

# ARRC

Annual Report

2001-02



# ARRC overview

The new Australian Resources Research Centre (ARRC) has brought together leading researchers from CSIRO and Curtin University of Technology, with the vision of creating a petroleum and minerals centre of expertise for the South-East Asian region.

With over 200 scientific and technical staff, the concentration of capability at ARRC provides a focus for enhanced collaboration with Cooperative Research Centres, universities, resource companies and suppliers to deliver world-class research solutions, services, technologies and highly trained people to the resources industries in Australia and around the world.

Located in Western Australia's Technology Park, ARRC is a major initiative of the Western Australian Government, CSIRO and Curtin University which has been established in conjunction and consultation with the petroleum and mining industries. Its location in Western Australia's Technology Park is highly appropriate, given that the State produces two-thirds of Australia's metalliferous products and about half of its petroleum.

With access to a vast global research network, ARRC represents a new environment in which scientists interact, exchange information and explore new ideas in partnership with industry to ensure the ongoing sustainability of our resources industries, our environment and our way of life. In working to achieve a number of shared objectives, CSIRO and Curtin University have already appointed three joint research chairs in the areas of geophysics, isotope geoscience and drilling engineering. Through Curtin University, ARRC is producing world-class graduates and new ideas for the future of the industry.

Mineral exploration and mining research at ARRC is concentrating on technologies that contribute to the discovery and extraction of new world-class, high quality mineral deposits at the lowest possible cost, with emphasis on safety and the environment.

Research for the oil and gas industry is focusing not only on improving oil exploration performance but also on preparing Australia and the region for the transition to new energy sources in the future. As domestic production of liquid transport fuels declines, ARRC researchers are developing technologies that will enable us to utilise Australia's rich gas reserves and convert gas to liquid fuels. A longer-term objective is to develop the new technologies needed to position Australia to enter the hydrogen age in around 25 years time.

Of great importance at ARRC will be research strategies designed to minimise the resource industry's impact on our marine and land environments and limit greenhouse gas emissions.

**ARRC – setting the stage for a new way of working together in the 21st century**



# ARRC occupants

## CSIRO:

- Exploration and Mining
- Petroleum

## Curtin University of Technology:

- Department of Exploration Geophysics and the Centre of Excellence for Exploration & Production Geophysics
- State Centre of Excellence in Petroleum Geology<sup>1</sup>
- Department of Petroleum Engineering and the Western Australian Petroleum Research Centre (Curtin node)

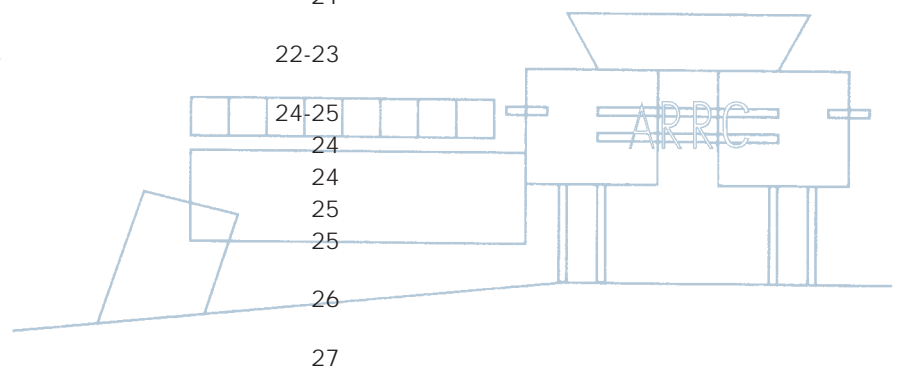
## IVEC (Interactive Virtual Environments Centre)

### Cooperative Research Centres for:

- Landscape Environments and Mineral Exploration (LEME)
- Predictive Mineral Discovery (pmd)
- Australian Petroleum

## Contents

Foreword	4
Executive summary	5
ARRC commissioning	5
Research activities in support of the Australian minerals industry	6-9
• Research focus	6-7
• CSIRO Exploration and Mining	8
• CRC LEME	8
• pmd* <sup>1</sup> CRC	9
• Research highlights	9
Research activities in support of the Australian petroleum industry	10-15
• Research focus	10-11
• CSIRO Petroleum	12
• Research highlights	12-13
• Curtin University of Technology	14-15
• Research highlights	15
IVEC	16
State funded ARRC start-up projects	17-20
• "Spectral mine sight"	17
• Automated Horadium mining equipment	18
• Seismic applications for Western Australian conditions	19
• Simulation systems for predictive exploration and resource extraction	20
Finance	21
Research support and human resources	21
Awards, achievements and community sponsorships	22-23
Committees:	
• ARRC Steering Committee	24-25
• ARRC Construction Committee	24
• ARRC Advisory Committee	24
• ARRC Directions Committee	25
Industry clients and partners	26
ARRC contacts	27



<sup>1</sup>The activities of this Centre have now been merged into the Department of Petroleum Engineering.



The Hon. Clive Brown, MLA

## Foreword

Western Australia's resource industries make a significant contribution to the economies of both the State and the nation. During 2001, the value of production from the State's resources industry was \$26.8 billion, and exports from this sector made up 70% of the total merchandising exports from Western Australia.

As the producer of two-thirds of Australia's metalliferous products and about half of its petroleum, the decision to establish the Australian Resources Research Centre (ARRC) in Western Australia was an easy one. It places Western Australia as the national and regional centre for minerals and energy research. Research at ARRC aims to improve the competitiveness of established industries and facilitate the development of new ones.

ARRC is a major initiative of the Western Australian Government, CSIRO and Curtin University of Technology. The State Government's funding contribution of \$35 million represents the largest single allocation of State funding for technology infrastructure ever made in Western Australia.

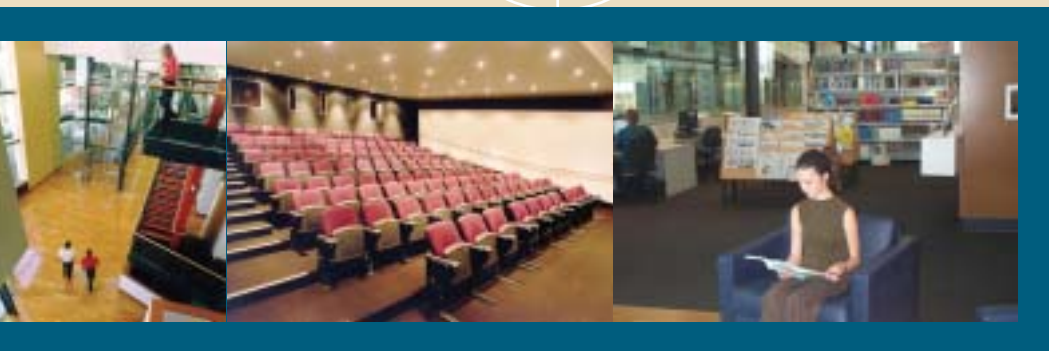
Successful modern economies require well-developed and internationally competitive technology infrastructure to contribute to sustainable industry development. Another significant factor in generating successful new knowledge-based industries is the level of integration between such infrastructure and the various research and academic institutions. The establishment of ARRC at Technology Park, adjacent to Curtin University, provides a cornerstone in the State's development of strategic technology infrastructure of a global standard.

The State's funding contribution for ARRC start-up projects has already seen significant progress made in the areas of spectral mine imaging, automated mining techniques, advanced seismic technologies, and computer simulation systems for predictive mineral and petroleum exploration.

I would like to congratulate all staff at ARRC for their contribution to a progressive and successful first year of operations. The continuing results of your endeavours will strengthen Western Australia's and the nation's ability to successfully compete in the global economy.

**The Hon. Clive Brown, MLA**

**Minister for State Development**



# Executive summary

The official opening of ARRC on 14 November 2001 by the Hon. Dr Geoff Gallop MLA, Premier of Western Australia, was a momentous occasion not only for CSIRO and Curtin University of Technology, but for Australia's energy and minerals industries, the research community and the State of Western Australia.

As founding members of ARRC, CSIRO and Curtin University are pleased to embrace the vision of making Perth and Western Australia a world centre for energy and minerals research. It is an important part of the agenda for Australia's success in the knowledge age, for our ability to find new energy and mineral resources and for the management of our fragile environment.

This new way of working together is designed to attract and nurture the very best scientists with a common purpose, providing them with world-class facilities for their journey of investigation and discovery. ARRC is also designed to be an integral part of the energy and minerals industries that are so critical to Australia, bringing the focus of researchers into the commercial environment and creating a source of new ideas and challenges.

As home to two CSIRO research divisions, five departments and Centres of Excellence from Curtin University, Cooperative Research Centres (CRCs) and the new Interactive Virtual Environments Centre (IVEC), an impressive range of capabilities can be accessed at ARRC and the opportunities for collaborative research are endless. The groups operating within ARRC are now embarking on an ever-increasing number of joint projects.

While the petroleum and minerals industries have enjoyed the great successes of past decades, the future looks to be much more challenging. For example, Australia's oil production is forecast to fall from 85 per cent of needs to about 50 per cent by the end of this decade, unless there are major new discoveries. In addition, the petroleum and minerals industries must adapt to meet greenhouse gas responsibilities. However, we see major opportunities through our rich endowment of natural gas and minerals such as nickel and titanium. Science and technology will provide us with the capability to meet these challenges in the best possible way.

In this, the first ARRC Annual Report, we provide a snapshot of the Centre's current and future research activities directed at the petroleum and minerals industries, describe the capabilities and expertise of the groups who now reside here and give a summary of the significant effort undertaken on four major research projects funded by the Western Australian Government as part of the agreement to establish ARRC.

Australia's success in the knowledge age, our ability to find new energy and mineral resources and the management of our fragile environment are inextricably entwined. They provide the national imperative for ARRC and for the vision of Perth as a crucial international centre for energy and minerals research.

ARRC Directions Committee 2001/02



Dr Adrian Williams (Chair)  
Chief, CSIRO Petroleum (until July 02)



Professor Neil Phillips  
Chief, CSIRO Exploration & Mining



Professor Paul Rossiter  
Deputy Vice Chancellor (R&D),  
Curtin University of Technology

## ARRC commissioning

ARRC is a purpose built centre for petroleum, minerals and mining research and development. Established at a cost of \$37 million, the facility is a joint venture between the Western Australian Government, CSIRO and Curtin University of Technology.

The Centre was commissioned in August 2001 and officially opened by the Hon. Dr Geoff Gallop MLA, Premier of Western Australia, on 14 November, 2001.

