mapping coincided with increased demand for AEM-based products. This is largely attributed to development of a new suite of interpretation products, including porosity-corrected maps of the thickness and extent of individual formations, river flush zone and recharge maps, maps of near-surface salt stores, near-surface freshwater distribution, irrigation-related anomalies, groundwater quality, new salt store, salt load, and salinity hazards. Program staff has been involved in transitional arrangements with core participants in response to this demand

While the focus of the AEM-based products has been on floodplains and irrigation districts, significant progress has also been made on developing a hierarchical system for regolith mapping following the ASRIS model. This new approach combines existing maps and various regional land system maps with up-to-date digital elevation models and gamma-ray spectrometric images.

A new approach to defining Groundwater Flow Systems (GFS) was also developed and assessed at regional scales. Based on mapping Hydrogeological Landscape Units (HGUs), it takes advantage of higher resolution topographic data and the development of a weathering index. Applying increased processing capability and improved slope and landform characterisation algorithms to large spatial areas indicates higher levels of resolution. This approach also approximates the landscape into discrete local flow system cells or catchments, providing more landscape detail overall.

An independent assessment of these new HGU products has found higher levels of resolution than existing GFS products, due to improved algorithms and the use of a weathering index that better correlates with salt store. It also improves confidence in the salinity model and provides improved landscape resolution using detailed spatial layers.

Program staff published over 50 technical reports, conference and journal papers, and presented over 30 papers at national and international conferences. Vanessa Wong received a best paper award at the AESC 2008 conference in Perth, for a paper demonstrating how remote sensing and AEM datasets could be integrated with regolith and hydrogeological data to understand controls on changes in vegetation health in the Murray Floodplain. CRC LEME was involved in the organisation and sponsorship of the 2nd International Salinity Forum (ISF) and conducted well-attended workshops on catchment characterisation and AEM mapping methodologies as well as co-organised a salinity science for policy and decision makers' workshop.

A collection of 9 papers for a Special Issue of the International Journal of Remote Sensing on the application of Digital Elevation Models for landscape mapping has been submitted and scheduled for publication in early 2009. Also, a special volume of 10 papers has been compiled for a special issue of the Australia Journal of Earth Sciences on the topic *Australian Cainozoic Sediments and Landscapes*. Papers include: M Sandiford (Tectonic framework of the Australian Cainozoic); K Page (Depositional landscapes of the modern Murray river and its tributaries); P Hesse (Macquarie Marshes); R Greene *et al*. (Distribution of parna in Australia from source to deposition); J Wilford (Upland depositional landscapes of eastern Australia); D Gibson and KP Tan (Terrestrial sedimentation in the Neogene Bland Basin, an alluviated palaeovalley in the Murray-Darling Basin, Eastern Australia); R Chan (Evolution of the Giliambone depositional landscape); Reid *et al*. (Sources of sediment within the Eocene Garford Paleochannel, South Australia, from detrital zircon geochronology); and Kernich *et al*. (Evolution of the lower Balonne Floodplain).

Over seven years CRC LEME, in partnership with a range of Natural Resource Management (NRM) agencies and regional communities across Australia, has successfully demonstrated how multi-disciplinary geoscience approaches can be used to effectively address a range of salinity-related NRM issues. New insights into Australia's regolith landscapes, combined with the

acquisition of new 3D geospatial data layers, have significantly improved confidence in models that are used to prioritise and target salinity management investments across a wide range of landscapes and land use settings. The joint Academies Salinity Mapping Review for Application to the Mapping and Prediction of Salinity Hazard and Risk in Australia recommended the adoption of the LEME strategy in all of the Australian Government's Salinity Mapping Projects.

The success of the Program's research is reflected in the incorporation of the Program staff into new groundwater and environmental programs within the core participants, and a significant increase in plans to acquire further hydrogeophysics datasets for groundwater resource and environmental management purposes in Australia. Much of this success is now echoed internationally.

Program Four: Research Milestones and/or Output Tables

Milestone and/or output	Milestone descriptions and/or outputs incl past milestones which have not been meet	Achieved (yes/no)	If achieved, progress during 07-08
Develop technical capacity and facilitate technological transfer	1) Develop management and technical capability to generate and undertake state-based salinity projects, and provide technological transfer to clients by December 2003	Yes	
Develop new geophysical methodologies	2) Develop new constrained inversion methodologies for modelling wide-band frequency domain helicopter EM data by December 2003	Yes	
Report on developed geophysical methodologies and its application	3) Develop and report on the application of geophysics-based methodologies for designing optimal recharge strategies, and developing hydrological models in lowland (for example irrigation) areas by December 2003	Yes	
Evaluate methodologies	4) Evaluate and demonstrate the value of airborne geophysics (particularly AEM) for mapping salinity, regolith architecture and groundwater systems in various regolith environments; produce an evaluation report and site study by December 2003	Yes	
Demonstration of 3D regolith modelling applications	5) Demonstrate and report on the application of three dimensional regolith models based on integrated multidisciplinary methodologies, to understand salt stores and groundwater dynamics in upland areas, by way of catchment-based projects	Yes	
Apply developed methodologies to environmental problems	6) Apply and extend the use of use of new-generation geophysics and remotely-sensed technologies to case studies requiring regolith input to environmental problems by December 2004	Yes	
Develop predictive models	7) Develop theoretical and practical models for predicting salt mobilisation and water quality in various regolith landscapes; release information annually from July 2003 to July 2006	Yes	
Publish thematic volume	8) Submit for publication a thematic volume on regolith input to South Australian NAP projects by June 2005, for publication in 2006	Yes	
Integrate salinity hazard and regolith inputs to the National Land and Water Resources Audit by December 2007	9) Integrate salinity hazard and regolith inputs to the National Land and Water Resources Audit by December 2007	Yes	
Developed improved framework for upland landscape salinity modelling	10) Deliver outputs on improved regolith frameworks for salinity modelling in upland landscapes and in-river salinity to the Murray Darling Basin Commission	Yes	
Demonstrate the importance of acquiring and interpreting geophysics for shallow regolith environments.	11) Demonstrate the importance of acquisition, processing and interpretation of frequency domain AEM to deliver operational functionality in shallow regolith environments by June 2005, and impart this knowledge to NRM stakeholders over the period till June 2008	Yes	
Demonstrate the value of regolith frameworks to remediate environmental problems in Western Australia	12) Demonstrate the value of geophysically derived regolith frameworks to the distinctive environmental and NRM issues in Western Australia by June 2005, and have such inputs accepted as an integral part of NRM procedures by June 2008.	Yes	

RESEARCH COLLABORATIONS

Throughout the year, LEME continued to engage in a high level of collaboration both internally and externally; maintaining effective collaborative linkages between its eight Core Participants, industry end users, the scientific research community, government authorities and community stakeholders.

Internal Research Linkages

Multi-party and multi-disciplinary projects were an integral part of LEME research activities. They have ensured that regolith knowledge remains focused on the needs of the diverse set of stakeholders in both mineral exploration and natural resource management industries. Of the 39 projects funded by the Centre, 19 had participation from more than one Core Participant. Most 'one-party' projects focussed on technology developments or specialist services.

Student Program Linkages

Honours and postgraduate student research projects were integrated into CRC LEME research projects with LEME staff members providing supervision. However, for ease in financial and IP management, they were not formally brought into individual projects in the core research programs. LEME students made significant contributions to the overall research effort. They benefited from networking with LEME staff, industry and government organisations.

Student projects benefited directly from support and linkages with WA Department of Environment and Conservation, WA Department of Agriculture and Water, DWLB South Australia, ANSTO, as well as Gold Fields Australia, Tanami Gold, Dominion Mining, Newmont Asia Pacific, Helix Resources, Agincourt Gold, Barrick Gold, Anglo American, Independence Gold, Zonge Engineering and Heathgate resources to name but a few. Details of many of these linkages are provided in the Research, Commercialisation, Technology Transfer and Utilisation Section, as well as the Education and Training sections of this Annual Report.

Linkages with industry and other end users

Of our 39 core research projects, 22 are classified as industry/commercial projects. They draw cash contributions from a wide range of Australian and State Government agencies, as well as some major mining companies for mineral-related projects. In addition to the cash contributions, there is a significant in-kind contribution to many minerals related projects.

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

Linkages with users of Centre research are also promoted through staff and student participation in conferences and industry workshops. This publicised LEME research and facilitated networking. Details of these activities are provided in the section on Communication Strategy. LEME personnel presented at 39 international and national conferences/symposiums during the reporting period. LEME was also involved in conducting the 2nd International Salinity Forum. This forum attracted more than 800 participants.

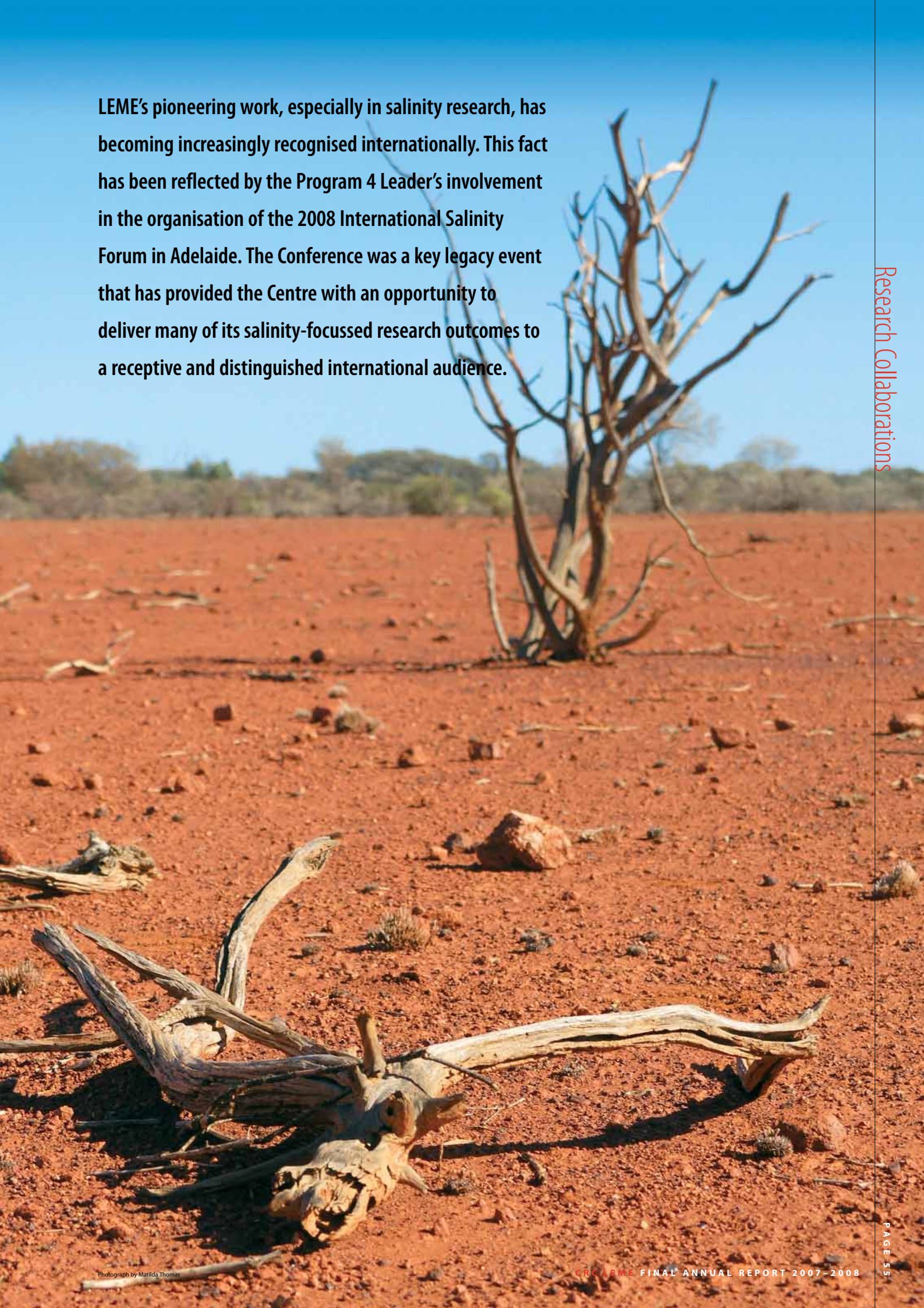
International Linkages

LEME has continued to develop international linkages where the collaborative knowledge gained can be used to improve the understanding of Australian regolith processes.

During 2007-08, the Centre continued its collaboration with Guilin University of Technology, China in order to evaluate the CHIM electro-chemical technique and other geochemical methods. LEME researchers, Baohong Hou and John Keeling, travelled to Guilin during October 2007 to present workshops and participate in field work in the Chinese Dachang mining district. As part of this field trip, Guilin University researchers, under Professor Xianrong Luo, completed soil conductivity and mercury surveys to define suitable areas for follow electro-geochemical CHIM surveys. A report on CHIM results from Australian field surveys was completed with associated papers published jointly in Australian and Chinese journals.

The Centre, as part of its involvement in the AMIRA P778, is participating in a metal mobility field trial at the Codelco-owned, Chilean Inca del Oro porphyry copper prospect in Chile. The work involves collaboration with Dr Brian Townley's group at the University of Santiago, Chile. A sponsors' meeting was also held at the Faculty of Mathematical and Physical Sciences of the University of Chile in Santiago.

LEME's pioneering work, especially in salinity research, has becoming increasingly recognised internationally. This fact has been reflected by the Program 4 Leader's involvement in the organisation of the 2008 International Salinity Forum in Adelaide. The Conference was a key legacy event that has provided the Centre with an opportunity to deliver many of its salinity-focussed research outcomes to a receptive and distinguished international audience.



Photograph by Matilda Thomas

INTERNATIONAL VISITORS TO THE CENTRE

Visitor	Visitor Organisation	LEME Host staff / location	Project / Activity	Date
Prof. Xianrong Luo	Guilin University of Technology, China	Baohong Hou, John Keeling and Adrian Fabris/ Adelaide	CHIM surveys in Beverley Uranium Mine, Challenger Gold Mine and Tunkillia Gold prospect, South Australia	4-29 August 2007
Mrs Meilan Wen	Guilin University of Technology, China	Baohong Hou, John Keeling and Adrian Fabris/ Adelaide	CHIM surveys in Beverley Uranium Mine, Challenger Gold Mine and Tunkillia Gold prospect, South Australia	4-29 August 2007

INTERNATIONAL VISITS BY CENTRE STAFF

LEME staff or student	Host Organisation and Location	Host staff	Project / Activity	Date
Baohong Hou, John Keeling, PIRSA	Grand Field Group-Hong Kong	Chairman: Waylang Tsang; Executive Directors: Vincent Au, Wong King & Lam Joseph; Director: Edward Wong	Briefings provided on the role of state government in administration and promotion of mining in South Australia, role of the geological survey and CRC LEME, and an explanation of research collaboration with Prof Luo, Guilin University	6 October 2007
Baohong Hou, John Keeling, PIRSA	Guilin University of Technology, China	Prof. Xianrong Luo	China – Australia collaboration	7-14 October 2007
Baohong Hou, John Keeling, PIRSA	Yunnan Muli Antimony Industry Co Ltd.	Prof. Xianrong Luo and Company President Dai Ling	China – Australia collaboration	15-18 October 2007
Baohong Hou, John Keeling, PIRSA	China Nonferrous Metal Corporation (CNNC) – Southwest Geological Exploration Bureau 306	Chief Geologist, Cao Wengshu	China – Australia collaboration	22 October 2007
Baohong Hou, PIRSA	Jiangxi Nuclear Industry Geological Bureau, Xiangshan Uranium Mine, 266 Geological Brigade of Jiangxi Nuclear Industry Geological Bureau	Bureau President: Minzhu Dai	As invited, this return visit was focused on studying China's largest uranium mine	25-28 October 2007
Baohong Hou, PIRSA	Beijing Research Institute of Uranium Geology, CNNC (China National Nuclear Corporation)	Prof. Ziying Li	Visiting to develop and agreement of international cooperation between the Beijing Research Institute of Uranium Geology and SA Geological Survey, IGCP-514	28-30 October 2007
Baohong Hou, PIRSA	Centre for Earth Science Studies, National Institute of Oceanography, and Goa University, India	Dr D.S.Suresh Babu	International Workshop: IGCP-514	1-10 November 2007

LEME's pioneering work, especially in salinity research, has becoming increasingly recognised internationally. This fact has been reflected by the Program 4 Leader's involvement in the organisation of the 2008 International Salinity Forum in Adelaide. The Conference was a key legacy event that has provided the Centre with an opportunity to deliver many of its salinity-focussed research outcomes to a receptive and distinguished international audience.

Collaboration with CRCs and other research providers

Collaboration with CSIRO Mathematical and Information Sciences continued to be a critical part of the LEME's Objective Logging Project. This collaboration focused on the development of unmixing algorithms for the rapid determination of relative regolith material abundance in core and chip field samples during the year. These algorithms have assisted in the refinement of CSIRO-developed HyChips technology. The overall aim of the collaboration is to build a regolith version of the software program *The Spectral Assistant* now used routinely by the minerals industry for spectral analysis. Progress to date has defined a potential pathway to using a mixture-model approach for software incorporation with the project significantly closer to delivering an automated regolith mineral abundance determination.

The Centre's work with the Geological Survey of Western Australia (GSWA) and the Minerals and Energy Research Institute of WA (MERIWA) concluded with the release of the report *Laterite Geochemical Database for the Western Yilgarn Carton*, Western Australia as a GSWA report and as OFR 116. Since its release in June 2007, the report has become a valuable tool for mineral explorers active in the area.

CRC LEME collaboration with the Queensland Geological Survey (GSQ), the Queensland Department of Natural Resources and Water (QLD NRW) and Geoscience Australia (GA) on the production of a 1:2.5 million-scale regolith map and atlas of Queensland (OFR 242) successfully concluded in June 2008. GSQ funded the project as part of its $20 million Smart Exploration Initiative.

During 2007-08, LEME CEO Dr Steve Rogers continued to represent the Minerals and Energy Sector on the Cooperative Research Centre Association (CRCA) Management Committee.

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.

SMALL, MEDIUM AND LARGE ENTERPRISES

Research User	Activity/Project	Interaction	LEME staff and students
Tanami Gold NL	Tanami Project	Research Collaboration	Lisa Worrall and the Tanami Project team
Dominion Mining	CHIM geochemistry, Challenger Mine	Electro geochemical surveys	Baohong Hou, John Keeling, Adrian Fabris
Mega-Hindmarsh Resources	Biogeochemistry and regolith-landform mapping	Discussion and preliminary survey planning	Steve Hill
NuPower Resources	Regional Biogeochemistry	Preliminary survey	Steve Hill
Toro Energy	Tenement biogeochemistry	Preliminary survey	Steve Hill
Heathgate Resources	Biogeochemistry	Preliminary survey and student research	Steven Hill, Michael Neimanis, Clint Dubieniecki, Deanne Gallasch, Andrew Hector, Mikaela Jennings, Joanna McMahon, Jessie Davey
Lincoln Minerals	Biogeochemistry	Project discussion	Steve Hill
Monax resources	Biogeochemistry	Preliminary survey	Steve Hill
Mamota Energy	Biogeochemistry	Project discussion	Steve Hill
Avalon Minerals	Biogeochemistry	Sampling and project discussion	Steve Hill
AustGold	Biogeochemistry	Project discussion	Steve Hill
Minotaur Exploration	CHIM geochemistry, Tunkillia	Electro geochemical and partial leach geochemistry	Baohong Hou, John Keeling, Adrian Fabris
Minotaur Exploration	Biogeochemistry and calcrete geochemistry	Project discussion and student research	Steve Hill, Robert Dart, Jack Lowrey
Newmont Asia Pacific	Tanami Project	Research Collaboration	Lisa Worrall and the Tanami Project team
Anglo American	Tanami Project	Research Collaboration	Lisa Worrall and the Tanami Project team
Heathgate Resources	CHIM geochemistry	Field trial surveys 4-Mile deposit	Baohong Hou, John Keeling, Adrian Fabris, Roger Fidler

Photograph by Steve Hill

SMALL, MEDIUM AND LARGE ENTERPRISES (cont'd)

Research User	Activity/Project	Interaction	LEME staff and students
Woodside Energy	The nature age and weathering history of rock surfaces associated with petroglyphs at Burrup Peninsula WA	Commercial Project	Brad Pillans
Newmont Asia Pacific	Regolith Geochronology in the Tanami Region	Research Collaboration	Brad Pillans
Rio Tinto Exploration	Regolith Geochronology	Research Collaboration	Brad Pillans
Rio Tinto Exploration	Weipa Project	Research Collaboration	Tony Eggleton and Graham Taylor
Rio Tinto Aluminium	Weipa Project	Research Collaboration	Tony Eggleton and Graham Taylor
Echo Resources Ltd.	Objective Logging Project	Market testing	Tim Munday and the Objective Logging Project team
Mega Redport Pty Ltd.	Objective Logging Project	Market testing	Tim Munday and the Objective Logging Project team
Gold Fields Australasia Pty Ltd.	Objective Logging Project	Market testing	Tim Munday and the Objective Logging Project team
Iluka Resources	Eucla Project	Research Collaboration	Lisa Worrall and the Eucla Project Team
Newcrest	Objective Logging Project	Market testing	Tim Munday and the Objective Logging Project team
Australian Premium Iron(API)	Objective Logging Project	Market testing	Tim Munday and the Objective Logging Project team
Golder Associates Pty Ltd	Objective Logging Project	Market testing	Tim Munday and the Objective Logging Project team
Independence Gold NL	Objective Logging Project	Market testing	Tim Munday and the Objective Logging Project team
Barrick Gold	AMIRA P778	Research Collaboration	Ravi Anand and the AMIRA P778 Project team
BHP Billiton	AMIRA P778	Research Collaboration	Ravi Anand and the AMIRA P778 Project team
Cameco Corporation	AMIRA P778	Research Collaboration	Ravi Anand and the AMIRA P778 Project team
Inco Resources (Australia) Pty Ltd	AMIRA P778	Research Collaboration	Ravi Anand and the AMIRA P778 Project team
Independence Gold NL	AMIRA P778	Research Collaboration	Ravi Anand and the AMIRA P778 Project team
SGS Minerals	AMIRA P778	Research Collaboration	Ravi Anand and the AMIRA P778 Project team
Newmont Australia	AMIRA P778	Research collaboration	Ravi Anand and the AMIRA P778 Project team
JOGMEC	AMIRA P778	Research collaboration	Ravi Anand and the AMIRA P778 Project team
Rio Tinto	AMIRA P778	Research collaboration	Ravi Anand and the AMIRA P778 Project team
CVRD	AMIRA P778	Research collaboration	Ravi Anand and the AMIRA P778 Project team
Codelco	AMIRA P778	Research collaboration	Ravi Anand and the AMIRA P778 Project team
Jabiru Metals	AMIRA P778	Research collaboration	Ravi Anand and the AMIRA P778 Project team
Tech Cominco Ltd.	AMIRA P778	Research collaboration	Ravi Anand and the AMIRA P778 Project team

