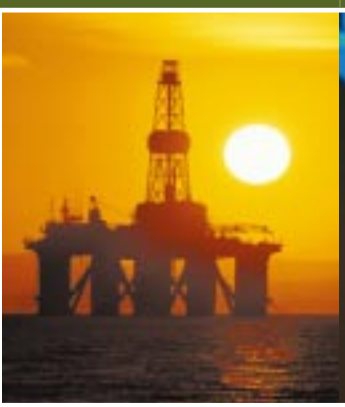
AUSTRALIAN RESOURCES RESEARCH CENTRE

ARRC



ANNUAL REPORT ■ 2003–04

CSIRO

Curtin UNIVERSITY OF TECHNOLOGY

ARRC OCCUPANTS

CSIRO

Exploration and Mining

Petroleum

Curtin University of Technology

Department of Exploration Geophysics

Department of Petroleum Engineering

Centre of Excellence for Exploration and Production Geophysics

Centre of Excellence for Petroleum Research

Cooperative Research Centres for:

Greenhouse Gas Technologies (CO2CRC)

Landscape Environments and Mineral Exploration (CRCLEME)

Predictive Mineral Discovery (pmd*CRC)

Sustainable Resource Processing (CSRP)

Interactive Virtual Environments Centre (IVEC)

Western Australian Energy Research Alliance (WAERA)

R2D3 – Research to Discover, Develop and Deploy energy solutions for a sustainable future

The University of Western Australia

AARNET

T E C H N O L O G Y >>

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FOREWORD

Western Australia's resources sector continues to drive the State and national economies. In 2003-04 the total value of Western Australian petroleum and mineral sales was $26.4 billion, with petroleum alone valued at more than $9 billion.

Hon. Clive Brown, MLA

The Australian Resources Research Centre (ARRC) has a key role in contributing to our economic success. The primary purpose in establishing ARRC was to substantially increase Western Australia's technological capability in the petroleum and minerals sectors, and its capacity to support the sustainable development of these sectors.

To date, greater collaboration with universities, increased international recognition of Western Australia, and the development of critical mass in mining and petroleum research and development have been credited to ARRC.

In 2003, the Western Australian Energy Research Alliance (WA ERA) between CSIRO Petroleum, Curtin University of Technology and The University of Western Australia, and with a $20 million injection over five years from the State Government, was established to provide innovative, sustainable energy technologies and solutions to the global oil and gas industry.

Further to this, WA ERA and Woodside Energy signed an agreement to foster the creation of a world-class energy research centre based in Perth in April 2004.

The partnership, called "Research to Discover, Develop and Deploy" energy solutions for a sustainable future ($R2D^3$), was embraced by Woodside to better direct more than $25 million it expects to spend over the next five years on oil and gas research. $R2D^3$'s focus will be research and development, training and competitive technology intelligence.

In June, the Western Australian Government agreed to provide support for the Western Australian Interactive Virtual Environments Centre (IVEC2).

IVEC2 aims to engage, encourage and energise the research and education communities and industry into understanding how advanced computing and visualisation technologies can enhance economic development or accelerate socio-economic activities.

The Government's support of $3.25 million over three years has been matched by contributions from the IVEC2 members ($1.125 million) and the Australian Partnership for Advanced Computing (APAC) ($1.215 million).

I congratulate ARRC staff for their ongoing commitment to this progressive and successful centre, and I'm confident that ARRC's endeavours will continue to contribute significantly to building our State's economy and strengthening Australia's position in the global market.

Hon Clive Brown MLA
Minister for State Development

EXECUTIVE SUMMARY

David Agostini

The Australian Resources Research Centre (ARRC) in south-east Perth was opened in late 2001 and is already a focal point for an emerging Western Australian minerals and energy knowledge cluster.

The headquarters of CSIRO Petroleum Resources, and a major node of CSIRO Exploration and Mining, together with two teaching and research departments of Curtin University of Technology are located at ARRC. In addition, ARRC houses nodes of four resources-based CRCs – Landscape Environments and Mineral Exploration, Predictive Mineral Discovery, Sustainable Resource Processing and Greenhouse Gas Technologies. The headquarters of the Interactive Virtual Environments Centre, Western Australian Energy Research Alliance (an alliance between CSIRO Petroleum, Curtin University of Technology and The University of Western Australia), R2D[3] (a major alliance with Woodside Energy) and two State Centres of Excellence are also based at ARRC.

The increasing level of collaboration between these groups and with other researchers in Perth, across Australia and around the world is one of the great successes of ARRC.

The core research capabilities at ARRC are Geoscience and Geo-engineering, and these are applied in two main areas: minerals and petroleum exploration and oil and gas production. Our work directly addresses the national research priority of *Developing Deep Earth Resources*. With more than 200 staff and postgraduate students, ARRC certainly constitutes a critical mass of geoscience expertise – and where better for it to be located than in Western Australia, where ten percent of the world's exploration and over half of Australia's mineral resource production takes place.

We are also finding increasing value in our links into other parts of CSIRO and the Universities, bringing multidisciplinary skills to help solve major petroleum and minerals challenges.

In 2004, CSIRO Petroleum participated as the pilot for a new system of external science reviews across CSIRO. The high-profile review panel with international representation visited all three nodes of the Petroleum Division over seven days. Their detailed report noted "…there are several lines of world leading research in the Division…The overall scientific quality is high…[with] some outstanding impacts on industrial and operational practices".

As the new Chair of the ARRC Advisory Committee I am delighted to see how much has been achieved in the first three years of ARRC's operation and the real momentum that is now building with ARRC at the centre of a truly world-class Minerals and Energy hub.

David Agostini
Chair – ARRC Advisory Committee

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OUR PROFILE AND WORKING ENVIRONMENT

ARRC houses more than 200 scientists primarily from CSIRO and Curtin University of Technology dedicated to solving significant problems facing the resources sector.

Our talented researchers share world-class facilities and expertise, encouraging greater collaboration between institutions and across disciplines, both internally and externally.

Through Curtin University of Technology, post-graduate and undergraduate students benefit from enhanced interaction with experienced scientists and ensure ARRC remains fertile ground for new ideas and the flow of top quality people to the industry.

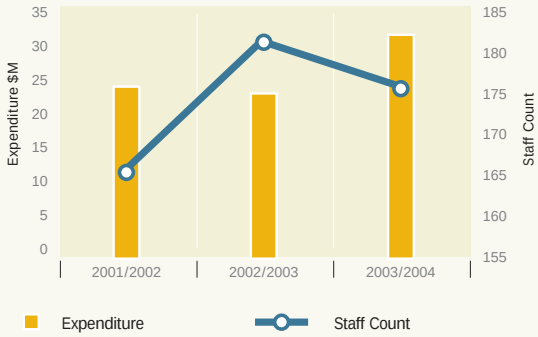
The vibrant and creative work environment at ARRC is supported by talented personnel who provide essential services such as: computing, library, finance, human resources, site maintenance and occupational health and safety.

ARRC attracted around 300 research projects during the 2003/2004 financial year, with a total budget of more than $30 million.

Total 2003/04 investment in research and support services at ARRC by CSIRO and Curtin University is summarised on the adjacent page.

Expenditure Category	Staff ($ '000)	Operations and Support ($ '000)	TOTAL
CSIRO	15,067	11,355	26,422
Curtin University	2,035	3,316	5,351
Total	17,102	14,671	31,773

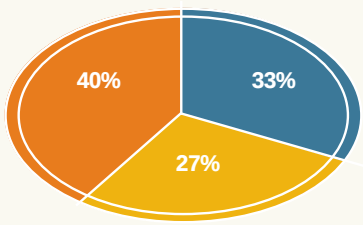
TIME SERIES PLOT EXPENDITURE AND STAFF NUMBERS



Funding	Institutional* ($ '000)	External ($ '000)	TOTAL
CSIRO	14,988	11,434	26,422
Curtin University	2,956	2,395	5,351
Total	17,944	13,829	31,773

*Direct Government funding to CSIRO and Curtin University

FUNDING SOURCES FOR CSIRO EXPLORATION AND MINING AND CSIRO PETROLEUM AT ARRC



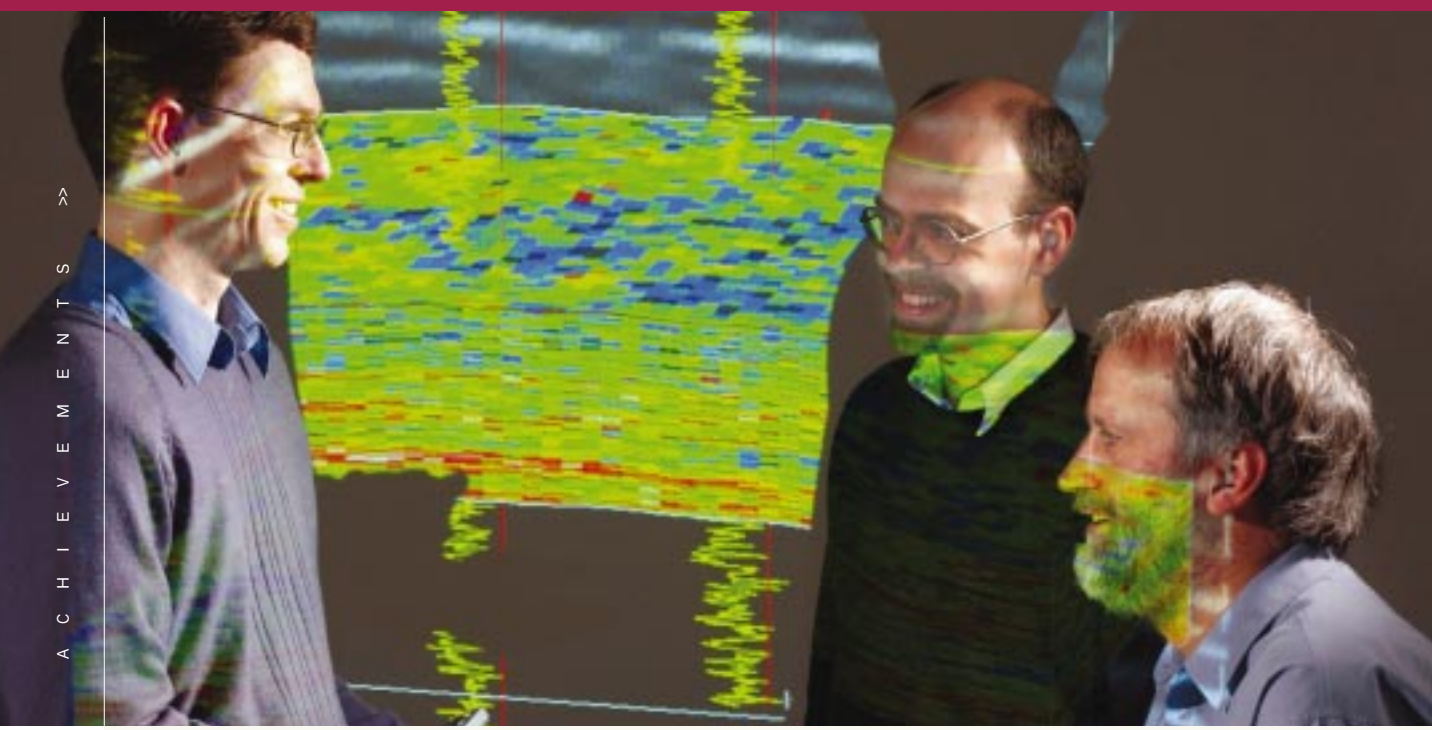
- State Government Departments & Universities
- Co-operative Research Centre (CRC) Program & Other Federal Funding
- Private Sector and other non-government sources

OUR STAFF PROFILE

The following paints a picture of our unique research staff:

- Two-thirds have oversees qualifications or experience.
- Two-thirds have PhD qualifications.
- More than half of our science leaders have worked within the petroleum and mineral exploration industries.
- Nearly half of our journal papers have international co-authors.
- Over half of our journal papers are published in the top quartile of journals.

AWARDS AND RECOGNITION



Left to right: Dr James Gunning, Dr Jonathan Ennis-King and Dr Lincoln Paterson discuss the characterisation of a petroleum reservoir. Photo: Mark Fergus

CSIRO Medal

CSIRO Petroleum researchers Dr Lincoln Paterson, Dr James Gunning and Dr Jonathan Ennis-King, together with Mike Glinsky from BHP Billiton Houston, have been selected for a 2004 CSIRO Medal for achievements in reservoir characterisation and CO_2 sequestration. These include a new element of seismic processing that has been highlighted as the "jewel" of BHP Billiton Petroleum's quantitative interpretation technology. A representative of BHP Billiton claimed enormous and immediate financial benefit was derived from these products, conservatively estimated in tens of millions of dollars.

Mike Glinsky considers the project a model for cooperative R&D. "I have worked at both Lawrence Livermore national laboratory and the Royal Dutch Shell Research Laboratories. I consider CSIRO a model of how industry and a national laboratory can work together," he said.

Technology Innovations and Applications Award (China)

CSIRO Petroleum's Dr Chris Dyt and Dr Cedric Griffiths received second prize in the Technology Innovations and Applications awards from the Chinese Research Institute of Petroleum Exploration and Development, PetroChina, for significant contributions to the petroleum and natural gas industry of China.

Chris and Cedric used the 'Sedsim' program to model the Tarim Basin, successfully predicting sediment distribution and depositional history.

Japan Society for the Promotion of Science – Research Fellowship

The Japan Society for the Promotion of Science (JSPS) has awarded CSIRO Petroleum's Dr Horst Zwingmann a long term fellowship to study recent faults in Japan. Only 78 JSPS long term fellowships are awarded (internationally) per year and generally only five in the Earth Sciences. Horst will carry out his project at Kyoto University, one of Japan's leading Universities.

Society of Exploration Geophysicists (SEG) '2004 Distinguished Achievement Award'

The Curtin Reservoir Geophysics Consortium (CRGC) secured this prestigious award in recognition of the CRGC's research in areas highly beneficial to the exploration geophysics industry, including signal processing, multi-component and rock physics. The award will be officially presented to the Founding Director Professor John McDonald at the SEG Conference in Denver, Colorado in October 2004.

Premier's Collaborative Research Grant

Wayne Robertson of CSIRO Exploration and Mining, together with representatives from the Department of Industry and Resources, The University of Western Australia and Central TAFE were awarded the inaugural Premier's Collaborative Research Grant for the project "Distributed Interactive Virtual Environment for Reconstructing Resource Sector Accidents/Incidents".

Society of Economic Geologists

Dr Brent McInnes of CSIRO Exploration and Mining has been elected Regional Vice-President (Australasia) of the Society of Economic Geologists.

Occupational Health, Safety and Environment (OHS&E) Achievement Award

Louise Beckwith of CSIRO Exploration and Mining received the 2003 CSIRO OHS&E Managers' Network Individual Achievement Award.

Excellent record in Lost Time Injury (LTI) rates

Both CSIRO Petroleum and CSIRO Exploration and Mining continue to maintain an excellent health and safety record at ARRC. CSIRO Petroleum achieved two years LTI free during the 2003/04 financial year.

Left to right: Dr Ken Fowle (Deparment of Industry and Resources), Wayne Robertson (CSIRO Exploration and Mining), Dr Karen Haines (UWA) and Dr Andrew Squelch (Central TAFE) accept the Premier's Collaborative Research Grant award.

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STRATEGIC ALLIANCES AND MAJOR RESEARCH INITIATIVES

Professor Robert Amin shows WA Premier Geoff Gallop and other VIPs through the Woodside Hydrocarbon Research Facility at Curtin University.

When ARRC was established three years ago, a major goal was to facilitate large collaborative research arrangements that would bring together a range of organisations and expertise for the benefit of the mining and petroleum industries and the State.

Four such arrangements have been initiated to date, enhancing the delivery of high-quality, internationally competitive R&D products to industry clients and partners.

The 2003/2004 highlights include:

Western Australian Energy Research Alliance (WA ERA) $20 million State Government grant

WA ERA – an alliance between CSIRO Petroleum, Curtin University of Technology and The University of Western Australia (UWA) – was established last year (reported in the 2002/03 ARRC Annual Report) to provide innovative, sustainable energy technologies and solutions to the global oil and gas industry. WA ERA received a tremendous boost at the end of the 2003/04 financial year when it was announced as the successful bidder for a $20 million grant under the Western Australian Government's Major Research Facilities (MRF) program.

