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CO₂ disposal
deep ocean or re-inject

OIL, GAS TIMESCALE
under the microscope

Climate history
frozen in Antarctic chill

BIGHT HOLES
puzzle scientists

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Also: Divisions take inventory, boundary possibly extended, geology in technicolour

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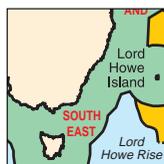
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Prydz Bay and the usual Antarctic hazards—icebergs and pack ice. Photo taken from the deck of *JOIDES Resolution*. See article page 3.

Photo: Phil O'Brien, co-chief scientist on Ocean Drilling Program leg 188 to Prydz Bay

The core of global climate change

Australia— Antarctica

The break up of the once huge continent of Gondwana to form Antarctica and Australia and the resultant changes in oceans and currents had a huge impact on global climate. If Australia had not broken away from Antarctica, worldwide climate probably would have remained warm.

Determining the role of Antarctica and the Southern Ocean in global climate is the focus of a series of ocean drilling expeditions. From January to May this year, two expeditions carrying scientists and technicians from various nations sailed into waters south of Tasmania (ODP leg 189) and into Australian Antarctic waters (ODP leg 188) to take sediment samples that give an account of Earth's climatic history.

Co-chief scientist of leg 188, Dr Phil O'Brien and co-chief scientist of leg 189 Dr Neville Exon (both from AGSO) give a brief summary of their expeditions.

Climate changes on Earth, no matter how small, influence where species live. Earth has experienced huge climatic changes over its four billion-year history—from ice ages to global warming. The number of climatic fluctuations, their frequency and influence on life forms, and predictions of Earth's climate this millennium capture worldwide attention. Grappling with climate change requires detailed scientific study of Earth's records—the layers of mud, detritus and microscopic plants and animals built up on the ocean floor over aeons.

Australia on the move

Forty-five million years ago, Australia started to move northward away from Antarctica at a rate of approximately five centimetres per year. At this time a cool-temperate rainforest covered Antarctica. Its vegetation was similar to that growing nowadays in the Tasmanian highlands, New Zealand and Patagonia. By 33 million years ago the Tasmanian land bridge had separated from Antarctica. Cold currents began to circulate around Antarctica and cut it off from the warm currents flowing south from the tropics. This created perfect conditions for ice sheets to form. By 15 million years ago most of Antarctica was a frozen continent. Vegetation vanished, unable to survive the dramatic climate change. Evidence of its existence, however, is encased in layers of ocean sediment off Australia and Antarctica.

ANTARCTIC WATERS—LEG 188

Ocean Drilling Program leg 188 to Prydz Bay experienced the usual range of Antarctic hazards with several storms, icebergs and pack ice forcing the relocation of a drill hole. Drilling equipment froze and snow blanketed the ship. There were light moments, however, such as the acrobatics of humpback whales that visited the ship on several occasions.

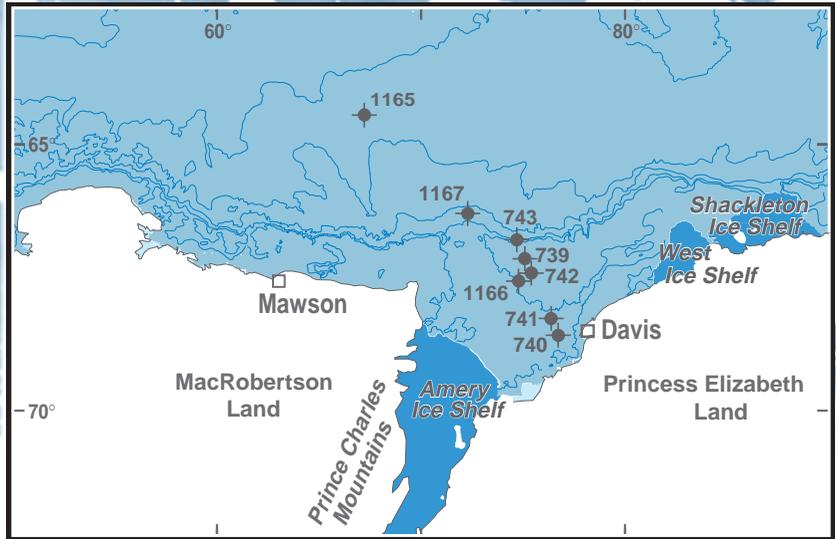
Prydz Bay was chosen because it is the downstream end of the Lambert Glacier–Amery Ice Shelf drainage system, the largest single ice stream flowing from the interior of east Antarctica. The ice flows along a major graben which has been active since the Permian and is partly sourced from the subglacial Gamburtsev Mountains. These areas are where the Antarctic ice sheet probably first developed. Thus, it was thought that Prydz Bay was likely to contain the earliest evidence of Cenozoic glaciation in Antarctica and that fluctuations of the Lambert–Amery system would reflect major changes in the east Antarctic ice sheet.

Three holes were drilled: each one aimed at providing insights into different aspects of Antarctic glacial history.



▲ The acrobatics of a juvenile humpback whale in Prydz Bay, Antarctica, provide welcome entertainment for those aboard *JOIDES Resolution* for leg 188.

Figure 1. Leg 188 drill holes (1165–1167) in Prydz Bay, Antarctica



Site 1166

Site 1166 on the continental shelf in 486 metres of water was drilled to sample the earliest Cainozoic glacial sediments, to date glaciation onset, and to see what the pre-ice sheet environment was like. (See figure 1.) Drilling penetrated 381 metres of pre-glacial, early glacial and glacial rocks of Early Cretaceous (?) to Holocene age.

The oldest rocks, which are as yet undated claystone and sandstone, contain carbonaceous material and wood indicative of an alluvial environment with vegetation. Overlying these sediments are deltaic deposits with abundant spores, pollen and marine dinoflagellates. A disconformity separates these rocks from overlying transgressive sandstone and mudstone, and open marine mudstone with ice-rafted dropstones. The deltaic and mudstone units contain diatoms and dinoflagellates of mid- to Late Eocene age (34 to 37 Ma). Spores and pollen indicate that there once was a stunted, 'rainforest scrub' like that in alpine areas of Tasmania and Patagonia with *Nothofagus* species and gymnosperms. These are extinct relatives of the Wollemi Pine, a rare tree discovered recently near Sydney. A major unconformity separates these marine strata from diamicts of late Pliocene to Pleistocene age. The diamicts are mostly subglacial deposits. An interbedded unit of diatom-bearing silts probably formed during an interglacial period.

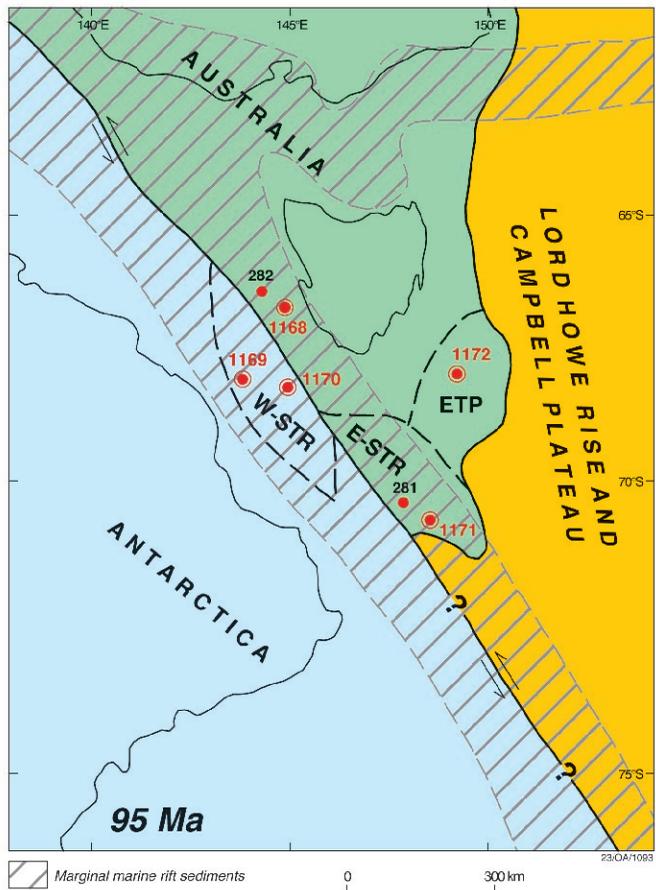


Figure 2. The Tasmanian area deep within Gondwana 95 million years ago. ODP leg 189 drill sites are shown with large circles and earlier deep-sea drilling project sites with dots. Australia and Antarctica are sliding apart along the Tasmanian–Antarctic Shear Zone. The future continental fragments off Tasmania are shown as W-STR (west South Tasman Rise), E-STR (east South Tasman Rise) and ETP (East Tasman Plateau).

Site 1167

Site 1167, in 1649 metres of water, penetrated the Prydz Channel trough mouth fan. (See figure 1.) This fan is a sediment body constructed of debris brought to the shelf edge in the base of the Lambert Glacier during periods of its maximum advance. At the shelf edge, the debris melts out and slumps down the continental slope or rises in turbid meltwater plumes before settling out. The hole sampled a 448-metre thick section of Pleistocene debris flows with minor interbedded, laminated mudstones and sandstones. The debris flows mark times of glacier expansion to the shelf edge, while mudstones mark phases of ice retreat. Sedimentation cycles caused by orbital forcing of ice volumes were expected. Instead several large-scale (up to hundreds of meters thick) cycles of systematic variation in magnetic-mineral content and other properties were observed. They probably reflect cyclic changes in ice volume in the order of 800 000 to one million years' duration in the Lambert Glacier drainage basin. This is much longer than known orbital cycles (Milankovich Cycles), and is the first observation of such cycles in a glacial trough mouth fan. Post-cruise work will consider the significance of these cycles.

Site 1165

Site 1165 (see figure 1), drilled in 3537 metres of water on the continental rise, penetrated a mostly continuous 999-metre section of early Miocene-Holocene age hemipelagic and contourite deposits. These deposits document changes in Antarctic palaeoenvironments. They show times of temperate glaciers with fluvial systems and large sediment supply (early Miocene). They also show increased polar conditions with glacial erosion of the shelf, increased ice rafted detritus (IRD) and lower sediment supply (mid-Miocene), and polar conditions like today with IRD and little sediment reaching the rise at this site. Cyclic sedimentation between terrigenous-dominated and biogenic-rich intervals is observed throughout the hole, and appears (where most evident in the upper 300 metres below seafloor) to have Milankovich periodicities that imply orbital forcing of the sedimentation processes.

Research team

AGSO's Phil O'Brien led the formulation of the drilling proposal and, with Alan Cooper of Stanford University, was the expedition's co-chief scientist. Proposal development started six years ago and incorporated ideas and data contributed by Russian and Japanese scientists. Data for siting the holes were collected on two Australian National Antarctic Research Expedition voyages in 1995 and 1997.

The drilling was carried out on ODP's *JOIDES Resolution* from January to early March 2000. The *Resolution* is a drill ship 143 metres long and 21 metres wide. It has a derrick 62 metres high and is capable of drilling in water depths up to 8325 metres. On board were 26 scientists from eight countries along with 25 technicians and 65 crew. Australian participants were Pat Quilty (University of Tasmania), Alex Kaiko (Curtin University) and Jason Whitehead (now of the University of Nebraska but previously at the Antarctic Cooperative Research Centre in Hobart). Since returning, Mike Macphail and Liz Truswell of the Australian National University are studying the palynology of key samples.

SOUTH TASMAN RISE—LEG 189

No sooner had the *JOIDES Resolution* berthed in Hobart after leg 188, than it was refueled, restocked and set sail again, but on leg 189—a deep-sea sediment coring expedition off Tasmania. On leg 189 the ship was at sea for 55 days and on site for 45 days. Despite being in the Roaring Forties with gale force winds, and vertical movement of the drill rig by up to eight metres, almost no coring time was lost. (Core recovery was an admirable 89 per cent.)

Four and a half thousand metres of core from five drill sites were recovered. End-to-end this core would extend ten times across Sydney Harbour beneath the Harbour Bridge. Several holes were drilled at most sites to duplicate or triplicate key sequences and thus ensure there were no core gaps. The most deeply drilled site extended 960 metres beneath the seabed, and the shallowest site was in water more than 2000 metres deep—deeper than Mt Kosciusko is high.



▲ Sedimentologists on board leg 189 study drill core material that shows the amazing Eocene-Oligocene transition: the change through time from brown mudstone to green glauconitic siltstone to pale grey chalk.



▲ Leg 189 paleo team (also known as The Dating Shop)



▲ Leg 189 leaders (from left) Neville Exon and Jim Kennett



▲ A 5th grade class in Brenham, Texas, sent Polar the bear on Leg 189.

The cores recovered consist of mineral grains, spores and pollen from the land, and hard parts of innumerable minute creatures that lived in the seas off Tasmania in the last 70 million years. They record conditions in the ocean and on land from the end of the Cretaceous (the age of dinosaurs) through to the present day, and put Australia's historical climatic fluctuations into a long-term context.

The drill sites were on sunken continental blocks off Tasmania, which had been at polar latitudes late in the Cretaceous when Australia was joined to Antarctica deep within Gondwana (see figure 2). In fact, the blocks could be considered part of Antarctica until 35 million years ago. The cores show that throughout this time this part of Antarctica was relatively warm, with little ice, and supported temperate rainforests with southern beeches and ferns. The sea was also relatively warm and shallow.

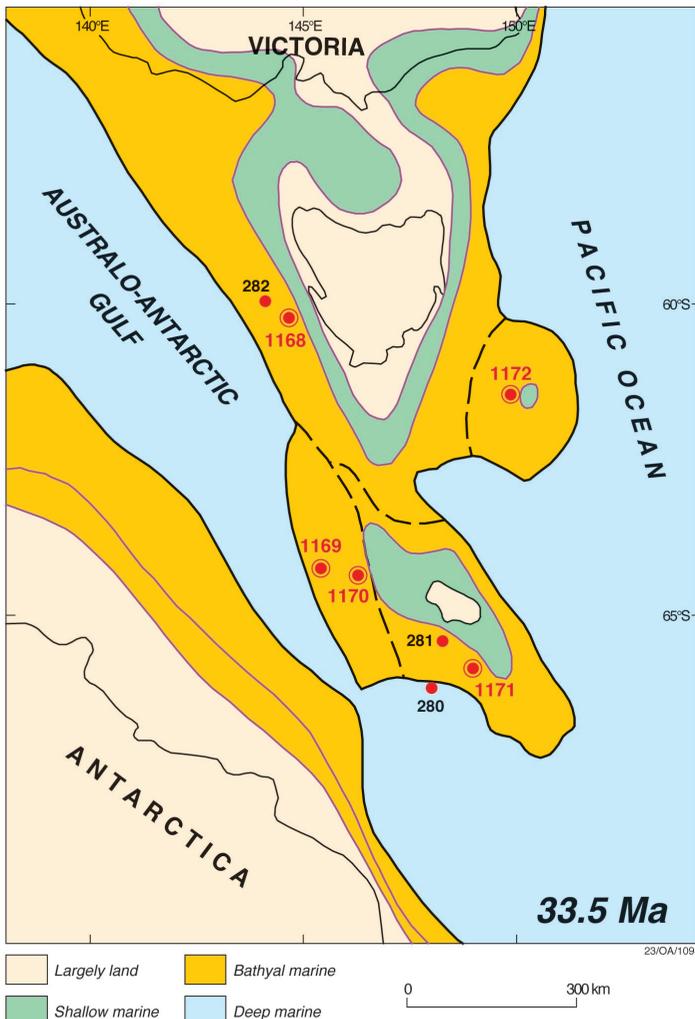
Temperatures reached a peak about 55 million years ago, when the planet was much warmer than today. By 35 million years ago the Tasmanian land bridge had separated from Antarctica (see figure 3), and the cold Antarctic Circumpolar Current started to circulate around Antarctica. The cores show that the formerly warm shallow seas around Tasmania were cooling and deepening, much of the land bridge had subsided beneath the ocean, and less sediment came from land. There were large temperature fluctuations over relatively short time periods, the details of which can be read in the cores. Soft sedimentary oozes consisting largely of calcareous and siliceous skeletons of microscopic plankton were laid down. By 15 million years ago, most of Antarctica was buried deep under ice caps.