GOVERNMENT ORGANISATIONS AND UNIVERSITIES

Research User	Activity/Project	Interaction	LEME staff and students
Geological Survey of WA	Tanami Project	Research Collaboration	Lisa Worrall and the Tanami Project team
Northern Territory Geological Survey	Tanami Project	Research Collaboration	Lisa Worrall and the Tanami Project team
Geoscience Australia	Tanami Project	Research Collaboration	Lisa Worrall and the Tanami Project team
Australian Collaborative Land Evaluation Program	Physiographic Regions Research Project	Collaboration	Colin Pain
Northern Agricultural Catchment Council	NACC Coastal Project	Research Collaboration	Lindsay Collins and the NACC Coastal Project Team
Conservation and Land Management WA	NACC Coastal Project	Research Collaboration	Lindsay Collins and the NACC Coastal Project Team
Griffith University	History of Aridity Project	Research Collaboration	David Haberlah
Simon Fraser University BC	Tanami Project	Research Collaboration	Lisa Worrall and the Tanami Project team
Simon Fraser University BC	Curnamona Project	Research Collaboration	Adrian Fabris and the Curnamona Project Team
US Geological Survey	Curnamona Project	Research Collaboration	Adrian Fabris and the Curnamona Project Team
Melbourne University	Regolith Geochronology	Research Collaboration	Brad Pillans
University of Wollongong	Regolith Geochronology	Research Collaboration	Brad Pillans
Geological Survey of WA	Regolith Geochronology	Research Collaboration	Brad Pillans

GOVERNMENT ORGANISATIONS AND UNIVERSITIES (cont'd)

Research User	Activity/Project	Interaction	LEME staff and students
Guilin University of Technology China	Curnamona MineX	Research collaboration	Adrian Fabris, John Keeling, Baohong Hou
CSIRO Mathematical and Information Sciences	Objective Logging Project	Research collaboration	Tim Munday and the Objective Logging Project team
DPI Victoria	BRS Victorian Salinity Mapping Project	Commercial Project	Ken Lawrie and Project Team
Bureau of Rural Sciences	BRS Victorian Salinity Mapping Project	Commercial Project	Ken Lawrie and Project Team
Central West Catchment Management Authority	Central West Project	Commercial Project	John Wilford and Project Team
SA Water	Eyre Peninsula	Commercial Project	Tim Munday and Project Team
DWLBC	Eyre Peninsula	Commercial Project	Tim Munday and Project Team
Lower Murray Darling Catchment Management Authority	Gol Gol Project	Commercial Project	Tim Munday and Project Team
SA Water	Loxton Project	Commercial Project	Tim Munday and Project Team
DWLBC	Loxton Project	Commercial Project	Tim Munday and Project Team
Murray Darling Basin Commission	Loxton Project	Commercial Project	Tim Munday and Project Team
SA Water	SA Murray Floodplains	Commercial Project	Tim Munday and Project Team
DWLBC	SA Murray Floodplains	Commercial Project	Tim Munday and Project Team
Murray Darling Basin Commission	Stockyard Plains	Commercial Project	Tim Munday and Project Team
SA Water	Stockyard Plains	Commercial Project	Tim Munday and Project Team
DWLBC	Stockyard Plains	Commercial Project	Tim Munday and Project Team
Goulbourn-Murray Water	Sunraysia	Commercial Project	Tim Munday and Project Team
Department of Agriculture WA	Yarra Yarra	Commercial Project	Paul Wilkes and Project Team
Yarra Yarra Catchment Management Group	Yarra Yarra	Commercial Project	Paul Wilkes and Project Team
Department of Environment and Heritage SA	ASS Project	Research Collaboration	Rob Fitzpatrick and Project Team
Department of Water WA	AG3 Project	Research Collaboration	Paul Shand and Project team
WA Engineering Evaluation Initiative	AG3 Project	Research Collaboration	Paul Shand and Project team
Department of Environment WA	AG3 Project	Research Collaboration	Paul Shand and Project team
Department of Agriculture WA	AG3 Project	Research Collaboration	Paul Shand and Project team
Avon Catchment Council	AG3 Project	Research Collaboration	Paul Shand and Project team
Conservation and Land Management WA	AG2 Project	Research Collaboration	Paul Shand and Project team
WA Engineering Evaluation Initiative	AG2 Project	Research Collaboration	Paul Shand and Project team
WA Channel Management Group	AG2 Project	Research Collaboration	Paul Shand and Project team
Yarra Yarra Catchment Council	AG2 Project	Research Collaboration	Paul Shand and Project team
Avon Catchment Council	AG2 Project	Research Collaboration	Paul Shand and Project team
Department of Environment WA	AG1 Project	Research Collaboration	Paul Shand and Project team
Department of Environment WA	AG1 Project	Research Collaboration	Paul Shand and Project team
Department of Agriculture WA	AG2 Project	Research Collaboration	Paul Shand and Project team
Department of Agriculture WA	AG2 Project	Research Collaboration	Paul Shand and Project team
Queensland Geological Survey	Queensland Regolith Project	Research Collaboration	Mike Craig and the QLD Regolith Project team
Queensland Department of Natural Resources and Water	Queensland Regolith Project	Research Collaboration	Mike Craig and the QLD Regolith Project team
COOPERATIVE RESEARCH CENTRES			
PMD CRC	Queensland Regolith Project	Research Collaboration	Mike Craig and the QLD Regolith Project team
INDUSTRY ASSOCIATIONS			
Minerals and Energy Research Institute of WA	Yilgarn Project	Research Collaboration	Mattias Cornelius and the Yilgarn Project team
Minerals Council of Australia	Education and Training Program	Development of MTEC courses	Ian Roach and Program staff

The vision for the CRC LEME Education, Training and Technology Transfer program is to be recognised as an Australia-wide world-class education provider in regolith geoscience.

Commercialisation and Utilisation

COMMERCIALISATION AND UTILISATION STRATEGIES AND ACTIVITIES

'National Good' Benefits

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

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

Some industry projects generate knowledge that remains confidential to industry sponsors until the expiry of an agreed confidentiality period, as per the project agreement.

Fee-for-service opportunities have continued to expand in the fields of natural resource and environmental management, where our clients are government agencies, Landcare Groups, Catchment Management Authorities (CMAs), or organisations contracted to them. LEME has an outstanding record of research into the use of new geophysical technologies to pin-point saline groundwater discharges into the Murray River, and to improve the understanding of saline groundwater flow dynamics and salinity mitigation. This research has had a particular focus on the southeast floodplains of the Murray River.

Through its contracts of work and strategic research projects, LEME is gaining credence for its methods for identifying salt stores above and below the watertable, and predicting saline movements in both upland and lowland areas. Demand for these abilities is anticipated to increase as water resource management becomes more of an issue for Australia.

Knowledge and Technology Transfer

Effective delivery of outputs to end-users is a focus of CRC LEME. Resources are focussed to facilitate delivery before completion, either through commercialisation or more direct transfer of the technology to end-users. The CRC's delivery plan is to maximise the Centre's outputs in the public domain by placement of research deliverables on the CRC LEME website. These outputs include Open File Reports, Thematic Volumes, Proceedings, Explorers Guides and other publications, as well as digital maps and a variety of datasets. User-friendly design of the CRC's website promotes and maximises uptake by end users. This is in line with the CRC's overall plan to maximise dissemination of the Centre's pre-competitive regolith geoscience research outcomes.

LEME successfully completed 13 contract and consultancy-type projects in 2007-08, with the majority of projects residing in Programs 3 and 4. LEME has also conducted a number of workshops and training courses, with a range of companies and government agencies.

INTELLECTUAL PROPERTY MANAGEMENT

LEME's commercialisation and Intellectual Property Management Strategy aims are to:

- Protect and disseminate knowledge
- Promote developments within Australia and overseas
- Transfer knowledge on a fee-for-service basis and
- Identify marketing opportunities of technological developments with industry partners.

Where Centre Projects generate knowledge that has potential economic or service value, it is considered 'Centre Intellectual Property.' All Centre Intellectual Property (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 Core Participant may generate 'Project Intellectual Property.' Project IP provisions are set out in the relevant project agreements, on a case-by-case basis. 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 LEME must negotiate with the university to agree on a sharing arrangement for the student IP.

Ongoing Protection and Management of Intellectual Property

The CRC has structures and procedures in place, prior to the end of the Grant Period, to manage the ongoing protection of the CRC's intellectual property (IP) including any assignment for commercialisation or further development and distribution of any commercial returns.

As per Clause 29 of the Centre Agreement, IP arising out of commercial projects (i.e. Commercial Projects) will be retained by some or all of the Core Participants (as agreed on a case by case basis) subject to terms and conditions stipulated in the executed project agreements with external organisations.

As per Clause 30 of the Centre Agreement, all IP arising out of projects totally funded by the Centre (i.e. Centre Projects) will be owned by the Core Participants equally as tenants in common in accordance with their respective Participating Shares. Any variations are subject to formal Board approval.

Whilst no IP with potential for commercialisation has been created during the Grant Period, research results have been disseminated to appropriate parties to ensure an efficient and effective transfer of technology and research utilisation. CRC LEME ensures that any proposed Intellectual Property (IP) arrangements are consistent with the IP clause in the Commonwealth Agreement. CRC LEME will use its best endeavours to make publicly available any IP to maximise the benefits accruing to Australia, including Australian industry, the Australian environment and the Australian economy generally. The use and exploitation of such IP is consistent with the Objectives of the CRC Programme.

COMMUNICATIONS AND PUBLICATIONS

Communication Policy

LEME had aimed to promote and communicate advances in regolith knowledge to its end-users, such that regolith science becomes an accepted and integral part of new applications and practices in mineral exploration and land management. The strategy to optimise uptake was by way of demonstration projects and applicable outcomes, and promotion on research delivery rather than intent.

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

- 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, 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 Annual Report Guidelines.
- Publish a separate 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, 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.

LEME communication of research activities and scientific results in 2007 – 2008 occurred through the following mechanisms:

- Production of an Annual Report which a) satisfies the reporting requirements of the CRC Program b) is a publicly available summary of activities which goes to a mailing list of more than 800 recipients and is available as a PDF from the LEME website.
- Release of comprehensive technical reports through the LEME Open File Report (OFR) series and various monographs including Explorer's Guides.
- Publication of scientific communications in national and international scientific journals.
- Staging conferences, seminars and workshops under the LEME banner, for example the annual Mineral Exploration Seminars
- 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 widely circulated newsletter to NRM stakeholders, produced jointly with CRC PBMDS.
- Sponsoring multi-disciplinary multi-agency scientific and technical events.
- Technical articles in special interest journals and industry magazines.
- Regular LEME media releases on significant research outputs

As the Centre moves forward into the wind up period the focus of communications activities at head office is being directed towards end-user delivery and uptake of its final research outputs. These 'legacy products', which have been distinctly packaged as end-user friendly products, include a series of explorers' guides, special issues of the Australian Journal of Earth Sciences, a digital atlas of regolith maps, an inland ASS thematic volume, a regolith textbook and an online searchable publications database.

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. To increase LEME knowledge transfer and accessibility to a wider audience, a decision was made in early 2007 to make all LEME publications digitally available as .pdf files. In addition, another decision was made to minimise the amount of hard copies produced so as to only meet the Centre's statutory obligations. The remaining Head Office hard copy stock of OFRs, thematic volumes and other publications will be sent out to Core Participant libraries, LEME students and interested end users before the conclusion of Centre operations.

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

The LEME website and Intranet have remained the main medium for the communication of Centre activities, developments and research news to staff, students and other end users. The website features regularly updated personnel directories (staff, students, Board, Advisory Councils), the LEME Strategic Plan, news and events, upcoming conferences, presentations and technical papers, program and project descriptions, as well as links to all Core Participant websites. The education section advertised MCA Courses, scholarships and proposed student projects while providing a forum for students to report their progress.

All LEME monographs/case histories and thematic volumes are available as .pdf files for downloading from the website. In early 2007, the website was updated so all OFRs became available as .pdf files downloads, accessible through the OFR Index page. The website currently holds over 350 OFRs, monographs, and thematic volumes available for download.

In July 2006 the LEME website was migrated from the Australian National University (ANU) server to the CSIRO server located at Australian Resources Research Centre (ARRC), Perth. This migration has provided the capacity from which the website's functionality and size can expand within a stable operating environment. This expansion is crucial, as the LEME website is being modified to become the key communication medium for the delivery of Centre research outputs to end users after operations cease on 31 December 2008. The website's enhancement is in line with the Centre's overall Wind up Strategy to maximise the dissemination of its pre-competitive regolith geoscience to all stakeholders.

By agreement with CSIRO the CRC LEME website will continue to be maintained by CSIRO until June 2013.

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. A full list of CRC LEME publications for 2007 -2008 can be found below.

Journal Articles (Published 2007 – 2008)

Anand RR, Cornelius M and Phang C, 2007. Use of vegetation and soil in mineral exploration in areas of transported overburden, Yilgarn Craton, western Australia. *Geochemistry, Exploration, Environment and Analysis* 7:267-288

Butt CRM and Stanley CR (Editors). 2007. From tropics to tundra. Proceedings, International Geochemical Exploration Symposium, Perth, 2005. *Geochemistry: Exploration, Environment, Analysis* 7: Part 2, 98-192; Part 3, 193-288; Part 4, 329-375. Special Issue. (Part 3 and Part 4 recorded in 2006-2007 Annual Report).

Colloff MJ, Wakelin SA, Gomez D and Rogers SL, 2008. Detection of nitrogen cycle genes in soils for measuring the effects of change in land use and management. *Soil Biology and Biochemistry* 40: 1637-1645.

Cresswell R G, Mullen I, Kingham R, Kellett J, Dent DL and Jones GL, 2007. Airborne electromagnetics supporting salinity and natural resource management decisions at the field scale in Australia. *International Journal of Applied Earth Observations and Geoinfo* 9: 91-102

Drewry JJ, Cameron KC and Buchan GD, 2008. Pasture yields and soil physical property responses to soil compaction from treading and grazing: a review. *Australian Journal of Soil Research* 46: 237-256.

Eggleton RA and Taylor G, 2008. Effects of some macrobiota on the Weipa Bauxite, northern Australia. *Australian Journal of Earth Sciences* 55, S71-S82.

Eggleton RA, and Taylor G, 2008. Impact of fire on the Weipa Bauxite, northern Australia. *Australian Journal of Earth Sciences* 55, S83-S86.

Eggleton RA, Taylor G, Le Gleuher M, Foster LD, Tilley DB and Morgan CM, 2008. Regolith profile, mineralogy and geochemistry of the Weipa Bauxite, northern Australia. *Australian Journal of Earth Sciences* 55, S17-S43.

Gleuher L, Anand RR, Eggleton RA, and Radford N, 2008. Mineral hosts for gold and trace metals in regolith at Boddington deposit and Scuddles massive copper-zinc sulphide deposit analysis Western Australia; an LA-ICP-MS study. *Geochemistry Exploration, Environment and Analysis* 8:157-172

Haberlah D. 2007. A call for Australian loess. *Area* 39.2: 224-229

Haberlah D, 2008. Response to Smalley's discussion of 'A call for Australian loess'. *Area* 40.1: 135-136.

Hou B, Frakes LA, Sandiford M, Worrall L, Keeling J, and Alley NF, 2008. Cenozoic Eucla basin and associated palaeovalleys, southern Australia – Climatic and tectonic influences on landscape evolution, sedimentation and heavy mineral accumulation. *Sedimentary Geology* 203: 112-130.

Hough RM, Noble RRP, Hitchen GJ, Hart R, Reddy SM, Saunders M, Clode P, Vaughan D, Lowe J, Gray DJ, Anand RR, Butt CRM and Verrall M, 2008. Naturally occurring gold nanoparticles and nanoplates. *Geology* 36 (7): 571-574

Hough, RM, Butt CRM, Reddy SM and Verrall M, 2007. Gold nuggets; Supergene or hypogene? *Australian Journal of Earth Sciences* 54: 959-964

Larizzatti JL, Oliveira SMB, Butt CRM, 2008. Morphology and composition of gold in a lateritic profile, Fazenda Pison "Garimpo". Amazon, Brazil. *Journal of South American Earth Sciences* 25: 359-376.

Lawrie K, George R and Woodgate, 2008 How can geoscience data and maps help me manage salinity?" *Journal of the Geological Society of London*

Lenahan MJ, Kirste, DM, Cresswell RG, McPhail DC and Welch SA, 2008. Chemical evolution of groundwater in the unsaturated zone. *Geochimica et Cosmochimica Acta* 72, A534.

McQueen K, 2007. A thirsty and confusing diggings; the Albert Goldfield, Milparinka-Tibooburra, northwestern NSW. *Journal of Australian Mining History* 5:67-96

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117	Nov-07	A. Fabris, J. Keeling, R. Fidler, B. Hou, X. Luo and N. Zeng	Chinese CHIM electrogeochemical method: Field trials 2005, South Australia
145	Dec-07	P. de Caritat and M.E. Lech	Thomson Region geochemical survey, northwestern New South Wales
151	Nov-07	M. Macphail	Australian Palaeoclimates – Cretaceous to Tertiary: A review of palaeobotanical and related evidence to the year 2000
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204	Dec 08	R. Fitzpatrick, M Skwarnecki	Geochemical dispersion at the Mt Torrens lead-zinc prospect, SA
205	Dec 08	R. Fitzpatrick, MSkwarnecki	Regolith geochemical dispersion in acid sulfate soils in relation to base metal mineralization of the Kanmantoo Group, Mt Torrens
210	Jun-08	M.J. Sheard (compiler)	Regolith benchmark atlas, Gawler Craton, South Australia
211	Jun 08	de Caritat, M.E. Lech and A Kernich	Gawler region geochemical survey, SA
213	Feb-08	K.M. Scott and K.G. McQueen	The mineralogy and geochemistry of New Cobar Au-Cu mineralisation in the oxidate and supergene zones, Cobar District, western NSW
214	May-08	M.F. Killick, H.M. Churchward and R.R. Anand	Regolith terrain analysis for iron ore exploration in the Hamersley Province, Western Australia – Final Report
221	Dec-08	D.J. Gray	Supergene gold dispersion at the Panglo Gold Deposit, WA
222	Dec-08	D.J. Gray	Gold concentrations in the regolith at the Mt Joel Prospect WA
223	Dec-08	Serfeev and D.J. Gray	Gold dispersion in the regolith at the Federal Deposit, WA
224	Dec-08	A. Britt and D.J. Gray	Supergene gold dispersion in the regolith at the Cleo Deposit, WA
225	Dec-08	A. Britt and D.J. Gray	Distribution of gold, arsenic, chromium and copper in the regolith at the Harmony Deposit, northern Yilgarn, WA
226	Dec-08	D.J. Gray	Supergene gold dispersion in the regolith at the Kanowna Belle and Ballarat Last Chance deposits, WA
227	Dec-08	A. Britt and D.J. Gray	Supergene gold dispersion in regolith and groundwaters of the Mt Holland region, Southern Cross Province, WA
228	Dec-08	D.J.Gray *et al*	Supergene mobilization of gold and other elements in the Yilgarn Craton, WA – Final Report P504
229	Nov-07	M. Lech and P. de Caritat	Protocol for sampling in regional geochemical surveys: Lessons from pilot projects
230	Nov-07	J. Corriveau	Estimation of isotopic composition of evaporated water at Loveday Disposal Basin using a constant-volume evaporation pan experiment
231	Jul-07	C.F. Pain, R.A. Chan, M.A. Craig, D.L. Gibson, P. Kilgour and J.R. Wilford	RTMAP regolith database field book and users guide (Second Edition)
232	Jul-07	M.J. Sheard	Regolith characterization as an aid to mineral exploration in the Wudinna North Area, Central Gawler Province, South Australia
233	Sep-07	I.C. Roach	Tomingly 1:25 000 regolith-landform map, central western New South Wales
234	Dec-07	P. de Caritat, M.E. Lech, S. Jaireth, J. Pyke and A. Fisher	Riverina Region geochemical survey, southern New South Wales and Northern Victoria
235	Jun-08	D. Gibson and K. Boston (compilers)	Neotectonics, salinity, palaeoclimates and volcanism – Australian Earth Science Convention Pre-conference Field Trip, Adelaide-Melbourne 28 June to 2 July 2006