Construction began in October 1998 and was completed in July 2001. The design philosophy of the Centre was to portray a practical research and commercially orientated image to attract visitors and stakeholders to a facility in which they feel comfortable and where ARRC residents can project a positive, progressive face dedicated to serving the industry and community in general.

The building itself is 18,239sqm, housing 210 offices, 66 laboratories and

process bays, plus meeting rooms, teaching facilities, an auditorium, library and canteen. The builder, Multiplex, was announced the overall winner of the 2002 Master Builders Excellence in Construction Awards for construction of ARRC. The architects, Design Inc Perth, received commendations in two sections in the Royal Australian Institute of Architects awards.

Some 230 staff are now resident within the ARRC building.



# Research activities in support of the Australian minerals industry



Over the next decade, the Australian minerals industry will continue to experience increasing pressure to maintain its international competitiveness in response to:

- Low commodity prices (at least in real terms).
- The discovery of world-class ore bodies overseas.
- The diminution of many of Australia's more easily accessible deposits forcing exploration and mining activities into deeper, more difficult environments.
- The emergence of major mining economies in the Asia Pacific Region.

In response to these pressures, the industry will need to continually increase the efficiency of existing operations and develop new technologies if it is to maintain its current position as a major player on the international minerals exploration and mining scene. Research conducted at ARRC in support of industry clients is aimed at addressing the following key issues.

## Understanding the Processes Leading to the Formation of World-Class Ore Bodies

A comprehensive knowledge of the geological properties that characterise world-class ore deposits, and the provinces that host them, is a crucial prerequisite to any successful exploration program. Such information is vital to the whole exploration program from area selection, through target search and identification to deposit delineation.

World-class ore deposits have the ability to significantly influence company profitability and a nation's economic performance. But what are the unique combination of geological events that led to the formation of deposits such as Olympic Dam, Argyle and Escondida and why are these deposits so large?

Understanding and identifying the geological, geophysical and geochemical signatures associated with these world-class deposits can provide Australian mining companies with a

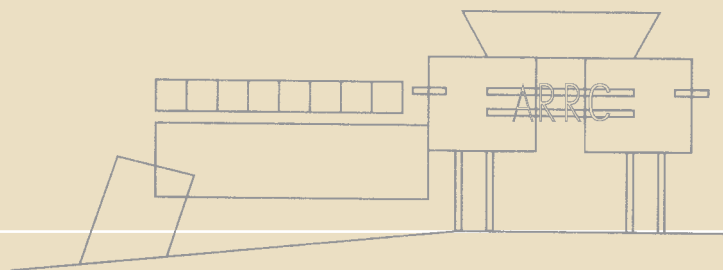
critical competitive advantage in their exploration programs both here and abroad. This advantage manifests itself in reducing the time to make new discoveries, increasing the probability of discovery and finding deposits of outstanding size and grade.

Much of the research undertaken in this area is conducted through the Predictive Mineral Discovery CRC (pmd\*[CRC](#)). See details under the pmd\*[CRC](#) section of this report.

## Exploration in Regolith Dominated Terrains

Much of Australia has a long, complex landscape history. The presence of ore deposits is often masked by extensive areas of thick soil, deep weathering and cover of continental and marine sediments and transported overburden – collectively referred to as the regolith.

Increasingly Australian mining companies are being forced to explore for ore deposits concealed beneath a landscape that has been subjected to a wide range of climatic conditions. The



resulting regolith has complex and overprinted geochemical and mineralogical characteristics that are not generally amenable to interpretation using traditional geophysical and geochemical techniques. Understanding the behaviour of elements under these changing weathering conditions is a problem of direct relevance to the discovery of buried ore deposits, and a major challenge facing the Australian mining industry.

Much of the research undertaken in this area is conducted through the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME). See details under the CRC LEME section of this report.

**Geophysical and Geochemical Technologies**

Over the next ten years an array of new exploration technologies that may change exploration practices and the basis of competition will become available. The most important will be those that contribute to regional and tenement scale exploration based on a three-dimensional view of the structure of the crust and the upper mantle, and of the processes at play in these regions. Of these, research at ARRC will include interactive and integrated three-dimensional forward and inversion modelling and hyperspectral imaging spectroscopy from both aircraft and satellites to identify the mineralogy of the ground surface directly, together with its detailed chemistry.

Other advances such as data manipulation, modelling and visualisation procedures will facilitate the exploration and interpretation process.

ARRC's geophysics capability is significant, given the co-location of geophysicists from CSIRO and Curtin University. Geophysics research carried out for the exploration and mining industry at ARRC is also linked with environmental and petroleum geophysics research.

**Mining Processes and Equipment**

The processes of excavating, loading and hauling rock materials within and from a mine, and the equipment used to perform these tasks, accounts for a major share of mine production costs.

Improvements in the handling and haulage of fragmented materials are necessary, since current operations (particularly in underground environments) are complex and include significant re-handling. To this end, the development of productive, autonomous or semi-autonomous equipment is a high priority for the industry and a focus of new research projects at ARRC in collaboration with researchers at the Queensland Centre for Advanced Technologies (QCAT).

Finally, alternative extraction methods are a long-term goal with current efforts focusing on safe, low cost, remote controlled mining methods (Remote Ore Extraction Systems). Automated Horadium mining is the first of these methods being addressed.

**The Environment**

Increasing community concern over the social and environmental impacts of mining have forced the industry to accept that it must play a proactive role in ensuring the sustainability of the community and physical environment in which it operates. Triple bottom line



reporting has gained increased acceptance within the industry over recent years.

In response to this heightened community awareness, ARRC researchers are looking at issues such as mine site emissions (gas, water, dust, pollutants and noise), dryland salinity, provision of water, waste minimisation and disposal, structural damage (blasting and subsidence) and mine site rehabilitation and site abandonment standards.

# CSIRO Exploration and Mining

With over 250 scientific, technical and support staff, CSIRO Exploration and Mining is Australia's largest supplier of strategic R&D to the Australian mining industry. The Division has a major presence in Brisbane (Queensland Centre for Advanced Technologies), Sydney and Perth (ARRC) and a smaller, but expanding, presence in Melbourne.

The Division's research activities span the full spectrum of the exploration and mining process from exploration concepts, exploration technologies, deposit delineation through to coal and metalliferous mining. Occupational health and safety and minimising the environmental impacts of mining are also key research themes.

CSIRO Exploration and Mining has identified three core science areas which underpin all of its research activities:

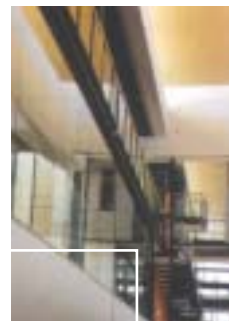
- Earth dynamics – the study of processes that operate from deep in the Earth's mantle through to surface interactions with the hydrosphere and atmosphere.
- Geo-Infomatics – understanding processes from whole-of-Earth down to the nanometer scale which requires the gathering, integration, visualisation and assessment of vast amounts of data.



- Mechatronics – the development of theory and practice for intelligent machine systems.

A current focus for the Division's researchers at ARRC and around Australia is on 'seeing' into the top kilometre of the Earth's crust to aid discovery of major new deposits concealed below the surface. The "Glass Earth" portfolio of projects will develop new technologies to recognise ore-bearing systems and new ways of integrating and visualising exploration data to produce exploration models for prospective areas. It also provides valuable scientific information for agriculture and land use programs.

In parallel with Glass Earth, the Division is developing the science and technology needed for safe, economic and sustainable access to new and existing mineral resources. A major thrust is the automation of mining systems to optimise efficiency, safety and economic success.



## CRC LEME

The Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME) is an unincorporated joint venture between CSIRO, Curtin University of Technology, Australian National University, University of Adelaide, University of Canberra, Primary Industries and Resources South Australia, New South Wales Department of Mineral Resources and Geoscience Australia. The Centre is dedicated to developing breakthroughs in mineral exploration and environmental management through

knowledge of Australia's regolith – the layer at the Earth's surface that is the result of weathering, erosion and deposition. Over time, such physical actions distort the landscape, alter the environment and disguise the existence of valuable ore bodies. By generating greater knowledge of such processes, the minerals industry is better able to develop effective exploration tools for detecting world-class ore bodies and land use management groups to address key environmental issues such as dryland salinity.





# pmd\*CRC

The Predictive Mineral Discovery Cooperative Research Centre (pmd\*CRC) is an unincorporated joint venture between CSIRO, University of Melbourne, Monash University, James Cook University, The University of Western Australia, AMIRA International and Geoscience Australia. The Centre was conceived by industry in partnership with the research community to focus geological research on issues of critical

importance to ore discovery. The aim of pmd\*CRC is to maximise the impact of research outcomes on exploration strategies by direct delivery of the research results to active explorers employed by the participating companies. The pmd\*CRC will develop a vastly improved understanding of mineralising processes and a four dimensional understanding of the evolution of the geology of mineralised terrains. Efforts are

focused on resolving key areas of uncertainty in current models for the formation of major economic mineral deposit types; building 3D and 4D images and histories of well known mineralised systems; and creating a computational environment to simulate the 4D evolution of mineral systems with the goal of developing predictive capabilities for location and quality of superior ore deposits.

## Research highlights



### Cost-effective Exploration for Nickel

Working with Black Swan Nickel, researchers from CSIRO have developed a new understanding and

knowledge of the eruptive processes responsible for the formation of volcanic sequences and associated nickel deposits in Western Australia's Black Swan area.

The project has involved petrographic, mineralogical and geochemical studies on surface and sub-surface samples, allowing the team to gain an insight into lava emplacement mechanisms and develop a volcanological model for the evolution of the Black Swan sequence.

Using the model and their improved understanding, researchers were able to provide specific recommendations regarding the continued prospectivity of the Black Swan area and the possible location of further mineralisation. The research results provide some crucial pieces of the nickel jigsaw which add considerable knowledge to the formation of nickel deposits and the development of enhanced industry-wide more cost-effective exploration strategies.

*"The model CSIRO has developed is important and when we select an area for exploration we are usually guided by that model. The model was used, for example, in the selection of the Black Swan project area where we subsequently discovered the Silver Swan ore body."*

- David Burt, Mining Project Investors (MPI), Perth, Australia

### Regolith Geology of the Yilgarn Craton

The Earth's surface layer (known as regolith) contains important chemical signals about mineralisation which can lead to the discovery of concealed ore deposits. However, because the regolith and landscape constantly develop and evolve, the application of certain exploration techniques can prove difficult. Effective geochemical exploration can only be achieved by understanding how the regolith evolves and by determining which sample and data-interpretation techniques are appropriate to the target being sought. A research team led by CSIRO has been successful in establishing the origin of the regolith, the geomorphological processes and the regolith-landform relationships for many districts of the Yilgarn Craton in Western Australia to help devise effective sampling and data interpretation strategies.

