HAS AUSTRALIAN OIL &

Most of the world's oil supplies lie in areas of relative political instability. As a result, many nations are concerned about the long-term security of their supplies. Australia has been largely isolated from this concern, because it is a modest consumer of oil by world standards and over the past 30 years has enjoyed a high level of oil self-sufficiency.

CONDENSATE *production peaked?*

Large oil fields were discovered in the Gippsland Basin (Bass Strait) in the 1960s. This was followed in the 1980s and 1990s by the discovery of numerous smaller fields in the Carnarvon Basin (North West Shelf) and in the Bonaparte Basin (Timor Sea). To date, the smaller fields and the growth in condensate from large gas fields have compensated for declining production in Bass Strait.

A vital question for Australia is whether this trend will continue.

Oil and condensate recovery

Australia's oil production comes from two types of fields:

- Crude oil fields where the hydrocarbons are in the liquid phase in the underground reservoir and are produced as a liquid at the well head;
- Gas-condensate fields where pentane and heavier hydrocarbons are in the gas-phase in the underground reservoir and are recovered as condensate from a separation system at the well head as the gas is produced.

The economics, logistics and investment criteria for the two types of fields are quite different. Condensate production is limited by the need to have markets and infrastructure for production and delivery of the gas, or the ability to re-inject gas into the reservoir for future use.

Estimates of future crude oil and condensate production depend on understanding the reserves, and how they change through time because of exploration and adjustment (usually positive) to the reserves in existing fields. There can be a significant time lag between identifying a new field and starting production. Technical assessments of the field's characteristics and economics, and acquiring and installing suitable infrastructure for field development take time.

Oil and gas resources of Australia

Year		1993*	1994*	1995*	1996*	1997*	1999*	2000*
Total reserves		1785	1764	2046	1897	1702	1724	1660
Category 1:	Commercial	918	998	1216	1198	1161	1017	1212
Category 2:	Not yet commercial	867	768	830	699	541	707	452
Category 2a:	Sub-economic	244	199	180	152	190	196	226

** As at January 1*

Figure 1. Crude oil reserves in Australia through time (millions of barrels). Category 2a comprises the 'Sub-economic demonstrated' reserves under the McKelvey classification of resources, and can be considered a sub-set of category 2 'Not yet commercial' reserves. These figures are published in the *Oil and Gas Resources of Australia* by Geoscience Australia (and its predecessors).

Viable reserves an issue

Australia's crude oil reserves over the past decade are summarised in figure 1. Total crude oil reserves peaked in 1995 and declined 19 per cent by the year 2000. They are now at levels not encountered since the 1980s.

Crude oil reserves are divided into two categories. Reserves that are being commercially produced, or have been declared commercial and are waiting production, fall into the first category (Commercial reserves, figure 1). The second category represents estimates of recoverable reserves that have not yet been declared commercially viable (Not yet commercial reserves, figure 1).

Commercial reserves have stayed constant or grown over the past decade due to reserves shifting from category 2 into category 1. As a result, production has remained constant or grown, even though total reserves have declined.

However, category 2 reserves are not being replenished through exploration. This indicates that the new reserves, which can be brought into production in the near term, are limited. As well, some of the 'Not yet commercial' reserves are non-economic at present (Sub-economic demonstrated reserves, figure 1) and are unlikely to be declared commercial in a reasonable time frame.

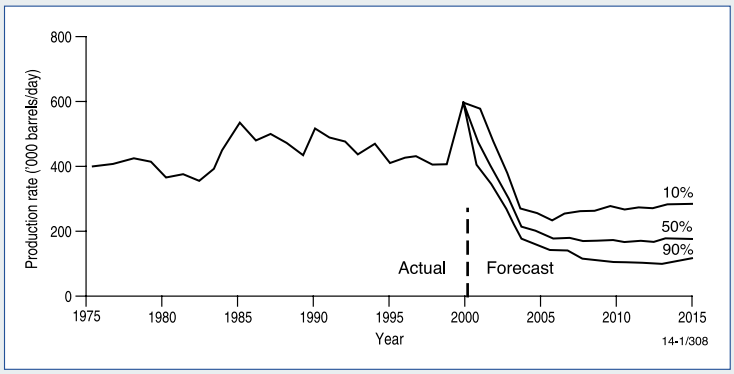
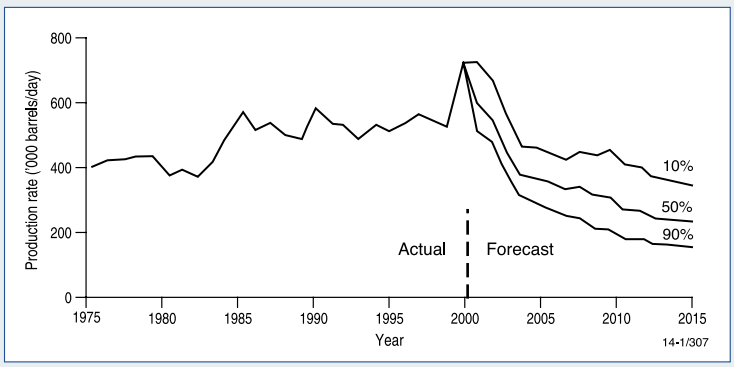


Figure 2. Australia's annual production of crude oil 1975–2000 and forecast annual production at 90%, 50% and 10% accumulation probability for the period 2001–2015 (*Oil and Gas Resources of Australia* 2000, 2001).