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236	Jan-08	I. Roach	Fowlers Gap regolith field class, National Undergraduate Regolith Geology School: Lecture notes and reading material
238	Dec 08	I. Roach	Explanatory notes for the Canbelego 1:100 000 regolith landform map, New South Wales
239	Dec 08	K. Scott and K. McQueen	The mineralogy and geochemistry of New Cobar Au-Cu mineralization in the regolith and exploration implications for the Cobar District, western NSW
240	Dec 08	K. McQueen, K. Scott, P. Ogivie and B. Crowther	Atlas of regolith materials from the weathered zone, New Cobar Deposit
241	Feb-08	I.C. Lau	Explanatory notes for the 1:30 000 Olary regolith-landform map of White Dam
242	Dec-08	M.A. Craig, I.D.M. Robertson, M. Thomas *et al*	Atlas of regolith materials of Queensland
246	Dec 08	M. Aspandiar	Geochemical dispersion mechanisms through transported cover: a review
247	Dec-08	A. Mauger, J. Keeling and I. Lau etc	Hyperspectral analysis as applied to regolith and mineral mapping in South Australia
248	Jul-08	S. Lamontagne, W.S. Hicks, N.J. Souter, M.J. Walter and L. Wen	Water quality monitoring at Loveday Disposal Basin during a wetting and drying cycle
249	Dec-08	A. Fitzpatrick and M. Sheard	Inland acid sulfate soil systems across Australia

CRC LEME Regolith Landform Maps (published on the CRC LEME Website 2007 – 2008)

New South Wales

Name	Central long/lat	Region
Balaclava 1:25,000	141.38E 32.19S	Broken Hill/Curnamona Craton
Bathurst 1:100,000	149.75E 33.25S	Central West/Lachlan Fold Belt
Bathurst landforms 1:250,000	148.75E 33.5S	Central West/Lachlan Fold Belt
Bathurst regolith 1:250,000	148.75E 33.5S	Central West/Lachlan Fold Belt
Blayney 1;100,000	149.25E 33.75S	Central West/Lachlan Fold Belt
Booberoi-Quandialla 1:50,000	147.63E 35.99S	Central West/Lachlan Fold Belt
Broken Hill 1:100,000	141.44E 31.86S	Broken Hill/Curnamona Craton
Broken Hill 1:500,000	142E 31.25S	Broken Hill/Curnamona Craton
Byrock 1:100,000	146.25E 30.5S	West/Lachlan Fold Belt
Byrock 1:25,000	146.3E 30.72S	West/Lachlan Fold Belt
Canbelego 1:100,000	146.25E 31.75S	West/Lachlan Fold Belt
Cobar Goldfields North 1:10,000	145.89E 31.58S	West/Lachlan Fold Belt
Cobar Goldfields South 1:10,000	145.93E 31.63S	West/Lachlan Fold Belt
Cobar Special 1:250,000	145.68E 31.31S	West/Lachlan Fold Belt
Cobar 1:500,000	146.25E 31.5S	West/Lachlan Fold Belt
Conners Paddock 1:12,500	141.72E 31.08S	Fowlers Gap, Broken Hill/Curnamona Craton
Coolabah 1:100,000	146.75E 31.25S	West/Lachlan Fold Belt
Cootamundra 1:65,000	148.15E 34.58S	Central West/Lachlan Fold Belt
Cowra 1:100,000	148.75E 33.75S	Central West/Lachlan Fold Belt
CSA minesite Cobar 1:10,000	145.82E 31.4S	Central West/Lachlan Fold Belt
Eagles Nest Catchment regolith, New Bendigo Inlier 1:7,500 Eagles Nest Catchment vegetation, New Bendigo Inlier 1:7,500	141.91E 29.66S	Northwest/Thomson Fold Belt
El Capitan 1:25,000	146.19E 31.2S	Central West/Lachlan Fold Belt

New South Wales (cont'd)

Name	Central long/lat	Region
Flying Doctor Prospect 1:10,000	141.53E 31.91S	Broken Hill/Curnamona Craton
Forbes 1:250,000	147.75E 33.5S	Central West/Lachlan Fold Belt
Gilmore project area 1:130,000	147.58E 34.38S	Central West/Lachlan Fold Belt
Hazeldean Plug area	148.96E 36.34S	Monaro Volcanic Province, South/Lachlan Fold Belt
Hermidale 1;100,000	146.75E 31.75S	West/Lachlan Fold Belt
Hotel Paddock 1:25,000	141.75E 31.05S	Fowlers Gap, Broken Hill/Curnamona Craton
Kinalung West-Quondong West 1:25,000	141.81E 32.13S	Broken Hill/Curnamona Craton
Krawaree West 1:25,000	149.58E 35.81S	Southeast/Lachlan Fold Belt
Lake Paddock 1:12,500	141.71E 31.1S	Fowlers Gap, Broken Hill/Curnamona Craton
Miandetta 1:25,000	146.97E 31.57S	West/Lachlan Fold Belt
Molong 1;100,000	148.75E 33.25S	Central West/Lachlan Fold Belt
Mt Browne and Mt Poole Inliers 1:30,000	141.69E 29.68S	Northwest/Thomson Fold Belt
Mt Gipps 1:25,000	141.63E 31.94S	Broken Hill/Curnamona Craton
Nowra Shoalhaven Delta 1:35,000	150.69E 34.86S	Southeast/Lachlan Fold Belt
Oberon 1:100,000	149.75E 33.75S	Central West/Lachlan Fold Belt
Orange 1:100,000	149.25E 33.25S	Central West/Lachlan Fold Belt
Pine Creek 1:10,000	141.34E 32.08S	Broken Hill/Curnamona Craton
Pinnacles 1:25,000	141.38E 32.06S	Broken Hill/Curnamona Craton
Quarry Hill 1:5,000	142.02E 29.43S	Northwest/Thomson Fold Belt
Racecourse Creek 1:10,000 Racecourse Creek 1:10,000 legend	142.04E 31.89S	Northwest/Thomson Fold Belt
Redan 1:25,000	141.63S 32.19E	Broken Hill/Curnamona Craton
Sandstone and Sandstone Ridge Paddocks 1:12,500	141.69E 31.01S	Fowlers Gap, Broken Hill/Curnamona Craton
South Sandstone 1:12,500	141.67S 31.05E	Fowlers Gap, Broken Hill/Curnamona Craton
Sussex 1:100,000	146.25E 31.25S	West/Lachlan Fold Belt
Tibooburra Inlier 1:25,000	141.98E 29.43S	Northwest/Thomson Fold Belt
Tomingley 1:25,000	148.22S 32.58E	Central West/Lachlan Fold Belt
Triple Chance 1:25,000	141.13E 32.19S	Broken Hill/Curnamona Craton
Wahratta 1:25,000	141.88E 31.93S	Broken Hill/Curnamona Craton

Northern Territory

Name	Central long/lat	Region
Arnhem Bay, Blue Mud Bay and Groote Eylandt 1:250,000	136E 13.5S	Arnhem Inlier
Balwina 1:100,000	128.25E 19.75S	Granites-Tanami Block
Breaden 1:100,000	129.75E 19.25S	Granites-Tanami Block
Buck 1:100,000 46	130.25E 19.75S	Granites-Tanami Block
Corridor Ck, Magela Ck 1:5,000	132.92E 12.66S	Pine Creek Inlier
Davidson 1:100,000	130.75E 20.25S	Granites-Tanami Block
Frankenia 1:100,000	129.75E 20.25S	Granites-Tanami Block
Gibbes-Murray 1:100,000	130.75E 20.75S	Granites-Tanami Block
Granites 1:100,000	130.25E 20.75S	Granites-Tanami Block
Granites-Tanami regolith 1:500,000 Granites-Tanami cover 1:500,000 Granites-Tanami Induration 1:500,000 Granites-Tanami magnetics 1:500,000	129.87E 20.29S	Granites-Tanami Block
Heughlin 1:50,000	132.17E 23.42S	Arunta Province
Inningarra 1:100,000	129.75E 20.75S	Granites-Tanami Block
Lewis 1:100,000	128.75E 20.25S	Granites-Tanami Block
Mallee 1:100,000	129.25E 19.25S	Granites-Tanami Block
McFarlane 1:100,000	129.25E 20.25S	Granites-Tanami Block
Mount Winnecke 1:100,000	130.25E 18.75S	Granites-Tanami Block
Oonagalabi 1:25,000	134.84E 23.13S	Arunta Province

Northern Territory (cont'd)

Name	Central long/lat	Region
Pargee 1:100,000	129.25E 19.75S	Granites-Tanami Block
Pedestal Hills 1:100,000	129.25E 20.75S	Granites-Tanami Block
Ptilotus 1:100,000	130.25E 20.25S	Granites-Tanami Block
Rand landforms 1:1,000,000 Rand regolith-landform terrains 1:1,000,000	132.75E 23.5S	Arunta Province-Ngalia Basin-Amadeus Basin-Musgrave Craton -Great Artesian Basin
Reiff 1:100,000	131.25E 20.25S	Granites-Tanami Block
Slatey Creek 1:100,000	128.75E 19.25S	Granites-Tanami Block
Solitaire 1:100,000	131.25E 20.75S	Granites-Tanami Block
Tanami 1:100,000	129.75E 19.75S	Granites-Tanami Block
Titania Mineralisation 1:10,000	129.99E 20.29S	Granites-Tanami Block
Titania Prospect 1:25,000	129.97E 20.28S	Granites-Tanami Block
Ware 1:100,000	129.75E 18.75S	Granites-Tanami Block
Watts 1:100,000	128.75E 19.75S	Granites-Tanami Block
Wilson Creek 1:100,000	130.25E 19.25S	Granites-Tanami Block
Winnecke 1:25,000	134.38E 23.33S	Arunta Province

Queensland

Buckley River-Lady Loretta 1:85,000 Buckley River-Lady Loretta 1:85,000 geochemical sampling strategy Buckley River-Lady Loretta 1:85,000 paleosurfaces Buckley River-Lady Loretta 1:85,000 Landsat TM image	139.17E 19.97S	Mt Isa Inlier
Cape York CYPLUS regolith 1:1,500,000 Cape York CYPLUS landforms 1:1,500,000	143.25E 13.5S	
Lower Balonne 1:250,000	148.51E 28.27S	Murray-Darling Basin
Mt Isa 1:500,000	139.25E 19.75S	Mt Isa Inlier
Mt Isa Geodynamic Transect 1:250,000	140E 20.79S	Mt Isa Inlier
Selwyn 1:65,000 Selwyn geochemical sampling strategy 1:65,000 Selwyn paleosurfaces 1:65,000 Selwyn Landsat Thematic Mapper 1:65,000	140.46E 21.69S	Mt Isa Inlier
Tringadee 1:50,000	140.8E 21.84S	Mt Isa Inlier
Tringadee 1:50,000	139.17E 19.97S	Mt Isa Inlier

South Australia

Anabama 1:100,000	140.25E 32.75S	Curnamona Craton
Biowrie Station 1:150,000 1	140.21E 32.04S	Curnamona Craton
Blue Rose 1:12,000	140.24E 32.64S	Curnamona Craton
Bon Bon/Eba 1:100,000	135.5E 30.13S	Curnamona Craton
Curnamona 1:500,000	140E 31S	Curnamona Craton
Earea Dam 1:25,000	140.98E 30.87S	Curnamona Craton
Edoldah Tank ET 1;10,000	133.32E 30.9S	Curnamona Craton
Faugh-a-ballagh 1:5,000		
Faugh-a-ballagh 1:12,000	140.21E 32.18S	Curnamona Craton
Glen Osmond 1:25,000	138.65E 34.97S	Mount Lofty Ranges, Delamerian Orogen
Half Moon Lake 1:100,000	133.5E 30.13S	Gawler Craton
Juuck 1:50,000	133.68E 29.87S	Gawler Craton
Luxeurg 1:2,500 regolith-landform map	140.57E 32.27E	Curnamona Craton
Mingary 1;100,000	140.75E 32.25S	Curnamona Craton
Moonta SA 1:25,000	137.58E 34.05S	Gawler Craton
Mount Babbage Inlet 1:25,000	139.62E 29.86S	Mt Babbage Inlier
Olary 1;100,000	140.25E 32.25S	Curnamona Craton
Onkaparinga River 1:25,000	138.51E 35.16S	St Vincent Basin/Delamerian Orogen
Parabarana 1:25,000	139.72E 29.99S	Mt Painter Inlier

South Australia (cont'd)

Name	Central long/lat	Region
Pinjarra Lakes 1:40,000	134.8E 32.12S	Gawler Craton
Tunkillia 1:62,500	134.75E 31.15S	Curnamona Craton
Wadnaminga 1:5,000	140.25E 32.55S	Curnamona Craton
White Dam Region 1:30,000	140.58E 32.14S	Curnamona Craton
White Dam 1:2,000	140.57E 32.1S	Curnamona Craton
Wilkins Prospect 1:10,000	134.55E 32.2S	Gawler Craton
Woomera/Koolymilka 1:100,000	136.88E 31S	Stuart Shelf
Wudinna North Part A 1:20,000	135.46E 32.81S	Gawler Craton
Wudinna North Part B 1:20,000	135.46E 32.9S	Gawler Craton

Victoria

Tidal River 1:32,500	146.34E 37.24S	Wilsons Promontory, Lachlan Fold Belt
Ararat 1:100,000	142.75E 37.25S	Murray Basin/South Lachlan Fold Belt
Ballarat 1:100,000	143.75E 37.75S	South Lachlan Fold Belt
Bendigo 1:100,000	144.25E 36.75S	South Lachlan Fold Belt
St Arnaud 1:100,000	142.75E 36.75S	Murray Basin/South Lachlan Fold Belt
Ballarat-Creswick Special 1:50,000	143.85E 37.5S	South Lachlan Fold Belt

Western Australia

Argo-Apollo 1:50,000	121.83E 31.37S	Kambalda/Yilgarn Craton
Balladonia 1:100,000	123.85E 32.31S	Eucla Basin
Baxter Mining area 1:25,000	118.65E 25.65S	Peak Hill /Yilgarn Craton
Coyote 1:21,400	141.69E 31.01S	Granites-Tanami Block
Hammersley (Brockman, Mt Sheila, Mt Margaret) 1:50,000	117.75E 22.23S	Hammersley Province
Kalgoorlie-Kurnalpi 1:250,000	121.5E 30.5S	Yilgarn Craton
Kanowna Belle 1:50,000	121.65E 30.61S	Yilgarn Craton
Leonora NGMA regolith-landforms and Landsat 1:250,000 Leonora NGMA regolith-landforms and gamma-ray spectrometrics 1:250,000	120.75E 28.5S	Yilgarn Craton
Menzies NGMA regolith-landforms and Landsat 1:250,000	120.75E 29.5S	Yilgarn Craton
Merredin North 1;100,000	119.08E 31S	Yilgarn Craton
Merredin South 1;100,000	119.08E 31.67S	Yilgarn Craton
Mt McClure 1:25,000	120.94E 27.43S	Yilgarn Craton
Ora Banda 1:50,000)	121.1E 30.52S	Yilgarn Craton
Sir Samuel NGMA regolith-landforms and Landsat 1:100,000 (4 Mb) Sir Samuel NGMA regolith-landforms and gamma-ray spectrometrics 1:100,000 Sir Samuel NGMA regolith-landforms and Landsat 1:250,000)	120.75E 27.75S	Yilgarn Craton
Sir Samuel NGMA regolith-landforms and gamma-ray spectrometrics 1:250,000	120.75E 27.5S	Yilgarn Craton
Steinway 1:50,000	121.45E 30.99S	Kalgoorlie/Yilgarn Craton
Wiluna NGMA regolith-landforms and Landsat 1:250,000 (13.4 Mb) Wiluna NGMA regolith-landforms and gamma-ray spectrometrics 1:250,000	120.75E 26.5S	Yilgarn Craton
Wollubar (Enigma) 1:50,000	121.56E 30.99S	Kalgoorlie/Yilgarn Craton
Wombola 1:25,000 Mb)	121.88E 31S	Yilgarn Craton
Yilgarn 1:1,000,000	118.75E 29.5S	Yilgarn Craton

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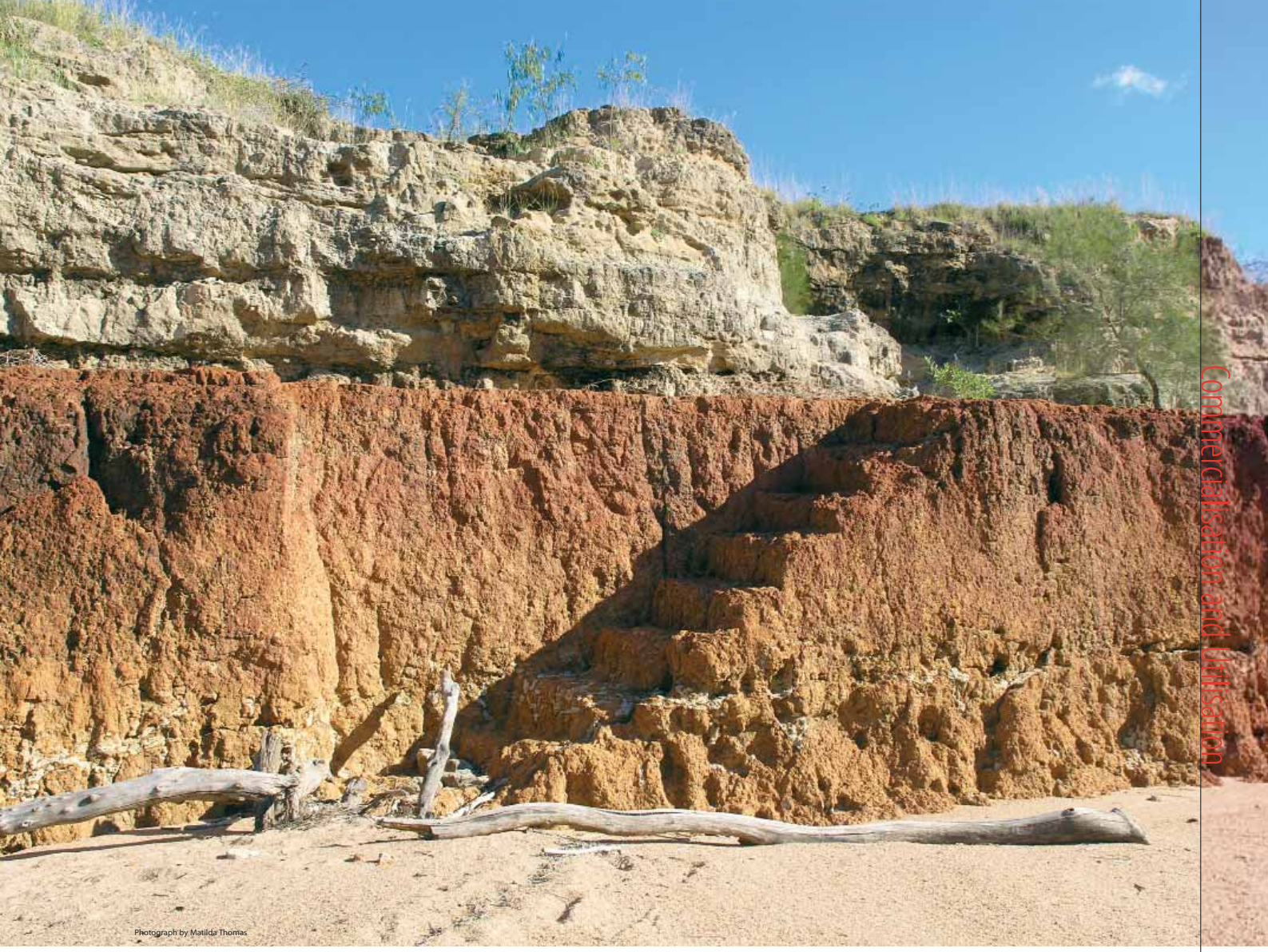

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Short course notes (2007 – 2008)

Roach IC. Fowlers Gap regolith field Class: Lecture notes and reading material. National Undergraduate Regolith Geology School (NURGS) 7-15 July 2007

Conference Activity (2007 – 2008)

LEME continued to highlight its research through participation in and attendance at national and international conferences. Research outputs were also disseminated via Centre-organised seminars, meetings and symposia. There were over 200 presentations including 9 keynote presentations and 29 invited presentations made by LEME staff and students in 2007–2008 as detailed in the following table.