In announcing the success, WA Premier Geoff Gallop said: "This significant initiative will mean Western Australia will be home to one of the world's leading research hubs for oil, gas and clean energy technologies. It is a major decision in the context of the future of the State. It will add value to the tremendous contribution that these industries make to the economic well-being of WA".

Australia's long term energy security is dependent on the development of step change technologies to find more oil, increase recovery from existing reserves, economically develop stranded gas and create the knowledge base that positions

Western Australia at the cutting edge of technology development for new clean energy sources such as hydrogen. The Alliance will work with industry and government to develop research and education programs expected to attract increased investment from the private and public sector and deliver high-impact, business-driven benefits to the industry in WA and across the nation. The grant allows 50 new research positions and around 30 additional PhD and Masters places from Curtin and UWA to be created.

The State will derive numerous benefits from the funding of WA ERA's research, including up to $229 million invested into research programs conducted in WA over the next decade; leveraged federal research funding of $66million; growth of new business to support an increased global oil and gas industry operating out of Perth; and the sustainable exploitation of WA's oil and gas resources.

Earlier this year, Woodside Energy became WA ERA's first major industry client with the signing of a $25 million, five year R&D agreement.

R2D^3 – Research to Discover, Develop and Deploy energy solutions for a sustainable future

In April 2004, WA ERA and Woodside Energy signed an agreement to foster the creation of a world-class energy research centre based in Perth. The partnership, called R2D^3 – "Research to Discover, Develop and Deploy" energy solutions for a sustainable future – was embraced by Woodside as a way to better direct more than $25 million it expects to spend over the next five years on oil and gas research. R2D^3's focus will be research and development, training and competitive technology intelligence.

Woodside's Chief Operating Officer, Keith Spence, said he was confident the joint venture would "result in Western Australia emerging as a key centre of Australian, regional and even world, research into cutting-edge oil and gas technologies".

Initially research and development is focussed on integrated reservoir characterisation and management to optimise recovery rates, and gas utilisation – including gas-to-liquids, small-scale LNG technologies and gas compression engineering to improve methods for extracting and transporting gas. R2D^3 will also focus on fundamental and specialist training for oil and gas engineers and technicians to deploy and operate the new technologies.

R2D^3 is expected to have a research budget in 2004 of up to $5 million. Under the agreement, the partners will share administration costs.
Like WA ERA, R2D^3 is headquartered at ARRC.

R2D^3

The launch of R2D^3

Back (left to right): Senator David Johnston, Professor Alan Robson (Vice-Chancellor, UWA), Mr Keith Spence (Chief Operating Officer, Woodside) and Hon. Clive Brown (Minister for State Development).
Front: Professor Barney Glover (Pro-Vice Chancellor R&D, Curtin University) and Professor Beverley Ronalds (Chief, CSIRO Petroleum).

AusGas – the energy choice for a low emissions economy

AusGas was produced as a discussion paper by CSIRO Petroleum early in 2004. The document follows on from APPEA's NatGas paper and suggests the formation of a national partnership between industry, government and research institutions to identify and deliver technology requirements to reduce the delivered cost of gas and promote its wider use.

Specifically AusGas looks at gas supply and demand and outlines key R&D opportunities in offshore and onshore exploration, development, production, processing and utilisation of gas. Interest in the document has been very high and consultation is under way with key gas industry participants to identify and prioritise a common approach to increase the role of gas in achieving the energy objectives of the nation. If all goes according to plan, major work will begin mid-2005.

Memorandum of Understanding (MOU) with Schlumberger

In March 2004, Schlumberger's Chief Scientist and Vice-President, Dr Philippe Lacour-Gayet, visited Australia and signed an MOU with CSIRO. The intent is for Schlumberger and CSIRO to collaborate across the services, near term and strategic research horizons, identifying, developing and implementing technologies and processes within global energy companies. Schlumberger will provide the big "D" in R&D, giving CSIRO access to their market networks.

IVEC2 – a focus for High Performance Computing (HPC) and visualisation

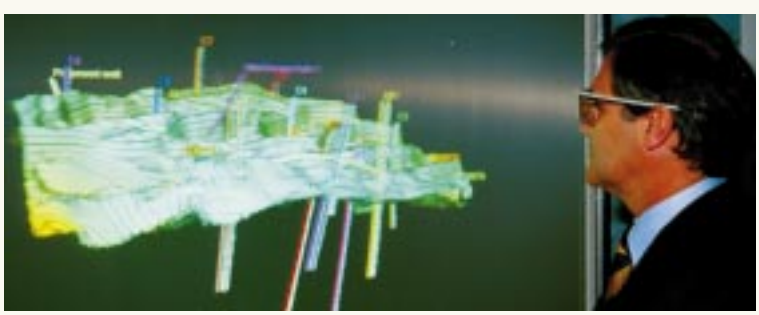
In June 2004, the Western Australian Government agreed to provide ongoing support for the Western Australian Interactive Virtual Environments Centre (IVEC2). The Government's support of $3.25 million over three years has been matched by contributions from the IVEC2 members ($1.125 million) and the Australian Partnership for Advanced Computing (APAC) ($1.215 million).

With an initial core membership consisting of Central TAFE, CSIRO, Curtin University, Murdoch University and The University of Western Australia (UWA) (the IVEC2 members), IVEC2 aims to engage, encourage and energise the research and education communities and industry into understanding how advanced computing and visualisation technologies can enhance economic development or accelerate socio-economic activities.

This will be accomplished through the provision of highly accessible HPC and visualisation equipment and the necessary operational support at two nodes: ARRC (where the IVEC2 headquarters will be located) and UWA.

Specifically, IVEC2 will:

- Work with the universities to develop high quality graduate students trained in advanced computational skills.
- Provide networked access to a range of HPC facilities within Western Australia.
- Provide access to national computing facilities and other international collaborative linkages.
- Provide the necessary infrastructure to support members in the active pursuit of advanced computing and scientific visualisation research programs.
- Facilitate the development of computational communities of interest. These will include researchers, industry and HPC suppliers.
- Work with APAC and members to ensure that APAC Programs are appropriately resourced to achieve agreed milestones.
- Promote and facilitate the uptake of advanced computing technology by industry.
- Supply training and associated support to help industry take advantage of advanced computing technology.



IVEC's Visualisation Laboratory.

CSIRO EXPLORATION AND MINING

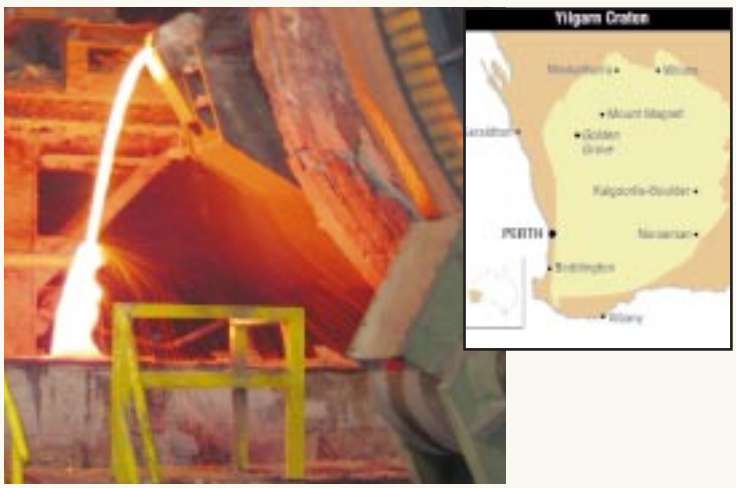
Courtesy KCGM. Photographer: Ian McNeil

Mission: Maximising value from Australia's mineral resources through increased exploration success and a sustainable and vibrant mining industry.

OUR INDUSTRY

Exploration in Australia has declined in recent years in line with dramatically reduced global expenditure and falling success rates in some commodities. In order to capitalise on an upturn in the global exploration cycle, Australia needs to be positioned to address the unique geological challenges of the Australian continent to attract and retain exploration interest. There are significant benefits that flow to Australia from having a strong mineral industry. For such an industry to be sustainable, it must include on-going exploration success. This can be achieved through increased levels of exploration activity and/or through increased exploration success rates.

Australia is a world leader in exploration and mining technology. During the next decade its mining industry will continue to lead, generating employment, exports, and wealth for Australia with on-going billion-dollar businesses in coal, aluminium, iron, gold, zinc, nickel, copper, mineral sands and uranium. Key factors behind this success will be competitiveness and license-to-operate. Industry strives for economic efficiency and the public expects that industry will deliver low cost products with the exploration and mining process having only a minimal short- or long-term adverse impact on the environment and providing overall benefits to the social fabric of the community.



Courtesy Timmins Daily Press. Photographer: Bruce MacKinnon

CSIRO EXPLORATION AND MINING'S RESEARCH PRIORITIES

CSIRO Exploration and Mining's research portfolio has been structured to address the key technological challenges facing Australia's metalliferous and coal mining industries. The Division employs over 200 staff at sites in Perth, Melbourne, Sydney and Brisbane. The core science capabilities at ARRC are in the areas of computational geoscience, regolith geoscience and hyperspectral remote sensing. These capabilities are focused on three major research themes:

- Where to Explore
- Recognising Ore Systems
- Exploring Through Cover

Some work under these themes is also conducted at the Division's Sydney and Melbourne laboratories. Research conducted within the Division's remaining research themes – Knowing What to Mine, Mine Productivity, Mine Safety and Social and Economic Integration – is conducted at North Ryde (Sydney) or the Queensland Centre for Advanced Technologies (QCAT).

Where to Explore

The primary objective here is to provide new data gathering and interpretative tools to boost the available terrane-scale geological information necessary for effective target area selection for key commodities in Australia.

There are two research streams within this theme:

Knowledge of terranes

The principal aim under this stream is to model all relevant information about established and emerging mineral provinces to assist mineral exploration. Examples of current activities being undertaken at ARRC include:

- Glass Earth Map of Australia – a common Australia-wide geoscience portal providing 4D geological data and interpretative tools over the web.
- Geosciences Grid – a common Australia-wide network linking geoscience data, facilities and interpretative tools for exploration.
- Ore district reconstructions – Thermochronology – evaluation of structural history of ore districts for tectonic reconstruction and exploration.
- Selected studies of geological terranes – terrane-based studies aimed at applying the Division's expertise to contribute to collaborative studies in major mineral provinces.
- Geochemical map of the Yilgarn – systematic broad-scale geochemical coverage of the Yilgarn Craton, WA.

New frontiers

This newly created stream aims to provide information and ideas relating to important mineral deposit types not presently known in Australia. Work at ARRC is currently addressing:

- Seabed ore systems – use modern seabed ore systems to facilitate exploration for Cu-Zn mineralisation in the Archaean of WA.
- Archaean Cu-Zn – define prospective target areas for Cu-Zn mineralisation in the Yilgarn Craton.
- Exploring in cover – targeting methods for new and existing styles of supergene ore deposits.

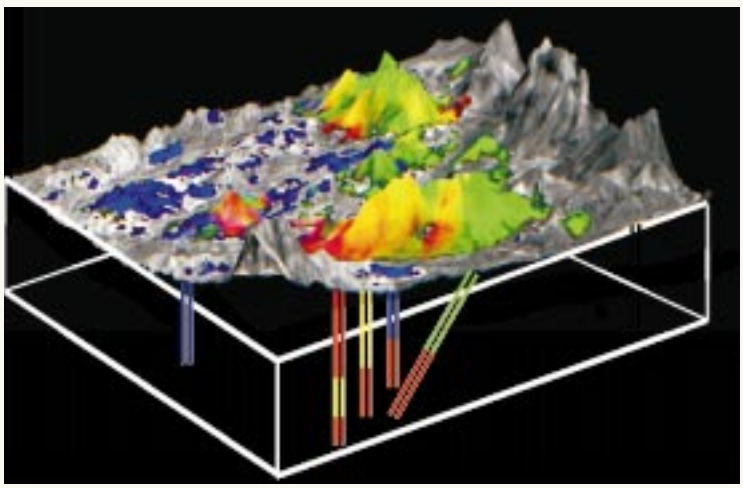
Recognising Ore Systems

The focus of this theme is to provide tools and geological criteria to differentiate significant ore deposits from minor occurrences and complex background signatures. There are two research streams within this theme.

Modelling of ore systems

The focus here is on understanding the local and regional scale controls on ore body formation to provide useful exploration criteria from ore deposit studies and computational modelling and other geological tools. This is a core activity of the Cooperative Research Centre for Predictive Mineral Discovery (pmd*CRC) but also has relationships to other areas of exploration related research e.g. petroleum systems and anomaly formation in the regolith. Work at ARRC includes:

- Computational modelling: software framework – development of the software environment required for computer-based modelling of ore-forming geological processes.
- Computational modelling: software functionality – developing numerical simulation software to enable increasingly robust, rapid and accurate simulations of earth processes so that a wider range of exploration targeting problems can be addressed.
- Computational modelling: application to exploration – applying numerical simulation software and mineral system understanding to mineral exploration targeting problems to generate predictive exploration strategies at all scales which are then used by exploration companies.
- Computational modelling: knowledge transfer – developing learning materials which enable the training of a large group of geoscientists with the knowledge to apply the developing system to exploration targeting problems in a wide range of ore environments.
- Computational modelling: developing 3D-GIS systems – developing the technologies to enable both exploration geologists and numerical modellers to develop and query multiple valid geological interpretations very rapidly using all available data sets.
- Mineral hosts for gold and trace elements – investigate mineralogical, geochemical and biological processes of weathering on selected gold and base metal deposits and prospects, in deeply weathered terrains of Australia.
- Yilgarn Regolith – investigating variations in the depth and nature of weathering in relation to bedrock geology, mineralisation, structures, groundwater regimes and palaeochannel systems, in selected areas of the Yilgarn Craton, WA.

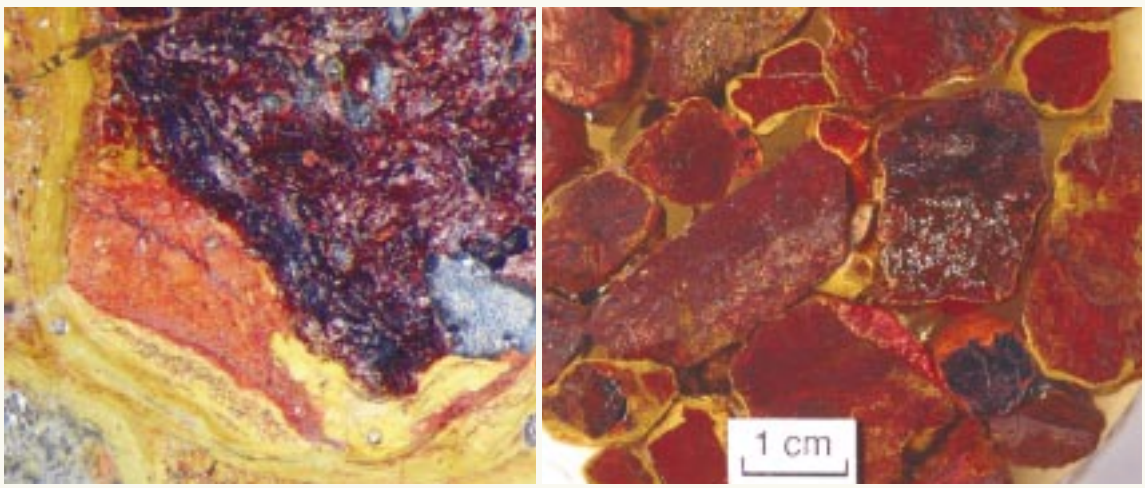


A 3D spectral mineral alteration model from airborne and drill core data.

Anomaly recognition

Work within this stream aims to develop technologies to separate geochemical and geophysical anomalies surrounding ore bodies, from false anomalies that do not warrant follow-up. Much of this work is conducted through CRC LEME. At ARRC, work is focused on:

- Regolith thematic volumes – publication of case histories of ore deposit discoveries and their regolith geology.
- Metal zonation – complex systems science in the interpretation of metal zonation in ore bodies.
- Objective regolith logging – using spectral logging techniques to complement existing methodologies to reduce the 'human variability' in current logging techniques to facilitate more effective exploration.
- Mineral hosts for gold and trace elements – see above.
- Airborne hyperspectral mapping commercialisation (HyVista Strategic Alliance) – develop operational airborne hyperspectral mineral mapping capabilities and commercialise IP through creation of an end-to-end business from acquiring data through to delivery of mineral mapping products operating worldwide.
- Field, airborne and spaceborne hyperspectral mineral mapping – develop algorithms, software and applications case studies, for enhanced exploration and mining using field and imaging spectroscopy (note: relationship with objective regolith logging above).