The 'Sub-economic' category of reserves comprises resources that for a variety of reasons are not considered economic to produce at present. This category of reserves has remained relatively constant over the past decade, but in 2000 it represents 50 per cent of the 'Not yet commercial' reserves compared with less than 30 per cent earlier in the decade.

Oil production in decline

Under these circumstances, oil production will decline in the medium term as the current commercial reserves are depleted (figure 2). The magnitude of the anticipated decline is partly due to the high current rate of production of crude oil. The current ratio of production to commercial reserves is very high at 1: 4.6 in 2000 compared with 1: 7.3 in the previous five years. Given the static nature of the category 1 reserves, this represents production brought forward compared with historical trends.

At present the best prospects for major new commercial crude oil reserves are in the Enfield–Laverda–Conniston complex in the Carnarvon Basin, where Woodside have recently published reserve estimates in excess of 310 million barrels. These discoveries have not been fully factored into the current reserve estimates and production forecasts. They will mitigate the production decline in the future, but will not make up the shortfall from present levels.

Figure 3. Australia's annual production of crude oil and condensate 1975–2000 and forecast annual production at 90%, 50% and 10% accumulation probability for the period 2001–2015 (*Oil and Gas Resources of Australia* 2000, 2001).

Condensate resources have grown significantly as major gas fields have been discovered. They exceed crude oil reserves. Only 787.75 million barrels of the 2164 million total reserves are commercial (category 1) reserves at this time.

Production of condensate is usually constrained by the timetable for development of the host gas resources. As a result, the rate at which condensate resources can be brought into production is limited.

Figure 3 shows the combined estimates of production for crude oil and condensate over the next 15 years. On average, production is expected to exceed 341 million barrels per annum in five years' time compared with more than 720 million barrels per annum currently and around 550 million barrels in the late nineties. There is a 10 per cent probability that production will exceed 429 million barrels per annum in five years' time.

If current trends of discovery are maintained into the future, production is expected to decline by 40 to 50 per cent in the medium term and then to steadily decline even further.

Broaden exploration base

There are two ways in which this scenario could change. Substantial new sources of crude oil are found and developed relatively quickly, or there is a big increase in the rate at which the identified (but as yet non-commercial) resources of gas condensate are developed.

The latter is unlikely to occur, but condensate production will underpin Australia's long-term oil supply. Condensate production is expected to represent around 50 per cent of Australian production by 2005.

If Australia is to maintain its indigenous liquid hydrocarbon supply, it needs to broaden the base for Australian exploration. Off north-western Australia there is still considerable potential for petroleum accumulations. But the chances of finding large crude oilfields rather than gas-condensate sufficient to arrest the projected decline in oil production is limited. Australia must look at other potential areas such as its southern margin, while continuing to explore the north-western basins and their deep-water fringes.

For more information phone Trevor Powell on +61 2 6249 9471 or e-mail trevor.powell@ga.gov.au

Geophysical technique mix
TO RESOLVE
offshore basement problems

The basement beneath Australia's offshore basins was the cradle for sediments involved in oil and gas formation. Knowledge of basement depth, boundaries and evolution provides clues to the petroleum potential of Australia's sedimentary basins.

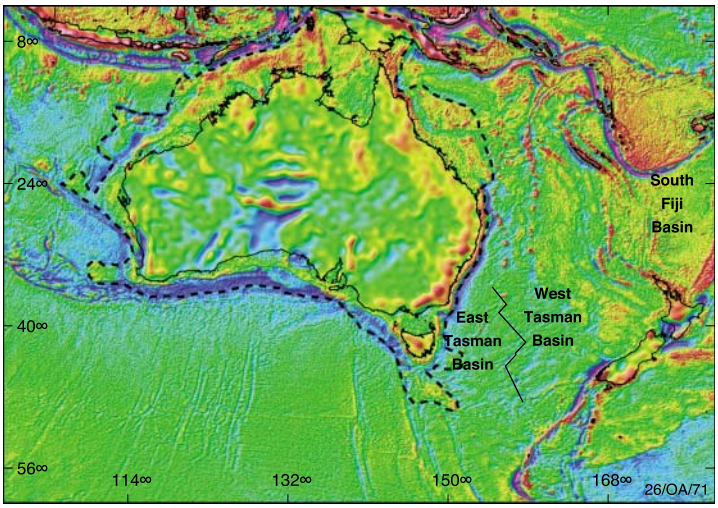
The problem is finding the right combination of geophysical techniques to define basement offshore, and knowing what adjustments to make to reduce unwanted effects in definition.

Geoscience Australia's Alexey Goncharov outlines his team's exciting new basement and crustal studies that are tackling the problems.

Factors that have a profound effect on the petroleum potential of a region, such as crustal-scale boundaries, the type and depth of basement, and heat flow, are the focus of a new Geoscience Australia project, the Basement and Crustal Studies project (BCS), which began late last year.

The BCS project is investigating the role of crystalline basement in the development of accommodation space for Australia's sedimentary basins. The main outcome will be a regional-scale framework that is linked to onshore geology, which can be used for studies of individual sedimentary basins. Outputs of the BCS project will be:

- improved maps of basement type, crustal type and thickness;
- an understanding of how basement controls basin accommodation space;
- improved plate tectonic reconstructions; and
- improved parameters for seismic interpretations in depth rather than a two-way time scale.



▲ **Figure 1a.** Satellite-derived, free-air gravity (Smith WHF & Sandwell DT. 1997. Global seafloor topography from satellite altimetry and ship-depth soundings. Science, Sep 26; 277:1956–1962.)