The cores also contain dust particles from a drying Australia, which became more abundant from five million years ago. By that time, Australia's movement northward into mid-latitudes, along with global climate change, led to massive aridity. The global cooling eventually led to the ice ages of the last two million years. Currently Earth is experiencing a warm spell between glacial periods.

Sites 1168–1172

The first site drilled, site 1168 on the west Tasmanian margin, cored to 883 metres below the sea floor (mbsf). It recovered an almost complete sequence of Oligocene to Recent chalk and ooze, and a little late Eocene shelf mudstone. The second site, site 1169 on the western South Tasman Rise, cored to 249 mbsf and recovered only chalk and ooze, with an expanded early Pliocene to Recent sequence, and small parts of the late and middle Miocene. The third site, site 1170, cored to 780 mbsf and recovered early Oligocene to Recent chalk and ooze, and middle to late Eocene shelf mudstone. This site lay closer to the developing Antarctic Circumpolar Current, which caused erosion or non-deposition of most of the mid-Oligocene and the late Miocene. These three sites were all on the western side of the Tasmanian land bridge.

The fourth site, site 1171 on the southernmost South Tasman Rise and the Pacific side of the Tasmanian land bridge, cored 959 mbsf. It recovered an almost-complete late Oligocene to Recent chalk and ooze sequence, and much of a late Paleocene to late Eocene shelf mudstone sequence. Several time breaks in the Eocene and Oligocene, and in the late Miocene, can be related to the nearby Antarctic Circumpolar Current.



◀ **Figure 3.** Tasmania and Antarctica had just separated 33.5 million years ago, and water was starting to flow between the Australo-Antarctic Gulf and the Pacific Ocean. This was the precursor of the Antarctic Circumpolar Current that had a profound effect on global climate. Before this time the different settings of the leg 189 sites led to profoundly different sedimentation, but thereafter it became more and more similar.



▲ On board the *JOIDES Resolution* for leg 189: AGSO's Neville Exon (right) and Peter Hill examine Paleocene carbonaceous claystones drilled off south-east Tasmania.

Site 1172 on the East Tasman Plateau was also on the Pacific side of the land bridge, but further from the Antarctic Circumpolar Current. It recovered almost-complete sequences of Oligocene to Recent chalk and ooze, and Late Cretaceous to late Eocene shelf mudstones. Short time breaks were identified in the earliest Paleocene, early middle Eocene and earliest Oligocene.

Successes and surprises

Major successes of the expedition included establishing differences for most of the Cainozoic between the Indian and Pacific oceans, and from north to south. Relatively complete sequences were recovered, enabling an unprecedented integrated biostratigraphic framework for the region to be established. In addition, there were surprises from two drill sites. At these sites researchers expected to penetrate only to the middle Eocene. But in the southernmost hole, drilling penetrated the Paleocene providing data that greatly improved understanding of climatic and tectonic history. Drilling the Paleocene and Cretaceous in the eastern hole yielded data that has revolutionised understanding of the geological history of the East Tasman Plateau.

More information

Leg 189 Preliminary Report is available through the ODP publications homepage at <http://www-odp.tamu.edu/publications>. Future research on the cores will refine the shipboard results and enable the scientists aboard to build up a detailed record of what happened through time in this climatically important region, and establish a coherent story of 'how' and 'why'. Comparisons with sequences drilled elsewhere on the Antarctic margin will improve understanding of these momentous changes in the Earth's history, and some of the constraints on modern climates.

Researchers

Leg 189 was carried out from March 16 to May 6. Aboard ship was an international group of 30 geoscientists, led by AGSO's Dr Neville Exon and Americans Dr Jim Kennett and Dr Mitch Malone. Other Australian participants were AGSO's Peter Hill and ANU's George Chaproniere.

ODP is an international partnership of scientific institutions and governments, and the world's biggest multinational geoscience research program exploring the Earth's history and evolution. Australia is a partner in the Australia-Canada-Taiwan-Korea Consortium for Ocean Drilling.

For details on ODP Leg 188 phone Phil O'Brien on +61 2 6249 9409 or e-mail phil.obrien@agso.gov.au. For further information about ODP Leg 189 phone Neville Exon on +61 2 6249 9347 or e-mail neville.exon@agso.gov.au 

Australia's LEGAL AND TECTONIC

boundaries mapped along earthquake- prone ridge

Another 85 000 square kilometres could be added to Australia's southern marine jurisdiction as a result of the recent AUSTREA-2 survey along Macquarie Ridge, an area noted for very large earthquakes.

The survey, led by AGSO staff, is the second phase of a major research program under Australia's \$50 million National Oceans Policy. The first phase was reported in the April issue of *AUSGEO News*.

Two types of boundaries—legal and tectonic—were examined during the AUSTREA-2 survey, which was carried out for the National Oceans Office and Environment Australia. There were two purposes for this survey. The first was to help Australia define its seabed jurisdiction south of the 200 nautical mile Exclusive Economic Zone (EEZ) around Macquarie Island, under the United Nations Convention on the Law of the Sea. The second was to gather important scientific information on the shape and nature of the seafloor. This information will be used by the National Oceans Office in development of the South-east Regional Marine Plan and by Environment Australia for management of the Macquarie Island Marine Park.

Area covered

The 25-day swath-mapping and geophysical survey off south-east Tasmania and south of Macquarie Island covered approximately 10 200 line kilometres and mapped about 140 000 square kilometres of seabed (an area roughly twice the size of Tasmania—see figure 1).

Swath and geophysical information collected included Simrad EM12D swath bathymetry and backscatter data, six-channel GI-gun seismic reflection profiles, 3.5 kHz sub-bottom profiles, and gravity and magnetic data. A suite of oceanographic information, such as seawater temperature and salinity depth profiles, augmented the data. Despite the southern latitudes of much of the survey, weather and sea conditions were very favourable, with only occasional periods of rough weather and rare encounters with icebergs. All data were acquired as planned and are generally of excellent quality.

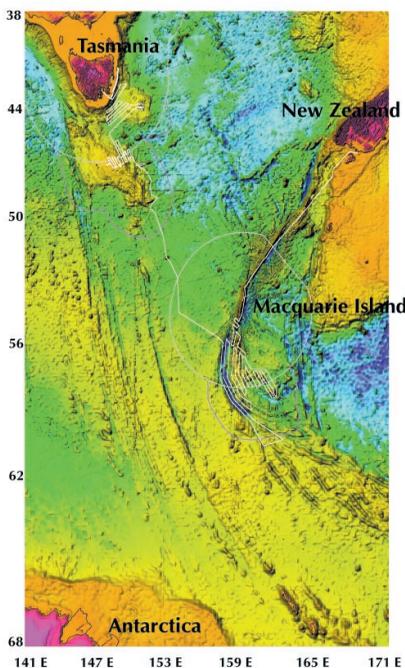
Most of the work in Tasmanian waters was to fill-in and extend previous swath coverage. It highlighted such features as a major system of slope canyons down the south-eastern Tasmanian margin, and the complex character of the Cascade Seamount on the

East Tasman Plateau and other seamounts on the eastern margin of the South Tasman Rise.

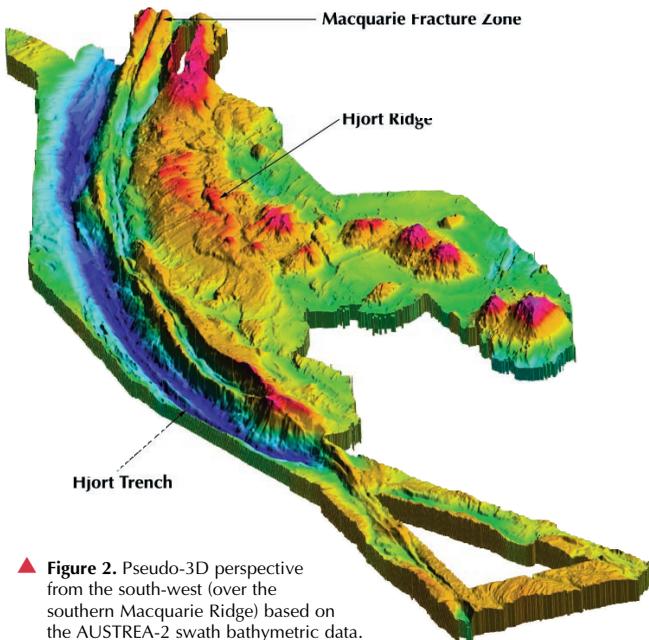
Work conducted over the southern Macquarie Ridge Complex highlighted such features as (see figures 2 and 3):

- a high relief axial valley adjoining the 6500 metre-deep Hjort Trench;
- the broadening to the south of the 2000-metre deep Hjort Ridge;
- the development of seafloor spreading tectonic fabric across the ridge's summit;
- a chain of large seamounts that come to within 400 metres of the sea surface to the south-east of the Hjort Ridge; and
- a north-north-west-trending linear transform trough that obliquely truncates the southern end of the Hjort Trench and links south-east to the active seafloor spreading ridge.

The seafloor mapping supports an extension of Australia's seabed boundary to the south of the EEZ around Macquarie Island, adding about 85 000 square kilometres of area (greater than the size of Tasmania) to Australia's seabed and subsoil jurisdiction.



▲ **Figure 1.** Bathymetry of the south-east part of Australia's marine jurisdiction showing the AUSTREA-2 survey lines (thin white lines), the Australian Exclusive Economic Zone (thick white lines) and the outer limit of the potential extended continental shelf seabed/subsoil regime (pink lines).



▲ **Figure 2.** Pseudo-3D perspective from the south-west (over the southern Macquarie Ridge) based on the AUSTREA-2 swath bathymetric data.

Spectacular topography

The survey mapped, for the first time, the southern sector of the 1600 kilometre long Macquarie Ridge Complex (MRC). The MRC is a tectonically active area because it is on the boundary between two plates—the Indo-Australian and Pacific plates—that are sliding past each other at up to 3.8 centimetres a year. This plate boundary connects northward to the Alpine Fault of New Zealand's South Island. It extends south to the complex ridge-transform system to the east of the Macquarie Triple Junction (MTJ) that involves the Antarctic Plate (figures 2 and 3).

The MRC exhibits strike-slip motion along the plate boundary to the north of the Hjort Ridge, but more convergent plate interaction in the Hjort Trench area. The largest earthquakes in Australia's jurisdiction (and some of the biggest in the world) occur in the MRC. In fact, the largest strike-slip earthquake recorded anywhere (magnitude Mw 8.2) occurred to the north of Macquarie Island in 1989. It is this tectonic interaction between the Indo-Australian and Pacific plates that has uplifted the oceanic crust of a pre-existing ocean basin to form the MRC and some of the most spectacular topography within Australia's marine jurisdiction.

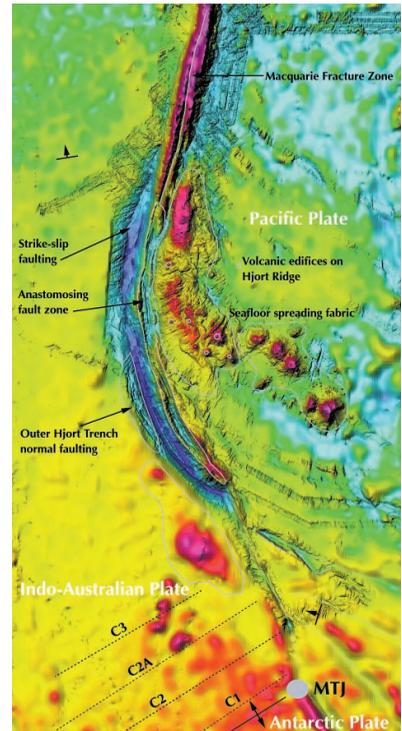
A simulated 3D journey over the seamounts, ridge and trench of the southern Macquarie Ridge Complex, constructed from the AUSTREA-2 multibeam data, can be viewed via the AGSO website (http://www.agso.gov.au/media/7_apr_2000.html).



◀ Iceberg watch on the deck of *L'Atalante*. From left Matthew Levinson, George Bernardel and Mark Alcock.

Survey staff

The AUSTREA-2 survey began in Hobart on January 15 and ended in Bluff, New Zealand, on February 9. The French oceanographic and geoscience research vessel *L'Atalante* was used for the survey. On board were 31 French crew, engineers and technicians as well as an Australian scientific team of five comprising AGSO's George Bernardel (cruise leader), Mark Alcock, Peter Petkovic and Steve Thomas, and Matthew Levinson, an honours student from the University of Sydney.



▲ **Figure 3.** Bathymetry of the southern Macquarie Ridge region based on a grid derived by merging the AUSTREA-2 data with swath data from the *Maurice Ewing* using the Hydrosweep DS system, the *Rig Seismic* using the HMR-1 system, and predicted bathymetry from satellite altimeter data.

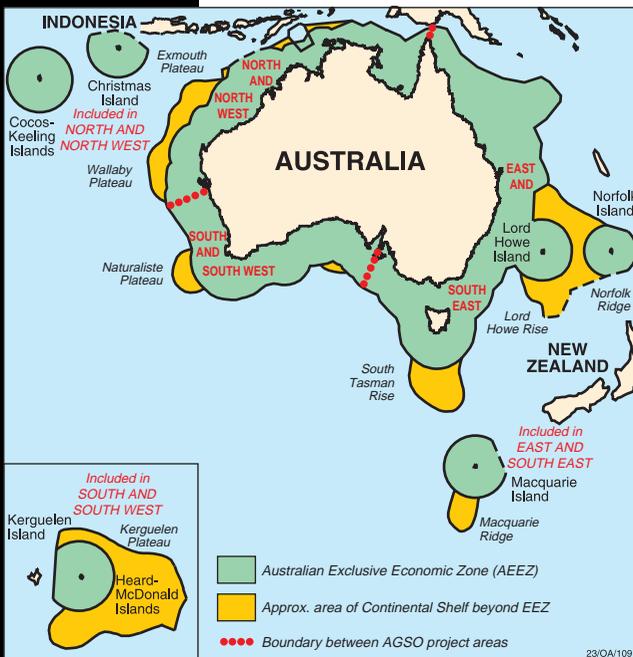
The figure shows various tectonic elements of the region such as:

- the seafloor spreading magnetic lineations associated with the South-east Indian spreading ridge (black dashed lines C1–C3);
- the axis of the South-east Indian spreading ridge (solid black line with arrows); and
- the Macquarie (ridge-transform-transform) Triple Junction (MTJ) associated with the Indo-Australian, Pacific and Antarctic plates.