Date	Event	Location	LEME Representatives	Activity
2007	5th International Conference on Mineral Exploration	Toronto, Canada	D Cohen, D Kelly, R Anand and B Williams	Presenter
May-08	Airborne Electromagnetic 08	Helsinki, Finland	K Lawrie, R Brodie, J Clarke, K Tan, C Pain, V Wong, D Edwards, H Apps, L Halas, K Cullen	Presenter
Oct-07	American Society of Agronomy	Wisconsin, USA	R Hough, H Hart, R Noble, D Vaughan, S Reddy, G Hitchen M Saunders, P Clode, R Anand	Presenter
Oct-07	American Society of Agronomy	Wisconsin, USA	R Hull, R Noble, M Stewart J Ammons	Presenter
Oct-07	American Society of Agronomy	Wisconsin, USA	R Noble, R Hough, R Watkins	Presenter
Feb-08	Australia and New Zealand Geomorphology Group	Queenstown, TAS	J Clarke	Presenter
Feb-08	Australia and New Zealand Geomorphology Group	Queenstown, TAS	J Field	Presenter
Feb-08	Australia and New Zealand Geomorphology Group	Queenstown, TAS	B Pillans	Presenter
Feb-08	Australia and New Zealand Geomorphology Group	Queenstown, TAS	C Pain	Presenter
Feb-08	Australia and New Zealand Geomorphology Group	Queenstown, TAS	D Gibson	Presenter
Feb-08	Australia and New Zealand Geomorphology Group	Queenstown, TAS	J Clarke	Presenter
Feb-08	Australia and New Zealand Geomorphology Group	Queenstown, TAS	L Worrall	Presenter
Feb-08	Australia and New Zealand Geomorphology Group	Queenstown, TAS	M Craig	Presenter
Feb-08	Australia and New Zealand Geomorphology Group	Queenstown, TAS	M Thomas	Presenter
Feb-08	Australia and New Zealand Geomorphology Group	Queenstown, TAS	M Williams	Presenter
Feb-08	Australia and New Zealand Geomorphology Group	Queenstown, TAS	V Wong	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	B Pillans	Presenter (keynote)
Jul-08	Australian Earth Sciences Convention	Perth, WA	A Petts	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	B Cooper	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	B Hou	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	C Butt	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	C Pain	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	D Gibson	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	D Gibson, J Wilford	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	D Gray	Presenter (keynote)
Jul-08	Australian Earth Sciences Convention	Perth, WA	G Bann	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	G Bann	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	G Bann	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	G Bann	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	J Clarke	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	J Wilford, J James, L Halas	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	K Lawrie	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	K McQueen	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	K Tan, K Lawrie, H Apps	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	L Halas, J Clarke, K Tan	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	M Aspandiar	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	M Smith	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	P de Caritat	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	R Anand	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	R Hough	Presenter

Date	Event	Location	LEME Representatives	Activity
Jul-08	Australian Earth Sciences Convention	Perth, WA	R Noble	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	S Adams, M Aspandiar	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	S Hill	Presenter
Jul-08	Australian Earth Sciences Convention	Perth, WA	S Rogers	Presenter (keynote)
Jul-08	Australian Earth Sciences Convention	Perth, WA	V Wong	Presented
Jul-08	Australian Earth Sciences Convention	Perth, WA	V Wong, K Lawrie, M Thankappan, K Cullen, J Clarke, L Halas	Presenter
Mar-08	Australian Geoscience Exploration Seminar	Alice Springs, NT	L Worrall	Presenter
Oct-07	Climate Change and Natural Hazards Workshop GA	Canberra, ACT	K Lawrie V Wong	Presenter
Aug-07	Congress of the International Association of Theoretical and Applied Limnology	Montreal, Canada	S Lamontagne	Presenter
Jun-08	CRC LEME Mineral Exploration Seminar	Perth, WA	C Phang	Presenter
Jun-08	CRC LEME Minerals Exploration Seminar	Perth, WA	D Gray	Presenter
Aug-07	CRC LEME Minerals Exploration Seminar	Perth, WA	R Anand	Presenter
Jun-08	CRC LEME Minerals Exploration Seminar	Perth, WA	R Anand	Presenter
Jun-08	CRC LEME Minerals Exploration Seminar	Perth, WA	R Anand, Hough R, Phang C	Presenter
Aug-07	CRC LEME Minerals Exploration Seminar	Perth, WA	R Hough, H Hart, R Noble, D Vaughan, S Reddy, G Hitchen, M Saunders, P Clode, R Anand	Presenter
Jun-08	CRC LEME Minerals Exploration Seminar	Perth, WA	R Hough, R Noble, D Gray, R Anand, C Butt, E Grenik, C Ryan, P Clode	Presenter
Jun-08	CRC LEME Minerals Exploration Seminar	Perth, WA	S Hill, J Davey, M Niemanis, C Dubieiecki, D Galash, A Hector, M Jennings, J McMahon, R Wilson, S Hore	Presenter
Aug-07	CSIRO Science Seminar	Adelaide, SA	A Barton	Presenter
Nov Dec-07	Earth Science History Group Conference	Melbourne, VIC	C Butt	Presenter
Apr-08	European Geophysical Union General Assembly	Vienna, Austria	C Pain	Session Chairman and Presenter
Apr-08	European Geophysical Union General Assembly	Vienna, Austria	J Clarke	Presenter
Apr-08	European Union Geophysical General Assembly	Vienna, Austria	C Pain	Presenter
Jul-08	Exploration in the House	Sydney NSW	K McQueen	Presenter (invited)
Sep-07	IHA Congress on Groundwater and Ecosystems Conference	Lisbon, Portugal	P Somerville, I White, B MacDonald S Welch, R Bush	Presenter (keynote)
Jul Aug-07	INQUA	Cairns, QLD	B Pillans	Presenter (invited)
Jul Aug-07	INQUA	Cairns, QLD	D Haberlah	Presenter
Jul Aug-07	INQUA	Cairns, QLD	D Haberlah	Presenter
Aug-07	International Association of Theoretical and Applied Limnology	Montreal, Canada	S Lamtagne, W Hicks, K Hall, D Baldwin, G Rees, R Fitzpatrick	Presenter
Aug-08	International Geological Congress	Oslo, Norway	J Clarke, K Lawrie, M Hatch, P Mill	Presenter
Aug-08	International Geological Congress	Oslo, Norway	K Lawrie, R Brodie, J Clarke, K Tan, C Pain, V Wong, D Edwards, H Apps, L Halas, K Cullen	Presenter
Aug-08	International Geological Congress	Oslo, Norway	K Lawrie, C Pain, R Cresswell	Presenter
Aug-08	International Geological Congress	Oslo, Norway	K McQueen	Presenter
Aug-08	International Geological Congress	Oslo, Norway	K Tan, K Lawrie, C Pain, J Clarke, H Apps, L Halas, V Wong, D Gibson, K Cullen	Presenter
Aug-08	International Geological Congress	Oslo, Norway	V Wong, K Lawrie, M Thankappan, K Cullen, L Halas, H Apps	Presenter
Aug-08	International Geological Congress	Oslo, Norway	B Hou, J Keeling, L Frakes, N Alley, X Luo	Presenter (invited)
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	G Street	Presenter
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	T Munday, A Fitzpatrick, J Reid, D Sattel, V Berens, N Christensen	Presenter

Date	Event	Location	LEME Representatives	Activity
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	M Hatch, T Munday, D Allen, A Fitzpatrick, G Heinson	Presenter
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	A Fitzpatrick, T Munday, R Brodie	Presenter
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	G Street and S Abbott	Presenter
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	L Worrall	Presenter
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	K Beckett	Presenter
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	D Baker, J Joseph, A Fabris, M Tingay	Presenter
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	J Joseph, D Kirste, L Worrall	Presenter
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	A Mauger	Presenter
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	B Harris, M Urosevic ,A Kepic M Sykes, M Martin, C Xu	Presenter
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	R Cresswell	Presenter
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	P Wilkes, B Harris and A Kepic	Presenter
Dec-07	International Geophysical Conference and Exhibition	Perth, WA	J Joseph	Presenter
Dec-07	International Geophysical Conference and Exhibition:	Perth, WA	A Fitzpatrick	Presenter
Nov-07	International Geophysical Conference and Exhibition:	Perth, WA	A Kepic	Presenter
Dec-07	International Geophysical Conference and Exhibition:	Perth, WA	A Mauger	Presenter
Nov-07	International Geophysical Conference and Exhibition:	Perth, WA	B Harris	Presenter
Nov-07	International Geophysical Conference and Exhibition:	Perth, WA	D Baker	Presenter
Nov-07	International Geophysical Conference and Exhibition:	Perth, WA	G Street and S Abbott	Presenter
Nov-07	International Geophysical Conference and Exhibition:	Perth, WA	G Street	Presenter (keynote)
Nov-07	International Geophysical Conference and Exhibition:	Perth, WA	J Joseph	Presenter
Nov-07	International Geophysical Conference and Exhibition:	Perth, WA	K Beckett	Presenter (keynote)
Nov-07	International Geophysical Conference and Exhibition:	Perth, WA	K Cahill	Presenter
Nov-07	International Geophysical Conference and Exhibition:	Perth, WA	L Worrall	Presenter
Dec-07	International Geophysical Conference and Exhibition:	Perth, WA	M Hatch	Presenter
Nov-07	International Geophysical Conference and Exhibition:	Perth, WA	M Tingay	Presenter
Dec-07	International Geophysical Conference and Exhibition:	Perth, WA	P Wilkes	Presenter
Dec-07	International Geophysical Conference and Exhibition:	Perth, WA	R Cresswell	Presenter
Dec-07	International Geophysical Conference and Exhibition:	Perth, WA	T Munday	Presenter
Jun-08	Mineral Exploration through Cover	Adelaide, SA	A Fabris	Presenter (invited)
Jun-08	Mineral Exploration through Cover	Adelaide, SA	G Heinson	Presenter (invited)
Jun-08	Mineral Exploration through Cover	Adelaide, SA	S Hill	Presenter (invited)
Jun-08	Mineral Exploration through Cover	Adelaide, SA	M Neimanis	Presenter (invited)
Jun-08	Mineral Exploration through Cover	Adelaide, SA	S Rogers	Presenter (keynote)
Apr-08	International Salinity Forum	Adelaide, SA	A Costar, T Wilson, G Heinson, A Love and Z Smit	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	A Fitzpatrick, T Munday, S Fulton, R Brodie, K Tan, K Cahill, A Cornelius	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	B Degens, R Fitzpatrick, G Douglas, R George, S Rogers, P Shand, A Lillicrap, D Gray, R Noble and M Smith	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	C Pain	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	D Cohen, D Kelly, R Anand and B Williams	Presenter

Date	Event	Location	LEME Representatives	Activity
Apr-08	International Salinity Forum	Adelaide, SA	D Gibson	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	G Bann	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	G Bann	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	G Bann, J Field	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	G Heinson	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	G Heinson, A Costar, T Wilson, A Love, Z Smit	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	J Clarke	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	J Clarke, K Lawrie, J Ginnivan, K Mathers,	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	T Munday, P Pfeiffer, G Sutherland, B Tatnell, B Amoafo, A Telfer, A Fitzpatrick	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	J James	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	J Wilford, J James, L Halas	Session Chairman and Presenter
Apr-08	International Salinity Forum	Adelaide, SA	K Lawrie	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	K Lawrie	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	K Lawrie, J Clarke, K Tan, C Pain, R Brody, D Edwards, H Apps, V Wong, K Cullen	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	K Lawrie, J Clarke, K Tan, C Pain, Brodie R, D Edwards, M Reid, H Apps, V Wong, J Luckman	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	K Tan, K Lawrie, M Turner, M Glover, L Hallis, H Apps, T Munday, R Cresswell	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	K Tan, K Lawrie, J Clarke, M Reid, V Wong, J Luckman, N Apps, D Edwards	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	K Tan, T Munday, T Graham, K Holmes, K Cahill, A Fitzpatrick	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	L Halas, J Clarke, K Tan	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	M Gildfedder	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	M Hatch, A Fitzpatrick, T Munday, D Allen, B Porter, A Telfer	Presenter (keynote)
Apr-08	International Salinity Forum	Adelaide, SA	M Lenahan, R Cresswell	Presenter (keynote)
Apr-08	International Salinity Forum	Adelaide, SA	M Reid, K Lawrie, C Pain, J Fawcett	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	P Wilkes	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	R Cresswell	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	R Fitzpatrick	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	R Fitzpatrick, B Degens, A Baker, M Raven, P Shand, M Smith, S Rogers, R George	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	R George, J Clarke, P English	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	S Beavis, S Welch, A Higgins, D Kirste	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	S Rogers, B Degens, R Fitzpatrick, G Douglas, R George, P Shand, A Lillicrap, D Gray	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	S Welch, S Beavis, D Kirste	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	T Dhu, G Heinson	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	T Munday, A Fitzpatrick, C Pocaro, R Brodie, K Cahill	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	T Munday, I Overton, A Fitzpatrick	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	V Wong	Presenter
Apr-08	International Salinity Forum	Adelaide, SA	V Wong, J Clarke, K Lawrie, K Tan, H Apps, C Pain, J Luckman, L Halas	Presenter
Jul-07	International Union Quaternary Research Congress	Cairns, QLD	D Haberlah, M Williams, S Hill, G Halverson, P Glasby	Presenter (invited)

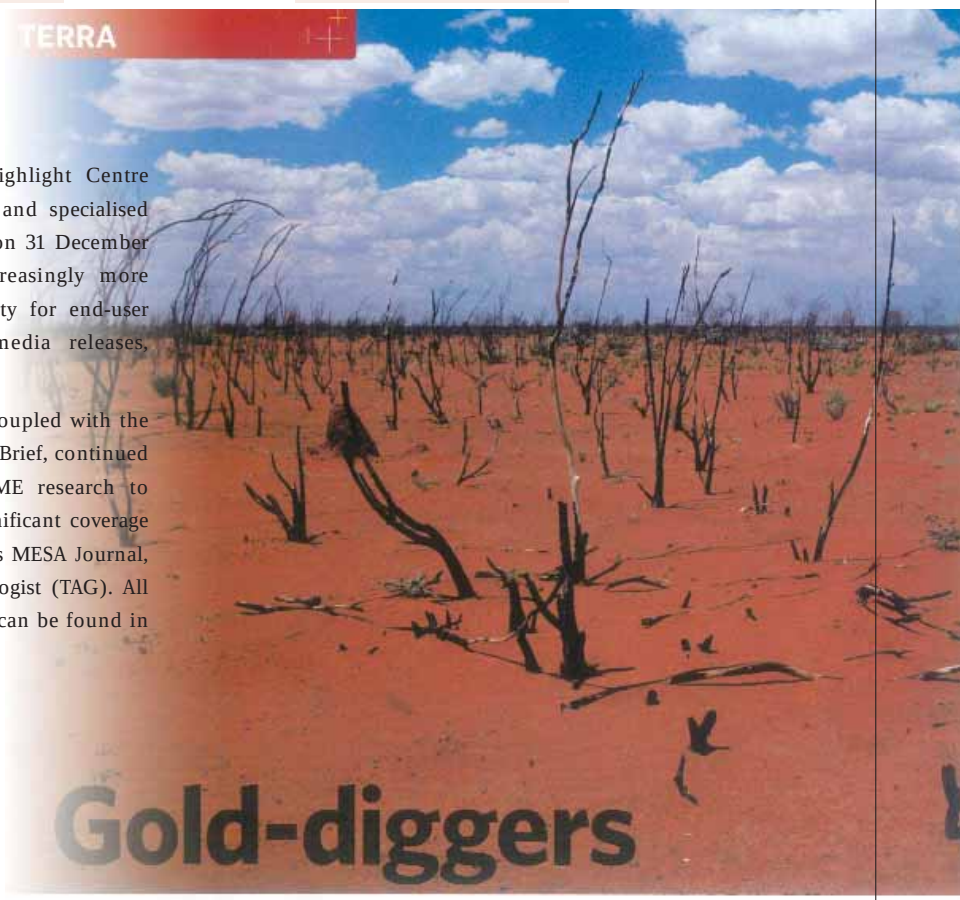
Date	Event	Location	LEME Representatives	Activity
Sep-07	Kalgoorlie 07: Old Ground, New Knowledge	Kalgoorlie, WA	B Pillans	Presenter (invited)
Sep-07	Kalgoorlie 07: Old Ground, New Knowledge	Kalgoorlie, WA	C Butt	Presenter (invited)
Sep-07	Kalgoorlie 07: Old Ground, New Knowledge	Kalgoorlie, WA	D Gray	Presenter (invited)
Sep-07	Kalgoorlie 07: Old Ground, New Knowledge	Kalgoorlie, WA	L Worrall	Presenter (invited)
Sep-07	Kalgoorlie 07: Old Ground, New Knowledge	Kalgoorlie, WA	R Anand	Presenter (invited)
Sep-07	Kalgoorlie 07: Old Ground, New Knowledge	Kalgoorlie, WA	R Hough	Presenter (invited)
Sep-07	Kalgoorlie 07: Old Ground, New Knowledge	Kalgoorlie, WA	S Rogers	Presenter (invited)
Oct-07	Lectures for invited international visitors	Beijing, China	B Hou	Presenter (invited)
Oct-07	Lectures for Milestone 4 of the China-Australia Fund	Guangxi, China	B Hou	Presenter (invited)
Oct-07	Loveday Disposal Basin Management Committee	Adelaide, SA	S Lamontagne	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	A Fabris	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	B Pillans	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	D Gray	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	D Gray	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	J Keeling	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	K Lawrie	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	K McQueen	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	L Worrall	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	P de Caritat	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	R Anand	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	R Noble	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	S Hill	Presenter
Jun-08	Mineral exploration through the cover: how far have we come?	Canberra, ACT	S Rogers	Presenter
Feb-08	Mineralogical Society of NSW Seminar	Sydney, NSW	K McQueen	Presenter
Nov-07	NSW Murray Wetlands Working Group	Adelaide, SA	A Fitzpatrick	Presenter
Oct-07	Presentations for invited international visitors	Hong Kong, China	B Hou	Presenter
Oct-07	Presentations for invited international visitors	Jiangxi, China	B Hou	Presenter
Oct-07	Soil Science Society of America Annual Meeting	West Virginia USA	R Hough, H Hart, R Noble, D Vaughan, S Reddy, G Hitchen, M Saunders, P Clode, R Anand	Presenter
Oct-07	Soil Science Society of America Annual Meeting	West Virginia USA	R Hull, R Noble, M Stewart, J Ammons	Presenter
Oct-07	Soil Science Society of America Annual Meeting	New Orleans, USA	R Noble, R Hough, R Watkins	Presenter
May-08	South Australian Resources and Energy Investment Conference	Adelaide, SA	J Keeling, B Hou, A Mauger, A Fabris	Presenter (invited)
Nov-07	South Australian Wetland Technical Working Group	Adelaide, SA	S Lamontagne	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	A Brown	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	A Fabris	Session Chairman and Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	A Hector and S Hill	Presenter (invited)
Nov-07	Sprigg Symposium	Adelaide, SA	A Mauger	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	A Petts	Presenter

Date	Event	Location	LEME Representatives	Activity
Nov-07	Sprigg Symposium	Adelaide, SA	B Cooper	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	C Dubieniecki and S Hill	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	D Gallasche	Presenter (keynote)
Nov-07	Sprigg Symposium	Adelaide, SA	J Davey	Presenter (invited)
Nov-07	Sprigg Symposium	Adelaide, SA	J Joseph, A Fabris, L Worrall	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	J Keeling, S Hore, R Sprigg	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	M Lintern	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	M Nemanis	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	M Sheard	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	N Reid	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	R Dart	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	R Fidler	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	S Pontual	Presenter
Nov-07	Sprigg Symposium	Adelaide, SA	S Rogers	Presenter
Nov-07	The International Workshop on Fluvial and Marine Processes of Cenozoic and Formation of Placers	Goa, India	B Hou	Presenter
Oct-07	Uranium Exploration	Perth, WA	C Butt	Presenter
Sep-07	XXXV International Association of Hydrogeologists Congress on Groundwater and Ecosystems	Lisbon, Portugal	A Barton	Presenter

Media

LEME communications have continued to highlight Centre activities and research outputs to the general and specialised media. Towards the conclusion of all activities on 31 December 2008, communications have become an increasingly more important avenue to ensure greater opportunity for end-user uptake and technology transfer through media releases, advertising and conference attendance.

Articles in external magazines and newsletters, coupled with the Centre's own quarterly publication, the Minerals Brief, continued to be an effective way to communicate LEME research to stakeholders nationally and internationally. Significant coverage of LEME research results was featured in PIRSA's MESA Journal, The Mining Chronicle and The Australian Geologist (TAG). All media releases and commentary on LEME work can be found in the following table.


TERRA

Gold-diggers

Scientists are using techniques honed by millions of years of evolution to locate new mineral deposits in the Australian desert.

Heather Catchpole

GOLD, IRON, COPPER, you name it – Australia is rich when it comes to metals. It is among the top 10 exporters for a host of the world's key mineral resources, and last year broke A$100 billion in export sales. Yet despite the massive investment in traditional mineral exploration technologies to date, the next step could be as low-tech as collecting a few leaves or digging into the side of a termite mound.

Though Australia reaps a rich reward from its rocks, its proportion of global investment in exploration for minerals is dropping. Between 2005 and 2007, Australia's share of the global expenditure decreased from 19 to 13 per cent, says environmental microbiologist Steve Rogers, chief executive of Perth's Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME).

One reason for this trend is that Australia is increasingly seen as difficult terrain to explore – and prospectors think most of the easy gains have been made. The continent is one of the oldest and most deeply weathered and in some areas, bedrock is covered by hundreds of metres of eroded soil and rock fragments, known as regolith.

"We've found everything there is to find over, but much of the rest of the continent is covered by deep regolith," says Rogers.

To find new deposits, the mineral industry needs to look underneath this shroud of soil. But with large areas to survey and the high

Miners may use fizzy drinks to check for metal deposits

Peter Morley

MINERAL explorers may be equipped with red wine or soft drink if CSIRO research proves correct.

The organisation's exploration and mining scientist Ryan Noble has found that chemical ingredients in the drinks can dissolve weakly bound metals into solution.

"When you mix the drinks with soil, acids dis-

analysis," Dr Noble said.

"The chemical ability of the drinks make them very suitable for use as a cheap extraction tool that can be applied to mineral research.

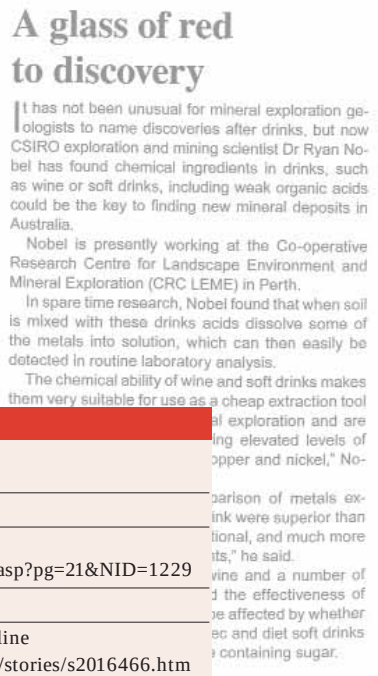
"The drinks are particularly good at discovering elevated levels of metals such as silver, zinc, copper and nickel."

Dr Noble, who did the research in his spare time, said he and colleagues initially sceptical the approach but ere astounded by its

"In many cases, the comparison of metals extracted using wine and soft drink were superior than those extracted using conventional, and much more expensive commercial solvents," he said.