Boundaries difficult targets

Surface of the basement, and the Moho discontinuity that marks the bottom of the crust, are very important geological boundaries. Both are difficult targets for the multi-channel seismic reflection technique conventionally used by industry to investigate sedimentary basins offshore and onshore.

Experience with a combined interpretation of reflection and refraction seismic data in Australia's North West Margin demonstrates there are big problems with basement identification. But a combination of several geophysical techniques such as seismic refraction, gravity and magnetics has the potential to resolve this problem in many areas.

A more accurate definition of the surface of basement and Moho is important because it affects estimates of petroleum prospectivity of a region. If the basement is too shallow or the crust is too thin, the region is an unlikely candidate for petroleum exploration.

Initial work

The BCS project has both regional and thematic components in its work. Last year the emphasis was on improvement of offshore gravity interpretation, crustal thickness correlation with gravity, and heat-flow data compilation. The research covered the Otway, Sorell, Gippsland and Bass basins around Tasmania, and also the Bellona Trough at the southern end of the Lord Howe Rise.

First results

The conventional gravity image, based on the Bouguer anomaly (BA) gravity grid onshore and the free-air anomaly (FA) grid offshore, is not an ideal way to represent the geologically controlled component of the gravity field offshore and the continent–ocean transition zone in particular.

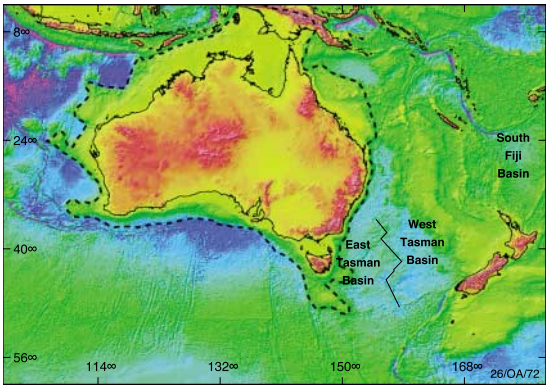


Figure 1b. Satellite-derived topography/bathymetry (Smith & Sandwell, 1997)

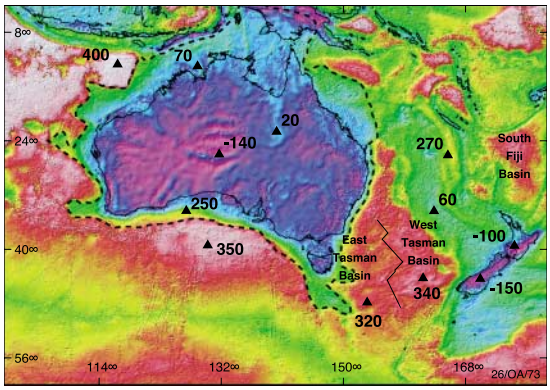


Figure 1c. (top right) Bouguer anomaly gravity computed from the data presented in figures 1a and 1b at reduction density 2.67 g/cm^3. The dashed line is the continent–ocean boundary defined on the basis of the bathymetry. Gravity values at selected locations (triangles) in milligals

The FA gravity field offshore is strongly controlled by effects that are due to water depth variation. It also contains a component controlled by the density variation below the seafloor, but this component is masked by the bathymetric effect.

Water depth effects

A water depth increase by five kilometres corresponds to an approximate 265 milligals decrease in the gravity field, depending on the residual density between water and the underlying rock. This is a huge value that exceeds the whole range of the BA for the entire onshore region (BA values onshore are typically within -150 to 50 mGal).

In reality, the FA gravity offshore does not drop as much as water depth variation dictates. It decreases by approximately 70–80 milligals. The remaining (~180) milligals are compensated by the effect of higher density material somewhere underneath the seafloor. Thinning of the crust from continent to ocean is probably the most recognisable source of such compensation, but it may not be the only source.

At the moment there are three potential ways to address the problem of water depth induced effects:

1. Implement the marine Bouguer reduction to produce a consistent BA grid for Australia's onshore and offshore areas.
2. Produce and analyse composite images of FA gravity draped over bathymetry.
3. Analyse deviations between normalised gravity and bathymetry.

Option 3 is still in early stages of development, but the first two options can be illustrated.

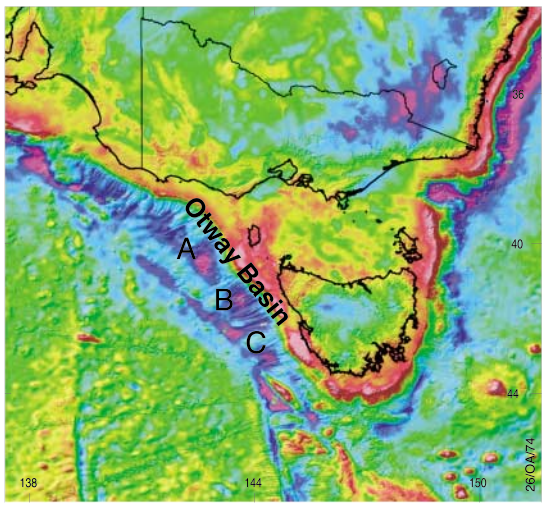


Figure 2. Composite image of the Bouguer gravity onshore and free-air gravity offshore draped over topography/bathymetry for south-eastern Australia

Consistent grid onshore–offshore

The offshore BA significantly reduces the effect of the water depth variation and emphasises the component of the gravity field controlled by the density variation below the seafloor.