This work was conducted under an agreement between AGSO and the National Oceans Office relating to Project OP2000–SE01. For more information about the survey phone Phil Symonds on +61 2 6249 9490 or e-mail phil.symonds@agso.gov.au. Alternatively, phone Gordon Anderson of the National Oceans Office on +61 3 6221 5009 or e-mail gordon.anderson@ea.gov.au ☐

Changing needs of the petroleum industry and a demand for geoscience information to support decisions regarding 'land-use' in the Australian Marine Jurisdiction provide Petroleum and Marine Division with a new direction, as AGSO's Deputy Chief Executive Officer Trevor Powell explains.

National inventory to boost PETROLEUM & MARINE geoscience information



▲ **Figure 1.** Australian Marine Jurisdiction. Over the next two years, three regional projects covering the east and south-east, south and south-west, and north and north-west areas (see red type) will complete an inventory and document all depositional centres in the AMJ. The Law of the Sea project defines the proposed legal exclusions of the continental shelf under the UN Convention on the Law of the Sea.

Consultation with the petroleum industry and government stakeholders points to the need for a greater focus on opportunities for oil exploration outside currently active areas, while gas remains an attractive target adjacent to east-coast markets. The division also has an emerging role in providing geoscience information to underpin management of the Australian Marine Jurisdiction (AMJ). This information concerns the nature of the seabed and its relationship to the distribution of ecosystems, geological controls on estuarine health, and the distribution of resource potential and associated economic values.

Petroleum strategy

The Petroleum and Marine Division is changing from a survey mode of operation to targeting particular issues (based on an assessment of current information and the knowledge base). Overall there is a large volume of data relating to the geology of Australian sedimentary basins that have exploration potential, but much of the data is undigested and what is known is not captured in any systematic way.

Over the next two years, the division will improve its ability to better advise on the petroleum potential of many geographic areas likely to interest industry and land-use planners such as Environment Australia. It will articulate where and why additional work needs to be done. This requires an improved overview of Australia's petroleum geology and petroleum potential, including deep-water regimes now accessible to the drill. The overview will be supported by a consistent information management strategy that preserves knowledge and data into the longer term.

The division will be more proactive in recommending release areas for exploration. This will take into account an analysis of the potential for petroleum occurrence. There is a significant risk that in the new global focus of companies, release of unprospective acreage may be detrimental to Australia's image for petroleum investment. The division will explain the rationale for recommendations in terms of prospectivity, bearing in mind the economics of the industry and the need for opportunities that suit the strategies of various sized companies.

All relevant and current information on Australia's frontiers (geographic and conceptual) will be assessed and captured as a platform for future work. However, in the next two years no major new data acquisition programs will be commissioned by AGSO. Although data will be acquired through the national facility arrangements (RV Franklin) to fill identified knowledge gaps, particularly in the eastern offshore.

Petroleum projects

The core of the new approach will be three regional projects covering the east and south-east, south and south-west, and north and north-west areas of Australia's marine jurisdiction (figure 1). Over the next two years these projects will complete an inventory and document all depositional centres in the AMJ.

The fundamental drivers of petroleum occurrence such as tectonic setting, source rock distribution and maturation will be examined to establish priorities for promotion of frontier areas for petroleum exploration. In so doing these projects will bring knowledge of the AMJ up to a common base by:

- re-visiting plate reconstruction and evolution of the margin;
- characterising source rock depositional sequences; and
- mapping likely distribution of source rocks and hydrocarbon generation kitchens on a continent-wide scale.

These regional projects will capitalise upon what is known about the geochemistry of Australian petroleum systems, and pay particular attention to the geological context and opportunities for identification of new systems. Where possible, information on hydrocarbon seeps and 'direct hydrocarbon indicators'

will be captured. Formal assessments of potential will be revised (using updated methods) and extended to deep water.

Similarly AGSO will be undertaking a stocktake of its understanding of the impediments to exploration in frontier onshore basins as part of its contribution to the National Geoscience Agreement with the States and Northern Territory.

To provide ongoing advice on undiscovered resource potential, techniques for petroleum resource assessment will be updated through a new project 'Prospectivity and Advice'. Development of the geochemical technologies continues through the Petroleum Geochemistry Research and Development project that is now part of AGSO's participation in the Australian Petroleum Cooperative Research Centre (APCRC). The division also contributes to the APCRC through the GEODISC project (geological disposal of carbon dioxide).

A new approach is being taken to AGSO's responsibility for maintenance of the Australian Geological Timescale (Timescales project). Specialists will document the science underpinning informal zonation schemes and develop them for the longer term. The focus will be on parts of the stratigraphic column of relevance to industry. The specialists will be targeted and funded through partnerships with universities, governments and industry.

Another divisional responsibility is providing technical advice on the administration of the offshore petroleum industry. As part of the government's strategy for providing greater access to industry information submitted to government under the Petroleum (Submerged Lands) Act, the Mitchell and Chester Hill Archives of AGSO and industry data will be transferred to Symonston. A long-range plan for improving efficiency and effectiveness of management and access to basic data will be developed and implemented.

Marine zone geoscience

The government's Oceans Policy and associated Marine Science and Technology Plan set a clear strategic framework for the division's activities in marine zone geoscience.

A key priority for the Law of the Sea project is completing the mapping, data interpretation and processing required for defining the AMJ—in particular, legal extensions of the continental shelf beyond the Australian Exclusive Economic Zone (figure 1). This data is required for a government submission to the UN Commission on the Limits of the Continental Shelf, which must be closed by November 2004. AGSO will participate in major bathymetric and seismic surveys in Antarctic waters in the forthcoming summer season.

In three regional projects corresponding to those under the petroleum activity, AGSO will map the form and nature of the seabed to support the development of the South-east Regional Marine Plan by the National Oceans Office, and the establishment of marine protected zones by Environment Australia.

Finally the division's role in provision of geoscience information to underpin coastal management is being strengthened through the Urban and Coastal Impacts project. AGSO's responsibilities to the Land and Water Audit (estuarine component) will be completed, and participation in the CRC for Estuarine and Coastal Waterways Management is likely. This will be in multidisciplinary activities to develop management solutions addressing the widespread degradation and pollution problems facing coastal waterways around Australia.

**For more details about the division's activities
phone Trevor Powell on +61 2 6249 9471 or
e-mail trevor.powell@agso.gov.au**



▲ AGSO staff meets industry at a petroleum geology workshop in Canberra—just one of AGSO's ways of supporting acreage release.

New arrangements target mineral provinces with unresolved questions

Minerals Division has a new focus as a result of last year's industry consultations and feedback from the Minerals Open Days.

There will be a move away from campaign mapping to providing specialist services, and a very strong emphasis on attempting to reduce exploration risk by offering a better understanding of mineral systems. Geochronology will be strengthened and the fundamental gravity network will be reconstructed. Data management will reach new heights and investigations into two new provinces (Gawler craton and the North Australian craton) will have begun.

New project areas

The Gawler craton was highlighted in industry consultations as a province where new work was required. Despite the excellent work by South Australia in the early 90s that stimulated exploration, the results were disappointing because the Gawler craton seems to have the right kinds of geology to be prospective. The major inhibition for a second wave of exploration appears to be a lack of a well-constrained geological framework. Over the next three years AGSO and the South Australian Office of Minerals and Energy Resources (PIRSA) will conduct research aimed at reducing exploration risk by subdividing the craton into its tectonic domains, assessing the relative prospectivity, and creating new geophysical datasets for the region (including gravity and seismic).

At the request of industry sponsors, a second major project will be a refocus of efforts in the Yilgarn craton: a synthesis project in the Norseman–Wiluna region. Results of two projects—AMIRA projects P482 and P437—will be combined for a synthesis of the geology of the Kalgoorlie–Leonora area (AMIRA P624). AGSO will run several new activities in parallel with P624 including new geochronology (see page 14), additional gravity and a major seismic transect. The seismic transect will extend from the Laverton area into the Southern Cross region and, if funds permit, across into the Murchison (a distance of up to 600 km).

The third new major project focuses on an extensive 'greenfields' region in the Northern Territory—the Tanami–Tennant Creek–Arunta area, referred to as the southern North Australian craton. The project, to be carried out in collaboration with the Northern Territory Geological Survey, will examine several aspects of the region. For example, the whole of the North Australian craton will be examined in an attempt to identify Archaean cores that are essential for targeting diamond exploration. Even though there have been significant discoveries of diamonds already, a lot more information is needed for effective exploration in the very large North Australian craton.

Ongoing projects

Several existing projects will continue. They include Broken Hill Exploration Initiative, Tasmap, National Maps and P552 (Fluid flow in the Mt Isa and McArthur Basins).

AGSO's role in national mapping is to draw together a whole-of-continent view. As part of that role AGSO continues its work on a national agreed nomenclature for Australian provinces and basins. This is essential from an information management perspective and crucial to future search capabilities and metadata catalogues. Other key tasks include the compilation of a 1:1 million digital geological coverage of Australia, and work towards a fourth edition aeromagnetic map of Australia to be released in 2002. For this release, the synthesis for Western Australia is done; the central one-third of Australia (South Australia, Northern Territory and parts of western Queensland) will be completed this year; and next year the remainder of eastern Australia will be added.

The continuation of Tasmap involves completing some age dating to examine the differences in basement between east and west Tasmania in the mineral areas along the northern sector. A model for the evolution of Tasmania suggests that the eastern and western sectors have two different histories. The model will be tested by (among other things) zircon dating of cores.

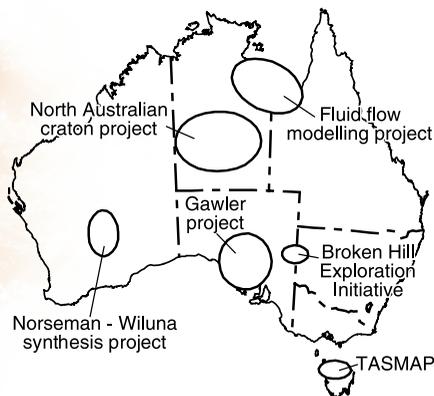


Figure 1. Location map showing Minerals Division project areas.

30-6/88

Clarification: On page 15 of our last issue there was a 'weighted composite mineral potential map' for Tasmania. This map was one of a number used as a reference tool in the Regional Forest Agreement process. In the caption of this map we did not acknowledge the huge part State Geological Surveys play (in this case Tasmania) in carrying out mineral potential assessments and the compilation of such maps. We apologise for this oversight.

Initiatives

Industry's request to 'tell us how old the rocks are' and for 'more dates please' has been answered by AGSO increasing its SHRIMP-dating capacity. Through a contract with the University of Western Australia, AGSO will increase its zircon-dating capacity by about 30 per cent. As well, AGSO has employed an argon-argon specialist who will use Australian National University laboratory facilities under an extended agreement negotiated with the Research School of Earth Sciences.

To meet the growing demand for regolith data, two former contract staff are now permanent and another has relocated from Perth to Canberra. As well, a hydrogeochemist has been recruited to work at the University of Canberra.

Airborne geophysical work will occur if and when it is required to solve problems, but most of this data will be acquired from contractors. Generally AGSO will focus its geophysical efforts on more specialised methods such as gravity and seismic to fill knowledge gaps.

The development of national information management standards remains high on AGSO's agenda, as does the construction of a geoscience portal for Australia. This portal will become a web site that provides access to all Australian-based suppliers of geoscience information. Access will be very simple but behind it will sit a very sophisticated metadata catalogue that allows users to dig deep into layers of data. The simplicity means that people need not be aware of AGSO or know about a State Survey's site to locate information about Australia's geology. Such sites will be linked to the portal, however.

By the end of this year, AGSO expects to take delivery of an absolute gravity meter from the United States. The instrument will be used to re-establish the fundamental gravity network across the continent. The instrument will be lent to State Surveys to fill in and tighten up the grid on an opportunistic basis.

For more about minerals projects read the related articles on the following pages or phone Chris Pigram, Chief of Minerals Division, on +61 2 6249 9397 or e-mail chris.pigram@agso.gov.au 

GAWLER'S PROBLEMS IN PERSPECTIVE

Numerous gold and copper prospects and other mineral resources have been identified in the Gawler craton. But since the discovery of the giant Olympic Dam copper-uranium-gold deposit in 1975, no new world-class mineral deposits have been found in the craton.

Major exploration impediments exist in this South Australian region. Large areas of the craton are remote and difficult to access, and the extensive regolith and sedimentary basins obscure much of the prospective basement rocks. Despite recent advances, there is only a fragmentary understanding of the three-dimensional geology, evolution and metallogeny of this large, complex Archaean to Mesoproterozoic craton.

From July 2000, AGSO and Primary Industries and Resources South Australia (PIRSA) start a new program of collaborative geoscientific work in the Gawler craton. The new AGSO-PIRSA project builds on earlier South Australian government initiatives, and aims to reduce exploration risk by significantly improving the regional geological and metallogenic framework of the craton.

The project consists of five components that address the following key questions.

1. How may tectonic domains of the Gawler craton be defined, and what are the relative prospectivities?
2. What are the regional magmatic, lithostratigraphic, volcanological and tectonic characteristics and processes that controlled fluid flow and mineralisation within the Olympic Sub-domain (Stuart Shelf-Roopena-Moonta-Wallaroo Cu-Au districts)? How can this understanding be used in exploring areas with shallow cover?
3. How does magmatism of the Hiltaba Suite-Gawler Range volcanics relate to formation of gold and base metal systems of the Gawler craton? From this work can parameters be defined to assess mineral prospectivity?
4. What is the regional tectonothermal and lithostratigraphic history of the Archaean Mulgathing Complex, the host to gold mineralisation in the north-western Gawler craton? What are the regional mappable controls on gold mineralisation?
5. How can the efficiency in geochemical exploration in the Gawler craton be improved, particularly within transported regolith materials?

A range of multidisciplinary datasets will be compiled and acquired to address these problems. In the first year, activities and planned outputs include:

- detailed scoping of the project and sub-project work;
- compilations and re-interpretations of gravity, aeromagnetics, basement geology, geochronology, geochemistry, metallogenic, and drill hole information for sub-project areas;
- a preliminary tectonic map, and time-space representation of the Gawler craton; and
- a proposal for a seismic reflection program in the craton.

Airborne electromagnetic (AEM) surveys of the Moonta-Wallaroo, Tunkillia and Challenger areas were flown in May-June 2000. These surveys will provide new datasets for developing integrated models of regolith landscape evolution, hydrological processes and geochemical dispersion in diverse mineralised environments in the craton. They will also test AEM as a basement mapping tool.

In keeping with PIRSA and AGSO practices, data will be captured in corporate databases and information systems, and project products will be released regularly in digital formats.