The work, which has involved mining companies, Curtin University of Technology, The University of Western Australia and Geoscience Australia, has resulted in the production of a regolith-landform map of the Yilgarn Craton and

Western Australia showing the location of the Yilgarn Craton.

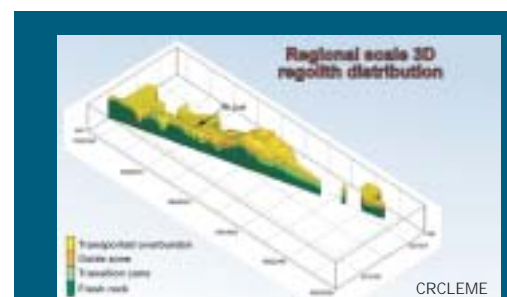


publication in the Australian Journal of Earth Sciences (Thematic Issue: Regolith Geology of the Yilgarn Craton). The users of this new reference material include the scientific community, mining companies, earth scientists and tertiary students. The material summarises the distribution and characteristics of regolith materials, presents models of the landscape and regolith evolution, looks at implications for mineral exploration – including choice of geochemical sampling media, data interpretation and application of geophysical techniques – and presents an improved understanding of landscape and regolith impacts on agricultural and environmental issues.

This new knowledge of the Yilgarn Craton will reduce exploration costs, leading to more economical mining.

*"Congratulations on the publication of your magnum opus in the latest Australian Journal of Earth Sciences. It is an excellent overview which I'm sure will become widely cited."*

- Peter A. Cawood, Tectonics Special Research Centre and Centre of Excellence in Mass Spectrometry, Curtin University of Technology, Perth, Australia



Mt Joel.

# Research activities in support of the Australian petroleum industry



The energy sector is a key component of the Australian economy, heavily influencing domestic economic performance, international competitiveness and export earnings, directly through energy commodity exports, and as embedded energy in downstream manufactured products.

The world energy system is on a path of transition with:

- World oil supply expected to peak within the next two decades, while demand continues to rise.
- An abundance of gas with increasing market penetration.
- Declining market share of coal.
- Increasing concern for environmental issues (greenhouse, clean air) driving increased interest and growth in renewable energy.

Australia's transport sector consumes some 41 per cent of the nation's demand for energy, with 90 per cent of the sector reliant on liquid fuels. While our overall demand for oil is forecast to increase to 50 per cent above year 2000 levels by 2020, it is predicted Australia's oil production will decline sharply during this period.

Research for Australia's oil and gas industry needs to focus on increasing reserves through more successful exploration and recovery rates, particularly for oil, whilst developing the technologies needed to address Australia's declining liquid fuels outlook. As a regional hub for oil and gas technology development, research at ARRC in support of the petroleum industry covers the following areas.

## Exploration and Appraisal Technologies

Increasing exploration success through better understanding of all the elements of the petroleum system from source rock characterisation and thermal maturity studies through migration and entrapment will attract continued exploration activity and investment.

Research capabilities at ARRC applied in this area include:

- Isotope chemistry techniques for determining the age of mineral formations; and reservoir characterisation using Nuclear Magnetic Resonance (NMR) imaging to determine rock properties.
- Investigating fluid history of petroleum reservoirs and petroleum

systems to evaluate hydrocarbon occurrences and oil migration and entrapment.

- Fault seal and basin hydrodynamics research looking at present and palaeo fluid flow and transport processes in sedimentary basins, fault seal potential and CO<sub>2</sub> geological sequestration.
- Modelling of fluid in porous media
- New methods for incorporating sub-surface and surface geophysical and well-test information into detailed descriptions of hydrocarbon reservoirs, involving the combination of high resolution and low-resolution data in an advanced geostatistical framework.
- Seismic physical modelling
- Computer-based stratigraphic modelling to simulate the process of sedimentary basin fill over time in order to predict reservoir quality and better understand where oil might be trapped.
- 3D visualisation using IVEC facilities.

CSIRO has already developed technologies and techniques in many of the above areas. Co-location with Curtin University researchers is now creating

even greater opportunities to further develop technologies relevant to exploration in Australia and around the world.

Geophysics research in this area is carried out by CSIRO and Curtin University's Department of Exploration Geophysics who work together closely on projects and have jointly appointed a Chair of Petroleum Geophysics. Together the two organisations are carrying out a research program funded by the Western Australian Government dedicated to developing seismic applications for the minerals and petroleum industries.

### Drilling and Drilling Fluids

Wellbore instability is an industry wide problem with global annual costs estimated at more than \$2 billion. Research directed at these problems is focused on drilling fluid design, development and optimisation to tackle problems of wellbore stability, sand production and waste management. Success will see further adoption by oil companies of CSIRO's state of the art wellbore stability technologies and new water-based environmentally friendly drilling fluids.

Research directed at drilling is also conducted in close association with oil companies to develop technologies that will cut drilling and well completion costs. Knowledge management (learning, case-based reasoning, statistical analysis, artificial intelligence), as demonstrated through the recent commercialisation of CSIRO's Genesis 2000 technology, is a particular strength of the research group. Further development of the Genesis software is underway and a new Hard-to-Drill Rock project aimed at improving drilling performance in hard and impermeable formations through controlled vibrations of the drilling system has begun.

### High Quality Decision-Making and Fast Learning

Decisions within the oil and gas industry are particularly vulnerable to uncertainty. Decisions are made at

every level of a company and range across technical, economic, commercial and political issues. Yet traditional science offers little when issues of judgment, interpretation and choice of action arise.

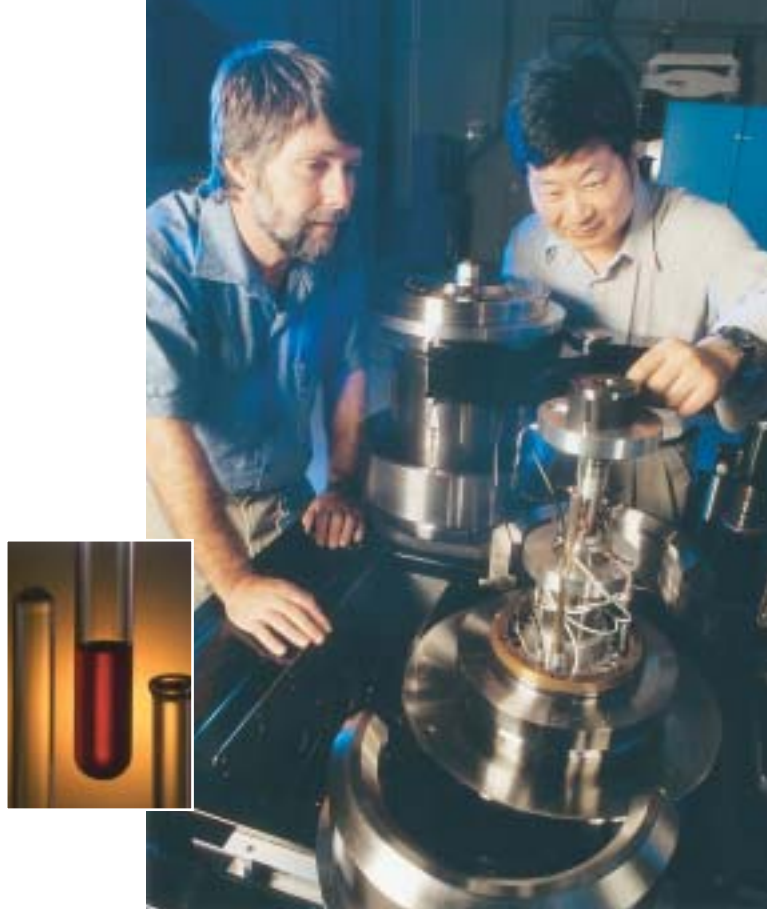
Research into decision-making under risk and uncertainty is focused on key enhancements of existing software technologies to deliver new technologies for decision support to industry. These include probability and statistics, and techniques to manage the qualitative/human side of decision-making. This tackles both the intellectual problems of interpretation, analysis and synthesis involved in conceiving ideas for effective decision-making, and the practical problems facilitating the resultant actions and change process itself.

### Sustainable Energy Development

Research into alternative energy sources to address Australia's declining liquid fuels outlook is a priority for CSIRO Petroleum scientists throughout Australia. Effort is concentrated on gas-to-liquids and geothermal energy.

Gas research is looking at the development of new and novel technologies for the exploitation of Australia's stranded gas reserves and other gas reserves world-wide. Current effort is focused on the development of technologies for the conversion of Australia's abundant gas to transport fuels, particularly clean diesel. Exploitation of the technologies developed will see commercialisation focused on Australia's remote location gas.

Geothermal energy is potentially a large volume, emission-free, renewable, energy source for Australia that could significantly reduce dependency on fossil fuels and their associated greenhouse gas emissions. Australia has the hottest rocks in the world (outside volcanic regions), as well as the easiest to access. The current research effort and new initiatives proposed are focused on proving the viability of energy from "hot dry rocks", and directed at reservoir characterisation and management technologies, well stimulation strategies, heat transfer and energy conversion, drilling technologies and risk assessment.



CSIRO scientists Mr Leo Connelly (left) and Dr Bailin Wu (right) set up a rock strength test in the Autonomous Triaxial Cell.



# CSIRO Petroleum

CSIRO Petroleum provides R&D and technical services to the petroleum industry in Australia and around the world. The Division has 150 staff operating across three sites: Perth head office (ARRC), Sydney and Melbourne.



The Division's research is currently focused on increasing exploration success, improving appraisal and development efficiency, improving drilling and completion performance, CO<sub>2</sub> sequestration, geothermal energy, gas to liquids technologies, coalbed methane, management of gas-in-coal for mining and new tools for managing risk and uncertainty.