Figures 1a and 1b show that the FA gravity and topography/bathymetry data behave differently in different areas. For example: FA gravity values in the east and west of the Tasman Sea Basin are similar (green colour, figure 1a); however, water depth in the east of this basin is greater (figure 1b). These differences, when combined in the process of the BA calculation, show that the eastern part of the Tasman Basin is heavier below the seafloor compared to its western part by some 20 milligals (figure 1c). This is probably due to thinner crust in the east.

Similar analysis in other areas will bring interesting results that are not obvious if the FA and bathymetry images are treated separately.

Table 1. Simplified classification of crustal types based on Bouguer anomaly values

Crustal type	*BA minimum*	*BA maximum*	*Colour in figure 1b*
Continental	-150 mGal	50 mGal	Purple to dark blue
Transitional*	50 mGal	250 mGal	Light blue to green
Oceanic	250 mGal	400 mGal	Yellow, red to white

** Transitional crustal type most likely corresponds to several different subtypes that will be defined as the work progresses.*

The continent–ocean boundary as presently defined (figures 1a–1c) may have to be revised in some areas. From the analysis of the BA image presented in figure 1c, its appropriate location should correspond to the 250-milligals level where the colour changes from green to yellow. In simple terms, different ranges of the BA gravity values broadly define different crustal types around Australia (table 1 & figures 1a–1c). This classification will improve as BCS work progresses.

One unexpected outcome of this classification is that there appears to be less oceanic crust to the east of Australia than previously thought. Only the Tasman and South Fiji basins, as well as several disconnected blocks to the north seem to have oceanic crust (yellow, red and white colours in figure 1c).

To improve the resolution of the BA image (figure 1c), it should be created on the basis of the FA onshore/offshore grid incorporating Geoscience Australia data, rather than just the satellite-derived data used to produce figures 1a–1c.

Composite images option

Another option for separating the effects of water from geology in the gravity data is the production and analysis of composite images of FA gravity draped over bathymetry, similar to the one presented in figure 2.

FA gravity lows in the Otway Basin (purple spots marked A, B and C) are likely to correspond to basement lows. These gravity lows do not correlate with bathymetry. The seafloor is gradually dipping to the south-east, while the FA lows (A, B and C) are isometric in shape. Gravity lows A and B are at the same bathymetric level, but are clearly isolated from each other. They are most likely geological in origin, rather than water-depth related.

Collaboration, practical outcomes

The BCS project team will capitalise on collaborative links with outside researchers to add geological knowledge to Geoscience Australia's extensive holdings of regional geophysical datasets. As well, the team will work with industry and university clients to:

- develop models of rock properties using bathymetry and potential field grids;
- develop approaches and models that provide a better understanding of links between onshore and offshore geology; and
- develop a consistent approach to link basement character and provinces, to basin evolution and regional inter-basin relationships.

All work will have a practical focus and the value-added information in the datasets will be promoted to clients as a 'knowledge base' and an example of the potential use of the data.

For more information about basement and crustal studies at Geoscience Australia phone Alexey Goncharov on +61 2 6249 9595 or e-mail alexey.goncharov@ga.gov.au

NEW INSTRUMENTS EXPAND GEOCHEMICAL CAPABILITIES

Geoscience Australia's geochemical laboratories have upgraded their stable isotope facility.

The geochemists have been determining carbon isotopes of individual compounds and bulk sedimentary materials for some time, but with the new or upgraded instruments they can study a greater range of isotopes.

The additional instruments include two elemental analysers, and a gas chromatograph pyrolysis interface linked to a mass spectrometer.

'With our elemental analysers we are able to do bulk carbon, sulphur, nitrogen and hydrogen', says Dr Graham Logan.

'We can look at the hydrogen part of kerogen and of water as well', he says.

The gas chromatographs have the ability to separate complex mixtures, and determine the carbon and the hydrogen isotopic composition of hydrocarbons in the mixtures.

Dr Logan says the new capabilities of Geoscience Australia's laboratories will interest the petroleum industry, and also those working in mineral and marine environment studies.

For more details phone Graham Logan on +61 2 6249 9460 or e-mail graham.logan@ga.gov.au

EVENTS calendar

Compiled by Steve Ross

Mapping Sciences Conference 2002
Mapping Sciences Institute, Australia
12 to 15 May
Carlton Crest Hotel, Melbourne
Contact: Organisers Australia, PO Box 2393, North Brighton Vic 3186
phone +61 3 9595 0259
fax +61 3 9596 2538
e-mail melbourne@orgaus.com.au
www.mappingsciences2002.conf.au

16th AGC–Geoscience 2002
Geological Society of Australia
30 June to 5 July
Convention & Exhibition Centre, Adelaide
Contact: Organising Committee, 16th AGC, PO Box 6129, Adelaide SA 5001
phone +61 8 8227 0252
fax +61 2 8 8227 0251
e-mail 16thagc@sapro.com.au
www.gsa.org.au

Australian Map Circle 30th Annual Conference
Australian Map Circle
14 to 17 July
James Cook University, Cairns
Contact: Dr Peter Griggs, School of Tropical Environment Studies & Geography, James Cook University, PO Box 6811, Cairns Q 4870
e-mail peter.griggs@jcu.edu.au