For further information or input into the Gawler craton project phone Roger Skirrow (AGSO) on +61 2 6249 9442, e-mail roger.skirrow@agso.gov.au, or phone Sue Daly (PIRSA) on +61 8 8463 3066, e-mail sue@saugov.sa.gov.au 

New phase, new framework for east Yilgarn

AGSO's Regional Studies and Mineral Systems Research Group is about to start a new phase of geoscientific research on the Yilgarn craton in Western Australia. The new Norseman–Wiluna synthesis project will run initially for two years, and takes off from a program that is winding down—the successful NGMA (National Geoscience Mapping Accord) geological mapping and geophysical acquisition program in the Eastern Goldfields.

The new project will consist of a series of interlinking and complementary modules that together allow development of a geological and metallogenic framework for the eastern Yilgarn craton. The project will produce province-scale synthesis packages incorporating interpretations of geological, geochronological and geophysical data. Data acquisition is multi-disciplinary, targeted and focused on solving geological problems. The project includes:

- development of an improved geoscientific framework of selected mineralised terranes through targeted geochronological sampling and SHRIMP (sensitive high-resolution ion micro-probe) analysis, strategic field studies, and modelling of potential field data;
- new geophysical interpretation of granite–greenstone terranes; and
- targeted acquisition of gravity data and deep seismic profiles.

The incorporation of each of these within one umbrella project allows the integration of various data sets. This will result in an improved understanding of the geological processes involved in the development of the granite–greenstone terranes, and a better synthesis of the eastern Yilgarn.

The new project will involve a team of research geologists led by Kevin Cassidy. The project will benefit from close collaboration with staff from the Geological Survey of Western Australia.

Data accessibility will improve with the release of some digital data and research results via the internet, as well as through the more conventional methods of raw and processed digital data, interpretative map products and a series of reports.

Geochronology

Curtin University of Technology and AGSO will collaborate on research involving targeted samples that provide additional geochronological constraints for selected areas in the eastern Yilgarn, including the highly prospective Leonora–Laverton region. Geochronological data will be incorporated into the AGSO OZCHRON database, and the interpretation of the data will be incorporated into the synthesis packages.

Geophysical data

As part of the project, the comparative effectiveness of various geophysical methods will be tested—in particular as regolith and bedrock geological mapping tools in granite–greenstone terranes, such as the Balgarri area north-west of Kalgoorlie. This area was the focus of intensive research by the recently concluded CRC AMET (Cooperative Research Centre for Advanced Mineral Exploration Technologies). Recently acquired high-resolution gravity data will be tested against high-resolution airborne electromagnetic and magnetic data to enhance the comprehensive three-dimensional model of the regolith and bedrock



Call for research proposals for
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& *beyond*

Submissions by FEBRUARY 19, 2001

geological volume of this area. Over the life of the project, new geophysical interpretation of granite–greenstone terranes in the eastern Yilgarn craton will be undertaken in collaboration with GSWA at the 1:250 000 scale. A series of digital products will be produced. Some of these will be available via the internet.

In conjunction with a consortium of mineral exploration companies, AGSO will acquire better than two-kilometre gravity data for the greenstone areas in the Leonora–Laverton region. This data will enhance existing four-kilometre data acquired by AGSO in 1993–94 and, in conjunction with planned deep seismic imaging across the area, will help constrain the three-dimensional structure of highly prospective greenstone belts in this region.

Seismic

AGSO will acquire more than 400 kilometres of deep seismic reflection data as part of a major strategic objective of determining the crustal structure of one of Australia's major metallogenic provinces. The seismic profile will complement the existing seismic lines acquired in the Kalgoorlie region (several hundred kilometres to the south) and help in modelling

the development of granite–greenstone terranes of the late-Archean Yilgarn craton. An information workshop concerning the planned seismic profile is planned for late 2000.

The seismic data collection will be undertaken by ANSIR (Australian National Seismic Imaging Resource), one of the Commonwealth Government's major national research facilities supervised by AGSO. AGSO also plans to collect seismic refraction data to constrain deep crustal and sub-crustal structures, as well as additional gravity data along the seismic traverse to enhance the three-dimensional structure of the region.

Partnerships

The major component of the Norseman–Wiluna project is a new, Australian Minerals Industry Research Association project: P624.* The project follows on and synthesises results from the successful AMIRA P482 and P437A projects.* P624 is being conducted by AGSO in partnership with the University of Western Australia and Monash University. It currently has sponsorship from eight leading mineral exploration companies. The expected duration of P624 is 18 months.

In addition to project sponsorship, AGSO seeks industry input into the Norseman–Wiluna project in the form of access to tenement-based geoscience information—including drill logs, core and chips—in the selected areas of the eastern Yilgarn.

For further information phone Kevin Cassidy on +61 2 6249 9578 or e-mail kevin.cassidy@agso.gov.au, or phone Richard Blewett on +61 2 6249 9713, e-mail richard.blewett@agso.gov.au. Information regarding the planned deep seismic profile can also be obtained from Bruce Goleby by phoning +61 2 6249 9404 or e-mail bruce.goleby@agso.gov.au ✉

P624: *An integrated geological and metallogenic framework for the eastern Yilgarn craton: Developing geodynamic models of highly mineralised Archean granite–greenstone terranes.*

* P482: *Characterisation and metallogenic significance of Archean granitoids of the Yilgarn craton, Western Australia—AGSO & University of Western Australia.*
P437A: *Tectono-stratigraphic analysis of the eastern Yilgarn craton: An improved geological framework for exploration in Archean terranes—UWA & Monash University.*

The Australian National Seismic Imaging Resource (ANSIR) seeks bids for research projects for experiments in the second half of 2001 and beyond.

ANSIR is Australia's major national research facility in the earth sciences. It was created to encourage and assist world-class research and education in the field of seismic imaging of Earth. It operates a pool of state-of-the-art seismic equipment suitable for experiments designed to investigate geological structures from environmental and mine scale through to continental scale. ANSIR is operated jointly by the Australian Geological Survey Organisation and the Australian National University.

ANSIR equipment is available to all researchers on the basis of merit, as judged by an Access Committee. ANSIR provides training in the use of its portable equipment, and a field crew to operate its seismic reflection profiling systems. Researchers have to meet project operating costs.

Details of the equipment available, access costs and likely field project costs, as well as the procedure for submitting bids for equipment time are available on the web at <http://rse.anu.edu.au/seismology/ANSIR/ansir.html>. This web site also shows an indicative schedule of equipment for projects that arose from previous calls for proposals.

Over the next year, controlled source equipment will be used on both sides of the continent. People interested in proposing piggy-back experiments should contact the ANSIR Director for details of the scheduled experiments. The long-period portable instruments are in heavy demand; potential users are urged to submit bids at the earliest opportunity. Spare capacity on short-period portable instruments in 2001 is anticipated, however.

Researchers seeking to use ANSIR in 2001 and beyond should submit research proposals to the ANSIR Director (see right) by February 19, 2001.

Any further queries should be directed to:

- **Dr Barry Drummond (particularly for projects requiring ANSIR's seismic reflection equipment)**
ANSIR Director, GPO Box 378, Canberra ACT 2601.
Tel. +61 2 6249 9381 or e-mail barry.drummond@agso.gov.au or
- **Prof Brian Kennett (particularly for projects requiring ANSIR's portable seismic recorders), Research School of Earth Sciences, Australian National University, Canberra ACT 0200.**
Tel. +61 2 6249 4621 or e-mail brian.kennett@anu.edu.au ✉

ANSIR AUSTRALIAN NATIONAL SEISMIC IMAGING RESOURCE

Invisible gold mystery, subject of Nevada professor's research

'Eureka' may never have been shouted by fossickers in Nevada gold fields. But there is plenty of gold there. It is just not visible to the naked eye.

Nearly 10 per cent of the world's gold production comes from Nevada, USA. And most of it (240 million grams in 1997) comes from submicron-sized particles, known as Carlin-type deposits. Because the individual particles are too small to be seen even with a microscope, research into Carlin-type deposits has been limited. Nobody is sure how these deposits formed and where (other than Nevada) they are found in the world.

Recent visitor to AGSO, Associate Professor Jean Cline from the University of Nevada (Las Vegas), is considered an authority on Carlin-type gold, having spent the past 10 years researching these deposits. She says that the Nevada Carlin-type gold probably formed in the mid-Tertiary.

'It seems that northern Nevada 40 million years ago changed from being a compressive tectonic environment to an extensional environment.

'This extension opened things up, and caused fracturing and deep, high-angle faults to form. These may have tapped fairly deep-seated fluids that moved up along fractures, encountered the right rocks at higher elevations, and precipitated gold.'

In Nevada, the submicron-sized particles of gold occur in arsenic-rich pyrite or marcasite. The ore bodies go deep and up to the last five years, deposits were mined using open pit methods. Cline says four areas in northern Nevada contain these deposits.

'The largest area is known as the Carlin Trend, where over a hundred million ounces of gold have been identified in up to 60 deposits on the trend.'

She says the other three districts contain significant but smaller amounts of gold.

Cyanide leaching is generally used to separate the gold from rock. But one company is testing a bio-leaching technique that relies on bacteria. Cline describes this process as microscopic bacteria 'eating' sulphide rocks and 'excreting' gold.

'Essentially what the bacteria do is change the pyrite. They oxidise the pyrite mineral and liberate the gold.'

After qualifying as a geologist, Cline spent 11 years in Nevada exploring for porphyry-copper and epithermal gold deposits. Now as an associate professor, she combines teaching and research. Although she has spent the past 10 years investigating how Carlin-type gold deposits formed, her research has really just begun and will take her well into retirement.

'Even though there are lots of sophisticated analyses that one can do, getting a sample of ore-stage material to do the analysis is difficult.

'It is only recent advances in technology that have allowed us to do in situ analyses of one or two micron-sized spots and figure out anything about these deposits', she says.

Cline says that Carlin-type gold was discovered in Nevada in the mid-1960s. Unconfirmed deposits have been mooted in China and the Middle East. ❏



▲ Recent AGSO visitor, Associate Professor Jean Cline from the University of Nevada (Las Vegas) is considered one of the world's experts on Carlin-type gold deposits. She advised all to wash hands thoroughly after picking up these arsenic-rich Nevada rocks.



AGSO DOORS OPEN TO PUBLIC

AGSO opened its doors for six hours on Sunday, May 7, so the public could tour its award-winning, purpose-built building, listen to five free lectures, and (for the young and young-at-heart) have some fun building a volcano, identifying rocks and hunting for fossils.

Four hundred visitors turned up, many having pre-booked their children into the volcano-making activity.

Pictured above is Dr Leonie Jones, one of the AGSO scientists who volunteered to conduct building tours and answer questions.

Tours began in the foyer around the seismographs and eye-catching displays of Australia's rocks and minerals, and took in the rainforest and arid forest growing in opposite wings of the ground floor. The building's geothermal heating and cooling system also drew visitor attention. Seven kilometres of pipes run as deep as 100 metres below the building, tapping into the constant 17 degree Celsius heat under the ground that cools water in the pipes in summer and heats it in winter.

AGSO's Open Day was held during the Australian Science Festival celebrations in Canberra. Further public activities in the AGSO building are planned for Earth Science Week, October 8-14. ❏

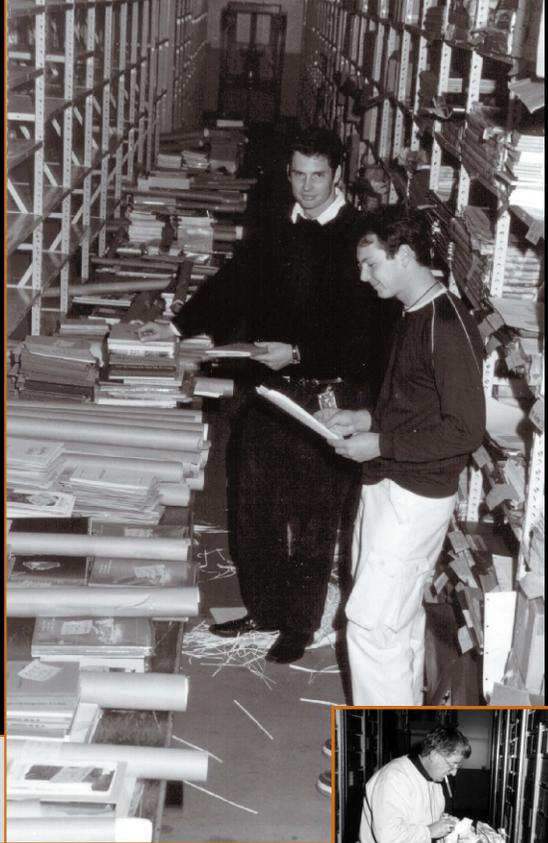
Restoring order—collections rationalised

What do you get after 50 years of a couple hundred geologists collecting field samples—most of which end up in storage and some without proper identifiers? The answer: a huge collection of rocks, minerals and fossils (some of which nobody knows anything about years later). Continuous gathering and donation are fine when there is staff to manage the collection and storage space is unlimited and free. But what if in-house storage nears capacity, warehousing costs are high, and you have to search for hours to find a specific sample (if you knew it was there in the first place)? Time to get the store in order, you'd say.

Earlier this year, National Archives in Canberra declined further digital data from AGSO and asked that it remove archive tapes stored in two repositories (Chester Hill and Mitchell). These tapes are important records and AGSO now has to archive its own material on site. Consequently, there has been a major reshuffle of storage space in the new AGSO building, evidenced by the huge sale of AGSO products in June. This reshuffling of stores is culminating in a long overdue review of AGSO's rock, mineral and fossil collection.

One spin-off in changing storage sites has been the transfer of staff from the Chester Hill repository to the AGSO building. This means there will be people to update storage and submission procedures, and greatly improve access to AGSO's collection. Another benefit is an estimated saving of \$220 000 annually in storage costs by vacating the Chester Hill repository.

Thank you readers for responding to last issue's 'enormous sale'. Making room in AGSO's store are Chris Thompson (front) and Alistair Leahy with some of the 18 000 items picked, packed and posted around Australia and to many overseas destinations.



▲ AGSO Chief Executive Officer Neil Williams rummages through boxes of field samples he'd collected as a geologist in the Mt Isa region. Even he had to part with hand specimens to make room for more worthy pieces.

Among the collections being reviewed are PSLA data (seismic tapes, cores and cuttings reports), the bulk fossil collection, rock store and marine geophysical data. None of the Commonwealth Palaeontological Collection—a collection of more than 35 000 illustrated or otherwise published specimens, and the largest collection of palaeontological types in Australia—will be transferred to another institution or 'thrown out'. Of the bulk fossil collection, only those with little relevance to AGSO programs will be relocated. For example, collections of recent stromatolites already have been transferred to the Australian National University; unpublished fossil mammal material will be given to State museums; and poorly located collections will be used by AGSO's Earth Science Education Centre and other teaching institutions.

AGSO's rock store needs attention. It is at 95 per cent capacity with space for only 700 more boxes of material. Less than a third of the boxes have been properly catalogued, and new material is sitting in project areas and the layout room pending storage. Material that is poorly marked and therefore incapable of being properly located is being discarded; so, too, are boxes of coarse crush material or residues (providing a representative hand specimen and powder are retained). Boxes containing only one or two samples will be rationalised so there are fewer storage boxes.