The Division's science base is made up of three core capabilities:

- Geosciences – organic geochemistry; organic petrology; geochronology and isotope geochemistry; carbonate geology; geochemical modelling; structural geology and fault analysis; hydrodynamics and fluid history in petroleum reservoirs; seismic geophysics; mathematical modelling of geological processes; rock physics and petrophysics; and geostatistics.
- Geo-engineering – petroleum geomechanics; reservoir engineering; hydraulic fracture mechanics; mathematical modelling associated with non-linear coupled processes; wellbore mechanics, drilling fluids hydraulics and multiphase flow; drilling performance; data management; drill string mechanics; and risk assessment and decision making.
- Gas Process Engineering – gas to liquids; energy transformation; nanotechnology at surfaces; production, distribution and storage of hydrogen; catalysis; environmental control; and fuels processing.

## Research highlights

### Green Drilling

Worldwide, the oil industry suffers an estimated \$2 billion loss every year due to collapsed and sidetracked holes, lost tools and abandoned wells. Researchers from CSIRO in conjunction with US firm Halliburton Energy Services' Baroid Drilling Fluids, have developed environmentally friendly drilling fluids to alleviate this industry headache and at the same time help the energy industry to meet its green commitments.

Drilling fluids help transport cuttings to the surface, clean and cool the drill bit, lubricate the drill-string, maintain the stability of the wellbore, protect formation productivity and control pressure in the rock formation. Most current drilling fluids for maintaining wellbore stability in shales are either oil or synthetic-based and, because they are usually disposed of at sea, do not meet environmental compliance obligations or are costly to use in a way that meets these obligations.

CSIRO's new water-based drilling fluids overcome environmental and cost drawbacks and have similar performance characteristics to oil and synthetic-based fluids in maintaining shale stability. The formulations are being commercialised by Baroid as the BarOmega drilling fluid system.

"With worldwide environmental restrictions becoming increasingly stringent on the use of synthetic-based and oil-based drilling fluids, the successful introduction of the high performance BarOmega drilling fluid system will provide the needed answer for the industry to mitigate shale stabilisation problems and at the same time, to meet stringent environmental compliance."

- Mike Cropper, Senior Drilling Engineer, Apache Energy Limited, Perth, Australia

"After years of research we have been able to identify a chemistry that will provide the inhibition and shale stabilisation characteristics which, until now, are only seen with 'oil based' invert emulsion fluids. At the Baroid Product Service Line of Halliburton, we're looking forward to seeing the performance of the BarOmega system realised in the field in the near future. With environmental restrictions governing the discharge of oil based and synthetic based fluids increasing around the world, the introduction of the BarOmega system will provide the answer for high performance water based fluids."

- Mr Tom Carlson, Technology Leader (Solutions Team), Halliburton Energy Services, Houston, USA

CSIRO Petroleum's Aileen Boudeville (left) and Dr Chee Tan (right) monitor mud filtrate flow rate in CSIRO's Membrane Efficiency Screening equipment.







### Faster, Cheaper Drilling

CSIRO drilling and completions researchers have successfully teamed up with Noble Engineering and Development Ltd to commercialise a new generation oil-drilling tool with the ability to help slash the costs and boost the success of drilling for oil.

Offshore exploration wells typically cost up to \$10 million – but unforeseen snags can blow this out to nearly \$30 million. The Genesis 2000 software package allows easy analysis of existing oil well data which can be used as a planning tool for improving new wells. The technology gives drilling engineers, rig staff, asset managers and financial controllers the ability to assess risks and costs, and amend plans on the basis of experience gathered from previous oil well developments.

Under the alliance, CSIRO retains ownership of the intellectual property used in the original \$12 million project to continuously develop the technology through its internal and external scientific network. Noble has the exclusive right to commercialise the product. Over the next two years, Completion and Workover modules will be coupled into Genesis to offer oil companies a complete system for enhancing well quality over the life-span of the well.



Dr Edson Nakagawa (left) and Dr Thomas Gabler (right) of CSIRO Petroleum discuss future enhancements to the Genesis software package.

### Making the Good Oil Decisions

CSIRO's risk and uncertainty research group have been working with UK's Bristol University to come up with a powerful new way to ease the difficulty and uncertainty of critical decisions in the oil industry.

Designed to equip junior and mid-level executives with the judgment of experienced senior managers and to balance clear objectives, resources, team motivation and monitoring, the new Juniper software could potentially save the oil industry millions of dollars by providing improved decision-making processes. It provides a simple, powerful visual representation of evidence and belief for any management challenge.

The new approach captures values representing the user's strength of belief and the reasons behind them, turning it into an audit tool. It recognises that management is a process – not an event – that decisions don't just happen, but

mature over time, as gut feel, intuition and judgment develop in the light of better information and improved processes. Juniper provides a snapshot of the state of health of a process that can prompt action to be taken. As those actions lead to better evidence or clarity, it can be updated and become a living, repeatable and auditable guide for managers. Because the underpinning technology stores all the reasons behind the judgments being made, it has big implications for corporate learning and allows companies to tap the wisdom and experience of managers who may have left, retired or been promoted into other jobs.

In a recent independent market test exercise carried out for CSIRO by Nightingale Consulting, initial responses to the new decision-making approach from the oil and gas industry have been extremely positive. Three companies wish to trial the new process on pilot projects.

*"You can use it to manage the question 'do I develop this field?' There are environmental issues, there is due diligence.... You need to be able to work out your risks and whether you've mitigated them. The risks are typically in what you don't know rather than what you do know."*

- Keith Spence, Director, Woodside Energy Ltd, Perth, Australia

*"Two things look really good. The first is the social aspect of this. The second is the trail it leaves which is really important.... This is a very clever way of attacking part of that process."*

- Chris Wright, VP Exploration, Houston, USA

# Curtin University of Technology

The Curtin University of Technology Departments which form part of ARRC include Petroleum Engineering and Exploration Geophysics. These groups are part of the Curtin Division of Resources and Environment, which will soon be headquartered in Technology Park, directly opposite ARRC.

Each department has been recognised by the Western Australian Government with Centre of Excellence status – the Western Australian Petroleum Research Centre and the Centre of Excellence for Exploration and Production Geophysics. ARRC also housed the Centre of Excellence for Petroleum Geology during 2001/02.<sup>1</sup>

Research at the **Department of Exploration Geophysics** and the **Centre of Excellence for Exploration and Production Geophysics** is directed at improving recovery of hydrocarbons and minerals from known sources by the use of advanced geophysical imaging techniques. It is also involved in mineral and groundwater exploration research. The development of future geoscientists for industry is also one of the Department's major roles.

The **Centre of Excellence in Petroleum Geology**<sup>1</sup> has expertise in areas such as petrophysics, basin modelling and seismic interpretation. Research projects are geared at developing a better understanding of the North West Shelf and other key reservoirs, improving the predictability of reservoir quality and improving petroleum recovery.

The **Department of Petroleum Engineering and the Western Australian Petroleum Research Centre (Curtin node)** is a supplier of top quality teaching, research and consultancy to the oil and gas industry. Its industry-focused research and development program offers novel, cost-effective solutions to complex engineering problems. Staff have a proven track record in academia as well as many years of experience in the petroleum



industry. This combination of talent provides a strong theoretical base coupled with a practical approach to solving real-life industrial problems.

The **Woodside Research Foundation** is another arm of the Department of Petroleum Engineering. Located opposite ARRC in Technology Park, facilities include:

- Hydrate Facility – natural gas hydrate production to establish the viability of utilising a synthesised natural gas hydrate as a cheaper/alternate form to transport natural gas other than LNG.
- LNG Microcell – The LNG Micro-cell technology enables the conversion of natural gas to liquid natural gas in small-scale production by means of an innovative transportable refrigeration system. It has the

potential to make small and isolated gas accumulations economically viable.

Each Curtin group has an industry advisory committee and total funding is mainly from sources external to the normal DETYA funding flow. The Woodside Foundation, Curtin Reservoir Geophysics Consortium and the Curtin Minerals and Environmental Geophysics Consortium are industrial sponsor groups, in addition to individual project sponsors.

## Degrees offered

- Bachelor of Science, with Honours in Applied Geology and in Geophysics
- Graduate Diplomas in Geophysics
- Postgraduate Diploma in Geophysics
- Master of Science degrees in Geophysics, Applied Geology and Geoscience Exploration

<sup>1</sup>The activities of this Centre have now been merged into the Department of Petroleum Engineering.



- Master of Petroleum Engineering
- Master of Engineering (Petroleum Engineering)
- Doctor of Petroleum Engineering
- Doctor of Philosophy in Geophysics, Applied Geology and Petroleum Engineering
- Double degree in Geophysics and Computing, jointly offered by Curtin University and University of Western Australia

In addition, the three groups are participants in the Master of Petroleum Technology based at the Miri Sarawak campus of Curtin.

**Staff**

- Professors: .....8
- Associate Professors: .....4
- Senior Research Fellows/  
Senior Lecturers: .....7
- Lecturers/Research Fellows: .....3

**Specialised facilities**

- Seismic processing centre with Landmark/Promax software
- Seismic physical modelling system
- Hydrate processing pilot plant
- Cryogenic PVT
- Small scale LNG processing equipment



**Students based at ARRC 2001/02**

Course	Geophysics	Geology	Petroleum Engineering	Total
BSc	40			40
BSc Hons	17	2		19
Grad Dip				0
Postgrad Dip	2	2		4
MSc	3	5		8
M Pet Eng			19	19
Doc Pet Eng			1	1
PhD	18	5	5	28
Extension			5	5

## Research highlights

### Continuous Seismic Monitoring of Operating Oilfields

Investigations into the use of time reversed acoustics as a tool for geophysical processing has led Curtin researchers to develop a methodology for using time reversed acoustics to image changes in the sub-surface, allowing better monitoring of reservoir changes. This has resulted in a technique for continuous monitoring of oilfield production. Using a multi-source, multi-receiver seismic system, it is also ideal for monitoring CO<sub>2</sub> injection in oil and gas wells. A provisional patent for the technique has been granted.

The interest of Shell International has been secured for a field trial of this concept of continuous seismic

monitoring of operating oilfields. Researchers at the University of Paris would also like to participate and assist in laboratory tests and contacts have been established with the University of Manitoba and the University of Calgary, as field tests may also take place in Canada.

### Metal Grade Results in the Palm of Your Hand

Curtin University's Dr Anton Kepic has worked in conjunction with an Honours student to help develop an instrument designed to directly measure the nickel and copper content of ore and drill samples using field portable X-ray fluorescence analysis.