The effectiveness of the technique was not affected by the variety of wine chosen.

"A shiraz or a malbec works and diet soft drinks are just as effective as those containing sugar," Dr Noble said.



A glass of red to discovery

It has not been unusual for mineral exploration geologists to name discoveries after drinks, but now CSIRO exploration and mining scientist Dr Ryan Nobel has found chemical ingredients in drinks, such as wine or soft drinks, including weak organic acids could be the key to finding new mineral deposits in Australia.

Nobel is presently working at the Co-operative Research Centre for Landscape Environment and Mineral Exploration (CRC LEME) in Perth.

In spare time research, Nobel found that when soil is mixed with these drinks acids dissolve some of the metals into solution, which can then easily be detected in routine laboratory analysis.

The chemical ability of wine and soft drinks makes them very suitable for use as a cheap extraction tool al exploration and are ing elevated levels of opper and nickel," No-

parison of metals ex- ink were superior than tional, and much more ts," he said.

vine and a number of d the effectiveness of e affected by whether ec and diet soft drinks containing sugar.

Media Releases, Magazine Articles, Radio Interviews and Podcasts

Date	Subject	LEME Contact	Medium/Link
Aug 07	"What's the secret of your Devil's Lair?"	Ryan Noble	Geraldton Guardian Newspaper
Aug 07	"Mining creams profit"	Ryan Noble	Sunday Times Newspaper
Aug 07	Research results on novel geochemical extractions	Ryan Noble	Science Network WA website http://sciencewa.net.au/science_news.asp?pg=21&NID=1229
Aug 07	Research results on new geochemical extractions	Ryan Noble	"Resources Beat" ABC News Radio
Aug 07	Research results on new geochemical extractions	Ryan Noble	"Resources Beat" 29/08/07. Report online http://www.abc.net.au/rural/resources/stories/s2016466.htm
Sept 07	"Research uncorks wine's potential"	Ryan Noble	Mining Chronicle Vol 12, No.8. p. 108.
Sept 07	Research results on new geochemical extractions	Ryan Noble	ABC Radio National "Bush Telegraph"
Sept 07	Research results on new geochemical extractions	Ryan Noble	ABC Radio National "Bush Telegraph" podcast http://www.abc.net.au/rural/telegraph/index/weekly.htm
Sept 07	Research results on new geochemical extractions	Ryan Noble	CSIRO Podcast with media release "Using wine and soft drink in mineral exploration" http://www.csiro.au/multimedia/pf10u.html 14/09/07
Sept 07	"Miners may use fizzy drinks to check for metal deposits"	Ryan Noble	Courier Mail
Sept 07	"Mineral exploration goes better with cola"	Ryan Noble	The Australian Newspaper
Sept 07	"Glass of wine can help finds new mineral deposits" http://www.sciencedaily.com/releases/2007/09/070914105954.htm	Ryan Noble	Science Daily USA
Sep 07	Cainozoic palaeochannel-hosted uranium and current exploration methods, SA	Baohong Hou *et al*	PIRSA – MESA Journal, 46.
Sept 07	Research results on new geochemical extractions	Ryan Noble	ABC Central Australia (Alice Springs), NT Country Hour
Nov 07	"Edle Tropfen – Wein konnte bei der Suche nach Metall-Lagerstatten helfen"	Ryan Noble	German publication Selte 20 / Suddeutache Zeltung Nr. 252. http://www.sueddeutsche.de/wissen/artikel/30/140730/
Nov 07	Using wine "goggles" to find minerals	Ryan Noble	Geotimes November 2007 p. 18-19.
Dec 07	Gold Nuggets reveal inner secrets	Rob Hough	Qld Govt; Mining Journal – Summer 07 – No 1229.
Dec 07	Deep sense reveals minerals	Laterite Geochemical Atlas of the Yilgarn – project team	DIISR/CRC Programme quarterly newsletter – CRCs Success Through Innovation.
Dec 07	Workshopping smart exploration techniques.	Featuring joint LEME and pmd CRC work	Qld Govt; Mining Journal – Summer 07 -No 1229.
Dec 07	Regolith mapping boosts exploration: Qld Regolith Mapping Project	Mike Craig	Qld Govt; Mining Journal – Summer 07 – No 1229.
Dec 07	Forensic soil science helps solve double murder	Rob Fitzpatrick	CSIRO Newsletter – Monday Mail
Dec 07	Science Class with a Difference: CSIRO in Schools	Steve Rogers	CSIRO Newsletter – Monday Mail
Dec 07	A glass of wine can help find new mineral deposits	Ryan Noble	CSIRO Media Release 07/179
Jan 08	Exploration In New Frontiers in NSW – CRC LEME Thomson regolith geochemistry	Lisa Worrall and Thomson project team	NSW DPI – MINFO Issue 86.
Jan/Feb 08	Salt of the earth: examining the relationship between salinity and atmospheric CO_2	Vanessa Wong	Article in ANU ScienceWise Vol 5, No 1.
Feb 08	Hydrogeochemical sampling for minerals	Ryan Noble and David Gray	ABC Local Radio Geraldton
Feb 08	Gold Diggers	Anna Petts and Nathan Reid	Cosmos Magazine 19
Feb 08	Applying geophysics to environmental problems	Andrew Fitzpatrick	ARRC Annual Report 2007 – Research Highlights

Date	Subject	LEME Contact	Medium/Link
Feb 08	Yilgarn Craton Lateritic Atlas	Program 2 work – Ravi Anand, Ian Robertson and Team	ARRC Annual Report 2007 – Research Highlights
Feb 08	Termite-spinifex research	Anna Petts and Nathan Reid – LEME UA PhD students (Program 1)	ARRC Annual Report 2007 – Research Highlights
Feb 08	Groundwater tests point to untapped riches – hydrogeochemical exploration	David Gray and Patrice de Caritat	Northern Guardian WA
Feb 08	Finds blowing in the wind – hydrogeo-chemical exploration	David Gray	Countryman WA
Feb 08	The national acid sulfate soil atlas, and Inland acid sulfate soils	Rob Fitzpatrick	ABC Radio, Adelaide and Channel 9 TV interview
Mar 08	Gold Diggers	Steve Hill, and LEME UA PhD students Anna Petts and Nathan Reid	Cosmos 19 – www.cosmosmagazine.com
Mar 08	Natures little diggers	Ravi Anand and Steve Hill	ABC TV – Catalyst
Mar 08	Nature's Little Diggers	Ravi Anand and Steve Hill	ABC TC – Catalyst
Mar 08	2007 in Review: CRC LEME	UA and PIRSA – LEME project teams	PIRSA – MESA Journal 48
Apr 08	Gold nuggets	Rob Hough	ABC TV – Catalyst
Apr 08	Fire, Flood and Acid Mud – Murray Darling in crisis	Rob Fitzpatrick	ABC TV – Catalyst
Apr 08	Heavy metals threatening Murray River	Rob Fitzpatrick	ABC TV News
Apr 08	Groundwater pinpoints mineral riches – hydrogeochemical exploration	David Gray	CSIRO Media Release 08/19
Apr 08	Murray River threatened by heavy metals	Rob Fitzpatrick	The Australian
Apr 08	Lateline Special Report – Heavy metals threaten Murray River	Rob Fitzpatrick	ABC TV
May 08	Acid sulfate soils: mapping the risk	Rob Fitzpatrick	CSIRO Science Project Profile
May 08	The National Geochemical Survey of Australia: underpinned by geochemical surveys by GA and CRC LEME	Lisa Worrall and Program 1 team	NSW DPI – MINFO.
Jun 08	Queensland regolith map released (pre release at LEME Symposium at GA)	Mike Craig	Geoscience Australia Media Release
Jun 08	CSIRO Scientist discovers natural 'invisible' gold. Nano particles of gold too small to be seen with the naked eye have been created in laboratories, but up until now, have never been seen in nature – until now.	Rob Hough	CSIRO Medial Release 08/102 ABC Radio – National :Science Show West and Central Qld Rural South Australia Over 50 web sites, National and international also ran this story. Hough *et al*, Journal paper published by Geology
Jun 08	Eucla Basin – emerging as a new heavy mineral province of global significance	Baohong Hou and John Keeling	PIRSA – MESA Journal – pp18-24
Jul 08	Geoscientist awarded for excellence in Research: LEME-CSIRO Sponsored Butt-Smith Medal to Dr Nigel Radford	Steve Rogers	CSIRO Media Release 08/126
Jul 08	CRC LEME highlights, benefit and impact of regolith geoscience R&D	Steve Rogers	AusIMM Geoscience News
June 08	Gold Nanoparticles	Hough *et al*	ABC Radio National: Science Show – Live Interview
June 08	Gold Nanoparticles	Hough *et al*	ABC Radio Western Queensland – Live Interview
June 08	Gold Nanoparticles	Hough *et al*	ABC Radio Central Queensland – Live Interview
June 08	Gold Nanoparticles	Hough *et al*	ABC Radio Victoria – Live Interview
June 08	Gold Nanoparticles	Hough *et al*	ABC Radio Rural South Australia – Live Interview
June 08	Gold Nanoparticles	Hough *et al*	nanotechwire.com/news
June 08	Gold Nanoparticles	Hough *et al*	www.physorg.com/news
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June 08	Gold Nanoparticles	Hough *et al*	science.kukuchew.com

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June 08	Gold Nanoparticles	Hough et al	www.rdmag.com
June 08	Gold Nanoparticles	Hough *et al*	www.scitech-news.com
June 08	Gold Nanoparticles	Hough *et al*	www.sciencewa.net.au
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June 08	Gold Nanoparticles	Hough *et al*	www.itexaminer.com
June 08	Gold Nanoparticles	Hough *et al*	sciencex2.org C
June 08	Gold Nanoparticles	Hough *et al*	www.news24online.info
June 08	Gold Nanoparticles	Hough *et al*	in.news.yahoo.com
June 08	Gold Nanoparticles	Hough *et al*	www.powerhousemuseum.com
June 08	Gold Nanoparticles	Hough *et al*	www.newsmixer.net
June 08	Gold Nanoparticles	Hough *et al*	www.utilisegold.com
June 08	Gold Nanoparticles	Hough *et al*	www.silobreaker.com
June 08	Gold Nanoparticles	Hough *et al*	www.nano.org.uk
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June 08	Gold Nanoparticles	Hough *et al*	www.sciencecentric.com
June 08	Gold Nanoparticles	Hough *et al*	www.abfx.com
June 08	Gold Nanoparticles	Hough *et al*	www.edonkers.org
June 08	Gold Nanoparticles	Hough *et al*	www.inovacaotecnologica.com.br
June 08	Gold Nanoparticles	Hough *et al*	www.artmaja.com
June 08	Gold Nanoparticles	Hough *et al*	www.iconocast.com
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June 08	Gold Nanoparticles	Hough *et al*	tmcnet.com
June 08	Gold Nanoparticles	Hough *et al*	nanowerk.com
June 08	Gold Nanoparticles	Hough *et al*	Huliq News
June 08	Gold Nanoparticles	Hough *et al*	Samachar.com
June 08	Gold Nanoparticles	Hough *et al*	Malaysia Sun
June 08	Gold Nanoparticles	Hough *et al*	webindia.com
June 08	Gold Nanoparticles	Hough *et al*	Economic Times India
June 08	Gold Nanoparticles	Hough *et al*	azonano.com
June 08	Gold Nanoparticles	Hough *et al*	Australian Mining (www.miningaustralia.com.au)
June 08	Gold Nanoparticles	Hough *et al*	netindia123.com
June 08	Gold Nanoparticles	Hough *et al*	zeenews.com
June 08	Gold Nanoparticles	Hough *et al*	Cambodian Times
June 08	Gold Nanoparticles	Hough *et al*	Bahrain Tribune
June 08	Gold Nanoparticles	Hough *et al*	newkerala.com
June 08	Gold Nanoparticles	Hough *et al*	spacedaily.com

ploration with cola

turned out that Spanish red wine was best of all."

The soft drinks have weak solutions of phosphoric, benzoic and citric acids, but red wines have citric acid and 20 or more other acids in weak concentrations.

Dr Noble said yesterday the work might sound a bit tongue in cheek, but the results were impressive.

"Working on a sample using soft drink or wine costs about $3 a sample (not including the geologist's time)", he said. "But proprietary brands can cost anywhere from $20 to $50 a sample, and some as much as $100, with results that are not as good."

Dr Noble has presented the results of his testing at home and abroad, starting with the International Applied Geochemistry symposium at Oviedo in Spain in June, to widespread interest and acclaim.

"Most people were entertained," he said.

"It supported what many had thought all along."

Dr Noble added: "We started on the work in our spare time and, by the way, we didn't waste any of the samples."

Dr Noble and colleague Cliff Stanley of Acadia University in Nova Scotia were looking for a widely available and cheaper tool for geologists to use, instead of proprietary brands whose chemistry is often a trade secret.

"We got the idea when Ed Dronseika, from a commercial laboratory, used Guinness Stout and Emu Bitter (a West Australian beer) in a promotional poster," he said. "We looked at his results and found the Guinness was better."

"Then, in a more rigorous experiment, we tried Coca-Cola and Pepsi and the Pepsi was marginally better, but then it

END-USER INVOLVEMENT AND CRC IMPACT ON END USERS

CRC LEME is a knowledge based CRC and as such is restricted in its ability to accurately measure its involvement and research impact on end users outside its collaboration activities, as it does not undertake commercialisation projects that result in the creation of patentable products for a known marketplace.

Instead, LEME research outcomes are publicly available through the release of hard-copy, and the placement of electronic publications and datasets on its website. How this knowledge is utilised by end users who have access LEME research through such means is difficult to determine. However, the Centre is able to provide some commentary on the end-user utilisation impacts that has resulted from its research outputs during the reporting period.

Release of the SA Palaeodrainage and Tertiary Coastal Barriers Map in May 2007 was followed (May to September 2007) by 78 new exploration tenement applications over palaeodrainage channels and associated sediments.

The culturally and environmentally significant landscape near the Four Mile uranium deposit in the northern Flinders Ranges required a particularly sensitive approach to mineral exploration. A CRC LEME biogeochemical exploration study in 2007 -2008, partly funded by the South Australian government's PACE program and Quasar Resources, has allowed for mineral exploration with minimal environmental and cultural impact. This study used river red gums and inland tea-trees growing along major creeks to successfully express the underlying mineralisation, where drilling access has been limited. This study also looked to draw upon plant and landscape knowledge from the local indigenous communities, and could potentially provide training and business opportunities for these groups.

In 2007 – 2008 CRC LEME research supported rapid mapping, risk assessment and characterisation of ASS in the Murray Basin. This meant that effective water allocation strategies could be developed. CRC LEME researchers are now involved in projects across the Basin, in partnership with State (SA Department of Environment and Heritage, SA Murray Darling NRM Board, Department of Water, Land and Biodiversity Conservation, Rural Solutions SA) and Federal agencies (Department of Water, Environment, Heritage and Arts) and the Murray Darling Basin Commission.

Information derived from CRC LEME's science was integrated with existing information and other technologies to provide improved data for numerical groundwater models and the design phase of salt interception schemes, which are being developed collaboratively by CSIRO Land & Water, Department of Water Land and Biodiversity Conservation and SA Water. Long-term potential benefits in NPV terms may be of the order of $300-400 million.

Photograph by Steven Hill

Education and Training

Program Leader:
Dr Ian Roach (ANU)
until April 2008
Dr Sara Beavis (ANU)
until June 2008

Highlights

- 90 postgraduate enrolments during life of CRC.
- 47 postgraduate completions during life of LEME with a total of 81 completions anticipated against a KPI of 60.
- 117 BSc Honours completions against a KPI of 60
- Core Participant universities experience significant enrolments in second and third year undergraduate regolith geoscience programs.
- Strong MINEX and NRM industry uptake of LEME graduates.
- LEME graduates continue to make new discoveries aiding Australian regolith science.
- Centre-funded contract staff appointed to continuing positions at CUT and UA.

Overview

Over the last seven years, LEME's Education and Training (E&T) Program has provided world-class education and training in regolith geoscience to undergraduates, postgraduates and industry professionals through its three Core Participant universities: ANU, CUT and UA. LEME is recognised as a relevant, world-class educator and provider of geoscience graduates for careers in research and the Mineral Exploration and Natural Resources Management industries.

During the reporting period the E&T Program was managed by Dr Ian Roach and, after April 2008, by Dr Sara Beavis, with support from the E&T Committee comprising: Dr Mehrooz Aspandiar (Deputy Program Leader, CUT), Dr Steve Hill (past E&T Program Leader, UA), Dr Karin Barovich (UA), Dr Sara Beavis (ANU) and Dr Richard Greene (ANU).

Postgraduate students

Supervision in the 2007-08 period was provided by in-kind contributed or Centre funded staff members and external advisers from industry or research institutions. No new LEME postgraduate scholarships were awarded in the 2007-08 financial year. The Postgraduate Scholarship Program was maintained until Centre closure at the end of June 2008, to support students currently in the system. Postgraduate student supervision by present in-kind contributed research staff continues at the core participant universities after the Centre's closure to ensure that ongoing students continue to excel in their research projects.

LEME Core Participant universities continue to succeed in attracting high-profile students who have gained scholarships from other sources including the Commonwealth Government and other university and Australian Research Council awards in 2006 and 2007, continuing into 2008. These students will carry on the legacy of regolith research beyond the life of the Centre. This will include four students at ANU (Fern Beavis, Andrew Higgins, Julia Jasonsmith and Nicole Mikkelson) and four students at the UA (Nathan Reid, Jessie Davey, David Haberlah and Michael Neimanis).

LEME is on track to meet or exceed its KPI target of graduating 60 postgraduates (PhD and MSc). At the end of the 2007-08, the Centre had 39 postgraduate graduations with an additional 8 completions notified. A further 38 students are progressing towards completing their degrees and are expected to complete after the Centre's closure.

During the current minerals boom and associated skills shortage, many Centre students are employed on a part-time or full-time basis in national or international resource exploration companies or government geoscience agencies while they complete their studies. This is an outstanding indicator of the high regard that industry has towards LEME students and graduates.

Honours students

The Centre offered no Honours scholarships during the 2007-08 periods, instead relying on project funds to cover operating expenses at the core participant universities. Students were supervised by Centre in-kind contributed or CRC funded staff members.

The Centre nearly doubled its KPI of 60 Honours graduates by June 2008, closing with an astonishing 117 graduations. More than 75% of the 2002-08 graduates have found employment in the MINEX or NRM industries. Others have gone on to pursue postgraduate studies, either within LEME Core Participant universities or other Australian universities. These statistics clearly show the Honours Program is the LEME E&T Program's standout success.

Short courses, workshops and seminars

MTEC short courses

LEME was a major contributor to the Minerals Council of Australia's Minerals Tertiary Education Council (MTEC) Honours and postgraduate minerals training program over its lifetime. In 2006-07, LEME E&T worked to ensure the continuation of the MTEC program by contributing towards strategic planning and the hand-over of regolith-related education and training to the individual core participant universities.

In late 2007 the three core participant universities were individually invited by MTEC to enter into a new contractual arrangement to deliver regolith-content Honours-level short courses for the period 2008-2010, the previous contract lapsing in December 2007. The invitations were based on the good work, good will and excellent course materials developed over the previous seven years of LEME's involvement in MTEC.

Continuing courses developed and delivered by the three core participant universities include many in-kind contributed LEME staff and associates, in 2008:

- Minerals Exploration Under Cover, Arkaroola SA, 16-22 March 2008, Steve Hill (UA), Stephen Hore (PIRSA), David Giles (UA);
- Mining Geology and Resource Evaluation, Kalgoorlie WA, 11-15 February 2008, Mehrooz Aspandiar (CUT), Ian Fitzsimmons (CUT), Peter Collins (CUT);
- Regolith Geoscience and Mineral Exploration, Canberra ACT, 14-18 April 2008, Bear McPhail (ANU), Brad Pillans (ANU), Ken McQueen (ANU), Keith Scott (ANU), Lisa Worrall (GA).
- These new courses continue to build on the excellent course materials developed over the 7 years of LEME involvement in MTEC, some of which are now available on the LEME web site, including:
- Environmental Mineralogy, authors Mehrooz Aspandiar (CUT), Tony Eggleton (ANU) and Ulrike Troitzsch (ANU);
- Regolith Geology and Geochemistry, authors Ian Roach (ANU), Steve Hill (UA) and Mehrooz Aspandiar (CUT).

Generic courses for LEME students

A range of generic-skills courses were held for students enrolled at LEME Core Participant universities including four-wheel drive training, first aid and field safety, plus workshops, seminars and mentoring programs on thesis writing, research publication writing and scientific communication skills.

Industry workshops and technology transfer

During the year, LEME conducted 'one-on-one' courses, workshops, presentations and technology transfer meetings through Programs 1 to 4 and by the E&T Program with the majority of the workshops aligned to specific research projects.

Undergraduate students

Undergraduate regolith courses are coordinated and taught by in-kind and contract LEME staff members at ANU, CUT and UA, together with staff from other LEME Core Participants. These courses provide an essential prerequisite for students either wanting to become regolith researchers or work as 'regolith-savvy' industry professionals. During 2007-08, 419 undergraduate students were introduced to the fundamentals and applications of regolith geoscience including regolith mineralogy, rock weathering, landscape evolution, groundwater flow, regolith-groundwater interactions, remote sensing of regolith and regolith geophysical techniques.

At ANU, regolith science is taught to undergraduates at second and third year level in a range of courses that provide students with the fundamentals of regolith and water interactions, landscape evolution and regolith-related environmental problems. Beginning in 2007, ANU had a major curriculum change and divided aspects of regolith geoscience from one stand-alone course in 2006 to three individual courses in 2007:

- Regolith and Hydrology 2006 (Second-year, 14 students)
- Environmental Chemistry 2007, including regolith-groundwater interactions (Second-year, 41 students)
- Groundwater 2007, including hydrogeology (Third-year, 16 students)
- Environmental and Regolith Geoscience 2007 – the principal regolith course at the ANU (Third-year, 14 students).