Distinctive, rare or unique material is being retained (e.g. samples from restricted areas or from a deposit that has been mined out), as is material from remote areas where the cost of recollecting samples would be too high. Also retained will be samples that have value-added measurements and information (e.g. field descriptions, chemical or isotopic analyses, geochronology), particularly if they have been documented in databases and can therefore be used at a later date to reassess old problems when new approaches and techniques become available.

Boxed marine samples will not be reviewed because they were culled three years ago, but 1350 drums of dredge samples are being assessed. ▣

■ 31st International Geological Congress

International Union of Geological Sciences

6 to 17 August

Rio de Janeiro, Brazil

Contact: Secretariat Bureau - Casa Brazil 2000, 31st IGC, Av. Pasteur, 404 - Urca, Rio de Janeiro - RJ - Brazil, CEP 22.290-240

phone 0011 55 21 295 5847

fax 0015 55 21 295 8094

e-mail 31igc@31igc.org

■ 3rd AMEEF Innovation Conference

Australian Minerals & Energy Environment Foundation

15 to 17 August

Marriott Hotel, Brisbane

Contact: AMEEF, Floor 9, 128 Exhibition Street, Melbourne Vic 3000

phone +61 3 9679 9911

fax +61 3 9679 9916

e-mail ameeef@ameef.com.au

■ Mining 2000 International Convention and Trade Exhibition

19 to 22 September

Melbourne Exhibition and Convention Centre, Melbourne Victoria

Contact: Mining 2000, Level 2, 6 Thelma Street, West Perth, WA 6005

phone +61 8 9485 1166

fax +61 8 9481 8023

e-mail enquiries@mining2000.com.au

■ Earth Science Week

Australian activities being coordinated by AGSO

8 to 14 October

Educational and scientific institutions across Australia

Contact: Jeanette Holland, AGSO, GPO Box 378, Canberra ACT 2601

phone +61 2 6249 9731

fax +61 2 6249 9990

e-mail jeanette.holland@agso.gov.au

■ Volcanic Environments & Massive Sulfide Deposits International Conference & Field Meeting

17 to 19 November

(Plus pre- and post-conference field trips to VHMS belt)

Wrest Point Convention Centre, Hobart

Contact: Centre for Ore Deposit Research, University of Tasmania, GPO Box 252-79, Hobart Tas 7001

phone +61 3 6224 3773

www.geol.utas.edu.au/codes

AGSO magnetism workshops attract international field

Geomagnetism

A common interest in the Earth's magnetic field and its applications drew 45 delegates from New Zealand, the United States and Australia to Canberra on April 26-27 for the 4th Australian Geomagnetism workshop. The workshop brought together users of geomagnetic information, those who generate the information, and those who investigate the past and present behaviour of the geomagnetic field. Delegates represented government science, research and educational institutions, private companies and researchers.

The workshop was opened with a presentation from AGSO's Deputy Chief Executive Officer, Dr Trevor Powell. This was followed by eight sessions spanning two days. Presentations and discussion covered all things geomagnetic, ranging from the origins of the solar and terrestrial magnetic field to the importance of the geomagnetic field in long-distance bird migration. A keynote address by Professor Ron Merrill on 'The geomagnetic field in the context of the Solar System' was incorporated into the regular AGSO Wednesday seminar series. There was standing room only for this address. This was followed by a stimulating presentation by Professor Ken McCracken on the climatic effects of long-period solar variability derived from ice-core data.

A traditional 'Oriental-Magneto banquet' was held at a local Thai restaurant, and attended by most delegates. Dr Dudley Parkinson gave a post-prandial presentation on the history of the science of geomagnetism and included some personal reminiscences on the early days of geomagnetism in Australia.

The workshop provided a good opportunity for those in geomagnetic-related research to come together and present their latest findings. It was organised by AGSO's geomagnetism group and Dr Ted Lilley from the Research School of Earth Sciences, Australian National University.

Palaeomagnetism, rock magnetism and environmental magnetism

This two-day workshop brought together 40 practising palaeomagnetists and geoscientists from the USA, Canada, Russia, New Zealand, Germany and Australia interested in recent developments in the field. Such international representation highlights the global importance attributed to Australian palaeomagnetic data and to new concepts developing here regarding supercontinent evolution during the Proterozoic (Rodinia) and the Palaeozoic (Pangea).

The workshop centred on three main themes:

- Palaeomagnetic constraints on the Palaeozoic evolution of the Tasman Orogen;
- Proterozoic palaeomagnetism and the evolution of Rodinia;
- New developments in environmental and rock magnetism and their application.

Memorable highlights of the workshop include:

- the invited talk by Professor Chris Powell on 'The tectonic setting of the Tasman Fold Belt and palaeomagnetism';
- the discussion on the pros and cons of alternative versions for

Australia's Late Palaeozoic polepath;

- the very fast development of techniques in environmental magnetism and their emerging wide applicability; and
- Professor Larry Harrington's entertaining address at the official workshop dinner.

The meeting ended with a tour of available facilities at the Black Mountain Palaeomagnetic Laboratory in Canberra.

The workshop was held at AGSO on May 3-4. It was organised by AGSO, CSIRO's Division of Exploration and Mining, and ANU's Research School of Earth Sciences.

Palaeomagnetism workshop abstracts are available from the Sales Centre as AGSO record 2000/36. Copies of the Geomagnetism workshop abstracts are available from Dr Heather McCreadie (see below).

For further information about the workshops phone Heather McCreadie on +61 2 6249 9254 or e-mail heather.mccreadie@agso.gov.au 



WORKSHOP OUTCOMES SHAPE GRAVITY PLANS

Outcomes of a Gravity Workshop hosted by AGSO's Minerals Division in Canberra in December last year are already having an impact on the direction of AGSO's gravity research. Workshop participants represented State and Territory Geological Surveys, AUSLIG and private companies.

Major issues and outcomes

Gravity database. AGSO's new gravity database was outlined with an explanation of the rationale behind AGSO's integrated database structures. The table structures of the new database will be distributed to interested parties when the database has been completed.

Gravity data transfer standards. A standard is needed for the transfer of gravity data between people and between software applications. AGSO was asked to lead and coordinate the development of the standard, and present it to the Australian Society of Exploration Geophysicists (ASEG) Technical Standards Committee and to the Government Geoscience Information Policy Advisory Committee (GGIPAC) for comment.

Gravity network. The Australian fundamental gravity network is in disrepair with numerous stations destroyed and the condition of many others unknown. Workshop participants felt that AGSO has the major responsibility for the fundamental gravity stations and that the States and Territory are responsible for establishing secondary stations at about 100-kilometre spacing.

Since the workshop, AGSO has ordered an absolute gravity meter. The meter should be delivered in October and AGSO will begin re-establishing the network early in 2001. The aim is to have the new network established within five years.

Workshop participants also thought that where possible AUSLIG geodetic network survey marks should be used as gravity base stations and secondary stations should be established on State and Territory land survey marks.

Survey design. AGSO has agreed to develop a gravity field manual with input from State and Territory Surveys and from industry organisations. When the manual is completed, a meeting will be held for all interested parties to discuss and promulgate the major recommendations.

Future workshops

Because of the useful exchange of information, participants felt the need for future workshops and that these should be held (initially) on a yearly basis. They asked that workshops concentrate solely on gravity issues.

More information can be obtained from Alice Murray, phone +61 2 6249 9264, e-mail alice.murray@agso.gov.au or Ray Tracey, phone +61 2 6249 9279, e-mail ray.tracey@agso.gov.au ☐

INFORMATION MANAGEMENT IN THE GEOSCIENCES

5th national forum *Geoscience Online*

With the growing use of the internet for access and delivery of data and services, it is timely to address issues relating to the provision of geoscience online. In 2001 the Federal Government implements its online policy. AGSO will present its initiatives associated with 'Government Online' at the forum.

Scope

The forum will address:

- future access and delivery of government geoscience online;
- user perspectives of online delivery;
- business and policy issues of e-commerce;
- technical issues; and
- future directions of applications and technology.

The forum will include keynote speakers for each session, presentations from State representatives, and invited papers. The annual meeting of GGIPAC will precede the forum.

Call for papers

Papers focusing on the topics listed opposite are invited for presentation. As well, participants have an opportunity to present posters and demonstrations. Abstracts of papers and notifications of intentions to present posters and/or demonstrations should be sent by October 30 to:

Jenni Castles

Geoscience Online Forum Coordinator
GPO Box 378,
Canberra ACT 2601

phone +61 2 6249 9794

fax +61 2 6249 9984
e-mail jenni.castles@agso.gov.au

Technical exhibition

The afternoon of Tuesday, March 27 will be devoted to the technical exhibition. This will allow exhibitors and participants to make more effective use of their time for interacting with the technical exhibition. Potential exhibitors should contact Jenni Castles to express their interest in mounting a display or exhibit.

For more details phone John Creasey on +61 2 6249 9395 or e-mail john.creasey@agso.gov.au ☐

March 27–29, 2001

SEISMIC DATA ON SHOW AT YILGARN WORKSHOP

The recent Yilgarn Seismic Workshop gave industry a chance to see how useful seismic data can be in building a picture of greenstone terrane in Western Australia.

Held in Kalgoorlie on May 2–3, the workshop presented results from the AGCRC's (Australian Geodynamics Cooperative Research Centre) Yilgarn Seismic and Fluid Flow Modelling projects. Of the 68 workshop participants, more than 50 were from mineral exploration companies.

Day 1

Dr Jon Hronshy (Western Mining Corporation), member of the AGCRC's Industry Advisory Panel and the Yilgarn Support Group, opened the workshop and chaired each session. Dr Hronshy summarised the AGCRC's involvement in the Yilgarn and acknowledged the valuable industry contributions provided to the various AGCRC projects. He emphasised that quantum leaps in understanding the three-dimensional greenstone structure were due to the seismic data acquired in the region.

The remainder of the first day was dedicated to summarising the geological and deformation constraints, and presenting the old and new seismic results. Dr Steve Wyche (Geological Survey of Western Australia) summarised the regional geological history and Dr Bruce Groenewald (GSWA) presented some local geological constraints to the interpretations. Drs Russell Korsch, Bruce Goleby and Tanya Fomin (AGSO) outlined the project, discussed limitations of seismic in 'hard-rock' terranes, and described the acquisition and processing of the new data. Dr Roger Bateman (Kalgoorlie Consolidated Gold Mines) presented, for the first time, the complete 1997 AGCRC–KCGM Seismic Survey results.

Bruce Goleby and Russell Korsch then presented preliminary interpretations of shallow and deep crustal sections for each of the 1999 seismic lines. These presentations generated valuable discussion and numerous questions from the audience.

Day 2

The second day focused on results from the value-adding AGCRC projects. Ben Bell (AGSO) presented cross-sections based on the new gravity and magnetic modelling studies. Dr Nick Archibald (Fractal Graphics) showed a 3D visualisation of the Menzies–Norseman region and of the new seismic results. He described the various data sets used to build the model, emphasising the consistency these have to each other within the final model. Dr Wally Witt (Sons of Gwalia) summarised the regional metamorphism and presented a horizontal fluid flow model to explain the gold distribution.

Dr Peter Sorjonen-Ward (CSIRO) described 3D numerical modelling and fluid flow and showed several 3D images of fluid flow within variants of the 'Y-front' model. Dr John Walshe (CSIRO) presented his concept of the large-scale mineral system, highlighting the importance of identifying the location of the second fluid-source needed to produce the large gold deposits.

In the final session, results presented during the workshop were discussed. This discussion included a series of brief presentations on the future directions of AGSO, CSIRO and the GSWA. Several companies stated that they were keen to contribute to the development of the seismic interpretation, particularly at 1:100 000 scale or better.

Conference data

The AGCRC offers seismic sections to interested companies in return for feedback on the preliminary interpretations presented at the workshop. After some updating, abstracts from the workshop will be re-published as an AGSO record this year.



For more information about the workshop or available data phone Bruce Goleby on +61 2 6249 9404 or e-mail bruce.goleby@agso.gov.au

Australia pitches for exploration dollars

Australia's share of world exploration budgets is estimated to be 18.7 per cent, substantially higher than the USA (10%), Canada (10.8%) or Africa (14.9%). To maintain or increase this share, Australia must remain an attractive option to international exploration and mining companies. Australia also needs to promote what it has on offer internationally.

A recent opportunity was Mining Millennium 2000 (MM2000) held in Toronto from March 5–10. AGSO's Lynton Jaques and Mike Huleatt report on the conference and feedback from exploration companies.

Toronto, the mining finance capital of the world, was the ideal location for MM2000. The conference combined the annual Prospectors and Developers Association of Canada (PDAC) convention, the annual Canadian Institute of Mining, Metallurgy and Petroleum meeting, and an inaugural World Mines Ministries Forum (WMMF). More than 10 000 people from 70 countries attended. The estimated attendance in the first four days of PDAC alone was 8000.

The trade show had 900 booths. There were investment promotion exhibits from 20 governments, Canadian provinces and several US states. Australia had strong governmental representation. Ministers McGrady (Queensland) and Lennon (Tasmania) and senior staff visited the trade display and attended the WMMF. AGSO coordinated the Australian governments' display.



Company visits

Prior to MM2000, the Australian government team visited exploration and mining companies in Vancouver and Toronto. Issues discussed included:

- current Australian exploration levels;
- recent Australian discoveries and developments;
- company directions, exploration targets and strategies;
- opportunities for joint ventures; and
- native title issues and the new Australian business arrangements.

All companies indicated they had a global approach to exploration and had either recently become active in Australia or were actively seeking opportunities in Australia. Most said their immediate growth strategies were based on acquisition of existing projects and exploration at and around the project rather than via greenfields exploration. Nickel, gold and base metals (Cu, Zn) were the major commodities sought.

Although funding was still difficult to obtain, especially for junior companies, most thought the decline in exploration expenditure had bottomed and that the outlook had improved. All stated that Australia was viewed very favourably for mineral investment because of its strong proven mineral resource base, its mature and stable investment and legislative environment, and its mineral potential. They acknowledged the importance of geoscientific information provided by Australia's geological surveys in reducing exploration risk.

Trade display

The Australian governments' display was in the high-profile Australian pavilion, which included GeoJAG (Geoscience Australia Joint Action Group) members, ENCOM Technology and Desmond FitzGerald and Associates. Other companies in the Australian pavilion were Queensland Epithermal Minerals, Whittle Programming, AMIRA, Clayton-Utz, and Mining 2000. Over a thousand people visited (750 'serious' visitors) the Australian governments' display—more than any other monitored site. Survey results indicate a very high level of satisfaction with the display and information provided.

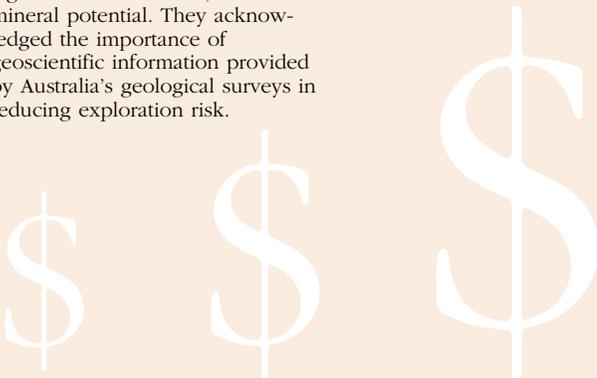
Visitor interest focused on prospectivity and investment opportunities, the level of exploration activity, and whether the new lateritic nickel operations in Western Australia would deliver as forecast. Also of considerable interest was the impact of native title on exploration and development. This was the subject of a paper (offering an Australian minerals industry perspective) presented by Clayton Utz in an open forum session.