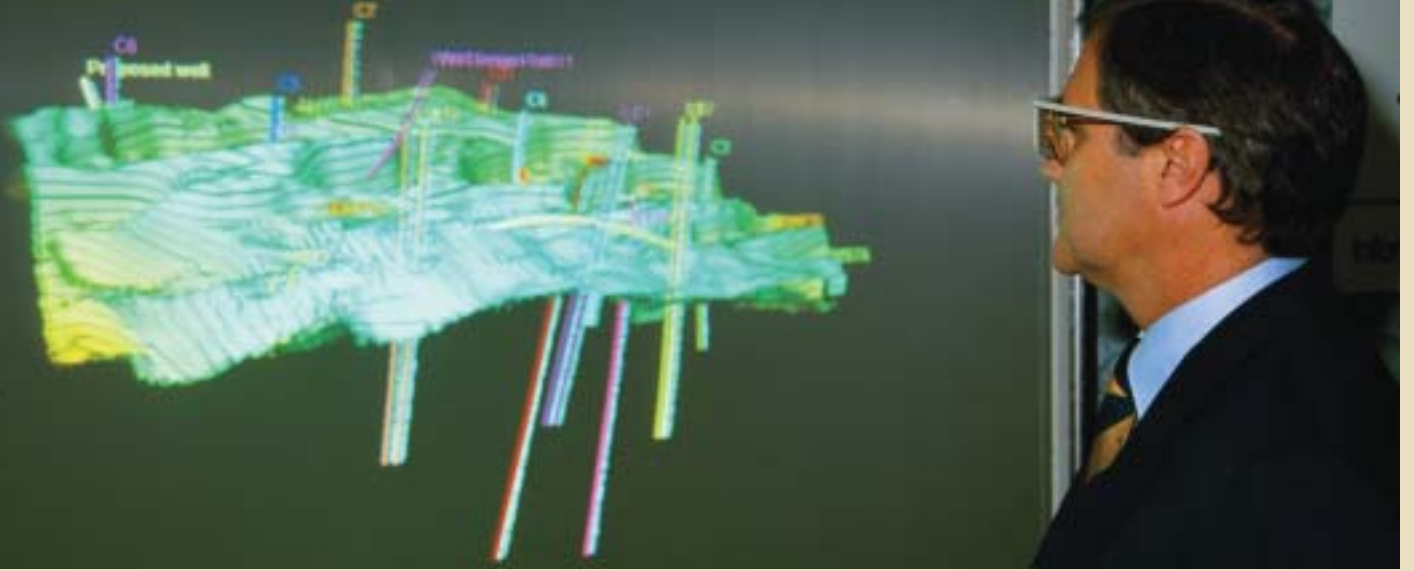


The pair evaluated a prototype field portable instrument, commonly used for measuring lead content in paint, to determine its effectiveness in measuring metal grade. With some known difficulties and differences compensated for, they were able to advise the equipment manufacturer on the necessary modifications needed to adapt the existing instrument for use in the mining industry.

The resulting instrument, the hand held NITON XL-500 Prospector, now means a geologist may know within minutes the grade of mineralisation rather than wait days or up to a week for chemical analysis from a laboratory. Anaconda Nickel has adopted the instrument for mine grade control and other companies are now evaluating the instrument for rapid and effective exploration.



# Interactive Virtual Environments Centre (IVEC)



Officially opened on 10 May, 2002, by the Hon. Dr Geoff Gallop MLA, Premier of Western Australia, the Interactive Virtual Environments Centre (IVEC) is a high performance computer visualisation centre focussing on the application of interactive virtual environments into major industries such as: mining and petroleum, medical training and research, architecture and construction, multimedia, education and urban planning.

IVEC is a joint venture between CSIRO, Curtin University, Central TAFE and The University of Western Australia. The commissioning of IVEC's high performance fibre optic network at ARRC links fast computers and exciting virtual reality devices at IVEC's three Perth nodes and connects IVEC's researchers to Australia's fastest super computer, the Australian Partnership for Advanced Computing National Facility, in Canberra.

Virtual environments are particularly effective when they allow users to tackle problems in areas of high capital or social cost. Three-dimensional virtual environments are being increasingly used to visualise mineral and petroleum reserves that may be hundreds and even thousands of metres below the surface

of the earth or the sea. Imagine taking investors through a computer-modelled gold mine — before mining has started! Imagine engineering safe mines, with fewer mine failures and more efficient exploration and production of oil and gas reserves. This tool is of great significance to CSIRO and Curtin University researchers who can now view these resource deposits using specially designed computer-models in the comfort of IVEC's 3-D visionarium at ARRC. Using such techniques will reduce exploration costs, increase extraction efficiency and increase the competitive edge of the Australian resources industry.

Also located at ARRC is a haptic workbench, which is an amazing force-feedback robotic device providing users with 3-D virtual reality viewing, and IVEC's super computer capable of

making 10 billion calculations per second. This super computer is at one end of the fibre optic network which links IVEC's other two nodes – Central TAFE in Perth and The University of Western Australia (UWA) in Nedlands – where additional 3-D screen systems and haptic workbenches are operated by experts recruited from around the world.

IVEC has funding of \$4 million from the State and Federal Governments and joint venture partners.



The Premier officiates the opening of IVEC with IVEC Chairman Alex Allan.



The Premier tries out IVEC's haptic work bench.



# State funded ARRC start-up projects

## “Spectral Mine Sight” – mineral mapping technologies for enhanced mining applications in Western Australia

Iron ore mining in Western Australia is a major source of export income for Australia, but with falling reserves of high-grade ore, companies are under increasing pressure to provide consistent chemical and mineralogical ore grade. To tackle this problem a revolutionary mine-based imaging system called “Spectral Mine Sight” has been developed by CSIRO Exploration and Mining researchers at ARRC. Spectral Mine Sight is based on visible-near-infrared – short-wave-infrared (VNIR-SWIR) reflectance spectroscopy which provides information about ore types, their chemistry and mineralogy. The new technology allows mineral images of the mine face to be generated.

The capability has already been demonstrated by spaceborne and airborne imaging systems as well as hand-held instruments. The aim of the project has been to fill the gap and bring this technology to the mine-scale level to produce new mineralogical maps that will have major impact on ore grade characterisation and ore recovery. The newly developed Spectral Mine Sight system comprises a field portable spectrometer, a double axis rotating stage, a one-degree field of view telescope and custom software.



### Project deliverables

- A prototype mine-based system – Spectral Mine Sight.
- Documentation of operational methods and software for Spectral Mine Sight data validation.
- A number of case-history reports detailing the successful application of Spectral Mine Sight to iron and gold ore mining in Western Australia.
- Spectral Mine Sight derived 3-D ore grade maps.
- Technology transfer to the State's minerals industry through reports, conferences and workshops.
- Specifications for an end-to-end operational Spectral Mine Imaging system.

### Potential benefits and progress to date

In addition to improved ore grade models, other benefits of the Spectral Mine Sight technique include: improved understanding of mine design and geotechnical issues; improved understanding of ore forming processes; and safety (away from the high walls). Beneficiaries of the research will include State-based mining companies such as Hamersley Iron, Robe River, BHP Billiton, Anglo-American, KCGM and Western Mining Corporation. The iron ore, gold, talc and nickel industries will benefit from Spectral Mine Sight as it will help them to enhance deposit delineation and ore grade characterisation as well as improve recovery. Better deposit delineation will also lengthen the life of the mine and has



CSIRO's Erick Ramanaidou sets up the Spectral Mine Site System to use in field trials.

obvious impact on preserving regional employment levels.

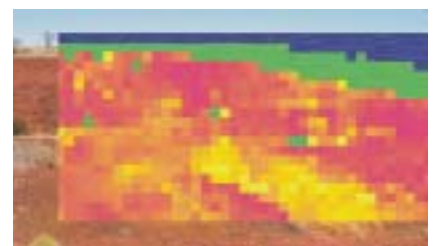
Communication of project results to date has taken place through case history reports, conferences, industry workshops and through a feature article in the Australian Institute of Mining and Metallurgy's Bulletin magazine (March/April 2002).

Funds were provided by the State Government for this project until June 2002. The team are now seeking funding from iron ore companies to further develop the existing technique and produce customised software for mines.

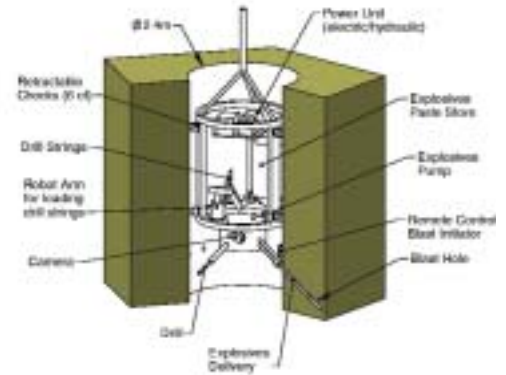
Contact: Erick Ramanaidou  
Ph: + 61 8 6436 8810  
Email: Erick.Ramanaidou@csiro.au



Pack Saddle road cut, 130km NW of Newman.



Same location as above showing a hematite:geothite ratio generated from spectral analysis. Hematite-rich is purple, geothite-rich is yellow, vegetation is green and sky is blue.



Horadium stopping platform

## Automated Horadium mining equipment

According to AGSO (Geoscience Australia), Australia currently has a large “para-marginal” resource that could easily become economic with the introduction of new mining technology. An analysis of AGSO figures and known orebody characteristics shows the potential exists for more than \$100 billion of contained metal in this resource to become economic using Automated Horadium – a new technique being developed by CSIRO and Curtin University. Automated Horadium is part of CSIRO’s long-term research into Remote Ore Extraction Systems (ROES).

Existing horadium methods require miners to drill blast-holes from within a shaft and radially outward in a sub-horizontal plane. The holes are filled with explosives and then blasted. The confinement of the shaft and the risk of rock falls make the task hazardous, and therefore it has limited application. Automation or remote control of this process will allow miners to work from the safety of remote control rooms without the associated hazards. Automated Horadium mining can be applied to a wide range of orebody types and replace existing techniques such as open-stopping. It has potential to deliver significant cost savings and safety improvements to make many sub-economic orebodies viable (expanding the economic resource). Ultimately the Automated Horadium machines will safely drill, load explosives and initiate blasts.

Project participants include CSIRO, Curtin University (Western Australian School of Mines), mining companies and equipment suppliers.

### Project deliverables

- Design and fabrication of a basic automated mining platform to be used for testing automated drilling and robotic manipulators from within a raise bore hole.
- Included in this equipment will be a level of survey/guidance technology required for testing.
- Comparative feasibility and cost studies for comparison with conventional techniques.
- A report covering preliminary laboratory test work of the equipment and recommendations for the complete mining system design.