At CUT, regolith geoscience components are taught in the second, third and fourth years of undergraduate training (excluding MTEC courses):

- Second Year Remote Sensing 2007, including regolith, landforms, mapping (60 students)
- Regolith and Exploration Geochemistry 2007, the principal regolith course at CUT and includes presentations by practicing regolith mineral exploration professionals in as part of its curriculum (Third-year, 33 students)
- Third-year Sedimentology Field Class 2007 (26 students)
- Fourth year (Honours) Remote Sensing 2007 (11 students).

Regolith geoscience at UA is taught to undergraduates in the second, third and fourth years:

- Second-year Landscape Processes and Environments 2007, (80 students)
- Third-year Environmental Geoscience Processes 2007 (50 students)
- Third-year Environmental Geoscience Applications 2007 (50 students)
- Fourth year (Honours) Mineral Exploration Under Cover (24 students).

During the year, in-kind and contract staff from a number of LEME Core Participants taught undergraduate courses at ANU, CUT and UA, including Mehrooz Aspandiar, David Chittleborough, Patrick De Deckker, Tony Eggleton, Steve Hill, Graham Heinson, Karin Barovich, Andreas-Schmidt-Mumm, Brad Pillans, Ian Roach, Bear McPhail and Sue Welch.

The bulk of the teaching load at CUT and UA was undertaken by Mehrooz Aspandiar and Steve Hill, respectively, who are to be congratulated for maintaining their teaching excellence despite heavy teaching, research and student supervision loads.

National Undergraduate Regolith Geology School (NURGS)

This annual undergraduate regolith geology field class was held over 9-12 July 2007 at the University of New South Wales' Fowlers Gap Arid Zone Research Station in far western NSW. NURGS uses examples of LEME's research in the Curnamona Province and Thomson Orogen to provide students with essential grounding in regolith and landscape evolution and regolith-landform mapping, together with some hands-on demonstrations of regolith and biological sampling procedures, regolith geophysical techniques and soil description. The field trip is an essential part of the undergraduate curriculum at ANU and UA and contributes to the direct entry of students into the Honours programs at both institutions. Over 70 students from ANU and UA attended. Staff involved in organising and running the course were Steve Hill (UA), Ian Roach (ANU), David Chittleborough (UA) and Graham Heinson (UA).

The E&T Program's Regolith Teaching and Training Materials (RTTM) Project contributes to the development and delivery of teaching materials for undergraduate courses at the Core Participant universities and NURGS.

NURGS will continue after CRC LEME winds down, with class visits from the University of Adelaide planned to continue in 2008 and beyond.

Regolith Teaching and Training Materials

The RTTM program was designed to help the development and delivery of teaching materials for use in undergraduate and postgraduate teaching at the Core Participant universities and NURGS. Materials from this program included maps, photographs, remotely-sensed and geophysical imagery, aerial photography, GIS databases and on-line teaching resources, which were delivered in various forms during 2007-08. Some examples of RTTM materials include the NURGS notes (now published as LEME Open File Report 236) and a series of regolith-landform maps and accompanying papers developed for the Fowlers Gap Arid Zone Research Station, all available on the LEME WWW site. The RTTM project, which grew from the earlier Virtual Regolith Worlds project, was successfully concluded in 2007-08. The project ensures that valuable teaching materials are available for the continuing delivery of world-class regolith training at all universities needing regolith content in undergraduate and postgraduate curricula.

Postscript

As the Centre activities conclude, it is pleasing and positive to note that the outlook for regolith geoscience teaching and training in Australia looks assured. Regolith geologists have been appointed to continuing teaching positions at CUT and UA, and LEME's E&T activities have raised the profile of regolith science so that it is now an integral part of graduate and postgraduate geoscientist training in a large number of Australian universities.

2007 – 2008 Graduate destinations

The Centre has been advised of the following:

Honours Graduates

Gabriel Yeates (ANU) – Snowy Mountains Engineering Corporation

James Hughes (ANU) – Rio Tinto

Jason Raapana (ANU) – Coffey Geotechnics

Jacob Paggi (CUT) – Independence Group

Sean Adamas (CUT) – Barsons Brinkerhoff (BB)

Andrew Hector (UA) – Heathgate Resources/Qasar Exploration

Clint Dubienecki (UA) – AREVA

David Baker (UA) – SA Department of Education and Children's Services

Joanna McMahon (UA) – Cazaly Resources

Mikaela Jennings (UA) – Heathgate Resources /Qasar Exploration

Rachael Wilson (UA) – AREVA

Postgraduates

Andrew Baker (UA) – Environmental Consultant, UK

Kirsty Beckett (CUT) – Rio Tinto

Paul Carlile (ANU) – Murray Darling Basin Commission

Katie Dowell (ANU) – Department of Defence

Kathryn Fitzsimmons (ANU) – Research School of Earth Sciences, ANU

Chris Gunton (ANU) – Coffey Environments

Kamal Khider (ANU) – Geoscience Australia

Mark Thomas (UA) – CSIRO Land and Water

Vanessa Wong (ANU) – Geoscience Australia

Brian Barrett (UA) – Further postgraduate study

Michael Craig (UC) – Geoscience Australia

Matthew Lenahan (ANU) – CSIRO Land and Water

Mohammad Rosid (CUT) – Indonesian Geological Survey

Michael Turner (ANU) – Applied Mathematics, ANU

Sam Lee (CUT) – Sinclair, Knight, Merz

Karen Hulme (UA) – Dominion Mining

Nathan Reid (UA) – CSIRO Exploration and Mining

Pierre Allain Wulser (UA) – AREVA

Phillip Heath (UA) – PIRSA

Ian Lau (UA) – CSIRO Exploration and Mining

POSTGRADUATE STUDENTS (2007 – 2008)

Student	Project	Prog	Supervisor(s)	Funding	Year	Uni
Doctor of Philosophy (PhD) – Graduated						
Andrew Baker	Metal geochemistry of regolith in the Mount Lofty Ranges and associated alluvial fans of the Adelaide plains	3	Rob Fitzpatrick (CSIRO), Andreas Schmidt-Mumm (UA)	APA + LEME top-up	2007	UA
Kirsty Beckett	Multispectral analysis of high spatial resolution, 256-channel radiometrics for soil and regolith mapping	1	Jayson Meyers, Anton Kepic (CUT), Richard George (WADA)	LEME OpEx only	2008	CUT
Paul Carlile	A Semi-Distributed Catchment Hydrology Model for Simulation of Land use Change, Streamflow and Groundwater Recharge	3	Tony Jakeman, Barry Croke, Brian Lees (ANU)	APA + LEME top-up	2007	ANU
Kathryn Fitzsimmons	Relationships between regional landform patterns and landscape history in the Lake Eyre Basin dunefields	1	John Magee, Ed Rhodes (ANU)	APA + LEME top-up	2007	ANU
Chris Gunton	Element dispersion and mobility in the regolith	2	Bear McPhail, Andy Christy (ANU)	APA + LEME top-up	2007	ANU
Kamal Khider	Regional chemical dispersion processes in the regolith of Cobar-Nymagee area, Central West, NSW	1	Ken McQueen, Bear McPhail (ANU)	LEME	2007	ANU
Ian Lau	Minerals, lithologies and structural mapping using integrated techniques incorporating hyperspectral, AEM, radiometrics, magnetics and ground gravity for regolith covered basement nterrains, Olary district, Gawler Craton and Musgrave Block, SA	1	Steve Hill, Graham Heinson (UA),Alan Mauger (PIRSA)	LEME/UA + LEME top-up	2007	UA
Mark Thomas	New landscape analysis approaches for soil-regolith patterns and their salinity types in South Australia	3	Rob Fitzpatrick (CSIRO), Graham Heinson (UA)	LEME/PIRSA	2007	UA
Alastair Usher	Gold mobility and geochemistry in hypersaline solutions	2	Bear McPhail (ANU), David Gray (CSIRO)	APA + LEME top-up	2007	ANU
Vanessa Wong	The effects of salinity and sodicity on soil carbon stocks and fluxes	4	Richard Greene, Graham Farquhar (ANU)	ANU + CRC Greenhouse + LEME top-up	2007	ANU
Student	**Project**	**Prog**	**Supervisor(s)**	**Funding**	**Year**	**Uni**
Doctor of Philosophy (PhD) – Completed						
Sam Lee	Hydrogeology of the Cape Range karst and coastal plain aquifers, Exmouth, NW Australia	3	Qadeer Rathur, Lindsay Collins (CUT)	APA + LEME Top-up	2008	CUT
Matthew Lenahan	The hydrogeochemistry of a saline aquifer system: central New South Wales, Australia	4	Bear McPhail, Dirk Kirste (ANU)	LEME	2008	ANU
Aija Mee	Origin, formation and environmental significance of sapropels in shallow Holocene coastal lakes of southeastern Australia	1	David McKirdy, Martin Williams, Evelyn Krull (UA)	APA + LEME top-up	2007	UA
Nathan Reid	Biogeochemistry of regolith associated with Au deposits in the Tanami, WA and NT	1	Steve Hill, David Lewis (UA)	Nil LEME	2008	UA
Greg Shirtliff	Weathering of waste rock dumps at Ranger Uranium Mine	1	Tony Eggleton (ANU)	EWL Science pty ltd	2007	ANU
Michael Turner	Hydraulic and physical properties of friable regolith	4	Bear McPhail, Mark Knackstedt, Tim Senden (ANU)	APA + LEME top-up	2007	ANU
Pierre-Alain Wulser	Mobility of uranium and rare earth in the Mt Painter-Lake Frome-Curnamona Craton Regions, SA : Geochemical and temporal controls	2	Joel BruggerSA Museum), John Foden (CUT)	IPRS + LEME Top-up	2008	UA

POSTGRADUATE STUDENTS (2007 – 2008)

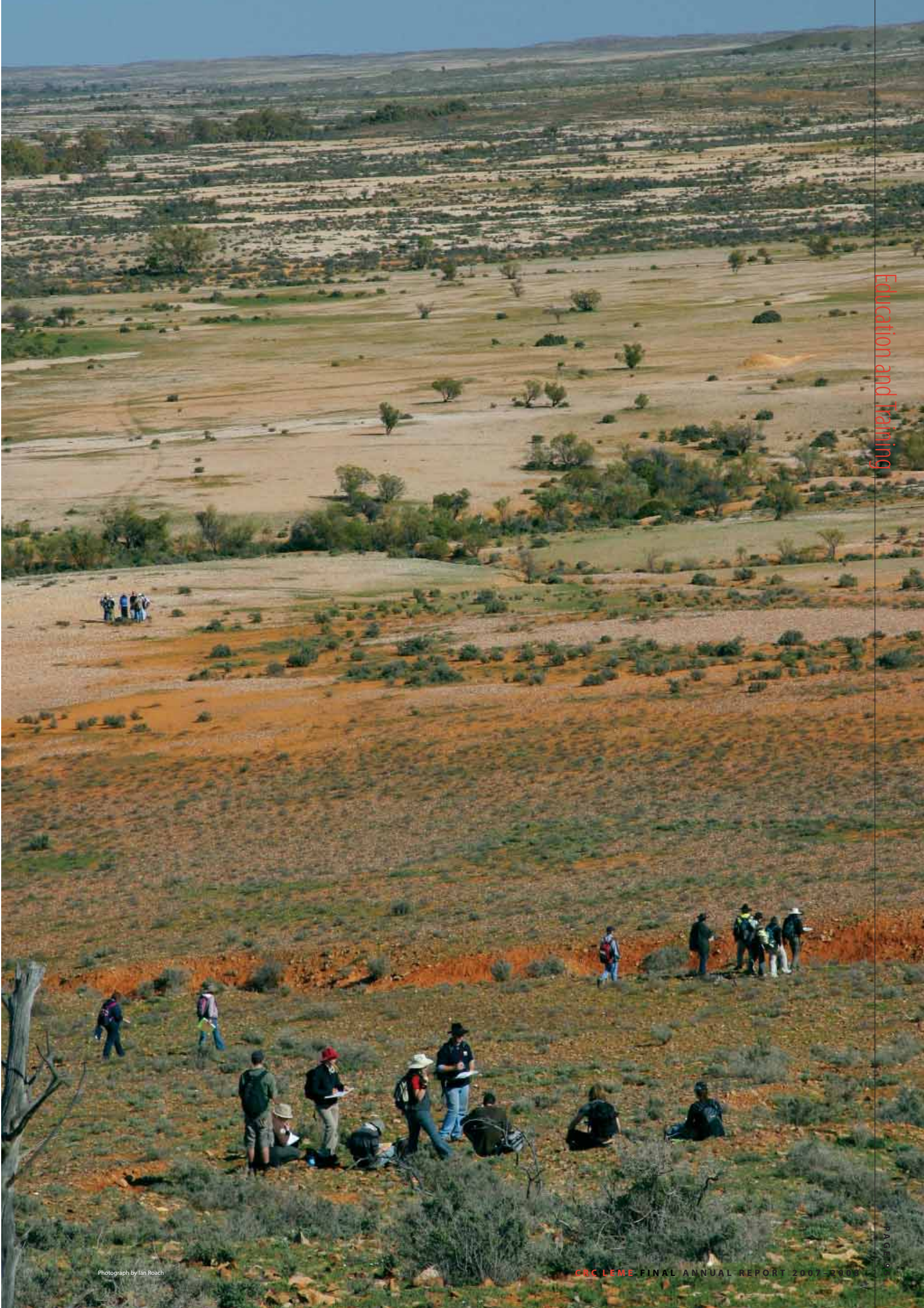
Student	Project	Prog	Supervisor(s)	Funding	Year	Uni
Doctor of Philosophy (PhD) – Continuing						
Simon Abbott	Application of geophysical technologies for 3D visualization of palaeochannels and use of this information for management of dryland salinity in Western Australia.	4	Jayson Meyers, Anton Kepic, Keith Smettem (CUT)	CUPS + LEME top-up	2004-	CUT
Glen Bann	Dryland salinity, biodiversity and geodiversity: biotic and abiotic indicators	4	John Field (ANU), Colin Pain (GA)	LEME	2003-	ANU
Fern Beavis	Diagenetic and anthropogenetic transformations of metals and other elements in regolith	1	David Ellis, Sue Welch (ANU)	APA + LEME OpEx	2006-	ANU
Aaron Brown	Regolith geochemistry and biogeochemistry of the White Dam Cu-Au deposit, Curnamona Province, SA	1	Steve Hill (UA)	LEME	2002-	UA
Troy Cook	Geochemical investigation into the acid generating potential of wetland sediments of the Gnaugara and Jandakot Mounds : Implications for long-term water quality	3	Ron Watkins (CUT)	APA + LEME top-up	2004-	CUT
Robert Dart	The origin and distribution of calcrete in Southern Australia	1	Karin Barovich, David Chittleborough, Steve Hill (UA)	LEME/UA	2004-	UA
Jessie Davey	Mesozoic regolith in SW Eromanga Basin	1	Steve Hill, Neville Alley (UA)	APA	2006-	UA
Tania Dhu	Electrical and EM studies of regolith and sub-regolith structure	1	Graham Heinson, Stewart Greenhalgh (UA)	LEME/UA	2003-	UA
John Drewry	Modelling nutrient generation in Australian catchments: land use, regolith and management factors affecting surface and groundwater quality	3	Tony Jakeman, Barry Croke (ANU)	APA + LEME top-up	2004-	ANU
Michael Durkey	Effect of drains on soil properties in SE SA	3	David Chittleborough, Steve Hill (UA)	UA/DWLBC	2003-	UA
Lachlan Gibbins	Measuring hydraulic conductivity with streaming potentials	4	Graham Heinson (UA)	LEME/UA	2004-	UA
David Haberlah	Aeolian dust accessions to regolith	1	Martin Williams, Steve Hill (UA)	IRPS	2006-	UA
Michael Hatch	The use of shallow geophysical techniques to help characterise hydrological parameters	4	Graham Heinson (UA)	Nil LEME	2005-	UA
Donald Hunter	Application of nuclear magnetic resonance in groundwater studies	2	Anton Kepic (CUT)	APA + LEME top-up	2002-	CUT
Sukhyoun Kim	Electrokinetic groundwater exploration	4	Graham Heinson (UA)	Nil LEME	2004-	UA
Melvyn Lintern	The role of biological and non-biological factors in the formation of Au anomalies in calcrete	2	Lindsay Collins, Mehrooz Aspandiar (CUT), Ravi Anand (CSIRO)	Nil LEME	2001-	CUT
David Little	Investigation, quantification and modelling of regolith interactions in rhizospheres in temperate landscapes in SE Australia	1	John Field, Sue Welch (ANU), Steve Rogers (CSIRO)	LEME	2003-	ANU
Nicole Mikkelson	Freshwater-saline water interactions in aquifers	4	David Ellis, Sara Beavis (ANU)	ANU + LEME OpEx	2006-	ANU
Michael Neimanis	Uranium biogeochemistry in plants	1	Steve Hill (UA), Stephen Hore (PIRSA)	APA	2006-	UA
Margarita Norvill	The use of distributed sensor arrays in electrical imaging	2	Anton Kepic, Jason Meyers (CUT)	APA + LEME top-up	2002-	CUT
Anna Petts	Termitaria and other landscape indicators of sub-surface regolith, Tanami	1	Steve Hill (UA), Lisa Worrall (GA)	LEME/UA	2004-	UA
Mark Reilly	Evolution and internal architecture of ephemeral streams and delta/splay complexes, Umbum Creek, Lake Eyre, Central Australia	1	Simon Lang, Steve Hill (UA)	LEME/UA	2003-	UA
Greg Shirtliff	Weathering of waste rock dumps at Ranger Uranium Mine	1	Tony Eggleton (ANU)	EWL Science pty ltd	1999-	ANU
Suzanne Simons	U-Th-Pb systematics of opaline silica: implications for the dating of surface processes	1	Alexander Nemchin (CUT)	LEME	2002-	CUT
Michael Smith	The geochemical evolution of alkaline salt-affected soils on the western slopes of northern New South Wales	4	Dirk Kirste, Bear McPhail (ANU)	ANU + LEME top-up	2003-	ANU
Margaret Smith	Groundwater acidification process with the Lake Muir-Unicup natural diversity recovery catchment, Western Australia	3	Ron Watkins, David Gray (CSIRO)	APA + LEME top-up	2005-	CUT
Peter Somerville	Dryland salinity in the Widden Creek Valley in the Upper Hunter Valley NSW	3&4	Ian White, Sara Beavis, Sue Welch (ANU), Ben Macdonald (FSEE), Richard Bush (SCU)	ARC + LEME OpEx only	2005-	ANU

POSTGRADUATE STUDENTS (2007 – 2008) cont'd

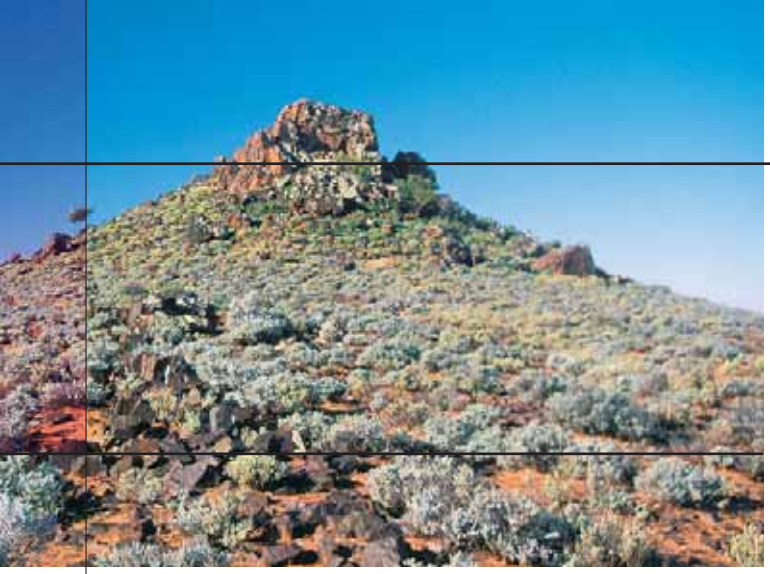
Student	Project	Prog	Supervisor(s)	Funding	Year	Uni
Doctor of Philosophy (PhD) – Continuing (cont'd)						
Siriporn Soongpankhao	Geochemical dispersion mechanisms into regolith with application to selection of sample media, Gnaweeda, WA	2	Mehrooz Aspandiar (CUT)	LEME OpEx only	2005-	CUT
Camilla Sorenson	Mapping of the regolith using Passive Seismics in combination with other geophysical methods	4	Ken Lawrie (GA)	Nil LEME	2005-	Monash
Greg Street	Interpretation of geophysics for catchment management	4	Jason Meyers (CUT)	Nil LEME	2000-	CUT
Sarah Tynan	Geochemistry of heavy metals in coastal and inland sediments	3	David Ellis, Bradley Opdyke (ANU)	LEME	2005-	ANU
Luke Wallace	Geochemistry and hydrogeology of inland acid sulfate environments	3	Bear McPhail, Sue Welch (ANU)	LEME	2004-	ANU
Paul Wilkes	Geophysics in the search for diamonds	2	Jayson Meyers, Simon Wilde (CUT)	Nil	2000-	CUT
Martin Worthy	Major water quality degrading events in the Cotter River Catchment: characteristics and management	3	Robert Wasson, Mike Hutchinson, John Magee (ANU)	ACTEW + LEME Operating	2004-	ANU
Master of Science (MSc) – Completed						
Katie Dowell	Low temperature silicification in the regolith using black opal as a primary example	1	John Mavrogenes (ANU)	APA + LEME top-up	2008	ANU
Master of Science (MSc) – Continuing						
Mark Fritz	Baseline geochemistry of South Australian saline and acid sulfate soils	3,4	Rob Fitzpatrick (CSIRO)	LEME/UA	2003-	UA

HONOURS STUDENTS (2007 – 2008)

Student	Project	Prog	Supervisor(s)	Funding	Year	Uni
Honours Degree – Completed						
Sean Adamas	Sedimentology, regolith and hydrogeology of the Goods Road Palaeochannel, Helena Catchment, SWA	1	Mehrooz Aspandiar (CUT)	LEME	2007	CUT
David Baker	Electromagnetic profiling of the regolith with magnetic modeling of deeper structures at Kalkaroo mineral prospect, Curnamona Province, South Australia	1	John Joseph (UA), Mark Tingay (UA)	Nil LEME	2007	UA
Clint Dubienecki	Regolith-landform mapping and morphotectonics of the upper Four Mile Creek catchment, northeastern Flinders Rangers Rangefront, South Australia	1	Steve Hill (UA)	PIRSA, Heathgate Resources	2007	UA
Deanne Gallasch	Regolith carbonate – bedrock – plants: trace element geochemical dispersion and hosts near the Four Mile West uranium prospect, South Australia	1	Steve Hill (UA)	PIRSA, Heathgate Resources	2007	UA
Andrew Hector	Upper Four Mile Creek palaeosediments and associated palaeolandscape reconstructions, Eromanga Basin, northern Flinders Ranges, South Australia	1	Steve Hill (UA)	PIRSA, Heathgate Resources	2007	UA
James Hughes	Geochronology and landscape evolution of the Wombat area, SE NSW	1	Ian Roach (ANU), Brad Pillans (ANU)	LEME	2007	ANU
Mikaela Jennings	Soil biota contributions to surficial geochemical signatures through transported regolith, Four Mile catchment near Beverley Uranium Mine, SA	1	Steve Hill (UA)	PIRSA, Heathgate Resources	2007	UA
John McDonald	Copper transport in the regolith	2	Bear McPhail (ANU)	Nil	2008	ANU
Joanna McMahon	Regional-scale geochemical and biogeochemical expression of uranium prospectivity in the Four Mile Creek catchment, South Australia	1	Steve Hill (UA)	PIRSA, Heathgate Resources	2007	UA
Jason Raapana	Biogeochemical indicators of mineralisation	1	John Field (ANU), Richard Greene (ANU)	LEME	2007	ANU
Rachael Wilson	Palaeodrainage reconstruction at "The Pimples", northern Flinders Ranges: implications for uranium mineralisation and exploration	1	Steve Hill (UA)		2007	UA
Gabriel Yeates	Salinity dynamics in a sand bed stream: the Wollombi Brook, upper Hunter catchment, NSW	3	Susan Welch (ANU), Ben Macdonald (ANU)	LEME	2007	ANU



Photograph by Ian Roach



Performance Measures

Key Performance Measures/Indicators (KPIs), along with the milestones and outputs, provide a numerical measure of performance against CRC LEME's stated objectives. The CRC LEME performance measures are those itemised in Schedule 6 of the Commonwealth Agreement, for which quantitative measures were developed and presented in the 2001-02 Annual Report and the 2002 – 2008 Strategic Plan.