Issues forum

MM2000 conducted a daily 'issues forum' with a panel of invited speakers and moderators from the resources and resources finance sectors, and relevant non-government organisations. The five forum topics were:

- Industry survival strategies for the 21st century;
- Land-use battles: will they ever end?
- Rebuilding investor confidence—a report card;
- Energy, the economy, and Kyoto; and
- Toward the zero discharge mine.

Just one of the great display panels created for the PDAC conference, held earlier this year.



AUSTRALIA: UNDER EXPLORED



Points raised in Session 1 included: the social obligations of miners to the community, sustainable development, the 'triple bottom line', the need to change public perceptions of mining (away from a 'dirty, low-tech industry'), the Global Mining Initiative, access to capital, industry competitiveness, and the flight of capital from the resources sector.

Session 2 speakers covered: the changed land-use environment with competing land-use requirements, the need for dialogue with indigenous peoples, the rights and needs of indigenous peoples, the current empowerment of indigenous peoples, and the need for effective land-use planning without the process being captured by special interest groups.

The Session 3 speaker dealt with: the damage caused by the Bre-X fraud; the need for tougher disclosure standards; the need for collective acceptance of responsibility by the geologist, mining industry, and the security regulators; the VALMIN and JORC codes as models for Canada; and the development of a new regulatory framework in Canada.

Technical program

Ten themes covered in the technical program included: exploration technology, environmental and socioeconomic issues, financing the mining business, global investment opportunities, and mineral deposits and exploration. Abstracts and further information can be found on the web at <http://www.miningmillennium.org/en/technical/index.html>.

World Mines Ministries Forum

The World Bank and the Ontario Ministry of Northern Development and Mines coordinated the forum. More than 300 senior officials from some 40 governments, mining companies, and national geological organisations attended. Also present were national and state/provincial mines ministers from Burkino Faso, Canada, Mauritania, South Africa, Nunavut, Ontario, Queensland and Tasmania. The program included a plenary session with papers, followed by workshops on four main themes: sustainable development, mining and the community, geoscience in the information age (including an invited paper by Lynton Jaques on AGSO as a modern geological survey), and the competitiveness of nations.

The plenary papers were:

- 'Mining and sustainable development', Alyson Warhurst, Director, Mining and Energy Research Network, University of Warwick, England;
- 'Mining and the community', Fernando Loayza, Executive Vice-President, ECOLOGICALINK Investment Group, Bolivia;
- 'Competitiveness of nations', James Bond, Director, Mining Department, The World Bank Group;
- 'What a multinational mining company expects from a geological survey', John Thompson, Chief Geoscientist, Teck Corporation;
- 'The triple bottom line: Key to project success', Patrick James, President and CEO, Rio Algom.

The workshops discussed issues associated with each topic and developed a series of recommendations aimed at defining best practice. Papers and workshop outcomes are on the web at <http://www.miningmillennium.org/en/spec/indexWmmf.html>

One significant message from the plenary session was that sustainable development is now a key goal for mining companies. The success of such an approach is recognised in the share price, with companies attaining the 'Dow Jones sustainable company list' outperforming the Dow Jones Index.

Another message is that mining companies need to involve communities in their development plans from the beginning (i.e. from the start of exploration). Social issues are as important as environmental issues. An approach incorporating the 'triple bottom line' (financial, environmental and social balance sheets) is regarded as the key to success.

In his paper on 'what a multinational mining company expects from a geological survey', John Thompson reaffirmed the importance of maps and the need for geological surveys to continue producing maps, interpretations, and other data in map format, and the need to disseminate information via the web.

The final message was that mining is an 'emerging markets business'. Globalisation has led to increased competition between nations for scarce, declining and mobile exploration and mining capital. Countries with clear and stable regulatory regimes and financial policies have an advantage, but

those providing industry with specific incentives that improve profitability will generally be viewed more favourably. Managing investor risk better is a key issue for industry.

Outcomes for Australia

The visits and display raised Australia's profile as a mining nation and a favourable site for mining investment. The level of interest in Australia was higher than in previous years with all companies visited either seriously considering or committed to increasing investment in Australia.

There is a need for continued promotion of mineral investment opportunities in Australia in an increasingly competitive environment, especially if mineral exploration continues to decline. (Although there was a slightly improved outlook for the sector.) The global collapse of the junior exploration sector that is almost totally dependent on raising equity capital was reaffirmed.

Talks with industry highlighted the need to continue to ensure Australia's international competitiveness through: a) reducing impediments to investment and b) using Australia's current competitive advantage in geoscientific information to best effect by making it readily accessible online.

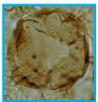
The continuing globalisation of the mining industry was confirmed with new and anticipated mergers and rationalisation. There is a convergence of strategies of many majors focused on growth through acquisition rather than exploration. Those that have retained a commitment to exploration have either outsourced the exploration through equity in junior companies or entered into strategic alliances with juniors.

For further information about MM2000 phone Mike Huleatt on +61 2 6249 9087 or e-mail mike.huleatt@agso.gov.au

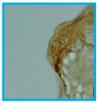


JURASSIC

microfossil *study refines* hydrocarbon reference



What the eye doesn't see... 150 million-year-old pollen grains in sandstones, shales and limestones that can be used as reference points in the search for oil and gas!



Visiting British palynologist, Dr James Riding, revels in these microscopic parts of plants and 'bugs'. For 10 months he has combed through hundreds of species on dozens of microscope slides to refine the Jurassic part of the Australasian palynological zonation—an important timescale for hydrocarbon exploration.



Dr Riding explained the interest in Australian Mesozoic palynological zonation at a recent AGSO talk.

The use of microscopic fossils to subdivide the Triassic–Cretaceous period was instigated in Australia by offshore oil and gas exploration. From the mid-60s to the mid-70s, there was intense reconnaissance along the North-West Shelf. But exploration companies owned these biostratigraphical data and there was little inter-company communication.

During this reconnaissance phase, Sydney-based analyst Dr Robin Helby did some groundbreaking research that is still used nowadays. He worked out a zonation based on marine dinoflagellate cysts from the Jurassic to the early Cretaceous for the Bonaparte Basin succession off the Northern Territory coast. Helby was later able to refine his initial zonation from Esso wells in Papua New Guinea and other parts of Australia.

Helby wasn't the only palynologist in Australia working on dinoflagellate cysts. Roger Morgan (Geological Survey of New South Wales) was studying Cretaceous cores from different areas of Australia. Alan Partridge (Esso Melbourne) was working on the Late Cretaceous and Tertiary of Australia's southern margin. These three (Helby, Morgan and Partridge) joined forces in the mid-70s to produce an integrated palynological zonation for the Mesozoic of Australia. The scheme would include terrestrially derived spores and pollen as well as dinoflagellate cysts so that the zonation could be applied to rocks originally deposited on both land and marine areas.

This preliminary scheme was published in 1987. Helby has since subdivided the original framework of broad zones into many sub-zones. But the sub-zones are defined using undescribed taxa, and the scheme and these sub-zones are in wide use by the petroleum industry. These sub-zones also appear on AGSO's stratigraphic database. Clearly the undescribed taxa underpinning the new sub-zones must be formally published before these subdivisions can be scientifically validated.

Riding's work

Many new forms of Jurassic and Cretaceous dinoflagellate cysts have been discovered since the Helby et al. zonation was first published. Formal description of these 'new' dinoflagellate cysts will increase the scheme's precision.

Riding has been working closely with Helby for 10 months to produce a very refined biostratigraphical breakdown of the Mesozoic in Australia. He has been illustrating and describing many of these new genera and species, while Helby is using the new taxa to define sub-zones.

One of Riding's first projects in Australia was to describe an assemblage from the Toarcian (Lower Jurassic) in the Skua Oilfield in the Timor Sea. Here Helby found an unusual suite of dinoflagellate cysts. They were unusual because all were new; they were endemic to the Timor Sea; and they seemed to represent a marginal marine succession.

To define a unit or sub-zone, palynologists look at not only the absence or presence of a particular species, but also the numbers and proportions of the microfossils. The amount of data to be processed can be huge. Often there are 50 or more species that need identifying on each microscope slide. In AGSO's laboratory, all specimens are recorded electronically and photographed digitally. There is no need for conventional celluloid photography. With electronic logging, data on thousands of species can be manipulated to find patterns. Work that once took years to complete is now compiled in months.

One problem for Helby is determining the timescales or the durations of the various zones. It is unlikely that the zones are of equal duration. And some of the very fine units within the sub-zones may be no more than a couple of hundred thousand years' duration. In some cases, the zones are correlated with European stratotypes using macroscopic fossil evidence and

European palynological bioevents. This is problematic because in the two hemispheres, some species appear to have similar ranges while others are profoundly different. Riding is very familiar with the Northern Hemisphere Jurassic. So one aspect of his work at AGSO has been to sort through taxa to work out which of the Southern Hemisphere ones correlate well with the Northern Hemisphere. He believes the way forward with these correlations is to use geochemical techniques (e.g. organic biomarkers and strontium isotopes) to get tie points between Europe and Australia and use these in conjunction with evidence from all the fossil groups available.

Biostratigraphic work in Antarctica

Riding's work in the Southern Hemisphere goes beyond Australia. As a leading Mesozoic–Cenozoic palynologist, he has worked on the Antarctic Peninsula for the British Antarctic Survey. The Antarctic Peninsula was on the southern margin of Gondwana for much of the Mesozoic, so the Helby et al. zonation is applicable to this area as well.

An area favoured by Riding and other palynologists in Antarctica is Seymour Island, dubbed the 'Rosetta stone of Southern Hemisphere palaeontology'. On this small island a very diverse range of fossilised flora and fauna are abundant, and they are superbly preserved. Another well-preserved find in the Antarctic Peninsula was a bed of huge ammonites—each one as large as a tractor tyre—in the Upper Cretaceous of a backarc basin fill.

In palynological terms, one thing Antarctica seems to have more of than anywhere else on Earth are Maastrichtian (uppermost Cretaceous) sediments. There are many endemic forms so many dinoflagellate cysts from places such as Snow Hill Island are yet to be described. The Maastrichtian was not especially well developed in onshore Australia, so this is one area of the Helby et al. zonation that may require further development.

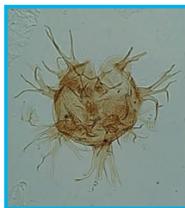
Value of refinement

Biostratigraphy is used in the initial stages of hydrocarbon (oil and gas) exploration—for putting ages on seismic reflectors and helping to construct the structure and geological evolution of an area. A very refined biostratigraphic scheme is invaluable for solving complex production problems as oil fields mature, and/or when there is a downturn in petroleum prices. If the price of oil is low, exploration companies focus on production (rather than exploration) and extracting as much oil as they can from existing sites.

As an example, there may be a producing reservoir that comprises several beds of sandstone—some of them oil charged and some of them not—separated by shales that form a hydraulic barrier between the sandstones. Should the producing horizon lower in pressure, the oil company would think about secondary and tertiary production on that reservoir. But the cost of pressure-injecting each sandstone in every well in order to flush out more oil may be prohibitive. A refined biostratigraphy can be used to determine the continuity of the producing sand between wells throughout the field, so that the company injects into the well that is going to give them the most recovery.

The need to define 'unclassified' dinoflagellate cyst species of the Mesozoic (particularly the index species for various Helby et al. sub-zones) is long overdue. Oil companies drilling in the Southern Hemisphere should find the refined biostratigraphy for the Australasian Mesozoic a most useful reference.

For more information about Australasian Mesozoic palynological zonation phone Jim Riding on +61 2 6249 9806 or e-mail jim.riding@agso.gov.au 📧



▲ An undescribed species of the genus *Oligosphaeridium* from the Kimmeridgian (Upper Jurassic). This species has large, branching spines and is approximately 130 micrometres wide, inclusive of the spines.

Dino-flagellates

Palynology is the study of all organic microfossils including terrestrial spores and pollen and the remains of various marine algal groups. In marine Mesozoic sedimentary rocks, the dominant marine organic microfossils normally are dinoflagellate cysts.

Dinoflagellates are a group of unicellular phytoplankton. Some dinoflagellates produce resistant cysts made of the same substance from which pollen is constructed. These fossil cysts were associated with seasonal changes and sexual reproduction.

In simple terms, the non-preserved cell covering of the motile dinoflagellate dropped away from the resistant cyst and the cyst then fell through the water column. In spring the cyst opened and the cytoplasm of the 'new' dinoflagellate oozed out to produce the next generation of phytoplankton. Aeons later the abandoned resistant cyst is found as a microfossil. An analogy to this scenario is finding an open fossilised shell but not the fossil animal itself.

In the Mesozoic, dinoflagellate cysts were relatively diverse and evolved rapidly. In comparison, there were generally fewer species of land plants—probably because in the equable climate of the Jurassic there was less need for land plants to compete and mutate. Hence the evolution of dinoflagellates outstripped that of the land plant pollen spores. Their evolutionary changes and abundance make them useful markers in biostratigraphy. 📧



◆ An undescribed species of the genus *Lithodinia* from the Callovian (Middle Jurassic). This species is covered by irregular crests and is approximately 80 micrometres wide.

Compared with what is happening in nature, anthropogenic emissions of carbon dioxide are quite small. Only about two per cent of the total greenhouse effect is caused by human activities.* Natural processes that are going on in the ocean and the atmosphere swamp anything we do. But what we do tips the balance a bit by increasing atmospheric concentrations.

Seven hundred and fifty gigatonnes of carbon dioxide are calculated to be in the atmosphere and this is increasing by three gigatonnes a year.* At a 1997 conference in Kyoto, Japan, Australia agreed with other nations to reduce greenhouse gas emissions.

AGSO's Denis Wright is one of a number of specialists advising the Commonwealth Government on what to do with CO₂. He provided some thoughts at a recent AGSO seminar.

Dry-clean or the **BIG SINK?** CO₂ disposal

Australia is an energy-intensive, primary producing country. Most of its greenhouse emissions are from producing energy—from black and brown coal-fired power stations. Some emissions are from industrial processes including solvents, and a lot (compared with other advanced countries relative to our population of 18 million) is from agriculture. A fair bit of CO₂ and methane also escapes into the atmosphere from oil and natural gas systems.

Most emissions from oil and gas production are via venting and flaring. In the past, the CO₂ contained and separated from natural gas was vented to the atmosphere. A few companies continue this practice today. Methane is vented in some crude oil production operations as crude oil stabilises. Methane, however, has 21 times the greenhouse effect of CO₂. The CO₂ equivalent of gases vented from Australia's petroleum fields is about .0028 gigatonnes a year.

Flaring is sometimes necessary to dispose of excess gas. The CO₂ produced is less harmful to the environment than directly releasing the gas (which is mostly methane). One emission-reduction strategy therefore is to reduce venting and flaring.