### Potential benefits and progress to date

- Reduced injury and severity rates for underground hard-rock mining due to reduced exposure.
- Increased profitability from bulk mining with reduced costs for existing mines.
- Increased ore reserves with greater conversion of resources into reserves.
- Improved business for the manufacture of heavy mining equipment in Western Australia.
- Increased royalty revenue to the State Government with increased mine life as a result of the increased reserves.

During the first phase of the project (July 2000 – June 2002) a comparative feasibility study for four ore bodies in Western Australia has indicated cost reductions of between 6 per cent and 20 per cent. A feasibility study of a Queensland and South Australian ore body also indicated significant saving. Initial mine designs have been prepared and at least three of the ore bodies previously considered sub-economic are now considered economic. The basic concepts of the proposed equipment have been developed further and costings obtained. Expressions of interest have been received from mining companies and further CSIRO funding to continue the project has been confirmed. Risk assessments, industry consultation and an independent review have also been completed. The project is expected to evolve into full-scale trial mining in 2 to 3 years with a possible first site in the Western Australian Goldfields. Success of the technique will depend on the ability to operate drilling and explosive placement equipment without access by operators and this will be the focus of the next stage of research beginning 1 July 2002.

In addition to direct consultation and communication of findings to industry, the Automated Horadium technique was featured in the May 2002 issue of Australia’s Mining Monthly.

Contact: Jock Cunningham  
Ph: + 61 7 3327 4699  
Email: Jock.Cunningham@csiro.au

# Development of seismic applications for Western Australian conditions for the mineral and petroleum industries

Seismic methods used for exploration are the most powerful of all the geophysical imaging techniques due to their depth of investigation, directivity and structural resolution. However, there still remain some technical impediments to seismic methods in both the minerals and petroleum industries. Seismic imaging in areas of the North West Shelf can be hampered by energy scattering processes and fundamental research to understand and develop the technology to address the problem is needed. In the mining industry, more research into applying seismic technology and petroleum-based ideas to the hard-rock environment is also required.

Advances in our ability to model the complexities of seismic responses both numerically and using scaled physical models will greatly improve the application of seismic methods. The co-location at ARRC of CSIRO Exploration and Mining, CSIRO Petroleum and Curtin University's Department of Exploration Geophysics, along with the joint appointment of a research professor in petroleum geophysics, has created an integrated centre of expertise for geophysical research with the ability to understand and develop solutions to fundamental seismic problems in Western Australia in order to develop a suite of effective technologies.

This first ARRC seismic project has been driven by the need for new simulation and visualisation tools, and revolves around the development of a distributed software architecture to access many forward modelling capabilities from a single user interface. This capability will provide a platform for interpretation based upon multiple data sets, of which seismic data is one.

Project participants include CSIRO, Curtin University and The University of Western Australia.

## Project deliverables

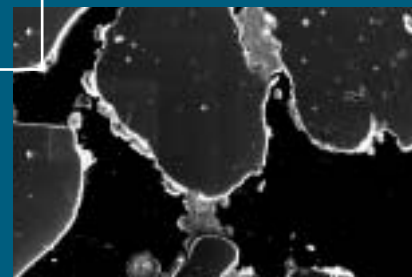
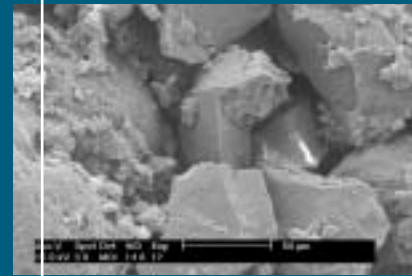
- Development of numerical modelling code using finite difference methods.
- Analog modelling of synthetic rocks to recreate reservoir processes.
- Time reversed acoustics to apply to reservoir imaging problems.
- Diffraction based imaging to stack scattered seismic energy in mineral exploration.

The broad research strategy for this project consists of three phases: research of the concepts, development of the techniques and transfer to industrial production processes.

## Potential benefits and progress to date

Improved and refined seismic techniques to explore and delineate petroleum reservoirs and hard rock ores have a direct impact on the discovery and the efficient recovery of these resources. Improvement of even 2 per cent in the recoverability of an oil reservoir and the reduced number of wells to delineate a discovery has an enormous impact on the economics of the reservoir, while the addition of the reconnaissance ability of seismic to the mining industry as an analog of what has revolutionised the petroleum industry would have immediate impact on exploration success and risk reduction in the mining sector. With a decrease in the discovery of shallow mineral deposits, this makes the development of viable seismic exploration methodologies critical to the future of the minerals sector.

To date, considerable progress has been made in numerical modelling, with the building of sophisticated code that can handle 3-D isotropic and anisotropic response in a heterogeneous media. It can also handle 2-D viscoelastic response with plans to develop to 3-D response. There is high recognition that this code is superior in flexibility and complexity than most codes currently available in the industry. The analog modelling research is based on



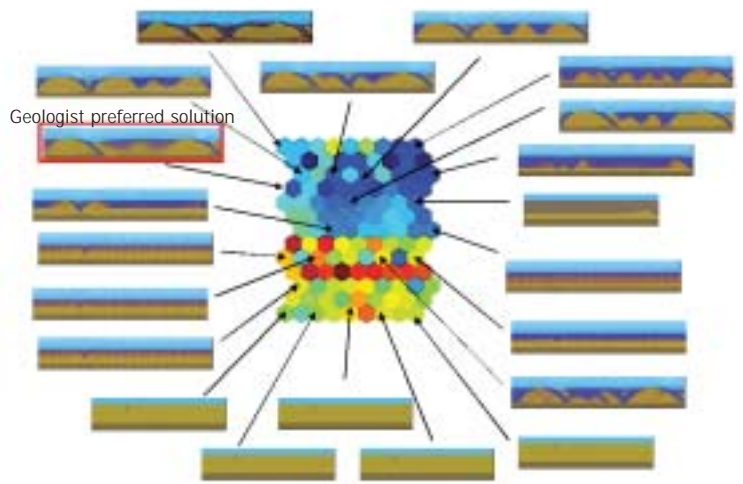
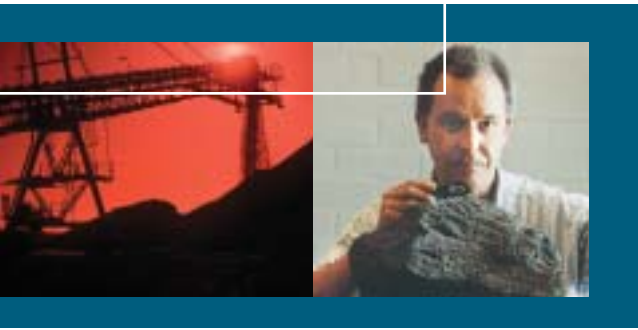
Artificial sandstones made from quartz sand and cemented with calcite using CIPS (Calcite In-situ Precipitation System). The rocks reproduce the acoustic and mechanical properties of natural sandstones and individual physical properties such as porosity, permeability and strength can be precisely controlled for laboratory experiments. The rocks have applications in geophysical, petrophysical and geomechanical research.

recent advances in physical modelling which combines sandbox experiments with a synthetic cementation technique (CIPS) developed by CSIRO Exploration and Mining. Initial work established the viability of this technique to constructing synthetic rocks, with a high degree of control on the properties such as cementation strength, velocity, porosity and permeability. The effort on time reversed acoustics has involved establishing the application of the techniques for focusing on multiple generation and looking at imaging changes observed in 4-D seismics.

Research findings are being continuously communicated to the industry through conference papers and direct meetings. Future work is planned to further develop the viscoelastic components of the numerical modelling code and joint development of the web modelling interface. Efforts will be concentrated on establishing the analog modelling techniques to a multiple set of problems in partnership with the petroleum industry and in support of research efforts in the proposed CRC in CO<sub>2</sub> sequestration.

Contact: Kevin Dodds  
Ph: + 61 8 6436 8727  
Email: Kevin.Dodds@csiro.au





Self organising map: 2D representation of multi-dimensional input parameter space mapping various model runs used by geologists in the modelling process.

## Simulation systems for predictive exploration and resource extraction

The mining and minerals industries make a fundamental contribution to the wealth of all Australians, however the mining industry in Australia is now facing a series of challenges. The spectacular growth experienced over the past decade in the real value of Australia's subsoil assets is the result of a series of impressive exploration successes in the 1970s and 1980s. It's now 25 years since the discovery of Olympic Dam – the last mineral deposit discovered in Australia with a Net Present Value (NPV) of greater than \$1 billion.

The next round of significant discoveries in Australia will depend on the development of far better conceptual targeting procedures based on a generic understanding of ore systems and the ore forming process, together with new geophysical and geochemical technologies. To address this, a research team at ARRC has been developing computer simulation systems for predictive exploration and subsequent resource extraction. The outcomes include a set of predictive exploration and engineering tools which form the basis for a set of models which simulate the origin and evolution of sedimentary basins and collisional mountain terrains.

Project participants include CSIRO, IVEC, The University of Western Australia and students from Curtin University of Technology and the University of Western Australia.

### Project deliverables

- 3D and 4D geodynamic modelling codes which simulate the geological and geo-engineering conditions within which petroleum and minerals systems form and from which they are extracted.
- Interactive software systems which enable users to consider “what if” scenarios associated with the 3D thermal-chemical-fluid flow-deformational history of a specific region of the Earth's crust, from basin scale through to engineering scale.
- Advanced interactive visualisation systems for exploration-friendly software. These are being developed through the Interactive Virtual Environments Centre (IVEC) and focus on geologically realistic numerical procedures.

### Potential benefits and progress to date

A new world-class discovery would make a significant contribution to Australia's economy and mean an increase in the per capita wealth of Australians. The major beneficiaries of this Predictive Systems research program will be the Australian petroleum and exploration industries (and in turn the Australian community).

Principal activities in this project during the 2001/02 financial year were in the area of ‘inversion in geology’ – a technique used in the computer simulation of earth processes associated

with ore body formation. In the past, a geologist conducting numerical models would vary a number of input parameters such as stress and heat at the boundaries of the model (a 2-D or 3-D “box”) to test which combination of variables would produce the geologically sensible outcomes they were attempting to reproduce. Given that each test can take hours to weeks to run in the computer, the process is slow and inefficient if done in a sequential manner. This slowness is a major impediment to the application of numerical modelling to many practical mineral exploration problems. A major step forward in addressing this difficulty is the inversion in geology algorithm developed by CSIRO. This provides a mathematical tool for changing a number of parameters simultaneously, meaning that many modelling runs can be undertaken at the same time to more rapidly produce geologically sensible outputs. Results can be selected for closeness to reality by an experienced geologist and the algorithm can then select starting parameters using the information gained from the geologist's visual inspection. Therefore, this work will allow rapid selection of parameters to produce realistic outputs in known geological environments. Exploration geologists will then be able to use these parameters to apply to their geological prospects to determine if mineralisation is possible and, if so, what form it might take.