Australian Science Festival
Australian Science Festival Ltd
17 to 25 August
Canberra ACT
Contact: Australian Science Festival Ltd, PO Box 193, Civic Square ACT 2608
phone +61 2 6205 0588
fax +61 2 6205 0638
www.sciencefestival.com.au

Applied Structural Geology for Mineral Exploration & Mining Symposium
Australian Institute of Geoscientists
22 to 25 September
WMC Conference Centre, Kalgoorlie
Contact: Jocelyn Thompson, Australian Institute of Geoscientists, PO Box 606, West Perth WA 6872
phone +61 8 9226 3996
fax +61 8 9226 3997 e-mail aig@aig.asn.au

Strong tides halt *reef burial*

Papua New Guinea's Fly River, which is close to the northern end of the Great Barrier Reef, discharges about 120 million tonnes of sediment a year—more than all of Australia's rivers combined. Is this huge volume of sediment advancing southwards towards the Great Barrier Reef and if not, why not?

These questions were the subject of a 21-day scientific survey in the Gulf of Papua in January–February this year aboard Research Vessel *Franklin*. The research team, led by Geoscience Australia's Dr Peter Harris, used sophisticated swath mapping and underwater video equipment to track the influence of the Fly River by mapping the seabed and taking sediment samples.

The research team discovered that the huge outpouring of sediment does not penetrate as far south into the reef as expected because of strong tidal currents. The currents at the northern end of the Great Barrier Reef scour the seafloor and make room for sediments that would otherwise bury the coral reefs.

The team found many channels, some up to 220 metres deep, that extend more than 80 kilometres from eastern Torres Strait across the northern end of the Great Barrier Reef. The scientists believe there are two sorts of channels.

Those in the north are ancient riverbeds that are eroded by the Fly River during periods of low sea level. Deep channels in the south appear to be formed by tidal current scour.

The channels provide a conduit onto the shelf for cool, nutrient-rich, up-welled Coral Sea water. The deepest channels form isolated depressions. These possibly were the sites of lakes during the last ice age when Torres Strait formed a land bridge between Australia and Papua New Guinea.

Survey data are still being analysed by the research team and will be released in coming months. The team included scientists from Geoscience Australia, James Cook University, the University of Sydney, University of Tasmania and CSIRO.

For more information phone Peter Harris on +61 3 6226 2504 or e-mail P.Harris@utas.edu.au

Research team on board RV *Franklin*

Enormous collections for CLIENT USE

Within Geoscience Australia's Data Repository is one of the world's largest petroleum data collections, which is frequented by the petroleum industry and research organisations.

The repository holds more than 10 000 well and survey reports from gravity, magnetic and seismic surveys. It also has cores and cuttings, fluids and gases, thin sections and other prepared samples from petroleum exploration conducted in Australian territory since the 1930s. These are catalogued and archived on more than 30 kilometres of shelving.

The repository holds in its collection, more than 150 000 metres of down-hole core drilling and three million metres of cuttings from some 5500 wells. In addition, more than 1200 open-file destructive analysis reports are available.

The digital data in the collection are on media such as 3590, 3480, DLT, and eight– and four–millimetre cartridges, and on nine-track and 21-track tapes. Obsolete types of media (such as the 9-track and 21-track tapes and 3480 cartridges) are being remastered to high-density media such as 3590 cartridges.

In the second half of last year, the petroleum industry carried out $395 000 worth of remastering on the data it borrowed. Remastering reduces the physical volume of data and preserves the data in a more useable and robust form. There are approximately 570 000 magnetic tapes in the collection.

Most data in the repository have been lodged with Geoscience Australia as a requirement of the *Petroleum Search Subsidy Act 1957* or the *Petroleum (Submerged Lands) Act 1967*.

Client access

Geoscience Australia continues to improve data availability and access to the collection. Map-enabled query forms allow clients to search a petroleum meta-database on the web, through either word searches or by using the mouse to zoom in on geographic regions of interest.

Data can be ordered via the web by selecting the relevant data returned from a query and submitting an order form. Most requests for data are now conducted on-line. Facilities are provided at the Data Repository for:

- inspection and non-destructive testing;
- gravimetric and chemical tests;
- core slabbing and plugging; and
- photography and sampling.

Destructive testing is available under certain conditions.

Other collections

The Data Repository also has a number of other collections that clients access.

The rock collection comprises approximately 500 000 individual samples gathered over the past 50 years by Geoscience Australia staff during project work. Some derivative material from these rock samples such as powders for chemical analysis, mineral separates, and thin section off-cuts are available to clients.

The palaeontological collection comprises samples collected by Geoscience Australia staff, samples acquired by exchange or donations, and a special reference collection called the Commonwealth Palaeontological Collection.

The minerals collection has samples from around the world, many of which have been donated by collectors and institutions. Some samples are held on behalf of the National Museum of Australia. A selection of mineral specimens is on display in the foyer of Geoscience Australia's headquarters.

For more information about the Data Repository phone Edward De Zilva on +61 2 6249 9222 or e-mail ausgeodata@ga.gov.au

Location, correct spelling in latest gazetteer

Where is Percy Treyvaud Memorial Park? If the park is in Australia, it is very easy to find thanks to the latest *Gazetteer of Australia* that was released in February and posted on Geoscience Australia's web site.

Each year an updated database of more than 270 000 authorised geographical place names is made available online. The latest gazetteer (*Gazetteer of Australia 2001*) can be accessed free of charge on Geoscience Australia's web site as the 'Place Name Search'. It is also available on CD.