Geochemical analysis of regolith materials to identify mineral hosts for gold.

Exploring Through Cover

Work under this theme is directed at contributing to the discovery of weathered and/or covered ore deposits in Australia. There are three research streams within this theme:

Determining the depth to basement

The focus of work within this stream is on the development of cost-effective ways to measure the depth of cover over large parts of Australia. The following is addressed at ARRC:

- Yilgarn Regolith – testing and refining geophysical techniques at suitable sites to map main regolith boundaries and depth to basement in the Yilgarn Craton, WA.
- Field and airborne methods – development of portable field-based and airborne methods to estimate depth to key regolith horizons with a view to constraining those areas of cover amenable to existing exploration techniques.

Seeing through cover

Work within this stream is aimed at the development of new geochemical and geophysical methods to penetrate depths of cover up to 500m, differentiate ore body types on the basis of their economic viability at different depths, and the ability of existing detection methods to identify them in various terranes. Work at ARRC is focused on:

- Geochemical technologies to see through the regolith (includes AMIRA P618 and GRAMME) – assessment of groundwater, partial extractions and Pb and S isotopic tracing to see through the regolith (to be integrated with new project 'Joint inversion through the regolith').
- Yilgarn Regolith – multi-disciplinary approach to determine which mechanisms cause metal migration through post-mineralisation cover; what the timeframes are that these mechanisms work in; what regolith materials host anomalous signatures; and what influence bedrock geology and structure has in areas where mineralisation is concealed beneath colluvial-alluvial sequences, and saline and hypersaline environments (Yilgarn Craton, WA).
- Mineral hosts for gold and trace metals – detailed insitu mineralogical and geochemical studies of mineral hosts for target and pathfinder elements in transported cover.

Weathering of ore deposits

Work within this area is aimed at determining the depth of weathering around ore deposits, and understanding the deep weathering of ore deposits, especially those of gold, base metals and iron, and the implications for exploration and mining. A prime aim will be to assist in the transition from open pit to deep underground mining. Key activities at ARRC include:

- Yilgarn gold mines – evaluation of depth of weathering in Yilgarn gold deposits and implications for mining and exploration.
- Ni Sulphide ores – evaluation of weathering and geochemistry in exploration for Ni sulphide ores.

CSIRO PETROLEUM

Mission: To deliver science and solutions vital to maintaining a globally competitive and sustainable Australian energy industry, with a primary focus on oil and gas.

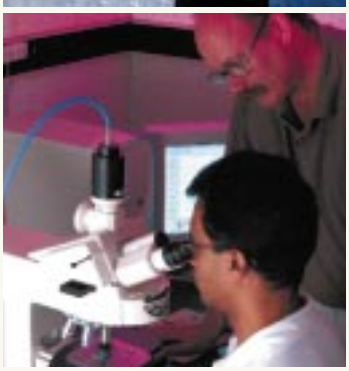
OUR INDUSTRY

The oil and gas industry is at the cusp of significant change – a number of countries including Australia are believed to have passed their oil production peak, signalling an impending tightening of supply in the coming decades. Large regions offshore Australia remain lightly explored, however, so there is a real chance of finding a new petroleum province. Ongoing research to maximise recovery from our producing petroleum reservoirs is also vital to maximise Australia's oil self-sufficiency into the future.

In contrast, unlike the USA and Europe, Australia is blessed with large gas resources. These offer the opportunity for Australia to take an international R&D lead in the evolving "methane economy" – developing, producing, converting and transporting these resources to markets across Australia and around the world. A significant proportion of the anticipated growth in demand for natural gas is relatively nearby, in the developing Asian economies. However, much of Australia's gas resources are either remote (deepwater north-west Australia) or unconventional (east coast coal seam methane) and hence there remain major technical challenges to cost-effective recovery.

Petroleum is one of Australia's two most valuable resource exports, and its dominance is expected to increase as we capitalise on the burgeoning worldwide gas market. A future hydrogen economy will almost certainly be fuelled by natural gas for a considerable period.

A further major challenge to the energy and transport sector is greenhouse gases. Geological sequestration of CO_2 is a primary future means of curbing emissions to the atmosphere, and relies heavily on R&D and technology skills from the petroleum sector.



CSIRO PETROLEUM'S RESEARCH PRIORITIES

CSIRO Petroleum's research is structured to directly address these industry priorities and help maintain an internationally competitive and sustainable Australian energy industry. We have 150 staff operating across Perth, Melbourne and Sydney, applying their multidisciplinary skills in geology, geochemistry, geophysics, mathematical modelling, geomechanics, reservoir engineering, gas processing and chemical engineering to two major themes:

- Maximising Australia's Self Sufficiency in Oil
- Developing Gas as an Energy Source for Australia

Maximising Australia's Oil Self-Sufficiency

Research addressing the discovery and production of oil is broken into three streams:

Reducing exploration risk

The objective is to better understand all elements of the petroleum system and provide industry with new technologies, techniques and knowledge to increase exploration success rates and encourage exploration in new or lightly-explored frontier provinces.

While work is aimed primarily at issues relevant to exploration in Australia and the nearby region, the results have much broader application. At ARRC, our research teams look at the following issues:

- Integrated seal and trap analysis
- Stratigraphic forward modelling
- Oil migration and fluid history
- Timeframes of basin evolution
- Thermal maturity and source rock evaluation
- Evaluation of reservoired petroleum
- Oil-oil and oil-source rock correlations

Optimising reservoir definition & performance

This stream is dedicated to increasing average oilfield recovery rates through accurate and predictive reservoir characterisation. When characterisation is inadequate, significant amounts of oil and gas may remain un-recovered or may be recovered inefficiently. We look at new methods for incorporating sub-surface and surface geophysical and well-test information into detailed descriptions of oil and gas reservoirs that involve combining high resolution and low-resolution data in an advanced geostatistical framework. Work at ARRC concentrates on:

- Integrated seal and trap analysis
- Prediction and analysis of pressure systems
- Geophysics
- Reservoir characterisation
- Reservoir modelling
- Experimental petrophysics and geomechanics
- Deep water turbidites

Improved drilling & well performance

Improving well planning, construction, and performance throughout the life of a well or field is the focus of the team working within this research stream. The objective is to develop and implement high-impact technologies in the form of processes, tools, and/or services to the oil and gas industry.

The following is addressed at ARRC:

- Wellbore stability
- Sand production
- Drilling fluids
- Formation damage
- Drilling mechanics
- Laboratory testing and simulation
- Knowledge management for drilling, completions and production
- Drilling performance improvement
- Drilling hydraulics

Supporting Australia's Gas Future

The second of CSIRO Petroleum's two major themes looks at ways to help strengthen Australia's energy security and world environmental sustainability. It is also broken down into three main research streams: *Producing unconventional gas; Developing CO2 sequestration;* and *Novel gas processing technologies*. One of these streams currently falls within ARRC activities:

Developing CO_2 sequestration

Geological storage of CO_2 is expected to be an important component of Australia's efforts to meet greenhouse gas emission targets. Research within this stream looks at reducing atmospheric CO_2 emissions by creating technologically safe, economically viable and socially-acceptable underground storage options for geological sequestration of CO_2, such as unmineable coal beds, depleted oil or gas fields or deep saline aquifers. The monitoring of CO_2 is also a critical aspect of work in this stream, carried out in close collaboration with the CO_2CRC.

CURTIN UNIVERSITY OF TECHNOLOGY

In addition to CSIRO's Petroleum and Exploration and Mining divisions, ARRC was also purpose built to house Curtin's Departments of Exploration Geophysics and Petroleum Engineering plus State Centres of Excellence for Petroleum Research and Exploration and Production Geophysics.

DEPARTMENT OF EXPLORATION GEOPHYSICS

Reputed to be the only one of its type in the world, Curtin's Department of Exploration Geophysics is part of Curtin's School of Resource Science and Technology. The Department provides an undergraduate course in Exploration Geophysics (BSc), with specialisation options in the Honours (fourth) year in mineral, petroleum and groundwater geophysics, plus postgraduate, MSc and PhD courses. Currently the Department is unique in Australia because it participates in three Cooperative Research Centres (CRCs): the CRC for Greenhouse Gas Technologies (CO_2CRC), CRC for Landscape Environments and Mineral Exploration (CRC LEME) and CRC for Mining Technology and Equipment (CMTE).

In 1998, the Western Australian Government designated the Department as a Centre of Excellence for Exploration and Production Geophysics (CEEPG). The Centre forms the research arm of the Department. Its brief is to 'apply new ideas for identifying and extracting increased quantities of ore and hydrocarbons from known locations'. The aim is to increase expertise in production geophysics, by adapting techniques in exploration geophysics.

Academic staff:	10
Support staff:	5
Students:	82 (30 Post Grad/ MSc/PhD, 2 undergraduate)

Major Areas of Research

- Petroleum geophysics.
- Minerals and environmental geophysics.

Major Ongoing Research Projects (Petroleum)

1. Seismic processing technologies

- Seismic exploration with continuous signals.
- Automatic event picking in the pre-stack domain.
- Fracture evaluation from multi-azimuth data.
- Fault detection using a combination of coherency and diffractivity anomalies.

2. Rock physics

- Theory for fluid substitution in porous fractured reservoirs.
- Theory for seismic attenuation and dispersion fractured porous rocks.
- Theoretical and numerical analysis of frequency dependent anisotropy of porous rocks with aligned fractures.
- Seismic attenuation and dispersion in randomly inhomogeneous porous rocks.
- Modelling the effect of fluid on shear-wave splitting in fractured reservoirs.
- Theoretical and numerical simulations of seismic signatures of depositional sequences.
- MATLAB rock physics software.

3. Reservoir simulation and sensing technologies

Major Ongoing Research Projects (Minerals and Environmental Research)

- Feasibility of seismic methods for gold exploration.
- The use of distributed sensor arrays in electrical and electromagnetic imaging.
- Innovative geophysical exploration for high-grade manganese ore under regolith and sedimentary cover in the East Pilbara of Western Australia.
- Indirect exploration for ore deposits in weathered terrains with airborne gravity gradiometry.
- Geophysical properties of the regolith near the Victory Gold Mine, Kambalda, Western Australia.
- Groundwater investigations using the seismoelectric method.
- Surface nuclear magnetic resonance (SNMR) for hydrological investigations in Australia.
- Interpretation of geophysics for catchment management.
- Multi-spectral analysis of radiometric data for improved regolith and soil mapping.
- Application of geophysical technologies for 3D visualisation of palaeo-channels and use of this information for management of dryland salinity in Western Australia.
- WA palaeo-channels for salinity mitigation.
- Rural towns – liquid assets.

DEPARTMENT OF PETROLEUM ENGINEERING

Established in July 1999, Curtin's Department of Petroleum Engineering offers a unique blend of academic excellence and industrial expertise and is committed to rapid technology transfer to the oil and gas industry. The Department also works with The University of Western Australia (UWA) under the Western Australian Petroleum Research Centre (WAPRC) collaborative agreement, committed to carrying out high quality research of value to the State's oil and gas industry.

During 2003/04 the Department signed an agreement with the National Iranian Oil Company and the Petroleum University of Technology (PUT), Tehran for collaboration in Education and Research. Pursuant to this agreement, the Department commenced a new post-graduate program leading to the degree of Master of Petroleum Well Engineering. This program is held partly at the PUT campus in Tehran and partly at Curtin's facilities in Perth. Over the past year our staff have also delivered industry training to Woodside secondees from Mauritania and BHP Billiton secondees from Trinidad.

Major Areas of Research

- Petroleum geology
- Production engineering
- Reservoir engineering
- Reservoir uncertainty studies
- Downstream processing
- Drilling engineering
- Enhanced oil recovery
- Petroleum economics

Major Ongoing Research Projects

- Phase behaviour of natural gas in its liquefied state.
- Drilling in gas hydrate environments – knowledge management.
- Investigation of miscible fluid injection into fractured reservoirs.
- Drilling of extended reach wells – wellbore stability, hole cleaning.
- Evaluating overall drilling performance when drilling in difficult reservoir environments or drilling complex wellbore trajectories.
- Improved performance of hard rock drilling.
- Regional petrophysical / geological study of the angel formation.
- Analysis of low magnitude pressure response in oil and gas reservoirs, aquifers and aquitards.
- Design and development of a petroleum engineering analytical software suite.
- Conversion of natural gas to higher hydrocarbon liquids.
- Flow behaviour in porous media, including "physical modelling".
- Up-scaling geological models for dynamic reservoir simulators.
- Long-term sequestration of CO_2.
- Microbial enhanced oil recovery.
- Perth basin aquifer modelling.
- Reservoir uncertainty studies using Experimental Design Analysis (EDA) methods.
- Risk and uncertainty in decision making.

Academic staff:	7
Support staff:	2
Students:	53 (38 MSc/ 15 PhD)

ANNUAL PERFORMANCE GOALS (APGS) – CSIRO EXPLORATION AND MINING AND CSIRO PETROLEUM

CSIRO EXPLORATION AND MINING

Strategic Alignment – Our Core Purpose

Maximising value from Australia's mineral resources through increased exploration success and a sustainable and vibrant mining industry.

KEY:

COLUMNS 1-4
Strong Significant Minor

RIGHT HAND COLUMN
APG achieved Significant progress toward achievement of APG APG not achieved

CSIRO's Flagships Initiative – National Research Flagships aim to deliver scientific solutions to advance six of Australia's most important national objectives: (1) strong, sustained economic growth, new industries, competitive enterprises and quality jobs; (2) healthier, more productive lives for Australians; (3) clean, cost-efficient energy; (4) more productive and sustainable use of water; (5) to generate sustainable wealth from our oceans; and (6) growth and prosperity for regional Australia.

Some of ARRC's activities contribute towards the Wealth from Oceans Flagship, Water for a Healthy Country Flagship and the Energy Transformed Flagship. For more information on Flagships, visit **www.csiro.au/flagships.**

THEME 1: Where to explore	**GOAL:** Provide data, interpretative tools, and terrane scale geological information necessary for effective target area selection for key commodities in Australia.	ARRC Activity	Benefits WA Industry	International Linkages	Contributes to Flagship	APG Performance
STREAM 1: Knowledge of Terranes	**OBJECTIVE:** To ensure access to all relevant information about established and emerging minerel provinces to assist mineral exploration.					
Conclude Curnamona Province Project and complete project deliverables Develop terrane based studies in consultation with partners and initiate funded projects		Minor	Significant	Minor	Minor	Significant
Develop broad-scale regolith investigations in relatively unexplored mineral provinces of Australia, e.g. parts of the Northern Territory.		Strong	Significant	Minor	Minor	Strong
Conclude Finnish nickel projects		Strong	Minor	Strong	Minor	Strong
Complete development of Alphachron Mk II prototype instrument (incorporating laser extraction and automation technology) and deliver on orders eventuating from successful bids (e.g. Curtin ARC grant)		Strong	Strong	Minor	Minor	Significant
Take a lead in developing the 'Glass Earth map of Australia' and the 'Geosciences grid'		Strong	Strong	Minor	Minor	Strong
Conclude funding for NT regolith project		Strong	Significant	Minor	Minor	Strong
Develop and fund project 'Geochemical map of the Yilgarn'		Strong	Strong	Minor	Minor	Strong
Engage relevant Geological Surveys and industry partners, to undertake collaborative broad scale regolith projects		Strong	Strong	Minor	Minor	Strong
Delivery and commissioning of the Alphachron Mk I prototype instrument to the University of Houston		Strong	Minor	Minor	Minor	Strong
Transfer Alphachron operations base from Sydney to Perth		Strong	Strong	Minor	Minor	Strong
Sign collaborative research agreement between CSIRO and Patterson Instruments Pty. Ltd. involving the development, commissioning and commercialization of Alphachron Mk II prototype instruments		Strong	Significant	Minor	Minor	Significant
STREAM 2: New Frontiers	**OBJECTIVE:** To provide information and ideas relating to important mineral deposit types not presently known in Australia.					
Establish new research teams and projects 'Non-sulphide zinc' and 'Archaean Cu-Zn'		Strong	Strong	Minor	Minor	Strong
Complete IASSHA 2003 expedition to Indonesia		Minor	Minor	Minor	Minor	Strong
Complete year end technical review and project assessments to demonstrate link between 'seafloor' work and exploration		Strong	Strong	Minor	Minor	Strong
Engage industry in design and implementation of new research projects		Strong	Strong	Minor	Minor	Strong
Develop collaboration with Australian and Canadian strategic research partners on new Cu-Zn projects		Strong	Strong	Minor	Minor	Strong
Lead industry conference on applications of seafloor studies to base metal exploration		Strong	Strong	Minor	Minor	Strong
Take a leading role in thematic volume of the Journal of Australian Earth Sciences on 'Submarine Hydrothermal processes in the Western Pacific'		Strong	Significant	Minor	Minor	Strong