Methane and CO₂ also escape from leaky gas distribution pipelines. Old cast-iron pipelines in New South Wales and Victoria laid down a hundred years ago are losing an estimated seven per cent of the gas being piped. Before pipeline repair, in a couple of cities such as Newcastle this was up to 30 per cent. AGL (Australian Gas Ltd) is relining old pipelines to stop leakage. Little escapes in new pipelines (but if it does it is generally as it goes into people's homes).

But even with these strategies, Australian needs other processes for dealing with its oil and gas systems emissions. Gas production is going to be a major part of Australia's energy exports in the future. Worldwide, Australia is already tenth in terms of gas reserves. By 2010 Australia expects to double its gas production. But the gas in a number of Australia's reservoirs comprises more than four per cent CO₂. To sell the gas, some of it must be removed. This rise in production and need to remove CO₂ equates to 147 per cent increase in fossil CO₂ emissions—an increase that will affect the eight per cent growth in total emissions Australia is allowed under the Kyoto protocol.



Carbon dioxide disposal

A number of processes for 'disposing' of CO₂ are being tested around the world. One is geological disposal. CO₂ can be sequestered into aquifers that may or may not have been oil or gas reservoirs at some time, and it can be re-injected into an oil reservoir for enhanced oil recovery. It can also be disposed of in deep-ocean or injected into deep coal seams that will never be mined. Another option is to make methanol from a methane-CO₂ reaction. Australia could also try to sell the CO₂ or, under the Kyoto protocol, it could trade its increased emission points with buyers of the gas who, for example, might have lowered their points by switching from coal to gas power.

* Denis Wright presentation

▶ *Continued on page 28*

GAPING HOLES

found by Bight MARINE park research

Huge holes eight kilometres wide and half a kilometre deep in the canyoned seabed of the Great Australian Bight have scientists puzzled. These are unknown anywhere else in the world in such deep water. What caused them?

Nadège Rollet, one of AGSO's geoscientists involved in sampling geological features in the Bight's marine park offers an explanation.

The marine reserve in the Great Australian Bight (GAB), dedicated by Federal Environment Minister Robert Hill in April 1998, was established to protect the endangered southern right whale and the Australian sea lion. Geoscience research is uncovering other rare features in this reserve.

The reserve covers 1 713 429 hectares, including a band 20 nautical miles wide that extends from the state park boundary to the edge of the Exclusive Economic Zone (figure 1.) The coastal area is designated for mammal protection, while the offshore area is defined as a benthic protected area to conserve a sample of the unique and diverse bottom-dwelling fauna and flora and unique seabed sediments. Both areas include the waters and seabed beneath the sea as well as the subsoil beneath the seabed to a depth of 1000 metres.

Boundaries and features

In May, the 65-metre CSIRO research vessel *Southern Surveyor* completed a 47-day cruise (SS001) off south-east Australia. The purpose was to examine benthic organisms and the substrate they live on in a number of small, critical areas on the slope and upper shelf of the region and in the GAB benthic protected area. As well, the voyage was to identify appropriate boundaries for large marine domains (LMD) of biological similarity and to define ecological units. The National Oceans Office, Environment Australia, CSIRO and AGSO supported the voyage.

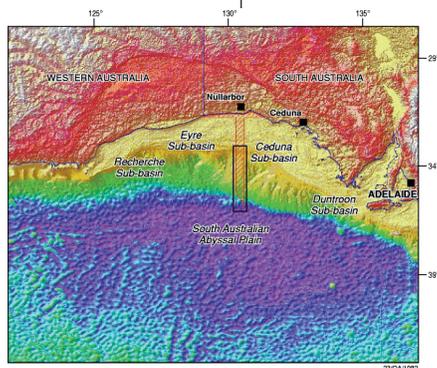
CSIRO's program was divided into three main legs (Hobart–Eden, Eden–Hobart, Hobart–Fremantle). AGSO participated directly in the third leg: on the western Tasmanian margin, on the western Victorian margin, and in the GAB marine park. Leg 3 was to refine techniques for mapping and classifying marine benthic habitats, and also to sample geological features in the park.

The deep water of the benthic protected area of the marine park was swath-mapped during the AUSTREA-1 AGSO cruise (figure 2) in January (reported in the April 2000 issue of *AUSGEO News*). This mapping assisted in formulating the sediments sampling program.

Swath-mapping in the GAB, using a multibeam sonar system, shows that the slope to about 3000 metres is relatively featureless. But below that, to a depth of more than 5000 metres, it is steeper, faulted, and heavily canyoned.

Associated with canyons, especially the large Nullarbor Canyon and elsewhere in deep water, are huge holes up to eight kilometres across and 500 metres deep. These features are not known (to AGSO) to occur anywhere else in the world at such depths, and their nature is as yet undetermined. Current thought points to these huge holes being produced by escaping fluids and, if so, they may host chemosynthetic organic communities.

On the third leg AGSO staff were involved in characterising the physical attributes of the seabed of the continental slope and rise and the deep holes in the Nullarbor Canyon. To investigate long-term changes in sedimentary, water column, and climatic conditions in the GAB region, a suite of sediment samples was obtained using a grab, a gravity corer and a benthic dredge. These sediments also 'ground-truthed' the previously acquired bathymetric image produced by swath-mapping.



▲ **Figure 1.** Sub-basins in the Great Australian Bight. The marine park is indicated by the striped area and the *Southern Surveyor* survey area by a black rectangle (bathymetry map prepared by AGSO's Peter Petkovic).



▲ On deck of the *Southern Surveyor*, an AGSO–CSIRO team extracts a core sample.



◀ Kriton Glenn (AGSO) assesses sediment samples on board the *Southern Surveyor*. The samples are given a preliminary shipboard description and then bagged for further laboratory analysis.

deposition of younger sediments in the holes. Deep contour currents in this region may also contribute to shaping the holes and keeping them clear.

Geological samples were needed to identify the acoustic units observed in geophysical data and to investigate palaeoenvironmental conditions in the last 50 000 years. AGSO's samples were taken from a water depth of 500 metres to the abyssal plain at 5300 metres, in two modes.

From 500 to 2500 metres deep, five stations were sampled every 500 metres on an AUSTREA-1 profile (with an eight-metre gravity core) to investigate long-term Quaternary changes in sedimentary, water column, and climatic condition. In 3000–5300 metres water depth, four cores were recovered at sites determined by swath-mapping, seismic and 3.5 kHz profiles to investigate the sediments in the deep holes (two in the Nullarbor Canyon axis and two in holes west of the canyon). In addition, three dredges sampled old detrital sediments (probably Late Cretaceous): two in the deep holes and one in a submarine fault scarp.

Of the range of sediments obtained from the shelf and the slope, most cores contained unconsolidated and reworked calcareous sands and muds. The samples were given a preliminary shipboard description and then bagged for further laboratory analysis. The core samples will be analysed to unveil the paleoclimatic history of the region, and to provide acoustic velocity information of value to CSIRO.

At the base of four cores and in all three dredges were black mud and mudstone, clearly of Cretaceous or Paleogene age. Only a thin veneer of recent ooze (about 2 cm) was recovered at the surface, proving that recent sediments have been eroded or were not deposited in the holes. Post-cruise geoscience studies of the samples from the GAB, and also from the previous *Southern Surveyor* legs, will include general sedimentology and studies of ostracods and foraminifera.

Results

On the basis of seismic reflection profiles acquired during the AUSTREA-1 cruise, it seems that the holes in the Nullarbor Canyon are tectonically controlled by a large number of faults (figure 3). These faults are rooted in the marine shales at the base of the Turonian sequence (about 90 million years old) which form a décollement for younger growth faults. This movement on the décollement surface was gravity-driven and does not reflect upper crustal extension at that time. The growth faults initiated the surface depressions of the holes; another phenomenon has kept them free of sediment.

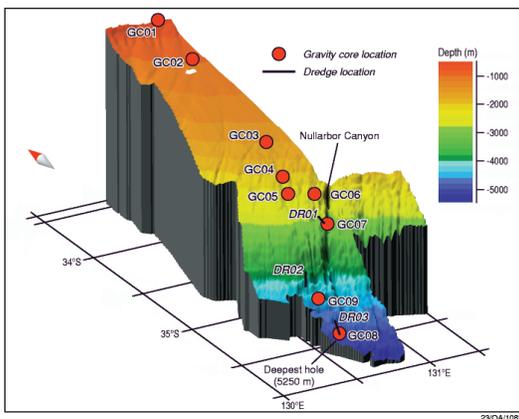
It seems that the growth faults were reactivated up to the surface more recently, after the initiation of gravity slides on the slope about 45 million years ago, and that the marine shales are over-pressured, allowing water to escape along the newly created faults. This water escape may have prevented new

Research team and equipment

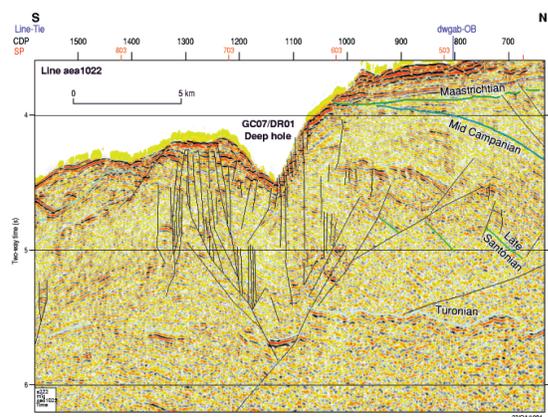
The equipment available for the sampling program included a Smith-McIntyre grab, a device to continuously measure temperature, salinity and depth (CTD), an eight-metre-long gravity corer, and a heavy rock dredge to which was attached two 15-litre pipe dredges.

Leg 3 of the *Southern Surveyor* cruise involved four AGSO staff and seven CSIRO personnel. Rudy Kloser (CSIRO) led leg 3, except during the two-day AGSO sampling program in the GAB. In charge of this program were AGSO's Kriton Glenn and Nadège Rollet, with Lyndon O'Grady and Jon Stratton providing valuable technical assistance.

For further information about AGSO's sampling program in the GAB phone Nadège Rollet on +61 2 6249 9428 or Kriton Glenn on +61 2 6249 9379, or e-mail nadege.rollet@agso.gov.au or kriton.glenn@agso.gov.au



▲ **Figure 2.** Seafloor topography and canyon systems of the Great Australian Bight Marine Park, produced from AUSTREA-1 swath data. The view is to the north-east and shows an area about 130 kilometres long. The location of AGSO samples acquired during the *Southern Surveyor* cruise is indicated by red circles for the cores and by black lines for dredges.



▲ **Figure 3.** AUSTREA-1 seismic reflection profile across a 240-metre-deep hole in the Nullarbor Canyon. The shape of the hole is controlled by deep faults taking root at the base of the Turonian shaly unit. The shales form a décollement for younger growth faults along which water escapes when the shales are over-pressured.

▶ Continued from page 25

One advantage of putting the CO₂ in geological structures is that amounts can be recorded and verified as still being there after many years. Currently there are a number of depleted fields onshore (e.g. in the Surat and Bowen Basins), but none will be available offshore for a few decades.

Re-injection can be risky. Various criteria need consideration including the location of traps and reservoirs, permeability, the storage capability of the reservoir, and how far it is from the CO₂ source. A large project called GEODISC, that involves researchers from AGSO, universities and other institutions in the Australian Petroleum Cooperative Research Centre, is assessing geological sequestration of CO₂.

Unlike Australia, Japan does not have large, geologically stable oil and gas reservoirs and aquifers. So they are pursuing deep-ocean disposal of CO₂. With this approach, the ocean is used as the 'big sink' for carbon dioxide. The theory is that nearly all the CO₂ is in the ocean anyway, and it has been very stable and not moved for hundreds of years. The CO₂ is injected below 1000 metres water depth either as droplets or plume in a towed pipe

on a boat, or tipped over the side as dry ice. If injected at a depth greater than 3000 metres, a stable CO₂ lake forms at the bottom of the ocean.

Enhanced oil recovery

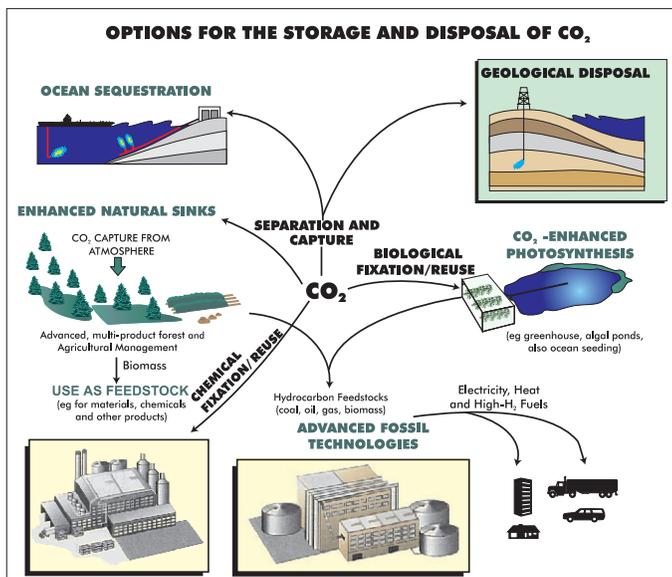
Enhanced oil recovery (EOR) using CO₂ is big business in the United States. More than two billion cubic feet of CO₂ is pumped daily around the US from 61 EOR-CO₂ projects in such states as New Mexico and Colorado. But why is CO₂ used to enhance oil recovery? It has a critical pressure and critical temperature very close to ethane. Either can be mixed with oil to make something a bit like LPG. When this LPG-like material (single-phase oil-CO₂ mixture) goes through the reservoir, it effectively dry-cleans the reservoir.

In Australia, 177 oil reservoirs have been screened for EOR using six different correlations. Results show that below 2100-metres depth, CO₂ is technically appropriate for injection. However, in shallow reservoirs the pressure would not be high enough. What this means is that in the Eromanga Basin, for example, a successful flood has doubled reserves in the Tirrawarra field; but it would be unsuitable for the shallower Jackson field.

The results also show that the most appropriate form of EOR is miscible gas flooding with CO₂ or enriched ethane. Australia's light crude makes other popular forms of flooding unsuitable (steam, in situ combustion, polymer and alkaline flooding). Nitrogen EOR is suitable only in very deep, very high-pressure reservoirs.

The total CO₂ in all Australian gas fields is 0.4 gigatonne. Many fields have high CO₂ reservoirs, including Big Lake, Tuna, Gorgon, Evans Shoal and Scott Reef. In terms of percentage of CO₂ present, the big one is Caroline in the Otway Basin. It has a 98 per cent CO₂ content that is sold to industrial producers of dry ice. Caroline has been producing since 1968 from a single well. Its reserves are much larger than original estimates. This single well is expected to produce millions of dollars worth of CO₂. But it has some competition. In 1994 the Boggy Creek field (97% CO₂) came into production.

Offshore, tests on the gas that came off oil in the Grunter field show it is very close to 100 per cent CO₂.



▲ **Figure 1.** Options for the storage and disposal of carbon dioxide (modified after US Department of Energy, FETC, 1999). Diagram courtesy of the Australian Petroleum Cooperative Research Centre

What to do

Australia agreed to reduce its greenhouse emissions. But it cannot shift its economy's emphasis (primary producing) by 2012 to achieve Kyoto protocol targets. Research into safe means of using or disposing of CO₂ therefore is a government priority.