The performance of CRC LEME against each of the LEME performance measures is detailed in the tables that follow.

Highlights

CRC LEME established 4 numerical key performance indicators.

- A Lost Time Injury Frequency Rate (an industry standard measure) of zero throughout the life of the CRC.

The lost time injury rate throughout the life of the CRC LEME has been zero.

- Scientists trained by LEME are sought for employment in the Australian and overseas minerals and land management sectors: the benchmark is more than 70% of LEME students working in regolith-related jobs within one year of graduation.

Over 90% of postgraduate students were working in regolith related jobs with one year of graduation, and over 75% of Honours students. The other Honours students have gone on to do higher degrees.

- Production of at least 60 new PhD graduates and 60 Honours students throughout the life of LEME.

CRC LEME enrolled 90 postgraduate students and 118 Honours students. 9 postgraduate students withdrew and 47 postgraduate students completed on or before the 30th June 2008. 54 students are expected to complete on or before the 31st of December 2008 and 58 postgraduate students are expected to complete on or before the 30th of June 2009. 117 Honours students have completed.

- 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 employee per year.

If the number of scientific outputs per full time equivalent employee (research staff only) is calculated as it was in previous years then CRC LEME has averaged 7.9 scientific outputs per research staff member this year. This output reflects the focus of CRC LEME on the delivery of research outcomes to clients and stakeholders as well as the general public in its final year.

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

Scientists trained by LEME are sought for employment in the Australian and overseas minerals and land management sectors: the benchmark is more than 70% of LEME students working in regolith-related jobs within one year of graduation.

Centre Objectives Performance Indicators

Output/ Outcome No:	Performance Indicator	2001/ 2002	2002/ 2003	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007	2007/ 2008	Total
1	Number of external research collaborators	47	86	75	80	80	21	18	N/A
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	26 $879,000	12 $542,000	N/A $7,001,540
3	Number of overseas researchers visiting LEME sites	4	10	10	6	8	12	9	59
3	Number of overseas visits by LEME staff	19	7	8	9	2	11	9	65
3	Number and value of overseas research projects	1 $27,489	0	0	1 $12,000	1 $8,300	3 $963,000	0	N/A $1,010,789

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 Research Program Outputs

1 Generation of high-quality regolith geoscience

2 Release of LEME publications and products

Quality and Relevance of Research Program Outcomes

3 Publishing of Centre Research in peer-reviewed journals

4 Publishing of Centre Research

5 CRC LEME staff presentations and keynote addresses

6 External recognition of the quality and relevance of LEME research outputs

Quality & Relevance of the Research Program

Output/ Outcome No:	Performance Indicator	2001/ 2002	2002/ 2003	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007	2007/ 2008	Total
3	Number of published and journal articles per year (in 2007-2008 includes articles in press)	54	23	18	40	30	37	44	206
4/5	Number of conference papers presented per year	50	134	186	210	146	181	202	899
1/4	Number of books or chapters in books	20	40	41	28	174	5	26	306
4	Other forms of publications includes maps, short course notes, field guides, electronic newsletters	28	21	19	16	13	1	297	379
2	Number of LEME Technical Reports released, includes Open File Reports	36	6	10	26	18	13	48	131
2	Number of confidential reports, maps	18	9	8	8	12	21	47	115
6	Number of keynote addresses given	4	2	6	7	5	3	6	26
6	Number of sabbatical leaves taken by overseas personnel at LEME sites	3	2	2	3	2	11	0	20
6	Number of awards to LEME researchers and educators	3	8	8	9	7	20	11	57
6	Number of professional appointments awarded to LEME researchers and educators	7	5	9	15	10	11	14	56

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 Research

Output/ Outcome No:	Performance Indicator	2001/ 2002	2002/ 2003	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007	2007/ 2008	Total
1	Number of short courses and workshops	7	11	6	4	9	1	9	47
3	Number of media reports and releases	8	9	21	17	39	46	201	341
2	Number of items sold and/or distributed (open file reports, manuals, course notes)	120	75	101	119	464	157	284	1320
3	Number of articles in prospecting magazines	3	1	9	11	22	25	5	76
2	Number of reports to sponsors and companies	15	9	13	8	12	21	47	125
4	Number of collaborative projects with industry users and user organisations	49	48	56	60	55	26	19	N/A
4	Annual external research income	$782,000	$616,000	$1,183,000	$1,662,000	$1,331,000	$2,242,000	$542,000	$8,358,000
1/2	Number of scientific outputs per FTE staff	2.4	3.4	4.2	4.4	5.25	5.5	7.9	4.7
4	Increase in external revenues from contract research	NA	-21%	+92%	+41%	-20%	-55%	-76%	N/A

Education & 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 Graduate research and Honours students have access to generic training courses during their studios in the centre.
- Allocate an advisor for al 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 aimed to produce at least 60 new PhD graduates and 60 honours graduates throughout the lifetime of the Centre. For the purpose of meeting PI's we define a LEME student where; LEME has given financial support either by way of scholarship or contribution to stipend and operating costs or a LEME in-kind or cash funded staff member has been a primary supervisor on a regolith project that aligns with LEME program objective.

Education & Training

Output/ Outcome No:	Performance Indicator	2001/ 2002	2002/ 2003	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007	2007/ 2008	Total
1	Number of postgraduate students working on LEME research projects	38	51	50	59	62	58	36	N/A
1	Number of MSc and PhD completions, each year/cumulative	1	7/8	7/15	5/20	10/30	10/40	7/47	47
1	Number of BSc Honours graduates completing LEME projects	16	11	21	17	12	12	11	117
1	Number of BSc Honours students commenced/ continuing LEME projects	37	20	10	13	12	26	0	118
2	Number of external supervisors of research students	20	12	16	21	14	9	11	N/A
1	Number of student class hours of instruction in Masters by Coursework degrees related to the regolith	80	80	80	80	80	0	0	400
1	Number of Honours graduates produced over the lifetime of LEME (incl graduands)	16	27	48	65	77	89	117	117

Collaborative Arrangements

To ensure that the research and educational programs have access to adequate resources & 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 Collaborations

Collaborative Arrangements Outcomes

2 External involvement in collaborations

Collaborative Arrangements

Output/ Outcome No:	Performance Indicator	2001/ 2002	2002/ 2003	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007	2007/ 2008	Total
1	Number of Centre-funded projects involving staff from more than one core participant	28/30	27/29	38/59	33/45	32/60	16/43	19/39	N/A
2	Number of external stakeholders involved in the direction of LEME through the Governing Board and Advisory Councils	14	27	26	22	24	24	26	N/A
2	Number of projects involving international collaborators	6	0	5	1	5	3	5	N/A



CRC LEME research results with no tangible commercial potential have been widely disseminated to ensure an efficient and effective transfer of technology and research utilisation. Generally, the research results are published or otherwise made available in the public domain. It is CRC LEME's intention to make all CRC LEME outputs freely available from the LEME website which will be maintained by CSIRO under a contractual arrangement until June 2013.

Photograph by Steven Hill

Specified Personnel

Business Manager and Board Secretary, Mr Gary Kong FCPA

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

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

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

Staff complement

LEME has world-class expertise in regolith geoscience, and supporting disciplines such as mineralogy, geochemistry, hydrogeochemistry, sedimentology, geophysics and geochronology. In this seventh year of operation, LEME had a total complement of 135 staff, of whom 127 were professional geoscientists. This distilled down to 52.4 FTE scientists, made up of 45.72 in-kind contributed and 6.68 cash funded scientists.

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

Specified Personnel

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

Dr Ravi Anand, Program Leader, CSIRO, 100%

Dr Charles Butt, Key Researcher, CSIRO, 75%

Dr Steve Rogers, Chief Executive Officer, CSIRO, 100%*

Dr Ian Roach, Program Leader, ANU, 100%*(1 July 07 to 24 April 08)

Dr Sara Beavis, Program Leader, ANU, 100% (22 May to 30 June 08)

Dr Ken Lawrie, Program Leader, GA, 100%

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

Dr Colin Pain, Key Researcher, GA, 100%

Dr Paul Shand, Program Leader, CSIRO, 70%*

Ms Lisa Worrall, Program Leader, GA, 100%

**Paid from the CRC Grant*

Research Staff In-kind Contribution

Name	Main Activity	Total % of Time	% Spent on Research Program					% Spent on CRC		
			Regolith Geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
The Australian National University (ANU)										
Beavis S	R	35	35				35			
Christy A	R	25	25				25			
Croke B	R	20	20				20			
DeDeckker P	R	20	20				20			
Eggins S	R	20	20				20			
Fallon S	R	25	25				25			
Field J	R	50	50				50			
Fitzsimmons K	R	50	50				50			
Greene R	R	30	30				30			
Grun R	R	15	15				15			
Harrold B	R	20	20				20			
Jakeman T	R	20	20				20			
McMorrow L	R	25	25				25			
McPhail D	R	75	75				75			
Norman M	R	10	10				10			
Opdyke B	R	20	20				20			
Pillans B	R	60	60				60			
Rhodes E	R	25	25				25			
Troitsch U	R	25	25				25			
White I	R	20	20				20			
Williams I	R	10	10				10			
		600	600	0	0	0	600	0	0	0
Geoscience Australia (GA)										
Apps H	R	100				100	100			
Craig M	R	100	100				100			
Gibson D	R	100				100	100			
Lawrie K	R	100				100	100			
Pain C	R	100	100				100			
Smith M	R	50	50				50			
Thomas M	R	50	50				50			
Wilford J	R	100				100	100			
Boston K	R	15				15	15			
Henry J	R	15				15	15			
Lowson C	R	15				15	15			
Worrall L	R	100	100				100			
		845	400	0	0	445	845	0	0	0
Curtin University of Technology (CUT)										
Aspandiar M	R	75					0	75		
Collins L	R	60	60				60			
Collins PLF	R	30	30				30			
Fagan R	R	20	20				20			
Jourdan F	R	20	20				20			
Kepic A	R	50	50				50			
Meyers J	R	50	50				50			
Wartho J	R	15	15				15			
Watkins R	R	40	40				40			
Wilkes P	R	50	50				50			
Wilde S	R	15	15				15			
		425	350	0	0	0	350	75	0	0
The University of Adelaide (UA)										
Barovich K	R	50					0	50		
Bruce D	R	10					0	10		
Brugger J	R	25					0	25		
Foden J	R	30					0	30		
Giles D	R	20					0	20		
Halverson G	R	50					0	50		
Heinson G	R	40					0	40		
Hill C	R	5					0	5		
Hill S	R	100					0	100		
Ladd D	R	5					0	5		
Schmidt-Mumm A	R	30					0	30		
Stanley J	R	5					0	5		
Williams M	R	2					0	2		
		372	0	0	0	0	0	372	0	0

Research Staff In-kind Contribution (cont'd)

Name	Main Activity	Total % of Time	% Spent on Research Program					% Spent on CRC		
			Regolith Geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
Primary Industries & Resources, South Australia (PIRSA)										
Cooper B	R	100	100				100			
Fabris A	R	100	100				100			
Gouthas G	R	20	20				20			
Hou B	R	100	100				100			
Keeling J	R	100	100				100			
Mauger A	R	80	80				80			
Sheard M	R	100	100				100			
Stoian L	R	30	30				30			
Zang Wen Long	R	50	50				50			
Gordon G	R	20	20				20			
		700	700	0	0	0	700	0	0	0
New South Wales Department of Primary Industries (NSW DPI)										
Burton G	R	50	50				50			
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	40	40				40			
Musgrave R	R	20	20				20			
Wega Faundezz M	R	100	100				100			
Vickery N	R	75	75				75			
Watkins J	R	10	10				10			
		400	400	0	0	0	400	0	0	0
Commonwealth Scientific and Industrial Research Organisation (CSIRO)										
Butt C	R	100		100			100			
Gray D	R	100		100			100			
Lintern M	R	50		50			50			
Robertson I	R	60		60			60			
Fitzpatrick R	R	30			30		30			
Anand R	R	100		100			100			
Cahill K	R	100		100			100			
Cornelius A	R	30		30			30			
Fitzpatrick A	R	100		100			100			
Hough R	R	100		100			100			
Munday T	R	100		100			100			
Noble R	R	50		50			50			
Phang C	R	50		50			50			
Pinchand G	R	50		50			50			
Barton A	R	15			15		15			
Cresswell R	R	10			10		10			
Davies P	R	20			20		20			
Dighton P	R	15			15		15			
Douglas G	R	5			5		5			
Gildfedder M	R	10			10		10			
Herczeg	R	10			10		10			
Hicks W	R	40			40		40			
Lamontagne S	R	10			10		10			
Raven M	R	5			5		5			
Shand P	R	50			50		50			
Stenson M	R	10			10		10			
Rassam S	R	10			10		10			
		1230	0	990	240	0	1230	0	0	0
TOTAL RESEARCH STAFF: IN-KIND CONTRIBUTIONS		4572	2450	990	240	445	4125	447	0	0

KEY: 100 = 1 person year

Research Staff CRC LEME Funded

Name	Employer	Main Activity	Total % of Time	% Spent on Research Program					% Spent on CRC		
				Regolith Geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
CRC Grant Funded											
Lenahan M	ANU	R	50	50				50			
McQueen K	ANU	R	38	38				38			
Pillans B	ANU	R	25	25				25			
Roach I	ANU	R	50					0	50		
Welch S	ANU	R	50			50		50			
de Caritat P	GA	R	20		20			20			
Aspandiar M	CUT	R	25					0	25		
Wilkes P	CUT	R	50	50				50			
Joseph J	AU	R	50	50				50			
Lintern M	CSIRO	R	50		50			50			
Cornelius A	CSIRO	R	8		8			8			
Noble R	CSIRO	R	50		50			50			
Phang C	CSIRO	R	50		50			50			
Pinchand G	CSIRO	R	50		50			50			
Barton A	CSIRO	R	13			13		13			
Cresswell R	CSIRO	R	40			40		40			
Davies P	CSIRO	R	5			5		5			
Dighton J	CSIRO	R	3			3		3			
Gildfedder M	CSIRO	R	5			5		5			
Herczeg A	CSIRO	R	5			5		5			
Hicks W	CSIRO	R	8			8		8			
Lamantague S	CSIRO	R	3			3		3			
Shand P	CSIRO	R	10			10		10			
Stenson M	CSIRO	R	5			5		5			
Rasaam D	CSIRO	R	5			5		5			
			668	213	228	152	0	593	75	0	0
Industry or Externally Funded											
NIL			0					0			
			0	0	0	0	0	0	0	0	0
TOTAL RESEARCH STAFF: CRC GRANT AND EXTERNAL FUNDS			668	213	228	152	0	593	75	0	0

KEY: 100 = 1 person year

Summary of Research Staff Resources

	Total Equiv. Person Years	Person Years Spent on Reserach Program					Person Years Spent on		
		SUBPROGRAM							
		Regolith Geoscience	Mineral Exploration	Environmental Applications	Salinity Mapping	Total on Research	Education	Commer-cialisation	Admin-istration
TOTAL IN-KIND CONTRIBUTED	45.72	24.5	9.9	2.4	4.45	41.25	4.47	0.0	0
CRC GRANT FUNDED	6.68	2.13	2.28	1.52	0	5.93	0.75	0.0	0
INDUSTRY FUNDED	0	0	0.0	0.0	0	0	0.0	0.0	0
TOTAL FUNDED BY CRC LEME	6.68	2.13	2.28	1.52	0	5.93	0.75	0.0	0
GRAND TOTAL	52.40	26.63	12.18	3.92	4.45	47.18	5.22	0.0	0
Proportion of total professional staff resources in each activity	100	51	23	7	8	90	10	0	0

Administration and Technical Staff

Name	Position	Main Activity	Total % of Time
In-kind Contributions			
Australian National University			
Coldrick M	Program Support Officer	A	25
CRC Grant Funded			25
Geoscience Australia			
Moon S	Program Support Officer	A	25
			25
CSIRO			
Game S	PA to CEO/Centre Support Officer	A	100
Hink H	Program Support Officer	A	5
Kong G	Business Manager	A	100
Lawrence G	Communications Officer	A	17
Rogers S	Chief Executive Officer	A	100
Mills J	Financial Accountant	A	60
Tyrell S	Admin Support Officer	A	20
			402
			452
Industry or Externally Funded			
Geoscience Australia			
	NIL		0
TOTAL ADMINISTRATION AND TECHNICAL STAFF:			452

KEY:100 = 1 person year

Staff OH&S Matters

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

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

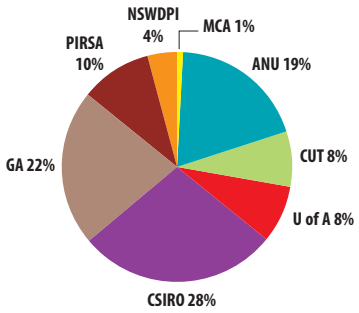
These publications did not supplant the requirements stipulated by the Core Participants for their staff, but prescribed minimum procedures where they may not be stipulated by the host agency. They were endorsed by the Board, drawn to the attention of all staff by way of the LEME intranet, and were fully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

There is a standing directive that all accidents and incidents that are reportable under Core Participant requirements are also reported to the CRC LEME Head Office. During the reporting period, three notifiable OH&S vehicle incidents occurred but no lost time injuries or incidents were recorded.

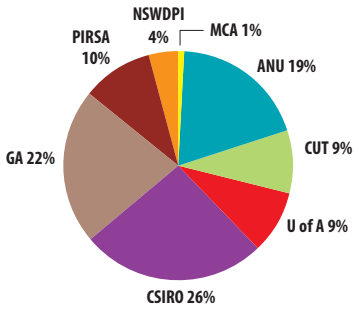
It is clear that CRC LEME has informed and guided decision-makers in the Federal and State policy arenas about the relevance and contribution of the Centre's research to Australia's future.

Photograph by Steven Hill

Financial Information



Core Participant Actual Cumulative Equity as at 30 June 2008 (Years 1-7)



Core Participant Equity as per Commonwealth Agreement as at 30 June 2008 (Years 1-7)

As at 30 June 2008, 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 7 is $0.54M.

The leverage of actual contributed resources to CRC Program funding from the Commonwealth is 9.8:1, for the reporting year.

Actual contributed resources:

Total Cash from Industry and other users, and from Core Participants: $1.36M;

Total In-Kind resources from participants $13.86M, giving a total of $15.22M.

CRC Program funds: $1.546M. All figures for the reporting year of 2007/2008 only.

Financial Reports for 2007/2008

The following statements and accounting policy notes represent the known financial status as at 30 June, 2008.

Core Participant equity positions are summarised above.