KEY:

COLUMNS 1-4
Strong | Significant | Minor

RIGHT HAND COLUMN
APG achieved | Significant progress toward achievement of APG | APG not achieved

THEME 2: Recognising Ore Systems	GOAL: Provide tools, geological criteria to differentiate significant ore deposits from minor occurrences and complex background signatures.	ARRC Activity	Benefits WA Industry	International Linkages	Contributes to Flagship	APG Performance
STREAM 1: Modelling of Ore Systems	**OBJECTIVE:** To understand the local and regional scale controls on ore body formation to provide useful exploration criteria from ore deposit studies and computational modelling and other geological tools. This is a core activity of the pmd*CRC but also has relationships to other areas of exploration related research eg. petroleum systems and anomaly formation in the regolith					
Delivery of software framework tools as outlined in pmd*CRC project plan						
Progressive improvement in capabilities to address various geological processes, notably:						
• fracture propagation coupled with fluid flow through the development of particle codes.						
• magmatic emplacement processes						
• compaction and fluid flow through porous media incorporating advection of heat						
Successful numerical modelling projects underway with five or more exploration companies leading to improved exploration						
Deliver the first edition of the modelling library to the pmd*CRC by 1 December 2003						
Development of several collaborative coupled modeling projects with AcCess						
Develop a multi-client project proposal in collaboration with pmd*CRC and CRC-LEME to address the formation of regolith anomalies						
Transfer modelling skills to partner organisations and companies through collaboration and two or more numerical modelling courses during the year including one hands-on course for postgraduate students						
Successfully establish a multi-client project to develop tools for joint inversion of geophysical data sets and more rapid geometric model-building (to be integrated with new project 'Joint inversion through the regolith')						
STREAM 2: Anomaly Recognition	**OBJECTIVES:** Develop technologies to separate geochemical and geophysical anomalies surrounding ore bodies, from false anomalies that do not warrant follow-up. Much of this work is currently undertaken by CSIRO EM within CRCLEME.					
Establish projects and teams to understand the processes of geochemical anomaly formation and develop procedures for ranking anomalies, in regolith environments						
Development of a 3D mineralogical and regolith framework for selected deposits and prospects and link with geochemical data and geological and structural models, in the Yilgarn, WA						
Complete investigation of spectral logging using Analytical Spectral Devices (ASD) and PIMA at St Ives Gold Mine and surrounds						
Complete two thematic volumes: Regolith Expression of Ore Systems; and Regolith Landscape Evolution of Australia						
Complete regional, tenement and mine scale hyperspectral alteration mapping of the Mt Lyell mineral belt						
Complete hyperspectral mineral mapping project at Broken Hill for Sumitomo Metal Mining demonstrating complementary capabilities of airborne and spaceborne sensors for mapping mineralogy (CSIRO-ERSDAC Satellite MOU)						
Develop next generation suite of hyperspectral information extraction software tools for rapid, large area and seamless mineral mapping						
Commence (district scale) database compilation of depth of weathering around selected ore deposits and prospects in the Yilgarn Craton, WA						
Develop relationships with industry and geological surveys (e.g. Goldfields, Sons of Gwalia, Newmont) to collaborate on projects related to the formation of geochemical anomalies in the regolith						
Complete two thematic volumes to publication stage with industry partners to complete						
Develop new tenement scale project opportunities with Broken Hill exploration companies (e.g. Perilya, Platsearch, Triako) to help find next generation mineralization						
Work with NSW DMR, PIRSA & GA. to develop next generation regional mapping products						
Grow external funding for mineral mapping in the Mt Read Volcanic belt of Tasmania with MRT, CMT, Newcrest and Placer Dome						
Develop operational processing capability, marketing strategies and business plan, for hyperspectral mineral mapping business within 12-18 months						
Develop hyperspectral business opportunities in exploration and mining, nationally and internationally, through the HyVista Strategic Alliance						
Review future of GETMAG in consultation with partners						

THEME 3: Exploring through cover	GOAL: Enable the discovery of weathered and/or covered ore deposits in Australia	ARRC Activity	Benefits WA Industry	International Linkages	Contributes to Flagship	APG Performance
STREAM 1: Determining the depth to basement	**OBJECTIVES:** Develop cost-effective ways to measure the depth of cover over large parts of Australia.					
Commence testing and refining geophysical techniques at suitable sites to map depth to basement, main regolith boundaries and subsurface features in the Yilgarn Craton & Northern Territory						
Further develop relationships with Government and Industry partners to undertake new research						
STREAM 2: Seeing through cover	**OBJECTIVES:** Develop new geochemical and geophysical methods to penetrate depths of cover up to 500m. Differentiate ore body types on the basis of their economic viability at different depths, and the ability of existing detection methods to identify them in various terranes.					
Development of relevant projects and teams to undertake new research in this area						
Further appraisal of mechanisms realistically responsible for observed metal migration through and within post mineralisation cover						
Appraise the use of existing technologies, eg. gas, ferruginous materials within, or at base of cover, and other potential sampling media						
Conclude AMIRA P618						
Engage industry partners in development of collaborative projects for research in this area						
STREAM 3: Weathering of Ore Deposits	**OBJECTIVES:** To determine the depth of weathering around ore deposits, and understand the deep weathering of ore deposits, especially those of gold, base metals and iron, and the implications for exploration and mining. A prime aim will be to assist in the transition from open pit to deep underground mining.					
Complete project proposals in consultation with industry						
Initiate research programs in partnership with industry						
Engage industry partners for collaboration on research projects related to weathering of ore deposits and prospects						
THEME 4: Knowing what to mine	**GOAL:** Cost-effective tools and strategies to convert resources to mineable reserves. Develop tools for delineating and quantifying ore body quality and grade. Develop systems to quantify geological uncertainties associated with the conversion of resources to reserves.					
STREAM 1: Value from drilling	**OBJECTIVES:** Develop techniques to substantially reduce drilling costs either by reducing the cost of each metre drilled, and/or by decreasing the metres that need to be drilled to achieve the same increase in knowledge. Develop techniques to increase the information derived for drilled material.					
Develop prototype Fourier-Transform-Infrared (FTIR) spectrometer engine for next generation core logging system						
Complete prototype chip-logging hardware sensing system						
Complete prototype next generation core logging software interpretation system						
Complete prototype laboratory micro core-logging spectrometer system for classification of ore types						
Conduct at least two operational, pre-commercial, externally funded, core logging service campaigns (case studies) for industry						
Complete commitments to EM-CMIS-Grain Research Board objective grain quality testing project						
Cross-hole Tomography • Continue data analysis and interpretation						
• Complete seismic tomography interpretation for Xstrata/ACARP						
Submit AMIRA proposal to demonstrate quantitative talc prediction to better than 5% to improve ore processing efficiencies						
Submit AMIRA proposal for Porphyry Copper core logging study in the US and/or Chile						
Refine business plan, find commercial partner(s) and develop commercialisation strategy for core-logger manufacture and service						
Submit ACARP proposal fopr core-logging applications in the coal industry						
STREAM 2: Resource delineation	**OBJECTIVES:** Develop new technologies and apply assessment techniques to identify, define and quantify the extent, grade, continuity and rock properties of a resource. Develop and apply new technologies and assessment techniques that contribute to enhanced understanding of geology as inputs to the total mining process.					
Ore delineation projects • Complete ACARP Seiswin depth integration						
• Finalise proof-of-concept for NMR Cu assessment and review next steps						
• Further development of automated petrographic analysis and interpretation techniques						
Ore characterisation projects • Coal biomass characterisation						
• Development of next generation SIROLOG technology that will contribute to geotechnical assessment of borehole data						
Complete prototype spectrometer sensing system using artificial illumination for mine face mapping for nickel laterite and iron ore applications						
Complete first prototype laboratory spectrometer system for classification of iron ore types Geological uncertainty • Complete scoping review						
Conduct externally funded, trial nickel laterite face mapping grade prediction for Falconbridge Nickel in New Caledonia (Phase 5 of ongoing relationship)						
Conduct externally-funded, trial iron ore grade mapping projects with at least one of OneSteel, Robe River, and Hamersley Iron						

KEY:

COLUMNS 1-4
Strong | Significant | Minor

RIGHT HAND COLUMN
APG achieved | Significant progress toward achievement of APG | APG not achieved

THEME 4: (continued)		ARRC Activity	Benefits WA Industry	International Linkages	Contributes to Flagship	APG Performance
STREAM 3: Data Integration	**OBJECTIVES:** Develop and apply enhanced data integration and 3D/4D visualisation techniques to maximise the value of all data inputs when determining the reserve and the mining method and process					
Virtual Mine: • Release new 3D graphics browser in Q3/2003						
• Develop additional models: – Robe River Iron-ore (Bungaroo Creek, Mesa J deposits) – ACARP 3D Risk Mapping						
Geological synthesis: • Complete phase 2 of the Bowen Basin aeromagnetic integration						
Continue with ACARP Rangall geological integration project						
STREAM 4: Geotechnical assessment	**OBJECTIVES:** Develop and apply methods and instrumentation that will predict the reaction of rock and fluids to excavation with the outcomes of improved selection of appropriate mining method, reduction of the risk in mine planning and investment.					
Apply COSFLOW to gas prediction and mine planning in Australia and develop further major projects in this area						
Code improvement to cover • Groundwater assessment						
• Subsidence control						
• Longwall top coal caving (LTCC)						
Rock mass geotechnical characterisation • Complete ACARP Quantitative Logging project						
Complete NEDO geotechnical characterisation from borehole geophysics						
THEME 5: Mine Productivity	**GOAL:** Increase the economic output of mining operations through the development and implementation of improved extraction methods and improved production consistency to yield an increase in the level of viable recovery of the resource.					
STREAM 1: Mining geoscience	**OBJECTIVES:** Develop and apply new technologies and assessment techniques that contribute to enhanced understanding of geology as inputs to the total mining process.					
Grade control • Implement SIROLOG blasthole logging system at Anglo South American mines						
• Implement new production logging tool for Codelco through IAEA						
• Complete assessment of SIROLOG application for defining reactive shales in blast holes for BHP-B						
Ore quality control • Complete ACARP Sticky Coal 2 project						
Use of real-time ash determination in coal preparation plants						
Reconciliation • Complete scoping study						
STREAM 2: Data Integration	**OBJECTIVES:** Develop and apply enhanced data integration and 3D/4D visualisation techniques to maximise the value of all data inputs when determining the reserve and the mining method and process.					
Landmark: Longwall Automation • Implement application server, database & seam horizon modelling system for the monitor station						
• Establish on-line environment at QCAT for monitor station system testing						
STREAM 3: Rock breakage	**OBJECTIVES:** Develop and implement the use of new cutting materials and methods that enhance the effectiveness of mining and excavation equipment for improved fragmentation, reduced power consumption and improved recoveries					
Improved wear & impact resistance of diamond composite materials						
STREAM 4: Mining geomechanics	**OBJECTIVES:** Develop and apply methods and instrumentation required for detailed mine design and optimisation in operating mines.					
Rock mass stress monitoring • Continue with fundamental research into microseismic measurement and rock fracture mechanisms						
Develop a prototype of longwall shield convergence monitoring systems						
Develop portfolio of research and consultative contracts under the Strata Control Technology (SCT) Strategic Alliance umbrella						

THEME 5: (continued)	ARRC Activity	Benefits WA Industry	International Linkages	Contributes to Flagship	APG Performance
STREAM 5: Mine Imaging — **OBJECTIVES:** Develop and implement advanced data capture, processing and interpretation techniques using digital imaging of rock surfaces within the active mining environment					
Develop an automated 3D imaging system suitable for use with equipment such as the Automated Continuous Bolting Machine					
Develop 3D imaging based software system for improved blast design and blast assessment					
STREAM 6: Automation and control systems — **OBJECTIVES:** Develop and implement advanced automation, guidance, sensing and communication technologies to build mining systems that improve the productivity of operations and remove people from the direct control of machinery.					
Longwall Automation • Face alignment and steering trials in current year					
• Commercial prototype timetable: – Shearer position measurement system – 04/04 – Face alignment system – 04/04					
Excavator Guidance Systems: • Follow-up WMC proposal					
Complete proposed project if successful					
Automated Vehicles • Complete commercial transfer agreement with DAS					
Complete proposal for Bell Bay hot metal transfer					
Carry out hot metal transfer work if proposal successful					
Continue to propose shuttle car automation					
Automated Vehicle Fleet Interaction • Follow-up potential sponsors towards proposal					
Draw Point Equipment • Propose method of remote inspection, rock depth measurement and explosive placement for draw points at Northparkes Mine					
Geological Sensing • Complete technology review and prioritise development plans for first prototype sensing system					
STREAM 7: Advanced Mining Systems — **OBJECTIVES:** Develop and implement innovative development and extraction approaches, both technical and managerial, to a range of deposit types including low-grade metal resources and coal, thick and steeply dipping coal resources, and the enhancement of current mining systems, such as rapid roadway development.					
Rapid Roadway Development – Complete trials • Bolts - Autonomous Conveying and Bolting Machine					
• Finalise commercialisation vehicle					
• Finalise specification of commercial system					
Investigate Continuous Haulage options					
Continue Systems Approach as a research consulting initiative					
Advanced Mining Systems • Progress commercial relationship with Yankuang (China)					
• Initiate technical and feasibility studies with prospective targets					
• Further the development of relationships with other equipment manufacturers					
Identify characteristics for viable underground coal gasification processes and environmental barriers to implementation					
Select a site in the Surat basin that is potentially suitable for a Underground Coal Gasification (UCG) demonstration					
Remote Ore Extraction Systems – Automated Horadiam Stoping • Undertake scoping project with ORICA					
• Establish partnership with ORICA if suitable					
• Progress development of commercialisation strategy and finance					
• Develop drill control methods					
• Design mechanical components of drill platform					
• Conceptual design of explosive placement					
• Complete scoping study on project 'Deep lead mining in Victoria'					
• Follow-up with Sord Technologies and prepare proposal if required					
Deep sea mining • Follow-up with Nautilus and prepare proposal if required					
Lake Deposit Mining • Follow-up with Lake Lefroy and prepare proposal if required					

KEY:

COLUMNS 1-4
Strong | Significant | Minor

RIGHT HAND COLUMN
APG achieved | Significant progress toward achievement of APG | APG not achieved