Contact: Paul Roberts  
 Phone: + 61 8 6436 8758  
 Email: Paul.A.Roberts@csiro.au



# Finance

Total 2001/02 investment in research and support services at ARRC by CSIRO and Curtin University is summarised in the following table.

Expenditure Category	Staff (\$ '000)	Operations (\$ '000)	Infrastructure & Support (\$ '000)	TOTAL
CSIRO	8,872	5,783	5,630	20,285
Curtin University	2,055	2,294	464	4,813
<b>Total</b>	<b>10,927</b>	<b>8,077</b>	<b>6,094</b>	<b>25,098</b>

Funding	Institutional* (\$ '000)	External (\$ '000)	TOTAL
CSIRO	11,741	8,544	20,285
Curtin University	2,021	2,792	4,813
<b>Total</b>	<b>13,762</b>	<b>11,336</b>	<b>25,098</b>

\* Direct Government funding to CSIRO and Curtin University

## Research support and human resources

ARRC houses some 230 staff from CSIRO Exploration and Mining, CSIRO Petroleum and Curtin University of Technology. CSIRO Petroleum, as the service provider for ARRC, is responsible for the building and its environment. This is managed through the ARRC Operations Team, who has responsibility for all aspects of this service provision – Human Resources, Finance, Information Technology and Operations, including the Library.

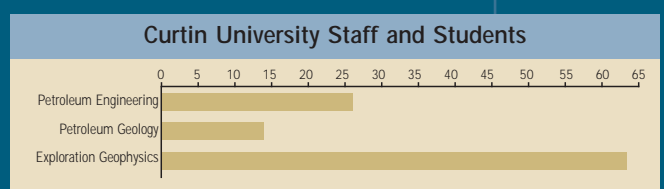
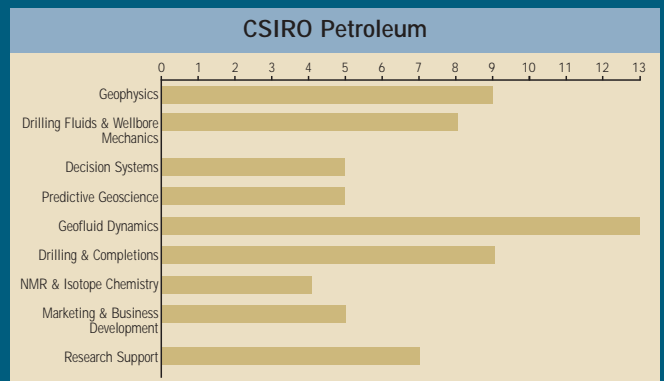
Staff have been recruited and relocated from CSIRO and the petroleum and minerals industry locally, from the eastern seaboard of Australia and overseas. In addition, a number of students, fellows and visiting scientists work within the research groups at ARRC.

Prior to staff moving in to ARRC, Information Technology (IT) staff worked around the clock to commission and configure new IT facilities, resulting in a smooth transition and minimal disruption to daily operation as the site became populated. ARRC's computing, telephone and video conferencing facilities are 'state-of-the-art', with the facility being the first CSIRO site to deploy a total IP telephony system with no reliance upon legacy PABX systems. This means that instead of having traditional separate data and voice circuits, ARRC has a converged voice, video and data network in which voice and video is treated simply as data, similar to the way in which email is treated. ARRC has also implemented a wireless data network that enables staff with suitably equipped laptop computers to roam freely within the building with no loss of network connectivity.

ARRC's professional Records Management staff develop, coordinate and implement records management procedures for participating CSIRO divisions on site. Staff gather and maintain scientific, corporate and commercial records in accordance with CSIRO policy and best practice procedures.

The ARRC Library is a gateway to a powerful suite of information services which enable CSIRO divisions on site, CRCs, Curtin University of Technology and Centres of Excellence to take advantage of sophisticated electronic information delivery options to realise ARRC's world class research vision.

ARRC staff numbers as at 30 June 2002



ARRC Centre Management and Operations staff have been instrumental in guiding the Centre through the building set-up and the warranty and defects period of the first twelve months. The Research Support Infrastructure provides a variety of administrative services for all ARRC staff.

# Awards, achievements and community sponsorships

## Western Australian CSIRO University Postgraduate Scholarships (WACUPS)

CSIRO, Curtin University of Technology, Edith Cowan University, Murdoch University and The University of Western Australia have established a fund for new postgraduate research scholarships that aims to enhance research into minerals and energy exploration, extraction and processing.

WACUPS are awarded for a two year period for Masters by Research and a

three year period for a Doctoral degree, and are open to both local and international applicants. Current WACUPS students and their research areas include:

- Damian Leslie, Curtin University/CSIRO Petroleum, Geophysics
- Affonso Lourenco, Curtin University/CSIRO Petroleum, Drilling and Completions

- Wolfgang Prassl, Curtin University/CSIRO Petroleum, Drilling and Completions
- Jasmine Rutherford, University of Western Australia / CSIRO Exploration and Mining, Environmental Geoscience
- Chris Wijns, University of Western Australia / CSIRO Exploration and Mining, Structural Controls on Mineralisation

**ARRC's most important asset is its diverse and highly talented mix of staff, a claim that is backed up by the awards and recognition they receive.**

## The "Performed by Schlumberger 2001 Silver Award"

The "Performed by Schlumberger 2001 Silver Award" was presented to the integrated team of CSIRO Petroleum, Chevron (formerly WAPET) and Schlumberger for work titled Prospect Risk & Uncertainty Management. This was a project to evaluate the overpressure risk for a drilling prospect by integrating technical studies with the drilling decision process using Juniper-based integrated probability decision trees. The technical studies involved geological modelling, velocity-pressure transform generation and mapping onto a 3-D velocity cube. The whole process provided an explicit, transparent decision process which changed the perception of risk in the area, with consequent reduced exploration costs per well, increasing its apparent prospectivity.



Kevin Dodds, one of the members of the CSIRO Petroleum research team that won the "Performed by Schlumberger 2001 Silver Award".

## 2002 Gibb-Maitland Medal

CSIRO Exploration and Mining scientist Dr Charles Butt has been awarded the 2002 Gibb-Maitland Medal by the Western Australian Division of the Geological Society of Australia. The medal is awarded yearly for contributions to geoscience in Western Australia, particularly in economic geology. Dr Butt received this year's medal for the development of geological and geochemical exploration procedures for deeply weathered terrains.



Dr Charles Butt, winner of the 2002 Gibb-Maitland Medal.

## 2001 Lindsay Ingall Award

Curtin University's Greg Street received the 2001 Lindsay Ingall Award from the Australian Society of Exploration Geophysicists for his efforts in the promotion of geophysics to the wider community. Greg played a significant role in expanding the application of geophysics into the environmental field. From encouraging fellow scientists to pursue environmental causes and identify solutions, to educating parliamentarians, Greg's active role in the fight against salinisation and other environmental hazards has resulted in numerous public appearances and contributions to all forms of media.



Greg Street (left) receiving the Lindsay Ingall Memorial Award from ASEG President Tim Pippett.

ARRC is also conscious of its responsibility to the community in which it is located and the general public. During 2001/02, ARRC has supported its community through a number of initiatives.

### Karawara Community Project

On moving in to ARRC, CSIRO donated \$5,000 to the Karawara Community Project's Go Kart Program. The Program is offered to local children considered "at risk" as well as those who would not usually have the chance to enjoy such activities. It aims to instil an improved sense of self-worth as well as increase problem solving and social skills in its young participants. The Go Kart Program teaches new skills such as driver safety and cart maintenance, and is facilitated by an experienced youth worker who is also a qualified mechanic. Karawara is a neighbouring suburb to Kensington, in which ARRC is located.

### Young Achievement Australia

ARRC is supporting the Young Achievement Australia Business Skills Program. This gives student participants exposure to the business world through a 16 - 24 week structured program which allows them to form their own company, raise capital and develop a product to manufacture and sell. Students completing the program gain a Certificate II in Small Business Management. ARRC's contribution is sponsoring students at Mt Lawley Senior High School.

### Curtin Entrepreneurs Challenge

CSIRO Petroleum is sponsoring the Innovation and Creativity award in the 2002 Curtin Entrepreneurs Challenge. The aim of the competition is to cultivate entrepreneurship in students in all subject areas at Curtin University of Technology. Participants are learning about entrepreneurship, identifying business opportunities, forming teams, writing executive summaries and business plans and building successful networks.

### Schools Information Program

The Schools Information Program is run by the Petroleum Club of WA and the Australian Petroleum Production and Exploration Association (APPEA). The Program organises excursions for year 10 science classes to visit various research organisations and companies involved in petroleum to learn more about the industry. During May 2002, ARRC hosted students from Duncraig Senior High School, Rossmoyne Senior High School and John Curtin College of the Arts. ARRC will continue to support this program each year.

### "Me No Hair Day"

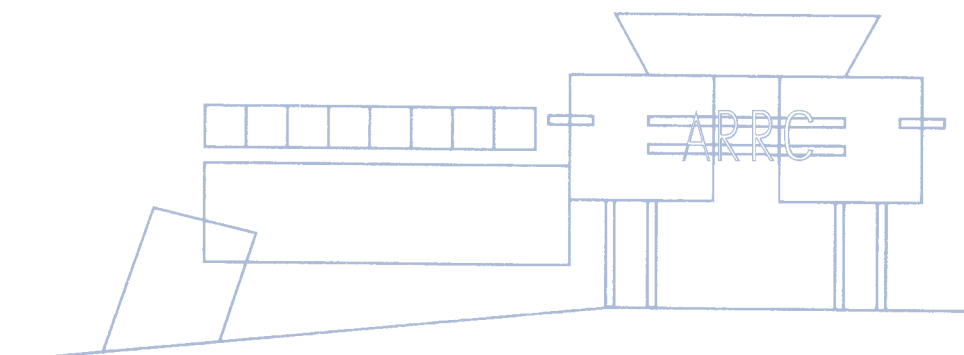
In March 2002 ARRC staff enthusiastically became involved in organising an event for "Me No Hair Day", with 5 staff members shaving their heads for charity. A total of \$1,700 was raised for the Cancer Foundation of Western Australia.