More than 7000 additions and tens of thousands of alterations have been included in this version, making it the ultimate resource for any application that requires the accurate location of Australian geographical names.

The *Gazetteer of Australia* was compiled with data provided by state, territory and commonwealth authorities. It is authorised by the Inter-governmental Committee on Surveying and Mapping (ICSM).

By the way, Percy Treyvaud Memorial Park is in Melbourne—but you probably knew that anyway.

If you want to check the spelling of a town's name or a geographical feature, visit www.auslig.gov.au/products/digidat/mapdata.htm#gaz

GOOD YEAR *for gas discovery*

Australia's petroleum activity last year was characterised by continuing significant gas discoveries and the absence of large oil discoveries. A total of 35 petroleum discoveries were made: 14 offshore and 21 onshore.

Of the 14 offshore discoveries, the most significant were at Audacious (oil) in the Bonaparte Basin (Timor Sea), Thylacine and Geographe (gas) in the Otway Basin of Tasmania and Victoria, and at Blacktip (gas) in the southern part of the Bonaparte Basin.

Twenty of the onshore discoveries were gas. The Cooper–Eromanga Basin accounted for 10 of these discoveries. The only onshore oil discovery was at Hovea in a producing area of the Perth Basin.

Crude oil and condensate production decreased last year by 9.7 per cent, with declining oil production in the Bonaparte and Gippsland basins.

Exploration was positive, however, with 127 wells drilled. Offshore exploration drilling accounted for 60 wells, which is one less than in 2000 but the fourth highest level recorded. Onshore exploration drilling (67 wells) is much higher than in 2000 (38 wells).

There was slightly less development drilling (88 wells) in 2001 compared to 2000 (104 wells), but it was still at a high level.

The number of active rigs in 2001 varied from six to seven offshore and, in the December quarter, 10 to 14 onshore. On current drilling activity levels and known programs, a probable 50 and a possible 70 exploration wells will be drilled offshore in 2002. Onshore exploration forecasts a probable level of 76 and a possible level of 100 wells for 2002.

The latest details of Australia's oil and gas discoveries are available in a report produced by Geoscience Australia titled *Australian Petroleum Exploration Development Activity, 1 October to 31 December 2001*. The report is available free of charge from the Geoscience Australia Sales Centre. It can be accessed via the web at www.ga.gov.au/general/technotes then select 'Petroleum Industry Quarterly Statistics'.

For more information phone Eugene Petrie on +61 2 6249 9270 or e-mail eugene.petrie@ga.gov.au

Passing SNAP captures fireworks *explosion*

An hour after the explosion, the Landsat 7 satellite captures the smoke still billowing from a fireworks factory near Perth on the morning of March 6 (the blue streak in the image). The fireworks factory is about 28 kilometres inland, in the hills east of Perth, Western Australia.

The USA-owned Landsat 7 Earth observing satellite passes over Australia at an altitude of 705 kilometres on average twice a day. Each pass acquires data over an area of 185 square kilometres. The satellite repeats its cycle every 16 days.

The image was published on the Geoscience Australia website. Geoscience Australia (ACRES) has archived 23 years of Landsat satellite imagery of the Australian continent.

For more details see www.auslig.gov.au/acres/prod_ser/

TIMOR SEA Symposium

18–19 June 2003
Carlton Hotel Darwin, Australia

First symposium on the petroleum geology of the Bonaparte Basin and surrounds

The Timor Sea Symposium is a forum for industry, government and academia to present and discuss such topics as:

- Jurassic–Early Cretaceous stratigraphy and reservoir distribution;
- Petroleum systems and geochemistry;
- New technologies, including remote sensing;
- Subsidence and thermal history modelling;
- Field development and appraisal case studies; and
- Structure and tectonics.

The program includes various keynote addresses and a symposium dinner. Abstracts of symposium papers will be available on CD. There will also be a trade display.

The symposium immediately follows the South-East Asia Australia Offshore Conference in Darwin, and June is the height of the dry season in Australia's top end—the best time to explore this beautiful part of the world.

For more details phone Greg Ambrose on +61 8 8999 5342 or e-mail greg.ambrose@nt.gov.au, or go to www.dbird.nt.gov.au/ntgs and click on the symposium logo.

Important dates

Call for papers—
April 2002

Abstract deadline—
31 November 2002

Registration circular—
15 February 2003

Final papers—15 March 2003

www.dbird.nt.gov.au/ntgs/timorseasymposium/home.html

BASS BASIN

petroleum well audit on CD

A comprehensive analysis of petroleum exploration in the Bass Basin will be released on CD-ROM at the end of April in time for the 2002 Petroleum Acreage Release areas in the western Bass Basin. This is the first of a series of proposed products for the region to be prepared by Geoscience Australia for the Tasmanian Offshore Collaborative Project.

The Bass Basin lies between the hydrocarbon-bearing provinces of the Gippsland and Otway basins, but it has undergone little petroleum exploration in recent years.

The CD-ROM titled *An audit of petroleum exploration wells in the Bass Basin: 1966–1999* provides reasons for the success and failure of previous exploration drilling in the basin. It highlights the risks and uncertainties of exploration drilling and offers insights into prospectivity for future exploration.

Seventeen of the 32 wells in the Bass Basin had significant hydrocarbon shows. The main reasons for failure of wells include seal failure, access to mature source, and/or structural validity.

The CD-ROM provides information on structure, petroleum systems elements, maturity, hydrocarbon shows, and an assessment of the validity of each of the 32 wells in the Bass Basin. It also contains images of seismic ties and composite logs for each well.