THEME 5: (continued)		ARRC Activity	Benefits WA Industry	International Linkages	Contributes to Flagship	APG Performance
STREAM 8: Mine Monitoring and Communication	**OBJECTIVES:** Develop and implement new communications for risk management in mines that are applied in hazard detection and people location, data acquisition and integration, and safety management systems.					
VOIS Complete commissioning of VOIS platform						
Define modifications required for integration with ROES						
THEME 6: Mine Safety	**GOAL:** Develop and implement technologies that assist in the reduction of injuries and fatalities by removing mine workers from hazardous environments, improving operating conditions and creating a safer and healthier workplace.					
STREAM 1: Mining geomechanics	**OBJECTIVE:** Develop and apply methods and instrumentation that will predict the reaction of rock and fluids to excavation with the outcomes of improved selection of appropriate mining method, reduction of the risk in mine planning and investment, and improved mine design in operating mines.					
Real Time Ground Monitoring and Interpretation: • Develop real time advanced roof monitoring system through the JCOAL roof monitoring project						
• Develop mine wide, integrated strata monitoring and interpretation system through the Grasstree project						
• Develop wireless extensometers for both coal and metalliferous mines						
• Develop commercial partnerships to provide ongoing supply and support of the new monitoring systems						
STREAM 2: Mine Imaging	**OBJECTIVE:** Develop and implement advanced data capture, processing and interpretation techniques using digital imaging of rock surfaces within the active mining environment.					
Develop extensions of 3D imaging to improve structural mapping						
With cooperation of GMRA partners, develop Stage 2 of project aimed at providing improved methods of predicting the reliability of rock stopes in large open-pit mines						
Develop extensions of 3D imaging for application to accident investigation and reconstruction						
Develop 3D imaging based software system for predicting the likelihood of formation of hazards and the assessment and visualisation of risk associated with hazards						
STREAM 3: Automation and Control Systems	**OBJECTIVE:** Develop and implement advanced automation, guidance, sensing and communication technologies to build mining systems that improve the productivity of operations and remove people from the direct control of machinery.					
Sand mining dredge remote control: • Complete scoping study						
• Co-ordinate implementation if required by CRL						
• Propose pond-bottom profile research						
Draw Point Equipment: • Propose method of remote inspection, rock depth measurement and explosive placement for draw points at Northparkes Mine						
Drill Monitoring (Coal): • Continue to develop proposal for system at Crinum mine						
Transparent Lid Flameproof						
STREAM 4: Advanced Mining Systems	**OBJECTIVE:** Develop and implement innovative development and extraction approaches, both technical and managerial, to a range of deposit types including low-grade metal resources and coal, thick and steeply dipping coal resources, and the enhancement of current mining systems, such as rapid roadway development.					
Progress commercial relationship with Yankuang (China) and other Chinese operations						
Initiate technical and feasibility studies with prospective targets						
Further the development of relationships with equipment manufacturers						
STREAM 5: Mine monitoring and communication	**OBJECTIVE:** Develop and implement new communications for risk management in mines which are applied in hazard detection and people location, data acquisition and integration, and safety management systems.					
A fully integrated system using the latest in ethernet and fibre-optic communications technologies						
Full-scale and operational system being installed at Grasstree Mine in Central Queensland						
LAMPS: • Complete IS certification						
• Lamp reader IS certification process submitted to SIMTARS						
• Complete commercial agreement with Minecom if possible						
Mine integration of robust gas monitoring & communication						
Submit requirements documentation						
Submit system design						
Demonstrate applications & graphical interface using off-line data						

THEME 6: (continued)		ARRC Activity	Benefits WA Industry	International Linkages	Contributes to Flagship	APG Performance
STREAM 6: Mine environment management	**OBJECTIVE:** Develop and apply technologies for the management of the total mine environment to enable safe and hygienic working conditions in surface and underground mines.					
Gas, Ventilation and Heatings: • Pro-active inertisation strategies – to prevent heatings						
• Longwall dust control						
• Spontaneous combustion – detection and control						
• Goaf gas control						
• Gas reservoir modelling – Greenfield sites						
• Integration of vent. and gas flow softwares						
Real time microseismic monitoring: • Complete final report for Lihir on Stage 1 and scope out and finalise stage 2 monitoring						
An advanced gas drainage system (the microtunneller) that can significantly lower the cost of extracting gas from coal						
Demonstration of a collision avoidance system at a mine site						
GAG upgrade						
THEME 7: Social & Economic Integration	**GOAL:** Improve the alignment of industry with community expectations (licence to operate) through understanding and minimising the impacts while maximising the social and economic benefit of mineral and energy production.					
STREAM 1: Hydrology and subsidence	**OBJECTIVE:** Develop and apply methods and instrumentation that will predict the reaction of rock and fluids to excavation with the outcomes of improved selection of appropriate mining method, reduction of the risk in mine planning and investment, and improved mine design in operating mines.					
Develop the overburden grout injection process within the ACARP project						
Develop expertise in mine ground water assessment in collaboration with Springvale Colliery						
Develop new projects in the mine groundwater assessment and control areas						
STREAM 2: Environmental management	**OBJECTIVE:** To provide methods for understanding, managing and mitigating environmental impacts, including: the management of greenhouse gas emission for mines; methods to measure and verify emissions; mitigation techniques which use mine methane to generate power and reduce emissions; rehabilitation of mined land and water management on mine sites.					
Subsidence assessment and control: • Develop the overburden grout injection process within the ACARP project						
• Develop advanced subsidence assessment methods						
Ground water assessment and control: • Develop expertise in mine ground water assessment in collaboration with Springvale Colliery						
• Develop assessment tools						
Predictive AMD and salinity characterisation: • Complete laboratory measurements and field trials						
A prototype design to provide coal producers with an efficient and economical technology to mitigate and utilise almost all of methane emitted from ventilation air: • Initial design for a demonstration of "clean" energy from coal						
• Patented turbine design powered by 1% methane						
STREAM 3: Social responsibility	**OBJECTIVE:** To understand the issues affecting the acceptability of mining and energy technology and their affect on research, technology development and commercialisation. Issues include the social and political perceptions about the mining and energy industries, options for new energy technology and interactions between community, industry and policy.					
Best practice guidelines for a social impact assessment around a UCG demonstration in the Surat basin						
Design for stakeholder engagement programme in the Queensland Energy Centre						
STREAM 4: Mine Imaging	**OBJECTIVE:** Use remote imaging techniques to plan and monitor mine rehabilitation.					
Complete airborne mapping pilot study						
Develop applications of terrestrial photogrammetry in collaboration with clients						

CSIRO PETROLEUM

Strategic Alignment – Our Core Purpose

Delivery of science and solutions vital to maintaining a globally competitive and sustainable Australian energy industry, with a primary focus on oil and gas.

KEY:

COLUMNS 1-4
Strong | Significant | Minor

RIGHT HAND COLUMN
APG achieved | Significant progress toward achievement of APG | APG not achieved

THEME 1: Maximising Australia's Oil Self Sufficiency	GOAL: By scientific research and development, contribute to the maintenance of at least the current level of Australia's oil self-sufficiency.	ARRC Activity	Benefits WA Industry	International Linkages	Contributes to Flagship	APG Performance
STREAM 1: Reducing regional exploration risk	**OBJECTIVE:** To develop and apply technologies and methodologies that will increase wildcat drilling success rate and will encourage exploration drilling in new or lightly-explored, frontier provinces.					
Laser micropyrolsyis GC-MS study of families of solid bitumens in reservoirs as a tool to understand filling history and oil change						
Use of borewater dissolved gas as a predictive tool for leakage from oil and gas reservoirs in NSW, method refinement and integration with geochemical analyses as an exploration tool						
Diffusion experiments on new minerals (zircon and titanite) for U-Th/He thermochronology, to extend the temperature range (thermal history) from 70ºC to 200ºC.						
Development of a laser-induced spectral fluorescence microscopy capability for thermal maturity assessment						
Establishing the combined FAMM-reflectance methodology for thermal maturity assessment, to aid uptake of the new technology into the existing industry data						
Evaluate different test methodologies for the investigation of microbial populations in biodegraded oil fields						
Develop technique for the reliable gross fractionation of extracted fluid inclusion oils prior to GC-MS analyses						
Determine factors controlling the abundance of oil inclusions: upgrade interpretation of GOI technique						
Determine temperature and pressure at which oil accumulates by fluid inclusion measurements						
Detect oil migration pathways, apply to Timor Sea oil province						
Demonstrate QGF-E technique for detecting oil zones						
Develop and demonstrate applications of Ar geochronology to dating diagenesis and brittle deformation						
Completion of Sr chronostratigraphy demonstration project on Cepu Field (NE Java)						
Publication of PNG Sr chronostratigraphy results						
Documentation of ongoing petroleum systems analysis of E Papuan Basin						
Investigate application of self organising maps and neural nets to chemostratigraphic correlation with demonstration project on Bayu Undan documented						
Testing and documentation of Sr RSA on turbidites						
Enhance links with FSA & CLW on Sr isotope applications to groundwaters and foods						
Continued improvement of Sedsim Code (Release of version 7 in 2004 with organic facies module, geostrophic currents, storms and improved carbonates)						
Externally funded regional study on the Southern Margin/GAB - present paper at EABS 2004						
Modern and palaeo-turbidites study documented for Chile-Peru Trench (in collaboration with Berlin Free University and WA-255 Cretaceous turbidites						
Perth Turbidite Interest Group established and recognised by workshop attendance						
Study primary hydrocarbon – migration as part of the CSS "Multiscaling in natural systems" and incorporate results in a Sedsim module						
STREAM 2: Optimising reservoir definition and performance	**OBJECTIVE:** To develop and implement methodologies that have the potential to increase average oilfield recovery factors in Australian fields.					
Predict top and fault seal integrity to enable industry to reduce seal breach risk both post and pre-drill directly and through integration with multi-disciplinary datasets and disciplines						
Delivery of integrated fault seal integrity Toolkit (June 04) with marketing by publication and industry workshops						
Collaborative industry project with TNO to develop North Sea Pressure database and analysis. Use our PressureQCTM, PressurePlotTM and PressureDBTM to deliver GIS-based pressure system analysis and fault seal analysis						
Develop the ARRC Petrophysics Laboratory providing new capability to investigate petrophysical properties of fault and top seal rocks as well as unconsolidated rock samples						
Deliver to HC Water Future WA-SW interpretation of deep aquifer interactions and incorporate in PRAMS model						

STREAM 2: (cont) Optimising reservoir definition and performance	OBJECTIVE: To develop and implement methodologies that have the potential to increase average oilfield recovery factors in Australian fields.	ARRC Activity	Benefits WA Industry	International Linkages	Contributes to Flagship	APG Performance
Extend the 'Delivery' software developed in 2002/03 to be applicable to 4D seismic inversion (June 2004)						
Compile final report for APCRC Program 2 Reservoir characterisation to cover the last 7 years of achievements (June 2004)						
Produce and demonstrate preliminary 3D syntactic reservoir characterisation methodology in collaboration with CIT syntax group						
Complete Phase 1 ARM turbidite channel project and position for Phase 2						
Prepare and submit for publication ARM experimental work						
Implement collaborative activity with Chinese Academy of Science; plan for geoacoustics participation, and post-doc input to imaging project						
Initiate collaborative activity with Italy						
Plan imaging research framework with Curtin targeting imaging and seismic resolution issues						
Complete international search on quantitative pore pressure prediction patent application						
Define commercialization/transfer strategy and partners for patent						
Complete pilot study and present results to industry at workshop/conference						
Complete wrap up documentation for APCRC Pore pressure Program						
Develop plan for post-Pore Pressure, Experimental Reservoir Physics program						
Integrate geophysics and petrophysics experimental work						
Continue development of commercialization of rock physics calibration for 4D modelling						
Investigation of inorganic manifestations of biodegradation and effects on reservoir properties						
Define, create new prototype, and test enhanced strategic risk assessment protocol based on evidence capture and representation						
With CSIRO Business Development and Commercialisation support, embed Juniper uncertainty representation into third party commercial software						
STREAM 3: Improving drilling and well performance	**OBJECTIVE:** In the next five years, develop and implement at least one high-impact technology per year in the form of processes, tools, and/or services to the oil industry, with the aim of improving well planning, construction and performance throughout the well/field life.					
Define and specify set of information management and decision-support tools for drilling and completions operations, with focus on complex wells, for future implementation into an advisory system tool						
Workshop for definition of main project topics in cooperation with CSIRO Manufacturing and Infrastructure Technology and external institutions						
Definition of project team and proposal to the industry						
Initial development towards Knowledge Framework and specific applications, such as drilling hydraulics, cuttings transport, and drilling rate						
Build experimental facility and collect laboratory and field data on drill-string vibration for model validation						
Modelling and software prototypes for: Drill string resonance vibrations; Slip stick vibrations; 3. Pulse depressurization.						
Develop Driller's Wellbore Stability Tool with application to Ceuta-Tomoporo shale stability project documented						
Enhance technologies for management of shale stability and determination of shale properties from down hole logs/rig site measurements with applications to projects worldwide documented						
Develop technology for managing wellbore stability in naturally fractured formations and hydrate-bearing sediments						
Enhance sand production prediction technology, incorporating effect of water and gas-cut, with applications to Perseus-Goodwyn project documented						
Develop technology to evaluate performance of drill bit cutter and to optimize cutter geometry for drilling in low permeability formations						
Field trialling of BarOmega mud system conducted						
Develop technology to characterise and remove mud-related formation damage						
Modify and evaluate starch for high pressure-high temperature drilling fluids						
Identify and evaluate vegetable oil-based dielectric fluid for transformers						

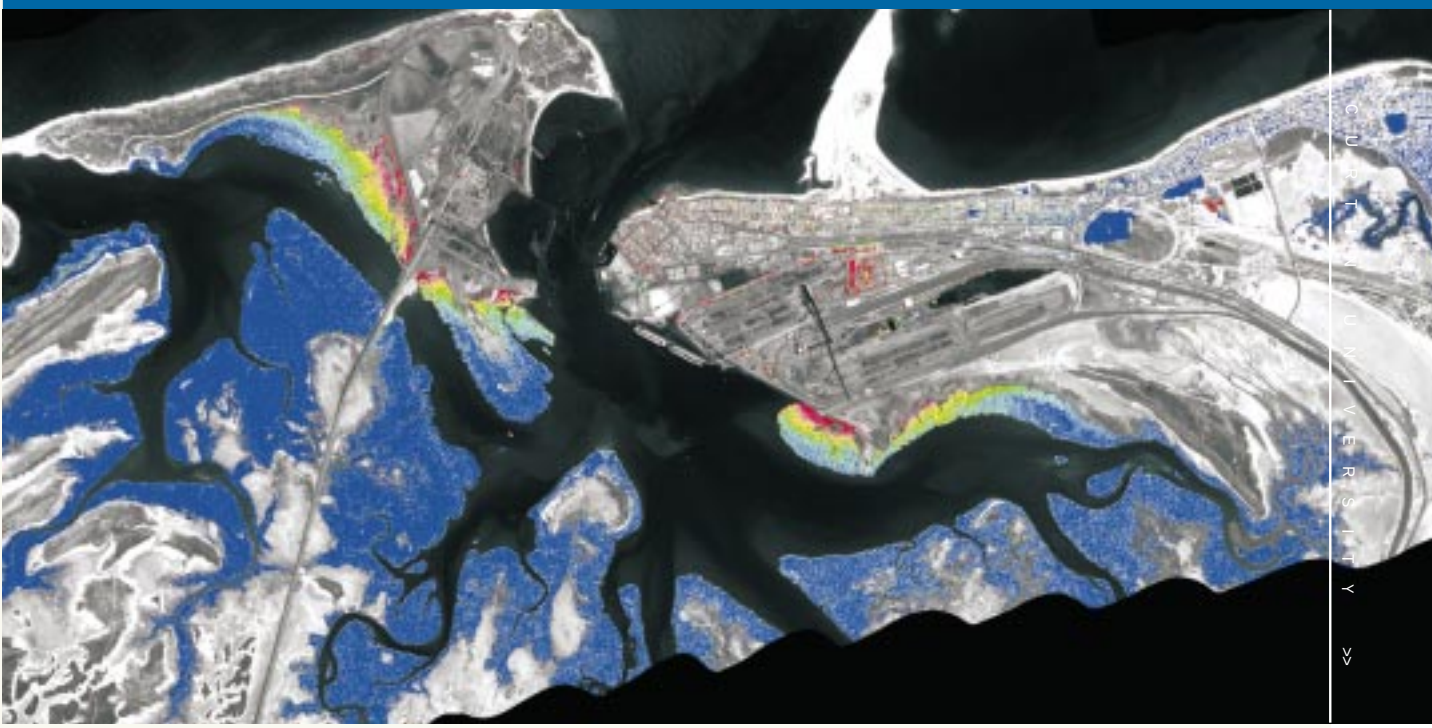
KEY:

COLUMNS 1-4
Strong | Significant | Minor

RIGHT HAND COLUMN
APG achieved | Significant progress toward achievement of APG | APG not achieved