Note 1: Significant Accounting Policies

Total Income (excluding CRC Grant and cash contributions from Core Participants)

	Year 1 $'000	Year 2 $'000	Year 3 $'000	Year 4 $'000	Year 5 $'000	Year 6 $'000	Year 7 $'000	Cumulative $'000
Budget	765	1,080	1,658	1,869	1,675	2,100	1,875	11,022
Actual	892	811	1,509	1,435	1,522	2,380	718	9,267
Variance	+127	-269	-149	-434	-153	+280	-1,157	-1,755

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

Income

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

Expenditure

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

Intellectual property

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

Capital expenditure/other expenditure commitments

There were no capital expenditure commitments approved and/or entered into as at 30 June 2007, and for which goods had not been receipted at 30 June 2008.

OTHER NOTES

Costing of contributions

Costing of salaries and on-costs contributed by the Core Participants is as reported to the Centre by each Core Participants. In no case does the reported amount of salary on-costs exceed the agreed valuation of on-costs shown in Schedule 4 of the Commonwealth Agreement and the Deed of Release and Variation, 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 & 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 & Resources, SA	1.2550	1.2550
NSW Dept. of Primary Industries	0.1700	0.1700
Minerals Council of Australia	N/A	N/A

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

	ACTUAL								CUMULATIVE TOTAL TO DATE		GRAND TOTAL		
	YEAR 1 2001 / 02 Actual	YEAR 2 2002 / 03 Actual	YEAR 3 2003 / 04 Actual	YEAR 4 2004 / 05 Actual	YEAR 5 2005 / 06 Actual	YEAR 6 2006 / 07 Actual	YEAR 7 2007 / 08 Actual	YEAR 7 2007 / 08 Agreement	Actual	Agreement	Projected Total 7 Years	Agreement 7 Years	Difference 7 Years
CORE PARTICIPANTS													
THE AUSTRALIAN NATIONAL UNIVERSITY													
SALARIES	474	431	765	798	877	788	725	859	4,858	4,808	4,858	4,808	50
CAPITAL	–	–	–	–	–	–	–	–	–	–	–	–	–
OTHER	1,126	1,169	2,336	2,352	2,547	2,305	1,854	1,687	13,689	12,706	13,689	12,706	984
TOTAL	1,600	1,600	3,101	3,150	3,424	3,093	2,579	2,545	18,547	17,513	18,547	17,513	1,034
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	766	939	764	5,983	5,462	5,983	5,462	521
CAPITAL	–	–	–	–	–	–	–	–	–	–	–	–	–
OTHER	1,973	1,928	2,457	2,600	2,573	2,413	1,788	1,942	15,733	15,461	15,733	15,461	272
TOTAL	2,947	2,767	3,271	3,446	3,378	3,179	2,728	2,706	21,716	20,923	21,716	20,923	793
CURTIN UNIVERSITY OF TECHNOLOGY													
SALARIES	329	423	433	486	500	487	545	512	3,204	3,052	3,204	3,052	152
CAPITAL	–	–	–	–	–	–	–	–	–	–	–	–	–
OTHER	469	646	629	765	784	686	667	689	4,646	4,480	4,646	4,480	166
TOTAL	798	1,069	1,062	1,251	1,284	1,173	1,211	1,201	7,849	7,532	7,849	7,532	317
THE UNIVERSITY OF ADELAIDE													
SALARIES	314	403	400	363	315	326	431	537	2,552	2,901	2,552	2,901	-349
CAPITAL	–	–	–	–	–	–	–	–	–	–	–	–	–
OTHER	373	626	753	728	950	933	820	711	5,183	4,665	5,183	4,665	518
TOTAL	687	1,029	1,153	1,091	1,265	1,260	1,251	1,248	7,736	7,566	7,736	7,566	169
PRIMARY INDUSTRIES & RESOURCES,SOUTH AUSTRALIA													
SALARIES	506	523	551	594	586	682	707	619	4,149	3,719	4,149	3,719	430
CAPITAL	–	–	–	–	–	–	–	–	–	–	–	–	–
OTHER	1,984	521	584	627	619	715	740	652	5,790	5,381	5,790	5,381	409
TOTAL	2,490	1,044	1,135	1,221	1,205	1,396	1,447	1,272	9,939	9,101	9,939	9,101	838
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	390	390	382	2,154	2,102	2,154	2,102	52
CAPITAL	–	–	–	–	–	–	–	–	–	–	–	–	–
OTHER	29	30	63	76	83	85	85	84	451	443	451	443	8
TOTAL	253	265	286	394	457	475	474	466	2,604	2,545	2,604	2,545	59
MINERALS COUNCIL OF AUSTRALIA													
SALARIES	–	–	–	–	–	–	–	–	–	–	–	–	–
CAPITAL	–	–	–	–	–	–	–	–	–	–	–	–	–
OTHER	–	–	35	35	35	35	35	35	175	175	175	175	–
TOTAL	–	–	35	35	35	35	35	35	175	175	175	175	–
CSIRO													
SALARIES	1,333	1,398	1,169	1,285	1,289	1,352	1,560	1,262	9,386	8,380	9,386	8,380	1,005
CAPITAL	–	–	–	–	–	–	–	–	–	–	–	–	–
OTHER	2,559	2,457	2,511	2,772	2,747	2,871	2,599	1,987	18,516	16,581	18,516	16,581	1,935
TOTAL	3,892	3,855	3,680	4,057	4,036	4,223	4,159	3,249	27,902	24,961	27,902	24,961	2,941
SUPPORTING CONTRIBUTIONS													
SALARIES	–	–	–	–	–	–	–	–	–	–	–	–	–
CAPITAL	–	–	–	–	–	–	–	–	–	–	–	–	–
OTHER	–	–	–	–	–	–	–	–	–	–	–	–	–
TOTAL	–	–	–	–	–	–	–	–	–	–	–	–	–
TOTAL IN-KIND CONTRIBUTIONS													
SALARIES	4,661	4,349	4,355	4,690	4,747	4,792	5,297	4,937	32,890	30,976	32,890	30,976	1,914
CAPITAL	–	–	–	–	–	–	–	–	–	–	–	–	–
OTHER	9,504	7,718	9,368	9,955	10,338	10,043	8,588	7,786	65,515	61,155	65,515	61,155	4,360
GRAND TOTAL (IN-KIND)	**14,165**	**12,067**	**13,723**	**14,645**	**15,085**	**14,835**	**13,885**	**12,723**	**98,405**	**92,131**	**98,405**	**92,131**	**6,274**

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

	ACTUAL								CUMULATIVE TOTAL TO DATE		GRAND TOTAL		
	YEAR 1 2001 / 02 Actual	YEAR 2 2002 / 03 Actual	YEAR 3 2003 / 04 Actual	YEAR 4 2004 / 05 Actual	YEAR 5 2005 / 06 Actual	YEAR 6 2006 / 07 Actual	YEAR 7 2007 / 08 Actual	YEAR 7 2007 / 08 Agreement	Actual	Agreement	Projected Total 7 Years	Agreement 7 Years	Difference 7 Years
CORE PARTICIPANTS													
ANU	100	150	200	200	200	100	100	100	1,050	1,050	1,050	1,050	–
CURTIN UNI	100	100	100	100	100	100	100	100	700	700	700	700	–
UNI OF ADELAIDE	100	100	100	100	100	100	100	100	700	700	700	700	–
UNI OF CANBERRA	100	50	–	–	–	–	–	–	150	150	150	150	–
CSIRO	150	100	150	200	200	100	100	100	1,000	1,000	1,000	1,000	–
GEOSCIENCE AUST	100	150	100	100	113	100	100	100	763	750	763	750	13
PIRSA	–	–	–	100	100	100	100	100	400	400	400	400	–
BRS	810	–	–	–	–	–	–	–	810	810	810	810	–
NSW DPI	250	250	250	100	100	50	–	–	1,000	1,000	1,000	1,000	–
MCA	100	100	105	80	80	80	40	–	585	500	585	500	85
TOTAL	1,810	1,000	1,005	980	993	730	640	600	7,158	7,060	7,158	7,060	98
Supporting Participants	–	300	–	141	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	2,242	542	1,100	7,770	5,425	7,770	5,425	2,345
Commercialisation	–	–						640	–	2,945	–	2,945	-2,945
Education	86	17	24	33	32		17	120	209	633	209	633	-424
Interest Income	110	195	199	187	159	138	159	15	1,147	119	1,147	119	1,028
TOTAL	892	811	1,509	1,294	1,522	2,380	718	1,875	9,126	11,022	9,126	11,022	-1,897
CRC FUNDING	2,754	3,300	3,300	3,300	3,300	2,700	1,546	1,546	20,200	20,200	20,200	20,200	–
TOTAL CRC CASH CONTRIBUTION (T2)	5,456	5,411	5,814	5,715	5,825	5,810	2,904	4,021	36,935	38,733	36,935	38,733	-1,799
Cash carried over from previous year Note (a)	777	2,504	3,566	3,492	3,087	2,349	2,003	2,003					
Less Unspent Balance	2,504	3,566	3,492	3,087	2,349	2,003.14	1,412	553		0			
TOTAL CASH EXPENDITURE	3,729	4,349	5,888	6,120	6,563	6,156	3,495	5,472	36,300	38,733	36,300	38,733	-2,433
ALLOCATION OF CASH EXPENDITURE BETWEEN HEADS OF EXPENDITURE													
SALARIES	1,916	1,898	2,541	2,794	2,788	2,642	1,278	1,161	15,857	15,857	15,857	15,857	0
CAPITAL	–	245	–	190	16	–		–	451	451	451	451	–
OTHER	1,813	2,206	3,347	3,136	3,759	3,513	2,217	4,311	19,992	22,425	19,992	22,425	-2,433

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 TOTAL TO DATE		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 6 2006 / 07 Actual	YEAR 7 2007 / 08 Actual	YEAR 7 2007 / 08 Agreement	Actual	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	14,835	13,885	12,723	98,405	92,131	98,405	92,131	6,274
GRAND TOTAL (CASH EXPENDITURE) from Table 2	3,729	4,349	5,888	6,120	6,563	6,156	3,495	5,472	36,300	38,733	36,300	38,733	-2,433
APPLIED TO ACTIVITIES OF CENTRE	17,894	16,416	19,611	20,765	21,648	20,991	17,380	18,195	134,704	130,864	134,704	130,864	3,841
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	7,434	6,575	6,098	48,747	46,833	48,747	46,833	1,915
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	13,557	10,805	12,097	85,506	83,580	85,506	83,580	1,926
TOTAL	17,894	16,416	19,611	20,765	21,648	20,991	17,380	18,195	134,704	130,864	134,704	130,864	3,841

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	2,409	11,577	41.25	5.93
EDUCATION	114	1,492	4.47	0.75
EXTERNAL COMMUNICATIONS	–	–	–	–
COMMERCIALISATION/TECHNOLOGY TRANSFER	–	–	–	–
ADMINISTRATION	972	816	–	–
TOTAL	3,495	13,885	45.72	6.68

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Independent auditor's report to the CRC LEME

Report on the Financial Information

We have audited the accompanying Financial Information of the Cooperative Research Centre for Landscape, Environments and Mineral Exploration ("the CRC LEME") 2007/2008 Annual Report, which comprises the statement of In-kind contributions per participant, statement of cash contributions, summary of resources applied to activities of the centre and statement of allocation of resources between categories of activities for the year ended 30 June 2008, a summary of significant accounting policies and other explanatory notes.

The responsibility of the board of management for the Financial Information

The board of management of the CRC LEME is responsible for the preparation and fair presentation of the Financial Information and have determined that the accounting policies described in note 1 of the Financial Information are appropriate to meet the requirements of the Commonwealth Agreement dated 13 August 2001 ("the Agreement") and are appropriate to meet the needs of the Cooperative Research Centres Program, Department of Innovation, Industry, Science and Research ("the Commonwealth"). The responsibility of the board of management also includes establishing and maintaining internal control relevant to the preparation and fair presentation of the Financial Information that is free from material misstatement, whether due to fraud or error, selecting and applying appropriate accounting policies, and making accounting estimates that are reasonable in the circumstances.

Auditor's responsibility

Our responsibility is to express an opinion on the Financial Information based on our audit. No opinion is expressed as to whether the accounting policies used, as described within note 1 of the Financial Information, are appropriate to meet the needs of the Commonwealth. We conducted our audit in accordance with Australian Auditing Standards. These Auditing Standards require that we comply with relevant ethical requirements relating to audit engagements and plan and perform the audit to obtain reasonable assurance whether the Financial Information is free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the Financial Information. The procedures selected depend on the auditor's judgement, including the assessment of the risks of material misstatement of the Financial Information, whether due to fraud or error. In making those risk assessments, the auditor considers internal control relevant to the CRC LEME's preparation and fair presentation of the Financial Information in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the CRC LEME's internal control. An audit also includes evaluating the reasonableness of accounting estimates made by the board of management as well as evaluating the overall presentation of the Financial Information.

The Financial Information has been prepared for the purpose of fulfilling the financial reporting obligations of the board of management under the Agreement. We disclaim any assumption of responsibility for any reliance on this audit report or on the Financial Information to which it relates

PRICEWATERHOUSECOOPERS

Independent auditor's report to the CRC LEME (continued)

to any person other than the CRC LEME, or for any purpose other than that for which they were prepared.

For further explanation of an audit, visit our website http://www.pwc.com/au/financialstatementaudit.

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

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

Auditor's opinion

In our opinion,

(a) The attached Financial Information for the centre for the Cooperative Research Centre for Landscape, Environments and Mineral Exploration presents fairly, in all material respects, with the accounting polices in note 1 to the Financial Information and clauses 3, 4, 5, 9 and 12.2 of the Commonwealth Agreement dated 13 August 2001, the Deed of Release and Variation dated 27 June 2005, the sources of funding and the application of that funding for the year ended 30 June 2008;

(b) The Financial Information presents fairly that contributions, both cash and in-kind, have been made and recorded in accordance with the Budget as specified in Schedule 4 of the Commonwealth Agreement.

(c) In accounting for Commonwealth Funding and Contributions, the CRC LEME has exercised proper accounting standards and controls.

(d) The CRC LEME has met its obligations to the Commonwealth in relation to the treatment of Capital Items as per clause 5.3.

(e) The Cash Contributions and Commonwealth Funding have been paid into and expended from the CRC LEME's account and in accordance with the Commonwealth Agreement and all interest on the balance of the account has been credited to the account.

Matters relating to the electronic presentation of the audited financial report

This auditor's report relates to the Financial Information of the CRC LEME for the year ended 30 June 2008 included on the CRC LEME's web site. The board of management is responsible for the integrity of the CRC LEME's web site. We have not been engaged to report on the integrity of this web site. The auditor's report refers only to the statements named above. It does not provide an opinion on any other information which may have been hyperlinked to/from these statements. If users of this report are concerned with the inherent risks arising from electronic data communications they are advised to refer to the hard copy of the audited Financial Information to confirm the information included in the audited Financial Information presented on this web site.

PricewaterhouseCoopers

Peter Buchholz
Partner

8 October 2008
Perth

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

Aquitard: a low permeable sedimentary layer that acts as an interface through which recharge and soluble salts from enters an aquifer

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, uncomfortably 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 diverse 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: A 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

Vadose Zone: the region of aeration above the water table

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

Acronyms

3D: Three-Dimensional

4D: Four-Dimensional (spatial + time)

4WD: Four-Wheel Drive

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

CALM: Western Australian Department of Conservation and Land Management

CDI: Conductivity Depth Image

CD: Compact Disc

CEM: CSIRO Exploration and Mining

CLW: CSIRO Land and Water

CMA: Catchment Management Authority

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

CRC: Cooperative Research Centre

CRC LEME 1: Cooperative Research Centre for Landscape Evolution and Mineral Exploration (1995–2001)

CRC LEME 2: Cooperative Research Centre for Landscape Environments and Mineral Exploration (2001–2008)

CRM: Chemical Remnant Magnetism

CSIRO: Commonwealth Scientific and Industrial Research Organisation

CUPS: Curtin University Postgraduate Scholarship

CUT: Curtin University of Technology

DAFWA: Department of Agriculture and Food, Western Australia

DNA: Deoxyribonucleic Acid

DEM: Digital Elevation Model

DTB: Depth To Basement

DTM: Digital Terrain Mapping=

EC: Electrical Conductivity

EKS: Electrokinetic Seismic

ELA: Exploration Licence Application

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

GEOpixie: 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

GSA: Geological Society of Australia

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

IUSS: International Union of Soil Sciences

KPI: Key Performance Indicator

LA: Laser Ablation

LAICPMS: Laser Ablation Inductively Coupled Plasma Mass Spectrometry

LEME: Cooperative Research Centre for Landscape Environments and Mineral Exploration

LUAC: Land Use Advisory Council

MAC: Minerals Advisory Council

MCA: Minerals Council of Australia

MDB: Murray-Darling Basin

MDBC: Murray-Darling Basin Commission

MERIWA: Minerals & Energy Research Institute of WA

MGA: Map Grid of Australia

MINEX: Minerals Exploration

MMI: 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

NGSA: National Geochemistry Survey of Australia

NGTN: National Geoscience Teaching Network

NHT: National Heritage Trust

NITO: Portable X-ray Fluorescence technology

NLWRA: National Land and Water Resources Audit

NMR: Nuclear Magnetic Resonance

NRM: Natural Resource Management

NEW DNR: New South Wales Department of Natural Resources

NSW DPI: New South Wales Department of Primary Industries

NTGS: Northern Territory Geological Survey

OFR: (CRC LEME) Open File Report

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

Q DNRM: Queensland Department of Natural Resources and Mines

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

SA DEH: South Australia Department for Environment and Heritage

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

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

t/a: Tonnes per annum

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

UA: The University of Adelaide

UNSW: University of New South Wales

UV-VS: Ultra-Violet Visible Spectrophotometry

UWA: The University of Western Australia

VHMS: Volcanic hosted massive sulfide (deposit)

VSWIR: Visual to Shortwave Infra red

WA DAF: Western Australia Department of Agriculture and Food

WA DEC: Western Australia Department of Environment and Conservation

WRI: Water-rock interaction

XRD: X-Ray Diffraction

XRF: X-Ray Fluorescence

Clearly, the harvest years of CRC LEME have been bountiful. It is particularly satisfying that the legacy arrangements will ensure the benefits, spanning widely across regolith science, will continue well into the future. Equally importantly, we see new groupings of researchers emerging to tackle expanding frontiers.

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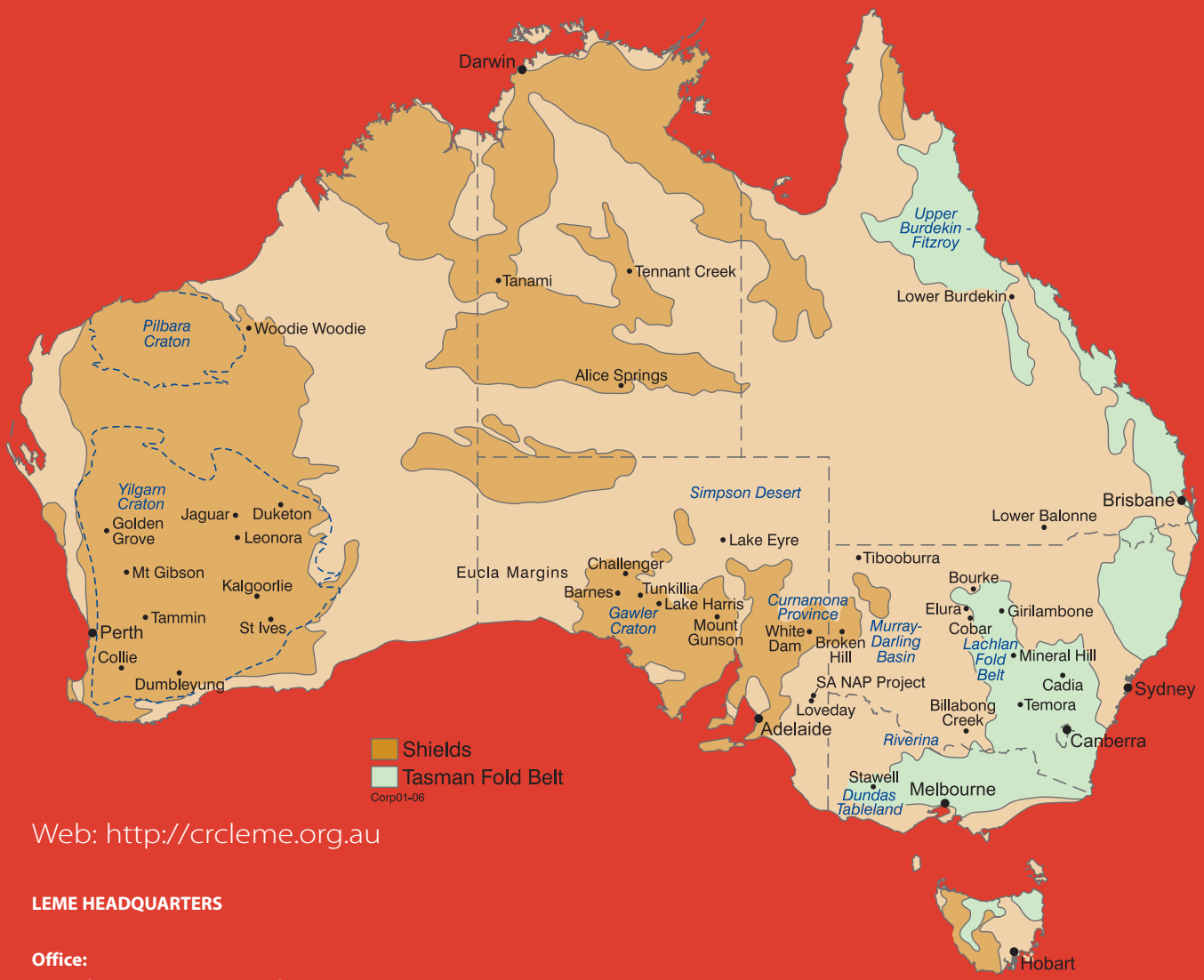
CRC LEME Research Locations



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