The Yolla gas-condensate field, the Pelican gas field and the White Ibis-1 gas discovery are discussed, as are the significant oil shows at Cormorant-1 and King-1.

There is information on the geochemistry and source-rock potential of sediments in the Bass Basin, as well as a summary on the biostratigraphic and sequence stratigraphic framework. A regional framework and analyses of the major structural and sedimentary elements add to what is a very comprehensive analysis of petroleum exploration in the Bass Basin.

An Audit of Petroleum Exploration Wells in the Bass Basin: 1966–1999 by Trigg, Blevin and Boreham is available from the Geoscience Australia Sales Centre.

The Tasmanian Offshore Collaborative Project is part of the Western Tasmanian Regional Minerals Program, and is a Commonwealth–Tasmanian Government initiative.

For more information about the product phone Kathe Trigg on +61 2 6249 9210 or e-mail kathe.trigg@ga.gov.au

FREE!

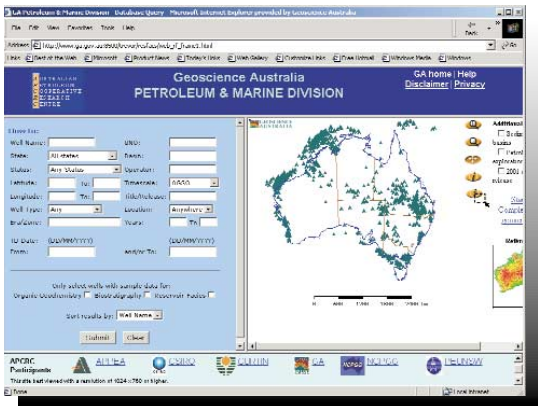
IMAGERY, SPATIAL DATA FOR ENVIRONMENTAL WORK

Satellite imagery used to monitor environmental changes and spatial data sets suitable for national-scale environmental modelling and customised mapping can now be downloaded free from the Geoscience Australia web site. The products involved are listed in the table.

Australian maritime boundaries information system 2001	Dams and water storages
GEODATA COAST–100K coastline and state borders	MAPDATA map sheet indexes (250K and 100K)
GEODATA TOPO–10M topographic data	Global map data Australia–1M 2001
Critical aeronautical heights	MODIS and NOAA satellite data
Australian surface water management areas	MAPDATA–2.5M topographic data

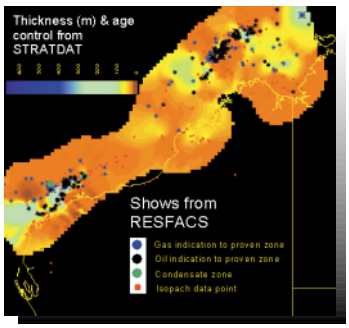
For more information about these products, visit www.auslig.gov.au/new/#28022002

Decade to build, free this month: *GA petroleum databases*



Integral to this year's petroleum acreage release in late April is a series of national-scale, Oracle-related databases that Geoscience Australia has been developing over the past decade. The petroleum exploration databases can be accessed via the internet from April 22, and data can be downloaded free of charge under the Commonwealth Government's new pricing policy for spatial data.

The databases include PEDIN (well header data), STRATDAT (biostratigraphy, well picks, events), RESFACS (reservoir, facies and hydrocarbon shows), ORGCHEM (organic geochemistry) and DEVIANT (down-hole survey data). They represent more than 50 person years of effort, and are powerful tools for petroleum exploration companies and researchers.



Geoscience Australia has developed and incorporated special applications for the databases. These allow users to produce maps and plots of hydrocarbon indices, and generate an age-depth curve for every well. The databases and their applications allow rapid generation of information on a time-series basis (timeslices, palynological zones, sequences and millions of years). Well variables from either a permit or an entire petroleum system can be compared for specific time intervals.

The map-enabled internet interfaces to the databases (with download capability), as well as time-series movies of organic geochemistry and reservoir parameters, were available at APPEA in late April when the new acreages were released. The products offer potential bidders easy access to high-quality, highly relevant data.

In addition to supporting the acreage release promotion program, the databases are an essential tool for Geoscience Australia's regional projects and have proven effective in refining a global geological timescale (AGSO 95 Phanerozoic Timescale).

The following web addresses have links to the online databases:

- www.ga.gov.au/oceans/projects/
- www.ga.gov.au/oracle

For further information phone David Rowland on +61 2 6249 9253 or e-mail david.rowland@ga.gov.au

Update on Australia's topographical maps

Sixty per cent of maps in the NATMAP 1:250 000 scale (250K) topographic map series have been revised over the past four years. In January this year, 20 more maps were published, bringing the total number of revised maps to 306. The table shows the number completed for each state (correct as at March 13).

The 250K NATMAPs provide the only national topographic coverage of Australia. They depict natural and constructed features of the Earth's surface including landforms (represented by contours and spot heights), streams, lakes, dams, swamps, roads and tracks, localities, built-up areas, vegetation, conservation, defence and forestry reserves and Aboriginal lands.

A list of new maps (completed under the revision program) that are for sale to the public can be found at www.auslig.gov.au/mapping/newmaps. Each NATMAP costs $7.70. The recommended price for GEODATA TOPO-250K tiles is $108 each.