		ARRC Activity	Benefits WA Industry	International Linkages	Contributes to Flagship	APG Performance
THEME 2: Supporting Australia's Gas Future	**GOAL:** To strengthen Australia's energy security and world environmental sustainability.					
STREAM 1: Producing unconventional gas	**OBJECTIVE:** To enhance discovery and economic production of gas from low permeability gas reservoirs					
Relate gas composition and source (bulk composition and isotopes) to porosity/permeability to determine 'sweetspots' of high production in CBM		Minor	Minor	Significant	Minor	Strong
Determination of hydraulic fracture crossing interactions with frictional and material property interfaces		Minor	Significant	Strong	Minor	Strong
Growth, stability and fracture path for a hydraulic fracture near a free surface		Minor	Significant	Strong	Minor	Strong
Inverse modelling of data from field experiments to obtain fracture orientation, extent, width, and growth rate		Minor	Significant	Strong	Minor	Strong
Design methods and models for fracture growth in fractured rock		Minor	Significant	Strong	Minor	Strong
Experimental trial modification of in-situ stress field for preconditioning of sandstone by propped hydraulic fractures		Minor	Significant	Strong	Minor	Strong
Develop techniques for casing		Minor	Significant	Strong	Minor	Strong
Conduct spatially intensive field and laboratory measurements of key reservoir and geomechanical parameters (particularly permeability and strength) of coal seams and develop geostatistical models of spatial variability of these parameters		Minor	Minor	Strong	Minor	Significant
Investigate the influence of parameter variability on coal seam gas drainage prediction and design, using recently developed coupled models (SIMED-FLOMEC-DYNAFRAG)		Minor	Minor	Strong	Minor	Significant
Develop improved safety and risk management criteria for underground mining in gassy coal seams		Minor	Minor	Strong	Minor	Strong
Develop and validate an improved well model for simulation and design of long horizontal gas drainage wells		Minor	Significant	Strong	Minor	Strong
STREAM 2: Developing CO_2 sequestration	**OBJECTIVE:** Create technologically safe, economic and societally acceptable underground storage technology options					
Complete input into Carbon Capture Project geomechanical seal monitoring project		Significant	Strong	Strong	Strong	Strong
Define and startup CO_2CRC verification and monitoring project plans		Significant	Strong	Strong	Strong	Strong
Deliver hydrodynamic analysis of site investigations for CO_2 storage, prove hydrodynamic trapping concept and integrate with geological model		Significant	Strong	Strong	Strong	Significant
Deploy evidence-based risk and uncertainty protocol as the framework for managing environmental science issues related to policy development and public stakeholder risk assessments		Strong	Strong	Strong	Strong	Strong
Apply agent-based modelling techniques to assessment of CO_2 capture economics and investment risk scenarios, including (in conjunction with University of Melbourne) modelling of impact likely green consumer behaviour		Strong	Strong	Strong	Strong	Significant
Complete investigation of the stability and convection of dissolved CO_2 in groundwater		Minor	Strong	Strong	Strong	Strong
Establish coupled geochemistry capability within CO_2 reservoir simulation based on using TOUGHREACT		Minor	Strong	Strong	Strong	Strong
Collaborative study utilising FTIR technologies to monitor CO_2 leakage at natural sites of CO_2 storage and determine natural background levels of leakage		Strong	Strong	Significant	Strong	Significant
Assess the role of microbes in the consumption of CO_2 to methane in coal-bearing sequences, and possible mechanisms to enhance microbial activity as a means of sequestering CO_2 permanently		Minor	Minor	Strong	Strong	Significant
Interpret the outcomes of field experiments (RECOPOL) and laboratory studies (DET) on the fundamental interactions of supercritical CO_2 with coal, and rates of adsorption / desorption of CO_2-CH_4-N_2 mixtures		Minor	Minor	Strong	Strong	Strong
Formulate mathematical descriptions of these interactions for incorporation in and further development of reservoir simulation models (SIMEDII, FLOMEC)		Minor	Minor	Strong	Strong	Strong
Relate adsorption /desorption of CO_2 and CH4 to coal types and rank		Minor	Minor	Significant	Strong	Strong
Study CO_2, saline water and mineral matter in and adjacent to coal seams with low and high CO_2 concentrations, using carbon budgeting and mass balance methods		Minor	Minor	Significant	Strong	Strong
STREAM 3: Novel gas processing technologies	**OBJECTIVE:** Identify game-changing technologies that make the economics of gas transportation and gas-to-liquids conversion compelling by 2009					
Complete study of partial oxidation process at low and high pressures in the presence and absence of CO_2		Minor	Strong	Strong	Minor	Strong
Investigation of catalyst coatings		Minor	Strong	Strong	Minor	Significant
Investigate the activity and selectivity of novel catalysts for syngas conversion to synfuel		Minor	Strong	Strong	Minor	Strong
Initiate studies of methanol production and use		Minor	Strong	Strong	Minor	Strong
Initiate studies of alternative routes from natural gas to liquids including acetylene processing		Minor	Strong	Strong	Minor	Strong
THEME 3: Wealth from Oceans Flagship	**GOAL:** To position Australia by 2020 as an international benchmark in the delivery of economic, social and environmental wealth based on leadership in understanding ocean systems and processes.					
STREAM 4: Seabed modelling and responses	**OBJECTIVE:** To deliver national capacity to forecast the future state of the oceans' seabed based on climate change and human influence by 2008					
Involvement in Wealth from Oceans Flagship Program – Australian Seabed Study defined and initiated		Strong	Strong	Significant	Strong	Strong
Coastal Management study documented (SA or WA report completed)		Strong	Strong	Significant	Strong	Strong

RESEARCH HIGHLIGHTS AND ACHIEVEMENTS



Port Hedland dust map produced from hyperspectral data.

New tool for better management of mine dust

Dust, derived from mining and handling ore, is a major issue for the Australian mining industry. Managing the environmental impact may be critical to some resource industries' future viability. Using conventional manual field methods could potentially involve a multi-million dollar expense.

Working with BHP Billiton at their Port Hedland iron ore handling facility, CSIRO Exploration and Mining scientists have developed a very cost-effective remote sensing method to monitor and manage dust. Focussing on dust impacts on some 4,800 hectares of mangroves surrounding the harbour, the study developed the operational use of hyperspectral data for dust monitoring.

This project has provided BHP-Billiton with a powerful, non-intrusive and non-destructive management tool to efficiently and effectively monitor its operations. The new tool has generated broad interest in environmental agencies and legislative bodies. Its success, also applicable to other iron ore handling facilities, could lead to the incorporation of this innovative method in the Government agreement for the operation of the handling facility.

Better computer models for faster exploration results

The computational simulation of ore forming processes is becoming an increasingly important exploration tool for mining companies, and the pressure is on to make them even faster.

The critical issue is assessing enough models so companies can solve mineral targeting problems in the time frame of a typical exploration program.

A project which has moved towards resolving this has been carried out by CSIRO Exploration and Mining's Computational Geoscience Group through the pmd*CRC. It focussed on the targeting issues of a major WA gold mining company on some of its Yilgarn Craton exploration tenements.

The Group has developed a system for model template development using the macro language, FISH, in the mechanical-fluid flow modelling program, FLAC3D.

This new system enabled researchers to vary parameters and geometries for many models much faster than previously possible. >>

The initial company study yielded results in a couple of months, and these were used to better guide target selection and drilling strategies.

The work has introduced a significant new tool into the company's exploration strategy mainly because results can be available more quickly.

Generating greater understanding of geological processes

Fluid flow, fracturing and brecciation are critical geological processes within mineralising systems and understanding them is vital for exploration and mining companies. CSIRO Exploration and Mining's Computational Geoscience Group, through the pmd*CRC, has contributed to this understanding by developing new computational simulations.

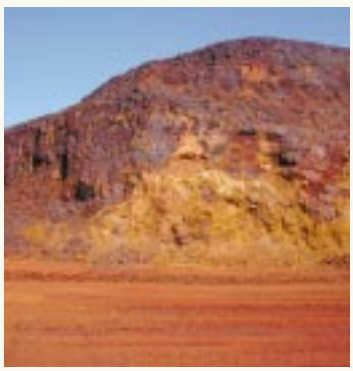
These simulations have demonstrated the development of fracture systems, in two and three dimensions. The work has validated the mechanics against physical deformation experiments, and against field observations of rock structures.

The project's success has led to industry acceptance of the concepts and technologies.

The work has also further developed researchers' skills in using the relevant software, and has increased the overall knowledge about the mechanics of fracturing and its mathematical descriptions.

Better definition of clay impurities in iron ore

The shift in the focus of Australian iron ore mining companies towards the more plentiful Marra Mamba, or Channel Iron Deposits (CID) type of iron ore, has generated a need for more efficient ways to determine clay impurities. Clay contaminants in Pilbara CID ores reduce their overall grade and quality, so companies must carry out expensive post-extraction processing. This means they are seeking new ways to quickly and efficiently quantify the type and abundance of clays in iron ore.



A profile of CID ore.

Working with Robe River Mining, CSIRO Exploration and Mining's Terrane Science Group has carried out a spectroscopic investigation of different clay minerals. This project showed that variations in spectral signatures can point to what clay types, and how much, are in CID iron ore.

The project outcomes are now being applied to aid the development of a large scale technique at a Perth-based commercial analytical laboratory. The ultimate aim is to develop a routine procedure for quantifying the chemistry and clay mineralogy of not only CID iron ore, but also of more traditional bedded ore types.

Looking for hidden wealth in the Yilgarn

Despite the long and successful history of mineral exploration in the Yilgarn Craton, one of the world's premier mineral provinces, regional geochemical data are patchy and commonly of poor quality. Because much of the Yilgarn is semi-arid, and has a poor drainage network, it has been difficult to select a suitable, uniform sample medium, to replace the stream sediments that are used in many other regions. However, ferruginous lateritic materials are widespread across the Yilgarn, and broad-spaced laterite sampling has been shown to be an effective substitute. Laterite surveys have shown that broad geochemical trends in the Yilgarn correspond to known mineral districts. Modelling of these trends indicates that continuations of these districts, or even new districts, may lie undetected below drainage basins or the covered margins of the Craton.

A three year project, by CSIRO Exploration and Mining in conjunction with the Geological Survey of Western Australia and CRC LEME will use laterite sampling at 9 km intervals to produce a geochemical map of the western part of Yilgarn Craton. The SW quadrant of the Craton is almost completed, with 650 new samples taken to date, supplementing those held in existing collections.

The key objective is to demonstrate the value of pre-competitive geochemical mapping to enhance the prospectivity of the Yilgarn Craton and increase exploration and exploitation of its mineral wealth.

Potential beneficiaries include the State and Federal Governments, mining and exploration companies. The geochemical map will also provide the mining industry with a high quality 'control dataset' to enhance the value of existing information. In addition, it will also provide regional background data for local exploration and base line data for environmental studies.

Web services provide access to exploration information

Mineral exploration is a knowledge-based process relying on access to accurate, up-to-date geo-spatial data and related scientific knowledge. However industry has highlighted difficulties in accessing pre-competitive geoscience information as the information is often incomplete, fragmented across government agencies and stored in incompatible management systems and databases.

The recent *Draft Minerals Exploration Action Agenda* recommended the Commonwealth, States, Territories and industry cooperatively develop a standard nation-wide system providing internet-based access to exploration-related data. CSIRO Exploration and Mining, along with Geoscience Australia, the State and Territory Geological Surveys, Social Change Online, the Minerals Council of Australia and pmd*CRC have taken the project on board, bringing together their technologies and expertise to improve on-line delivery of resources data.

Called the Solid Earth and Environment Grid (SEEGrid) Roadmap and Testbed, the project is now underway and being conducted in three phases: (1) development of a technology roadmap for inter-operability; (2) demonstration of a multi-level user access platform; and (3) stakeholder feedback workshop. The technology to be disseminated has been developed through CSIRO Exploration and Mining's Glass Earth and XMML (eXploration and Mining Markup Language) projects.

A successful outcome would be the improvement of national and international access to pre-competitive information and, potentially, on-line processing tools that enable exploration companies to assess exploration potential more rapidly. The same technology could potentially be applied to other Australian industry sectors, as well as public domain issues such as disaster management and security. It would position Australia as a global leader, not only in mineral exploration innovation, but in managing intelligence across a variety of industry sectors.

Simon Cox is developing a language for the geosciences that will enable data to be shared between multiple software packages. Photographer: Darren Peroni

Seismic methods prove valuable for gold exploration

Mineral exploration using geophysical methods, like gravity or magnetic surveys, is commonplace, but the use of seismic methods for gold exploration in hard rock terranes is not. The seismic method is the most powerful geophysical approach, but the accepted belief is that this cannot be applied in complex hard rock environments.

An on-going two-year project, by researchers at Curtin University's Department of Exploration Geophysics, is changing this view. They are applying innovative processing methods to new seismic data being acquired in the Goldfields.

The two-year project is being sponsored by the Minerals and Energy Research Institute of WA (MERIWA), St Ives Gold Mine, Sons of Gwalia, Placer Dome Asia Pacific and AngloGold.

An experimental program has already been conducted, involving 150 line kilometres of surface seismic data over six gold mine sites in the Kalgoorlie – Leonora region.

This specialised processing, consisting of pre-stack time and depth imaging, was employed for the first time for gold exploration. It has provided a significant improvement in seismic images, clearly showing that reflection seismic data will be of great value to the gold mining industry.

This research has meant that new exploration targets have been identified and drilled. The Program's success prompted the sponsors to start designing an early 3-D seismic exploration program in 2004, instead of 2006, as originally planned.

The Alphachron™ He Extraction/Measurement Instrument represents the latest developmen in (U-Th)/He technology. This is an automated, integrated and compact turnkey system, designed for the extraction and measurement of gases from mineral samples. The instrument is prefabricated and ready for implementation after delivery with minimal commissioning.

State-of-the art thermochronology lab re-located to WA

(U-Th)/He thermochronometry is a highly sensitive method of determining the low temperature thermal history of rocks in the Earth's crust. CSIRO's (U-Th)/He Thermochronometry Facility was successfully relocated from the Mineral Resources Laboratory in Sydney, New South Wales, to the John de Laeter Centre for Mass Spectrometry at Curtin University of Technology, Perth, Western Australia, during the first half of 2004.

As the only laboratory in the world to routinely apply low temperature thermochronology to mineral and petroleum exploration, the (U-Th)/He facility is co-owned and operated by CSIRO Exploration and Mining (for copper, gold and base metal exploration) and CSIRO Petroleum (for oil and gas exploration). The major benefit of this technology lies in the ability to quantitatively determine the low temperature thermal histories of mineral belts and petroleum basins, data that are critical to the understanding of deposit formation.

Key scientific staff from CSIRO were re-located from Sydney to Perth including Brent McInnes, Noreen Evans, Peter Crowhurst and Brad McDonald. Since recommissioning the facility, the CSIRO team has established close working relationships with other members of the John deLaeter Centre and with the School of Earth and Geographical Sciences at The University of Western Australia, where CSIRO has access to a mass spectrometer for U and Th analysis.

Current (U-Th)/He thermochronometry collaborators include Guangzhou Institute of Geochemistry, China; Geotrack International; BHP; University of Tasmania; California Institute of Technology; CODELCO, Chile; Institute of Geochemistry, Academy of Sciences, Russia; Australian National University (ANU); and University of Geneva, Switzerland.

Avoiding costly oil well blow outs

Abnormal geopressure is a major potential hazard when drilling oil wells. Pre-drill pore pressure prediction is important for oil companies' risk management in planning and drilling in overpressured sediments.

By analyzing laboratory and field data, CSIRO Petroleum's Abnormal Geopressure Program, under the Australian Petroleum Cooperative Research Centre banner, has examined the propagation of seismic energy under varying effective stress conditions associated with different mechanisms of overpressure generation. The work is sponsored by Schlumberger Oilfield Services, ChevronTexaco and BHP-Billiton with the participation of JNOC TRC (Japan National Oil Corporation - Technology Research Centre).

This research program has applied a decision support methodology with demonstrated savings of up to 25 per cent on the cost of drilling.
It has also achieved a step change in current practice in pore pressure prediction with a new attribute based >> pore pressure prediction methodology, based on the attenuation of seismic energy in overpressured conditions. An international patent is pending on this process.

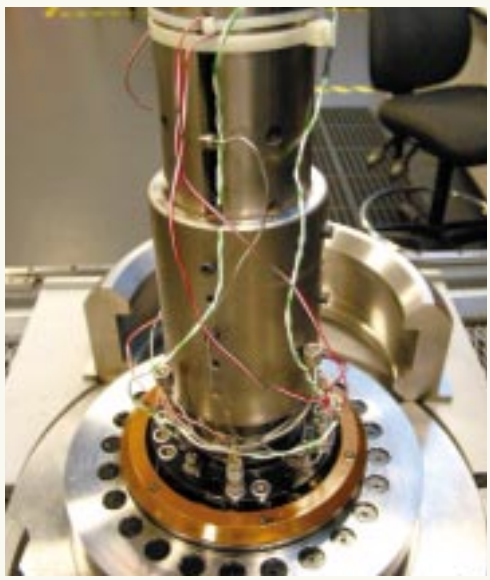
This research activity, carried out by CSIRO Petroleum scientists, has concentrated on the stress path elastic response of shales and sandstones from the Carnarvon and Otway Basins. The work has verified a number of fundamental concepts, including the importance of mean stress rather than vertical stress, in analyzing the data. It has contributed to the critical understanding of the role of the effective stress coefficient with its physical significance to the microstructure of the rock fabric. This has particular significance in the geomechanical modelling of the stress changes observable through time-lapse 4D seismic surveys. This contribution to the understanding of these processes has been recognised as world-leading by BP, Shell and Schlumberger.