Small amounts of extra CO₂ can be sequestered into plants. Levels of land clearing and reforestation therefore are being studied by government agencies. Gas pipelines are being upgraded, and Australia's coal-fired power stations (which will be producing energy for at least another 40 to 100 years) are looking at fluidised peat and coke in combustion to reduce emissions. But even with these strategies, Australia is likely to be told its greenhouse emissions are too high. Geological disposal is an obvious choice—but why throw it out if it can be used to increase oil recovery.

For further information phone Denis Wright on +61 2 6249 9277 or e-mail denis.wright@agso.gov.au

NEW COLOUR ATLASES INVALUABLE FOR RESOURCE EXPLORATION

Two new atlases for the Pilbara and Curnamona released next month will be welcomed by those interested in these old regions. Both products offer new and varied interpretations of geophysical data, gathered over more than five years, that will be useful starting points for effective resource exploration.

Atlas of North Pilbara: Geology and Geophysics

A new 36-plate, colour atlas of the geology and geophysics of the Archaean North Pilbara craton will be released in August. The spiral-bound, A3-sized atlas (1:1.5 million scale) illustrates the richness of the Pilbara's geology.

The Archaean rocks of the North Pilbara craton provide excellent insights into the evolution of the early Earth. These well-exposed rocks have been mostly mapped by classical geological methods to date. The value of this atlas is the revelation of many intriguing aspects of the geology not previously apparent. New datasets include many geophysical plates, including a number of variations of the magnetics, gravity, and gamma-ray spectrometry. A solid geology map and derivative maps, mineral deposits, geological events, 3D shapes, and Landsat 5-TM provide additional views. The presentation of the same area in different guises is invaluable for comparative, correlative and analytical purposes. New aspects of the geology include:

- the shape of basins under cover;
- the 3D geometry of the dome-and-basin pattern;
- the imaging of several large shear zones;
- the intra-batholith complexity;
- the inter-pluton relationships;
- the greenstone correlations based on chemistry;
- the new boundaries and subdivisions in the Hamersley Basin;
- a new chemical map;
- identification of the source regions of transported regolith; and
- new subdivisions of regolith.

This atlas is essential for mineral exploration companies, academics, and those working on the land in the North Pilbara. It also will be handy for students of Archaean geology, and for those training for work in more poorly exposed Archaean granite-greenstone terrains (e.g. Yilgarn) where the geological complexities are less apparent than those on display in the Pilbara craton.

The atlas was developed by the joint AGSO-GSWA (Western Australian Geological Survey) North Pilbara project for the National Geoscience Mapping Accord. The atlas is available from the AGSO Sales Centre for \$110 (includes GST) plus postage and handling. Low-resolution images can be viewed at <http://www.agso.gov.au/minerals/pilbara/>

Geophysical Atlas of the Curnamona Province

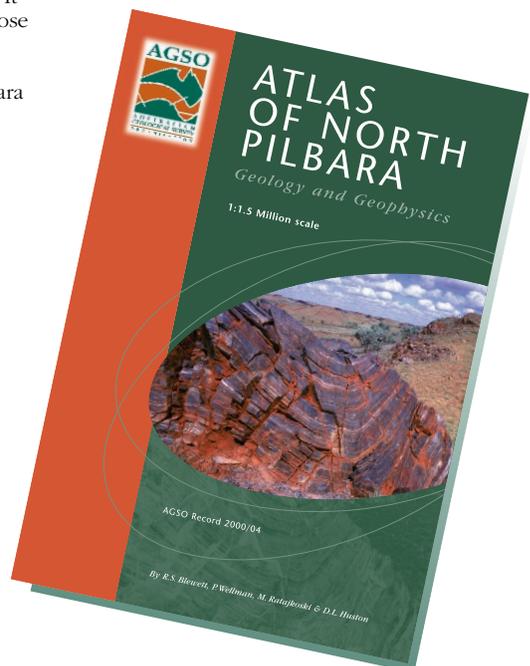
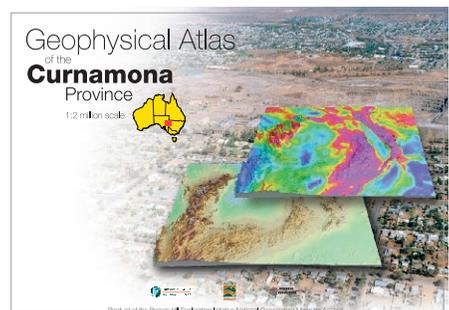
Another new product from the National Geoscience Mapping Accord is a 1:2 million scale atlas for the Curnamona province. This colour atlas of 20 plates plus explanatory notes is the companion volume to the Broken Hill Exploration Initiative (BHEI) final data CD.

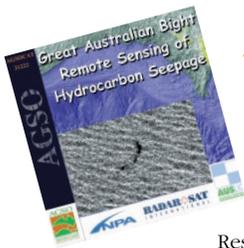
The Curnamona province spans the border between New South Wales and South Australia, and includes the well-known copper-silver-lead-zinc area of Broken Hill. The atlas contains images from high-quality data collected over the province as part of BHEI (an AGSO, Primary Industries and Resources South Australia, and New South Wales Department of Mineral Resources

project). This has been combined with regional data from State initiatives and surveys. The atlas highlights the amount of detailed interpretative data available to those interested in this province.

The Curnamona province geophysical atlas can be purchased from the AGSO Sales Centre for \$132 (includes GST), plus postage and handling, by phoning +61 2 6249 9519 or e-mailing sales@agso.gov.au

For more information about the Pilbara atlas phone Richard Blewett on +61 2 6249 9713, e-mail richard.blewett@agso.gov.au. For details of the Curnamona province atlas phone Peter Milligan on +61 2 6249 9224 or e-mail peter.milligan@agso.gov.au





new CD-ROM

GAB hydrocarbon seepage confirmed

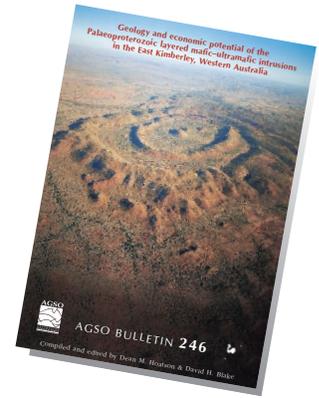
Results of an investigation into hydrocarbon migration and seepage in the Great Australian Bight confirm the presence of hydrocarbon seepage slicks. These slicks, interpreted as having been generated by hydrocarbons leaking from accumulations in the basin system, indicate that an active petroleum system is present. This confirmation significantly increases the hydrocarbon prospectivity of the region.

Results of the investigation have just been released on CD-ROM in ARCVIEW GIS format (which allows the viewing, integration and manipulation of the data). Two reports are in PDF format: the interpretation by Nigel Press Associates (NPA) of seepage slicks from SAR data, and AGSO's report which integrates regional geological data with the seepage interpretation. The CD-ROM includes:

- images of SAR scenes across the GAB, in waters between 116°E and 137°E;
- interpretation of all anomalies including classification of natural hydrocarbon seepage;
- coverage of basic geographic data and well and seismic line locations;
- images of bathymetric, gravimetric and magnetic data;
- the integration of seepage interpretation with regional petroleum geology.

The investigation was undertaken by AGSO's Southern Margin Frontiers project (Frontiers of Petroleum Program) in response to industry concerns regarding the presence of an active petroleum system. It was conducted in cooperation with Nigel Press Associates (UK), RadarSat International (Canada), and the Australian Surveying and Land Information Group (AUSLIG).

Copies of the CD-ROM titled *Great Australian Bight: Remote Sensing of Hydrocarbon Seepage* (AGSOCAT 31222) can be bought from the AGSO Sales Centre (price on application). For further information about the study phone Heike Struckmeyer on +61 2 6249 9646 or e-mail heike.struckmeyer@agso.gov.au



AGSO RESEARCH HERALDS MINERAL DEPOSIT FINDS

On May 24, many Australians awoke to the following headlines in the business sections of their newspapers: 'WMC tipped to have world's best metals hit' and 'Huge metals find by WMC'. These headlines referred to the recent Ni-Cu-Co sulphide discovery by Western Mining Corporation Resources Ltd in the western Musgrave Block of central Australia. Preliminary drilling of electro-magnetic anomalies obtained very encouraging results, with one hole having an alleged intersection of 26.5 metres @ 2.45% Ni, 1.78% Cu, 0.09% Co.

Although the geological setting of the deposit is yet to be published, the abundances and ratios of metals reported are very typical of massive sulphide accumulations from the basal parts of 'tholeiitic layered mafic intrusions'. Interestingly, the Ni-Cu-Co potential of the approximately 1080 million-year Giles mafic-ultramafic intrusions in the Musgrave Block was indicated in the 1996 *AGSO Bulletin 239* (*Geology of the western Musgrave Block with particular reference to the mafic-ultramafic Giles Complex*, by Glikson et al.). It was also mentioned in the 1997 *AGSO Research Newsletter 27* ('Are there Voisey's Bay-type Ni-Cu-Co sulphide deposits in the East Kimberley of Western Australia', by Hoatson et al.).

New bulletin, an authority on prospects

AGSO has just published a major report (Bulletin 246) that provides a framework for the prospectivity and resource potential of the layered mafic-ultramafic intrusions in the Halls Creek Orogen (HCO) of the East Kimberley.

free CD-ROM

Offshore Australia 2000

This CD-ROM provides background information to help petroleum exploration companies in their evaluation of the prospectivity of sedimentary basins within Australia's offshore jurisdiction. It encompasses new and previously published information from AGSO and the Department of Industry, Science and Resources and includes:

- Australia's Offshore Petroleum Strategy document;
- summary details of the geology of Australia's major offshore basins;
- Handbook on Petroleum Exploration and Development in Australia;
- Australian Petroleum Exploration and Development Activity Report;
- advance notice of areas under consideration for release by the government in 2000;
- details of exploration permits awarded since 1990;
- a map gallery; and
- contacts in AGSO and other key government and private sector organisations.

This is the first time this information has been brought together in the one 'package'. The CD-ROM should be particularly useful to overseas companies with little or no knowledge of exploring or investing in Australia's offshore basins. The product is available free-of-charge from the AGSO Sales Centre by phoning +61 2 6249 9519 or e-mailing sales@agso.gov.au



The intrusions in the HCO represent one of the most extensively mineralised igneous associations of their type in Australia. They contain a range of magmatic and hydrothermal deposits of platinum-group elements, chromium, nickel, copper, cobalt, titanium, vanadium, iron and gold. Despite intensive exploration during the past four decades and the discovery of many prospects, no economic deposits associated with the layered intrusions have been found in the HCO. However, the HCO is an attractive province to explore, for only the Giles Complex in the Musgrave Block of central Australia contains a larger area of layered intrusions in Australia.

The main aims of the investigations reported in Bulletin 246 were to determine the geological setting and evolution of the layered mafic-ultramafic intrusions and assess their economic potential. Detailed studies of individual intrusions (exploration history, stratigraphy, petrography, geochronology, mineralisation, depth of emplacement, and isotope, mineral and whole-rock geochemistry) have been integrated with regional studies of geology, geophysics, remote sensing, and tectonic processes. The bulletin is an essential reference for those involved in the:

- exploration of layered mafic-ultramafic intrusions in the HCO;
- the geological and geophysical framework of the HCO and its environs; and
- the regional geology, metallogenesis, and tectonics of Precambrian orogenic terranes.

Bulletin 246: Geology and economic potential of the Palaeoproterozoic layered mafic-ultramafic intrusions in the East Kimberley, Western Australia was compiled and edited by Dean Hoatson and David Blake. It presents the results of a collaborative study by AGSO, the Geological Survey of Western Australia, Monash University and the minerals industry.

The book comprises 496 (A4) pages, and includes 150 figures and plates (64 in full colour), 41 tables, comprehensive bibliographies, and 150 pages of appendices devoted to whole-rock, mineral, geochronological, and magnetic properties analytical data. Bulletin 246 costs \$93.50 (includes GST) plus postage and handling. It can be ordered from the AGSO Sales Centre via phone +61 2 6249 9519 or e-mail sales@agso.gov.au

For more information about details in Bulletin 246 phone Dean Hoatson on +61 2 6249 9593 or e-mail dean.hoatson@agso.gov.au 📧

FORBES COMPREHENSIVE DATA RELEASED

Final edition maps, explanatory notes, and digital data for the Forbes (SI55-7) 1:250 000 sheet have just been released by the Lachlan Fold Belt National Geoscience Mapping Accord project. The new products cover a highly prospective area of the north-eastern Lachlan Fold Belt, including parts of the Junee-Narromine Ordovician volcanic belt that hosts the Northparkes and Cowal gold deposits, and the Gilmore and Parkes fault zones.

The maps are the result of a regional mapping program carried out between 1995 and 1999, and a field conference held in April 1999. They are underpinned by 400-metre line-spaced airborne geophysical data collected by AGSO in 1993, and an extensive program of U-Pb zircon geochronology.

A new style of map is included in the data release—a 1:250 000 scale depth-to-bedrock map. Much of the Forbes map sheet area is covered by poorly consolidated alluvial sediments that form plains surrounding isolated bedrock outcrops. The depth and character of these alluvial sediments are important to farmers, mineral explorers and hydrologists. The sediments are the primary source of groundwater in the region, including the water supply for Forbes. The sediments also conceal much of the highly prospective bedrock. Explorers will find the new map invaluable in planning drilling and sampling programs.

The Lachlan Fold Belt NGMA project is a collaborative effort between AGSO and the New South Wales Department of Mineral Resources.

Maps—\$54 each

1:250 000 scale maps, Forbes (SI55-7)

Geology, edn 2
Simplified basement geology, edn 1
Depth to slightly weathered bedrock, edn 1
Regolith landforms, edn 1

1:100 000 scale geology maps, edn 1

Wyalong (8330)
Condobolin (8331)
Marsden (8430)
Bogan Gate (8431)
Grenfell (8530)
Parkes (8531)

Explanatory notes—\$55

Forbes (SI55-7): 230 pages of detailed unit descriptions, plus summaries of metallogenesis, tectonic history, igneous evolution and regolith development

Digital outcrop and basement geology data—\$132

Digital outcrop and basement geology data (in ArcInfo, ArcView, and MapInfo formats) are available for each 1:100 000 map at \$132:

Wyalong (8330)	Condobolin (8331)
Marsden (8430)	Bogan Gate (8431)
Grenfell (8530)	Parkes (8531)

GIS data package—\$550

Forbes (SI55-7) data on CD in ArcView, ArcInfo, and MapInfo formats. Data layers include: geological mapping, basement geology interpretation, regolith mapping, depth-to-bedrock data, mineral occurrences, cross sections, time-space diagram, topographic and cultural data; point databases of outcrop descriptions, thin sections, structural measurements and field photos; locations of geochemical and geochronological samples, drill holes and stream sediment sampling; geophysical survey locations, exploration licenses, summary images of magnetics and radiometrics and a digital elevation model.

For more details phone Ollie Raymond on +61 2 6249 9575 or e-mail ollie.raymond@agso.gov.au. The products can be bought from the AGSO Sales Centre. Prices include GST. Please add postage and handling costs. 📧