Students from Rossmoyne Senior High School won Best Project for Semester 2 of the Petroleum Club of WA's 'School's Information Program'.



CSIRO staff members David Gray, Catherine Durrant, Tony Gray and Greg Hitchen shaved their heads to raise money for Cancer research on "Me No Hair" day.







# ARRC Committees

## ARRC Steering Committee

The ARRC Steering Committee was established to provide a forum for high level liaison between CSIRO and the Western Australian government in regard to the operational and research objectives of the Centre and other relevant issues. Its role was also to appoint all members of the ARRC Advisory Committee. The Steering Committee met three times a year.

Membership for 2001/02:

- Hon Clive Brown (Chair) - Minister for State Development
- Mr George Harley - General Manager, CSIRO Corporate Property
- Dr Bruce Hobbs - Deputy Chief Executive, CSIRO
- Dr Adrian Williams - Chief, CSIRO Petroleum
- Prof Neil Phillips - Chief, CSIRO Exploration and Mining
- Mr Greg Thill - Principal Adviser, Resources, CSIRO
- Emeritus Prof John de Laeter - Curtin University
- Dr Paul Schapper - A/Director General, DoIT\*
- Mr Quentin Harrington - Executive Director, DoIT
- Mr Richard Muirhead - Chief Executive Officer, DCT\*\*
- Mr Simon Skevington - Team Leader, Infrastructure, DoIT
- Mr John Thompson - Chair, TIAC

The Steering Committee was disbanded after the commissioning of ARRC as per the formal agreement to establish the Centre.

## ARRC Construction Committee

The ARRC Construction Committee was responsible for overseeing the construction contracts for establishing ARRC and consisted of members from CSIRO and the Western Australian Government. The Committee met every six weeks during the construction period.

Membership for 2001/02:

- Mr Trevor Moody (Chair) - Assistant General Manager, CSIRO Corporate Property
- Dr Steve Harvey - Deputy Chief, CSIRO Exploration and Mining
- Mr Peter Bosci - General Manager, CSIRO Petroleum
- Mr Simon Skevington - Team Leader, DoIT
- Ms Lesley Smith - Executive Director, DCT
- Mr Bob Gadsdon - Client Manager, CAMS\*\*\*
- Mr Arthur Lyons - Project Officer, DoIT
- Mr Roy Chapman - Project Leader, DoIT

As the Construction Committee's function was to see the building through the construction, completion and defects period, its role has now ceased.

\* State Department of Industry and Technology

\*\* State Department of Commerce and Trade

\*\*\* State Department of Contract and Management Services

## ARRC Advisory Committee

The role of the ARRC Advisory Committee is to ensure ARRC operates in a manner that provides 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 is selected from representatives of appropriate institutions, government agencies and industry.

Membership for 2001/02:

- Mr Lee Ranford (Chair) - A/Executive Director, DMPR\*\*\*\*
- Dr Bruce Hobbs - Deputy Chief Executive, CSIRO
- Mr Jeffrey Gresham - General Manager – Exploration, Homestake Gold
- Mr Rob Male - Principal Development Engineer, Woodside Energy
- Prof. Michael Barber - Pro Vice Chancellor (Research), UWA
- Prof Paul Rossiter - Deputy Vice Chancellor (R&D), Curtin University
- Mr Geoff Suttie - Counsellor, DMPR
- Dr John Barker - Team Leader, DoIT

## ARRC Directions Committee

The ARRC Directions Committee consists of one senior representative from each of the CSIRO Divisions on site, one representative from Curtin University of Technology, ARRC Centre Manager and a representative from CSIRO Minerals in an observer capacity. The Committee's main functions are to:

- Provide advice and input to the ARRC Advisory Committee on the strategic direction of the Centre.
- Ensure the operations of the site are consistent with the ARRC Charter.
- Approve annual and out year ARRC budgets to meet current and future requirements.

The Committee delegates responsibility for the day-to-day operations of the Centre to CSIRO Petroleum line management, who have established an Operations Team for this purpose.

Membership for 2001/02:

- Dr Adrian Williams (Chair) - Chief, CSIRO Petroleum
- Prof Neil Phillips - Chief, CSIRO Exploration and Mining
- Prof Paul Rossiter - Deputy Vice Chancellor (R&D), Curtin University
- Ms Anne-Marie Cook - ARRC Centre Manager
- Dr Len Warren (Observer) - Senior Manager, CSIRO Minerals

\*\*\*\* State Department of Mineral and Petroleum Resources

# Industry clients and partners

## CSIRO

Alberta Research Council  
AMIRA  
Anglogold  
Apache Energy Limited  
AUSIndustry  
BHP Billiton Iron Ore  
BHP Billiton Petroleum  
Boral Energy Resources Ltd  
BP  
Chevron Texaco  
Codelco  
Conoco  
Coparex  
CRC Program (DISR)  
Esso  
Exxon Mobil  
Falconbridge Nouvelle Caladonie Sas  
Falconbridge Limited  
Fractal Graphics  
Halliburton Baroid Product Service Line  
Hamersley Iron  
Geotech  
GeoTrack International  
Inpex  
Japan Australia LNG (MIMI) Pty Ltd  
Japan National Oil Corporation  
Lemigas  
Magellan Petroleum Australia Limited  
MERIWA  
Metal Mining Agency of Japan  
Nippon  
Noble Drilling  
Norsk Hydro AS  
Oil Search Limited  
OMV Australia  
Pacific Power  
PanCanadian Petroleum Limited  
PDVSA  
Petrobel  
Petrobras  
PETRONAS  
Phillips Petroleum Company  
Phillips Oil Company Australia  
Premier Oil  
Robe River Mining  
Roger Townend & Associates  
Santos Limited  
Saskatchewan Research Council  
Schlumberger  
Tiwest  
Shell  
South Pacific Chevron Company  
Sumitomo Metal Mining  
Sydney Gas  
Tap Oil  
TNO  
Woodside Energy Ltd

## Curtin University of Technology

AAPG Foundation  
AGIP Australia Limited  
Anaconda Nickel Ltd  
Anglo American Exploration (Australia) Pty Ltd  
Anglogold Australia Limited  
Apache Energy Limited  
Attaka CFT, Unocal Indonesia Co.  
Australian Society of Exploration Geophysicists  
Research Foundation  
BHP Billiton Iron Ore  
BHP Billiton Petroleum  
CGG Australia Pty Ltd  
Chevron Australia Pty Ltd  
Chris DBF  
Consolidated Minerals n̄ Pilbara Manganese  
De Beers Australia Exploration Ltd  
Encom  
ER Mapper  
Fractal Technologies  
Fugro Survey Pty Ltd  
Geosoft  
Giant Reef Mining  
Heron Resources  
JCOAL - Japan Coal Energy Centre  
Kevron Pty Ltd  
Landmark Graphics Corporation  
Metals Quest Australia Limited  
M.I.M. Exploration Pty. Ltd.  
Minerals and Energy Research Institute of WA  
(MERIWA)  
Origin Energy Resources Limited  
Paradigm Geophysical Corp  
Paris University VII  
PGS Australia Pty Ltd  
Placer Dome Asia Pacific Limited  
Santos Limited  
Southern Geoscience Consultants Pty Ltd  
Tanami Gold ML  
Texaco Australia Pty Ltd  
Thales GeoSolutions  
Veritas DGC Australia Pty Ltd  
WesternGeco  
WMC Resources Ltd  
Woodside Energy Ltd





# ARRC contacts

## **Australian Resources Research Centre**

26 Dick Perry Ave  
Technology Park  
Kensington  
Perth WA 6151  
Australia

PO Box 1130  
Bentley WA 6102  
Australia

Ph: + 61 8 6436 8500  
Fax: + 61 8 6436 8555  
Web: [www.rrc.net.au](http://www.rrc.net.au)

## **CSIRO Exploration and Mining**

Dr Steve Harvey  
Deputy Chief  
Ph: + 61 8 6436 8610  
Email: [Steve.Harvey@csiro.au](mailto:Steve.Harvey@csiro.au)

## **CSIRO Petroleum**

Greg Thill  
Acting Chief  
Ph: + 61 8 6436 8701  
Email: [Greg.Thill@csiro.au](mailto:Greg.Thill@csiro.au)

## **Curtin University of Technology**

Professor Paul Rossiter  
Deputy Vice-Chancellor (R&D)  
Ph: + 61 8 266 3045  
Email: [p.rossiter@curtin.edu.au](mailto:p.rossiter@curtin.edu.au)

Head of Department  
Department of Exploration Geophysics  
C/- Deirdre Hollingsworth  
Ph: + 61 8 9266 3565  
Email: [deirdre@geophy.curtin.edu.au](mailto:deirdre@geophy.curtin.edu.au)

Professor John McDonald  
Centre of Excellence for Exploration and Production  
Geophysics  
Ph: + 61 8 9266 7194  
Email: [mcdonald@geophy.curtin.edu.au](mailto:mcdonald@geophy.curtin.edu.au)

Professor Raj Rajeswaran  
Department of Petroleum Engineering  
Ph: + 61 8 9266 7857  
Email: [rajr@peteng.curtin.edu.au](mailto:rajr@peteng.curtin.edu.au)

Professor Mike Middleton  
Department of Petroleum Engineering  
Ph: + 61 8 9266 7980  
Email: [middlem@lithos.curtin.edu.au](mailto:middlem@lithos.curtin.edu.au)

## **Cooperative Research Centres for:**

Landscape Evolution and Mineral Exploration  
Paul Wilkes  
Ph: + 61 8 6436 8695  
Email: [wilkes@geophy.curtin.edu.au](mailto:wilkes@geophy.curtin.edu.au)

Predictive Mineral Discovery  
Paul Roberts  
Ph: + 61 8 6436 8758  
Email: [Paul.A.Roberts@csiro.au](mailto:Paul.A.Roberts@csiro.au)

## **IVEC (Interactive Virtual Environments Centre)**

Dr Rod Thiele  
IVEC Director  
Ph: + 61 8 6436 8831  
Email: [Rodney.Thiele@csiro.au](mailto:Rodney.Thiele@csiro.au)  
Web: [www.ivec.org](http://www.ivec.org)

## **ARRC Centre Management**

Anne-Marie Cook  
Ph: + 61 8 6436 8511  
Email: [Anne-Marie.Cook@csiro.au](mailto:Anne-Marie.Cook@csiro.au)

## **ARRC Public Relations Office**

Ph: + 61 8 6436 8707



# ARRC



Australian Resources Research Centre