Developing seismic applications for Western Australian conditions

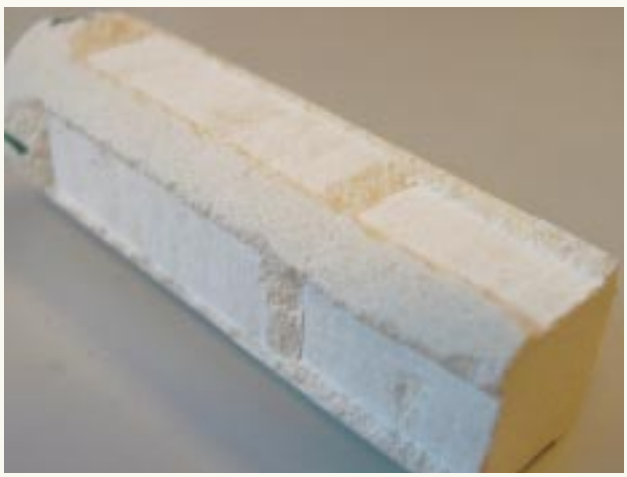
Seismic methods are the most powerful of all the geophysical imaging techniques, due to their depth of investigation, directivity and structural resolution.

Researchers with CSIRO Petroleum and CSIRO Exploration and Mining have been working since 2000 to develop specific seismic applications for Western Australian (WA) conditions for the minerals and petroleum industries.

The key objective is to develop the capacity to model the complexities of specific seismic responses numerically, and with scaled physical models.



Cutting device set up in expanded configuration before cutting the sample. Used in a project aimed at optimising drill bit cutter geometry for low permeability rocks.



A tested unjacketed sample.

The Project – funded under the ARRC Research and Development Funding Agreement – involves analogue reservoir modelling, numerical modelling of seismic wave propagation and seismic research for WA hard rock conditions. This last component of the Project is driven by the 'Glass Earth' vision of mine scale depth imaging to one kilometre.

The analogue reservoir model used experimental methodology for making synthetic rocks, with predefined properties, to build an analog of several intersecting channel sands. An exactly scaled time-lapse seismic imaging was run before and after the oil filled sands were produced by water flood. The production history was compared with a reservoir simulation model for the same geometry. The project received renewed funding from ChevronTexaco for 2004 and Woodside joined the Project in 2003 after seeing results from earlier prototype models. BP scientists said that this synthetic rock process was the leading method for such techniques and the scaled channel sands was the most significant advance in physical modeling in the past 10 years.

The codes generated within the project for numerical forward modelling of seismic energy propagation simulate a range of environments from fully elastic 3D to poro and viscoelastic. It has generated collaborative research activities with the Centre for Theoretical Physics in Trieste, Italy, and a developing relationship with the Chinese Academy of Science Institute of Ultrasonics.

Optimising drill bit cutter geometry for low permeability rocks

An experimental project carried out in conjunction with the University of Minnesota (USA), Faculte Polytechnique de Mons (Belgium) and Diamant Drilling Services (Belgium), will have the potential to assist manufacturers design more efficient cutters for drilling low permeability rocks and save drilling companies both time and money.

Shales represent about 75 per cent of the rocks encountered while drilling petroleum wells. Drilling penetration rates can vary widely with very good results of up to 60 metres per hour and little wearing of cutters experienced on the one hand, and poor penetration rates of one metre per hour and significant wear to cutters on the other hand. The poor performance in drilling low >>

permeability formations appears to be due to the very large specific energy required to cut the rocks encountered at great depths. The CSIRO Petroleum-led team has set out to quantify the dependence of specific energy on geometrical features of drill bit cutters, depth of cut and bottom-hole pressure in drilling low permeability rocks.

An instrumented cutting device has been used for the study and a 'finger' capable of simultaneous measurement of axial and normal cutting forces has been developed. The finger comprises a crown to hold the front cutter and an instrumented double stem to hold the rear cutter. This is to ensure the cutting force induced by the front cutter does not impact on the measurement of the cutting force generated by the rear cutter. A test programme is being conducted to evaluate the influence of cutter geometry, depth of cut and confining pressure, with six types of tungsten carbide cutters. This project is continuing during 2004/05.

Novel starch products for high temperature drilling

The oil and gas industry along with drilling and mud service companies are eager to find low-cost, more environmentally-friendly, thermally-stable fluid loss additives for high temperature drilling. Due to the thermal degradation of conventional starch-based fluid loss additives, current modified starches used by the drilling industry can only be used for drilling relatively low temperature wells.

CSIRO's Division of Petroleum and Division of Manufacturing and Infrastructure Technology embarked on a research program to address the thermal degradation mechanisms of starch-based products and develop new novel starch products using local agricultural produce (such as corn). This led to the design of superior drilling muds capable of drilling wells with bottom hole temperatures of up to 150^{o}C.

The use of local produce and the new technique will reduce production costs and ensure higher economic returns to Australian farmers. The availability of a low-cost mud additive will reduce both drilling mud and total drilling costs. Most importantly the higher purity of the additive ensures little or no impact on the ecosystems and surrounding environment.

Using data to improve oil and gas well operations

Australia's petroleum industry currently spends nearly $1 billion annually on drilling and completions, with most expense related to optimising the design and construction of oil and gas wells.

Petroleum companies face complex issues such as ensuring the quality and availability of information related to well interventions, including drilling, completions and workovers. This information is vital for performance evaluation, operational trouble analysis, including risk of failure, uncertainties in time and cost for future operations, and operational sequence planning.

Working with Brazilian oil giant PETROBRAS and US company ANADARKO, CSIRO Petroleum's Drilling and Completions Group, who developed the acclaimed 'Genesis 2000' software package, has developed new generation software, called 'Genesis Completions', for completions and workover operational analysis, planning and follow-up.

The use of the software contributes to lower risk of failure and better time and cost estimations of oil and gas well interventions.

In close cooperation with the project participants, CSIRO scientists defined the requirements and specifications of the whole system, including data, quality control, analysis tools, planning and operational processes, and data flow.

The initial implementation of the advanced analysis and design tool 'Genesis Completions', for PETROBRAS, is planned for February 2005. The expectation, in the first two years, is to produce faster learning curves, improve operational performance by between 10 and 20 per cent, and to reduce operational trouble time by up to 30 per cent.

Protecting offshore oil platforms and pipelines

Inadequate knowledge of the composition of the sea floor in Australia's Economic Zone has the potential to cause the failure of oil pipelines and offshore platforms through the movement of sediment and its changing composition.

CSIRO Petroleum researchers are studying how the seabed will evolve in the next 50 years in response to climate change, looking, in particular, at how the sediment composition changes, where catastrophic slope failure of sediments is likely and where are the regions of excessive pipeline scour.

The project uses the sedimentary simulation program Sedsim (originally developed by Stanford University in the USA and further developed by CSIRO) to model the Australian economic zone. Sedsim is capable of modelling sedimentary processes such as the inflow of rivers into the ocean, slope failure, the effect of waves, currents and storms over many years and at scales from one centimetre to hundreds of kilometres.

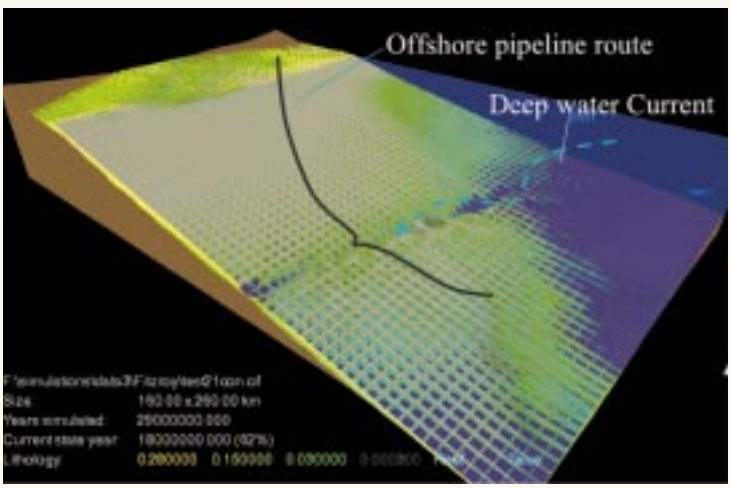
The project is funded through CSIRO's Wealth from Oceans Flagship, with negotiations in place with several major oil companies. CSIRO Petroleum is working with the National Tidal Centre, the Bureau of Meteorology, the Royal Australian Navy and the Australian Oceanographic Data Centre.

Predicting and restoring eroded coastline

The erosion of coastline by waves and storms can adversely impact communities and can be very costly to remediate.

In a project to expand the capabilities of the Sedsim program into environmental prediction, CSIRO Petroleum scientists undertook a study of the Netherlands coastal region of Terschelling, which lies along a barrier island on the North Sea coast.

A simulation of Sedimentary process in Australia's economic zone using the Sedsim program.



Sedsim is a sedimentary process modelling program originally developed by Stanford University in the USA and further developed and enhanced by CSIRO. It simulates the filling of a sedimentary basin over time and can be used to predict the regional distribution of reservoir sandstones that are important targets in oil exploration.

The Terschelling project used a recently developed Sedsim storm module for predicting the effects of extreme weather conditions, in conjunction with a module for predicting steady state sand movement caused by typical wave conditions.

The study sought to predict the possible response of the coast to a variety of nourishment plans. It found that, given a certain volume of sediment input, the best strategy was to apply large volumes of fill less frequently and the best dumping location was around the waterline.

The developed model can help to better assess long-term impacts and plan precautionary interventions. It offers an alternative tool for coastal protection decision support and nourishment optimisation.

Enhancing discovery and recovery of oil and gas

Understanding the behaviour of faults and top seals of oil and gas reservoirs is a critical issue for the petroleum industry, especially in Australia, where recent tectonic activity has affected the deep rock formations of our premier oil and gas province, the North West Shelf.

Fine-grained rocks such as shales and deformed rock in fault zones can act as barriers to fluid flow and allow oil and gas to accumulate. Pressure builds up during this process and underground reservoirs may leak depending on the quality of the fault or top seal. In addition, tectonic activity may breach these seals. An oil company's understanding of the timing of trap development and breach, with respect to charge history, is critical to the planning and execution of a successful drilling campaign.

Backed by both major national and international petroleum resources companies and the WA Government, CSIRO Petroleum scientists – working within the APCRC (Australian Petroleum Cooperative Research Centre) Seals Program – have developed valuable solutions to fault and top seal problems. They have devised tools and methods for assessing trap integrity and have also developed a way to forecast likely flow paths of any leaked oil and gas, using science developed to study the movement of deep underground water.

External funding for the Seals Consortium came from the APCRC and from the support of Woodside, BHP-Billiton Petroleum, Origin Energy, Statoil, Santos, OMV, ChevronTexaco, Marathon (originally Globex), Exxon-Mobil and Anadarko. JNOC also sponsored the project for two years.

This work helps the petroleum industry to more accurately define and locate potential oil and gas accumulations, reducing the financial risk and cutting exploration and production costs. An independent financial analysis of the APCRC Seals Consortium suggested that it provided a benefit:cost ratio of 14. Many of the consortium members – in particular BHP-Billiton Petroleum and Woodside – have noted the value of the research carried out for their companies.

Defining North Sea subsurface pressure off the Netherlands

Parts of the subsurface offshore from the Netherlands have long been recognised as being drilling hazards because over-pressure and formation water salinity can be extreme. Both factors have safety and economic implications for exploration and production of hydrocarbons.

Pending changes to Dutch mining law meant the Netherlands Organisation for Applied Scientific Research (TNO) was required to promptly conduct an inventory of the formation pressure, >>

temperature and water chemistry data from the Dutch subsurface. Operators in the Dutch offshore sector required a quality-controlled pressure and hydrodynamic database and an interpretation of the pressure systems.

CSIRO Petroleum initially took its hydrodynamics pressure database and unique Pressure QC™ methodology – developed for the Northwest Shelf of Australia – and, in collaboration with TNO, modified them to the particular requirements of the Dutch subsurface. The end product was the PressureSNS database system.

Various hydrodynamic techniques, including the utilization of GIS and CSIRO developed visualization software (PressurePlot™) were applied to the data from the Dutch offshore.

CSIRO Petroleum then proposed a two year collaborative research effort on the subsurface pressure systems of the offshore Dutch sector of the North Sea. This was supported by an industry consortium of five companies.

The result is that consortium members now have available to them the first regional evaluation and characterisation of the main reservoir units for the Dutch sector of the North Sea. One of the industry representatives said that they had already recouped the cost of their participation by having pre-drill knowledge of the pressure systems for well design.

CSIRO Petroleum and TNO have established a long-term collaborative research program and CSIRO technology has been licensed to TNO. Jointly, CSIRO and NITG-TNO have developed a database and QC system for the ongoing inventorying of data from the Dutch subsurface. The next hydrodynamics joint project will commence in January 2005.

Research benefits from new world class petrophysics lab

The commissioning of a state-of-the-art petrophysics laboratory at ARRC means major benefits for the Western Australian oil and gas sector research community.

CSIRO researchers now have in-house access to rapid and efficient methods for the petrophysical analysis of rocks, and the diagnosis of petrophysical problems. Such measurements will be key components of major reservoir characterisation projects now coming on stream, such as Digital Core, Integrated Predictive Evaluation of Traps and Seals (IPETS) consortium and the TURI (TUrbidites Research Initiative).

Good petrophysical characterisation is at the heart of evaluating the volumes of hydrocarbons in place, and quantifying what can be exploited economically. It is a key discipline of reservoir characterization.

The new laboratory contributes to collaboration between The University of Western Australia's (UWA) School of Oil and Gas Engineering, several projects with Curtin University of Technology's Exploration Geophysics and Petroleum Engineering Departments, UNSW and ANU's Digital Core Initiative.

CSIRO petroleum can now offer highly specialised petrophysical research services, plus an integrated suite of measurements. These range from helium porosity – permeability, routine and advanced electrical properties, to NMR spectroscopy and X-ray CT imaging of rock cores.

The facility has already involved the development of new technology such as an electrokinetics and electrical impedance spectroscopy system.

Excellent results have also been achieved using Nuclear Magnetic Resonance spectroscopy to investigate mudrocks that seal petroleum reservoirs.

Laser dating technique reduces exploration risk

A new facility for high-resolution Argon-Argon (Ar-Ar) laser dating of fine grained clays will provide valuable information to the resources industry about the precise timing of fluid flow events in sedimentary basins including migration and entrapment histories of oil and gas.

The microencapsulation facility for Ar-Ar geochronology is one of only five in the world. The Ar-Ar method of dating is a modified version of the Potassium-Argon (K-Ar) technique utilising the natural radioactive decay of 40K to 40Ar. The Ar-Ar method provides thermochronological information, meaning it gives coupled age and temperature information from rocks and minerals. The encapsulation facility overcomes a major technical problem in applying Ar-Ar thermochronology to very fine grained clays and will permit improved measurements of the time and temperature at which interstitial pore filling clays crystallised within sandstones that have acted as petroleum migration pathways and reservoirs. Such information will lead to improved exploration models thereby reducing exploration risk.

The microencapsulation facility was established using a joint CSIRO Petroleum and Curtin University of Technology small linkage grant and is part of the John deLaeter Centre of Excellence in Mass Spectrometry at Curtin University.

Combating 'stuck pipe' in extended reach wells

Stuck pipe is one of the most frequent drilling problems and accounts for more than 35 per cent of overall drilling problems worldwide, in one year alone (1992), costing the oil industry more than $US 250 million. The chances of this happening, and its impact on a drilling operation, dramatically rise with the increasing tendency to drill extended reach wells.

The incidence of stuck pipe must be reduced to ensure the technical and economical viability of complex drilling operations.

Curtin University of Technology's Department of Petroleum Engineering and CSIRO Petroleum researchers are involved in a study to develop a decision support tool that will integrate the variables affecting the mechanisms behind stuck pipe, into a knowledge-based structure.

Available data, analytical and heuristic knowledge are being combined, using artificial intelligence techniques. The aim is to avoid, or reduce, stuck pipe

problems through anticipated diagnosis and control of its most critical mechanisms.

The focus of the research is to develop a decision-support system for the analysis of stuck pipe events during drilling. This research aims to build a prototype model for the assessment of specific areas of the pipe-sticking problem while drilling extended reach wells.

Early results have been satisfactory and the ultimate goal is the enhancement of stuck pipe avoidance and mitigation techniques, using decision-support systems, to reduce drilling time and costs in extended reach wells.

Analysing difficult drilling projects

The drilling of complex wellbore trajectories through difficult reservoir environments is often required to access and produce un-drained hydrocarbon reserves in mature or depleted reservoirs. Because the coiled tubing does not rotate, one of the major challenges is the frequent short trips required to properly clean the wellbore. Improving the performance of the cleaning operation will therefore have a positive impact on the overall well construction costs.

Researchers from Curtin University of Technology's Department of Petroleum Engineering, working with CSIRO Petroleum, Santos, Leading Edge Advantage Limited (LEA) and Advanced Well Technologies (AWT), are developing a decision-support system for the analysis of drilling events. This system is being designed to evaluate overall drilling performance when drilling in difficult reservoir environments or drilling complex wellbore trajectories.

This research aims to structure a prototype model for the assessment of specific areas of the Coiled Tubing Drilling (CTD) and Under Balanced Drilling (UBD) processes while drilling horizontal wellbores through a depleted reservoir.

The goal is the enhancement of drilling process optimization using decision-support systems to reduce drilling time and costs without compromising the expected production rate.

These techniques have been proposed as feasible alternatives to exploit the gas reservoirs in the Cooper Basin of South Australia.

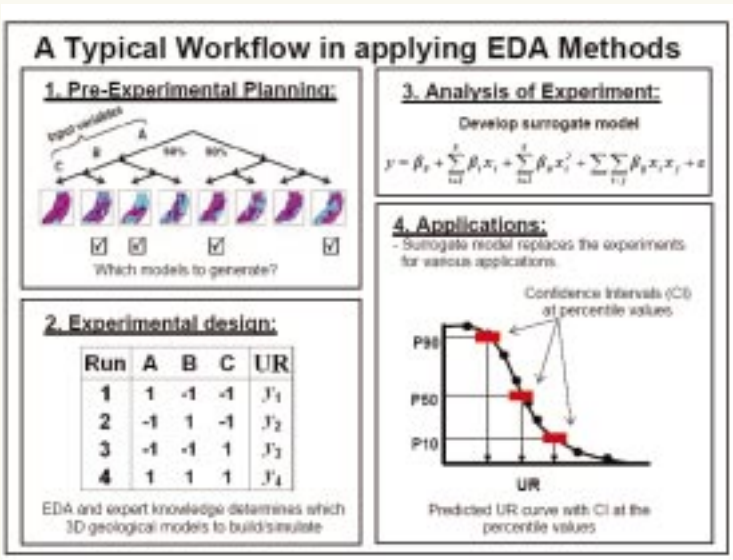
Reducing reservoir uncertainty using experimental design and analysis

Estimating the size and likelihood of recovery of oil and gas reserves, and managing subsurface reservoir uncertainties, is vital intelligence for exploration companies.

Researchers from Curtin University of Technology's Petroleum Engineering and Mathematics Departments, working with Woodside Energy Limited, have used experimental design analysis (EDA) methods based on computer experiments to manage subsurface reservoir uncertainties. They are focusing on quantifying the oil-gas output responses, such as in-place volumes and ultimate recovery.

The study is investigating the capability and practicality of EDA methods in developing surrogate equation models for such computer experiments.

The focus of the research is to apply EDA techniques, using the uncertainty range in input parameters, to achieve the goal of improved estimation of 'in-place' and recoverable oil and gas volumes.



A typical workflow in applying the EDA methods with expert knowledge.

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ARRC OCCUPANTS' YEAR IN REVIEW

CRC LEME

Applying regolith science to the challenges facing Australia in natural resource management and mineral exploration.

ARRC accommodates CRC LEME's Head Office, and two of its eight Core Participants – CSIRO Exploration and Mining and Curtin University of Technology (Dept of Exploration Geophysics). In all it supports 27 LEME researchers and administrators, notably Dr Dennis R Gee (CEO) and Dr Ravi Anand (Program Leader: Mineral exploration in areas of cover). Some scientific advances during the year emanating via LEME researchers at ARRC are:

- Spectral logging of regolith material which will enable exploration geologists to rapidly and consistently characterise the regolith in mineralogical and geochemical terms.
- Mapping metal dispersion in regolith materials at micro scale using LA-ICPMS. This particularly focuses on occurrences of hydromorphic mineralisation of gold.
- High nickel values in groundwater hydrogeochemistry indicate potential methods for exploring for hidden nickel deposits.
- Dispersion trails of anomalously high metal values in transported regolith provide vectors back to primary mineralisation sites.

pmd*CRC

Generating a fundamental shift in exploration practice and cost-effectiveness.

ARRC accommodates Program 5 of the CRC – Modelling and IT – conducted by staff from CSIRO Exploration and Mining. The specialist staff involved in this work represents the largest group of researchers dedicated to this type of work anywhere in the world.

Research highlights associated with pmd*CRC staff at ARRC during 2003/04 include:

- Substantial progress towards the development of environments for the management, storage, and transfer of data from field observations to numerical modelling using XXML.
- Development of three dimensional deformational, thermo-mechanical modelling packages capable of realistic physical simulations of geomaterials and geological structures at an extreme range of scales.
- Advances in the design of an Interactive Visual Modelling System based on the abovementioned modelling packages.

Centre for Sustainable Resource Processing

The Centre for Sustainable Resource Processing (CSRP) is a newly established Cooperative Research Centre under the Federal Government's CRC Program. Its objective is to find technological solutions for progressively and systematically eliminating waste and emissions in the minerals cycle, while at the same time enhancing business performance and meeting community expectations. Key themes will be effective resource utilisation and materials efficiency, minimising energy consumption and Greenhouse gas emissions, reducing process waste, enhancing co-product values, reducing water consumption and impacts and improving the control of minor elements and their dispersion.

With CSRP still in its infancy, focus has been towards implementing and commencing its four research programs – Strategic Analysis and Methodologies, Eco-efficiency of Existing Operations, Regional and Supply Chain Synergies, and Breakthrough Enabling Technologies. Success in these areas of research will move us toward our vision of satisfying the global material needs of society with significantly reduced ecological impacts.

CO2CRC

Developing technologies to capture and geologically store large quantities of CO_2 safely, sustainably and cost effectively.

ARRC accommodates CO2CRC's Commercial Manager, and two of its seven Core Research Participants – CSIRO Petroleum and Curtin University of Technology (Departments of Exploration Geophysics and Petroleum Engineering). In all it supports 26 researchers and administrators working on CO2CRC programs.

Some scientific advances during the year emanating via researchers working on CO2CRC programs at ARRC include:

- The Continuous Seismic Monitoring method, which allows low energy sources to continuously monitor the movement of fluids in a reservoir, gained further support with approval to test the method by Companie General Geophysique (Paris) over the next year.
- The wavelet transform has been developed for full automatic event picking of image gathers (with BHP-Billiton support). Successful primary event recognition through the use of hyperspace attributes makes this a very marketable tool.
- The new Pressure/Temperature chamber has provided an early indication of the seismic reflection response to pre-bubble fluids while a new bench-top low pressure cell has provided an early indication that amplitude and frequency both change as a result of both fluid phase change to a bubble and saturation percentage.
- Development of a new prediction methodology based on the attenuation of seismic energy in overpressured rock, and mapped using a variety of pore pressure sensitive seismic attributes. This is complementary to the existing velocity based methods. An international patent application for this process has been submitted
- A demonstrated decision support process that formalizes and weighs the technical and human contributions to drilling decisions associated with overpressured conditions.

Interactive Virtual Environments Centre (IVEC)

IVEC is an unincorporated joint venture formed in June 2000 between Central TAFE, CSIRO, Curtin University of Technology, and the University of Western Australia. IVEC is the WA partner of the Australian Partnership for Advanced Computing (APAC).

IVEC was established to provide enduring benefit to Western Australia and to the Members through developing high performance computing and visualisation in the State.

The ARRC node of IVEC (which incorporates the Centre's headquarters), together with the APAC National Facility, provided high performance computing and visualisation support for the following staff and activities during 2003/04:

- CSIRO Exploration and Mining (pmd*CRC) and CSIRO Petroleum.
- Curtin University (AJ Parker CRC and Nanochemistry Research Institute).
- Murdoch University (International Triticeae Mapping Initiative and Centre for Atomic, Molecular and Surface Physics).
- The University of Western Australia (Distributed Virtual Environments).

IVEC was also a supporting participant in the inaugural Premier's Collaborative Research Program Grant "Distributed Interactive Virtual Environment for Reconstructing Resource Sector Accidents/Incidents".

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ARRC'S FACILITIES

Dr Rob Hough uses microscopes and microanalytical tools to improve understanding of how minerals were formed. Photographer: Darryl Perroni.

Analytical Facilities Laboratory –

Sectioning facilities: petrographic and section preparation of samples. Thin and polished thin sections, polished mounts and grain mounts for optical examination, mineral identification and trace element analysis.

Sample facilities: specialised preparation of samples include crushing, sieving, milling and sample splitting for chemical analysis including INAA, XRF and XRD. Preparation conducted in a low contamination environment and to research standards.

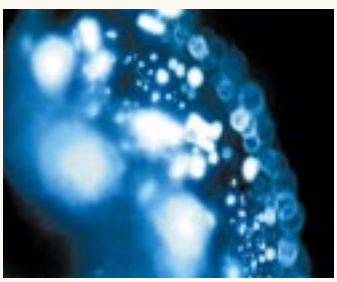
Argon geo- and Thermochronology – part of the Western Australian Argon Isotope Facility (WAAIF) at Curtin University of Technology. Provides K-Ar and Ar-Ar laser dating of rocks and minerals to researchers and industry in Western Australia and worldwide.

Core Flooding Equipment – the three phase high temperature, high pressure Core Flooding Equipment enables investigation of fluid flow in porous media at reservoir conditions. The equipment has been upgraded to include capability for oil PVT analysis.

Core Flooding laboratory.

Electron Beam and X-Ray Diffraction Laboratory – equipped with several controlled pressure SEM's (Scanning Electron Microscopes), XRD's (X-Ray Diffractometers) and a Cameca SX50 microprobe which are typically used for identification and analysis of mineral samples. Capabilities include automation of the XL40 SEM for tasks such as BSE (Back Scattered Electron) and CL (Cathodoluminescence) image collection, grain counting and rare phase searches (AutoGeoSEM); and microprobe analysis of trace elements down to the parts per million level (CSIROTrace).

Fluid History Analysis Laboratory – technologies to determine oil migration and timing of oil charge to petroleum reservoirs as a tool for reducing exploration risk in sedimentary basins. Fluid inclusion techniques include Grains with Oil Inclusion (GOI™) and Resistivity of Irreducible Water (ROI™), together with a suite of microthermometric measurements of aqueous and petroleum inclusions.



Fluid inclusions fluorescing under UV light.

Geophysical Field Equipment –

Curtin possesses some of the world's best TEM equipment: GDP-32 Nanotem, SmartEM and Protem systems. Additional upgrades this year have been the addition of two caesium vapour magnetometers, Geometrics 858, and a RAMAC radar system with 250 and 400 MHz antenna. The present 96 channel OYO DAS-1 is soon to be upgraded to a 120 channel EX-6 distributed system from Seistronix.

Geophysical Instrumentation Laboratory – used to test and manufacture instrumentation for electromagnetic and electrical methods. Currently supplying the exploration industry with a TEM induction coil sensor that has the lowest noise levels and high power transmitters for nickel exploration.

IVEC's Haptic Workbench.

IVEC –

High Performance Computing Infrastructure

- Compaq AlphaServer SC (SC40) which is nominally rated at 21 GFLOPS
- SGI dual processor Octane2 with a V12 3-D graphics card

Haptic Workbench – an interactive Haptic system for 3D visualisation and mechanical feedback.

Visualisation Laboratory – a large visualisation system for immersion visualisation of data and seismic interpretation.

Linux Computing System – a four processor cluster of Linux computers with a full range of seismic and geophysical software installed. In particular, seismic software currently being ported includes:

1. Full Paradigm package (2D, 3D seismic processing and Depth imaging).
2. Full Landmark package (2D, 3D, Log-analysis, Depth imaging).
3. Full Geoview package (AVO analysis).

Petrophysics Laboratory – provides high quality, calibrated measurements of rock physical properties. Capabilities include nuclear magnetic resonance spectroscopy and a suite of electrical/electromagnetic measurements.

Petrophysics laboratory equipment.

Quantitative Grain Fluorescence (QGF) Laboratory – provides quantitative fluorescence information from reservoir grains for detecting palaeo and current fluid contacts using patented QGF and QGF-E (on extract) techniques, and fluorescence fingerprints of (inclusion) oils for oil-oil and oil-source rock correlations using the Total Scanning Fluorescence (TSF) method.

Rock Mechanics Laboratory – a world-class laboratory providing key support to projects in wellbore stability, sand and solid production prediction, reservoir compaction and hydraulic fracture stimulation.

Seismic Modelling Laboratory – used to simulate the seismic response from petroleum reservoirs via ultrasonic scale modelling in a water tank. A major addition to the facility is a large pressure vessel to allow models to be tested under more realistic conditions.

Specialised Drilling Fluids Laboratory – simulation of drilling fluid-rock interactions, mud cake characterisation and accurate determination of drilling fluid properties.

Specialised Drilling Fluids Laboratory.

(U-Th)/He Thermochronometry Laboratory – a highly sensitive method of determining the low temperature thermal history of mineral belts and petroleum basins, providing data that are critical to the understanding of deposit formation. This laboratory is located at the main Curtin University campus.

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ARRC'S ADVISORY COMMITTEE

Back row (left to right): Mr Rob Male, Professor Doug McEachern, Professor Barney Glover, Mr Jeff Gresham.
Middle five (left to right): Dr Steve Harvey, Dr Jim Limerick, Dr Tim Griffin, Professor Neil Phillips, Professor Beverley Ronalds.
Front: Mr David Agostini.

The role of the ARRC Advisory Committee is to provide focus and direction for ARRC's activities, thus ensuring maximum benefit to Western Australian industry, research organisations and the community. Additionally it oversees the research plans for the Centre and reviews the activities of the Centre against objectives annually. The ARRC Advisory Committee meets twice a year and comprises representatives from research institutions, government agencies and industry.

Membership for 2003/04:

- Mr David Agostini (Chair)
- Dr Beverley Ronalds, Chief - CSIRO Petroleum
- Professor Neil Phillips, Chief - CSIRO Exploration and Mining
- Mr Jeff Gresham, Consultant - Gresham Mineral Consulting Services
- Mr Rob Male, Woodside Energy Limited
- Dr Jim Limerick, Director General - Department of Industry & Resources
- Dr Tim Griffin, Executive Director - Geological Survey of WA
- Professor Doug McEachern, Pro Vice-Chancellor Research and Innovation - The University of Western Australia
- Professor Barney Glover, Pro Vice-Chancellor Research and Development - Curtin University of Technology
- Dr Steve Harvey (Observer), Deputy Chief - CSIRO Exploration and Mining

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CO2CRC Management Pty Ltd
Copper Mines of Tasmania
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Corporacion Nacional del Cobre de Chile (Codelco)
CRC for Australian Petroleum
CRC for Landscape Environments and Mineral Exploration
CRC for Predictive Mineral Discovery
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Department of Industry and Resources - WA
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Martin Lack and Associates Pty Ltd
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Noble Engineering and Development
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Pontificia Universidad Catolica de Chile
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PT Corelab Indonesia
QED Environmental Services
Queensland University of Technology
Research Institute of Petroleum Industry
Rio Tinto Exploration Pty Ltd
Robe River Mining Co. Pty Ltd
Roc Oil Company Ltd
Roger Townend and Associates
Runge Ltd
Santos Limited
Saskatchewan Research Council
Schlumberger Oilfield Australia Pty Ltd
SCT Operations Pty Limited
Silva Family Trust
SRP Management Limited
Standards Australia International Ltd
State Government - WA
Strata-tek Pty Ltd
Strike Oil NL
Subilabs Pty Ltd
Sumitomo Metal Mining
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University of Sydney
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University of Western Australia
University of Western Sydney
University of Wollongong
UNOCAL Corporation
URS Australia Pty Ltd
Water and Rivers Commission (WA)
Western Power Corporation
WMC Resources Ltd
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