For more information phone Customer Support on +61 2 6201 4300 or e-mail mapsales@ga.gov.au

State	*Completed map sheets*	*Total number of sheets*	*Percentage of sheets completed*
NSW	41	50	82
Vic	12	17	71
Qld	82	122	67
SA	41	68	60
NT	49	84	58
WA	81	168	48
Tas	0	4	0
Total	**306**	**513**	**60**

MAJOR UPGRADE OF POTENTIAL FIELD AND BATHYMETRY GRIDS

Geoscience Australia has produced a set of digital bathymetry, gravity and magnetic grids for Australia's continental margin, in cooperation with Intrepid Geophysics and the Australian Hydrographic Service (AHS). These grids (see figures) are a major upgrade of marine ship-track potential field and bathymetry data in Australian waters.

Pre-existing compilations over the North West Shelf and the Southern Margins have been superseded by the addition of:

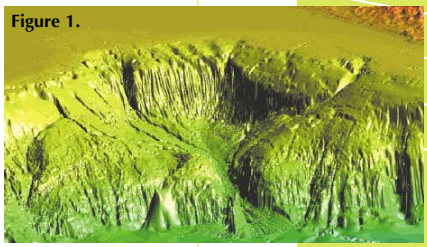
- bathymetric data on the shelf digitised from AHS charts;
- bathymetric data from swath surveys in deep water by Geoscience Australia, the National Oceans Office, Scripps Institute of Oceanography and Woods Hole Oceanographic Institute; and
- shiptrack bathymetry from numerous exploration surveys obtained under the Petroleum Submerged Lands Act.

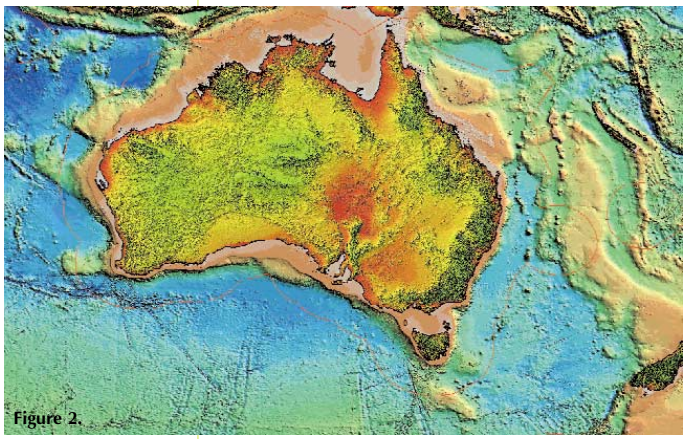
Integrating marine data from many sources is problematic. Levelling techniques therefore have been developed to correct crossover and other errors in the ship-track data, so that they can be merged with satellite and high-resolution onshore sources. The methods used to generate the grids have involved a number of compromises to accommodate the extreme variability of data density over the region and variations in data quality.

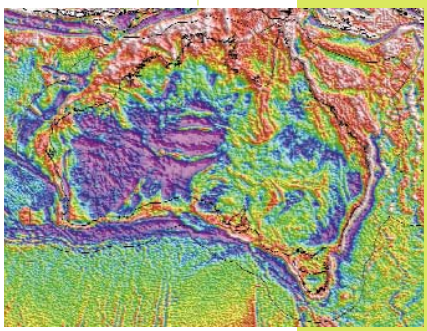
The bathymetry grid attempts to satisfy a wide client base. It is sourced from an underlying extendable database of more than 200 million points built according to particular rules and combinations of data. Other grids (say at higher resolutions) can be generated from this same database. The bathymetry data coverage is sufficient in some areas to justify gridding at cell sizes as small as 250 metres (see figure 1). Geoscience Australia is currently working on ways to routinely deliver such grids.

The grids will be used in Geoscience Australia's regional scale interpretation projects for modelling crustal structure, for defining province boundaries, and for developing a better understanding of seafloor environmental processes. The data are relevant to industry for petroleum exploration and engineering activities, to environmental research and to general geological research.

To obtain these products on CD-ROM phone the Geoscience Australia Sales Centre on +61 2 6249 9519 or e-mail sales@ga.gov.au. To access the data via the web refer to www.ga.gov.au.







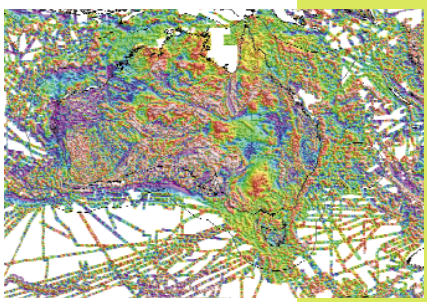


Figure 1. A 3-D view of bathymetry over Bass Canyon from a grid at 250-metre cell size. Swath data are from surveys by the National Oceans Office, Geoscience Australia and Scripps Institute of Oceanography.

Figure 2. The bathymetry and topography grid covers 8°–52°S, 102°–172°E at a cell size of 0.01°. The grid models 200 million data points from many sources.

Figure 3. The gravity anomaly grid at a cell size of 0.083°, covers 8°–48°S, 106°–162°E. The onshore component of this grid is Bouguer anomaly while the offshore is free-air anomaly. 'Geosat' satellite gravity anomaly is used as infill in deep water, and onshore Bouguer anomaly from Geoscience Australia's National Gravity Database.

Figure 4. Magnetic anomaly of the Australian region covering 8°–52°S, 106°–172°E. The new grid, at a cell size of 0.01°, combines levelled ship-track data with the continental magnetic anomaly derived from airborne surveys.

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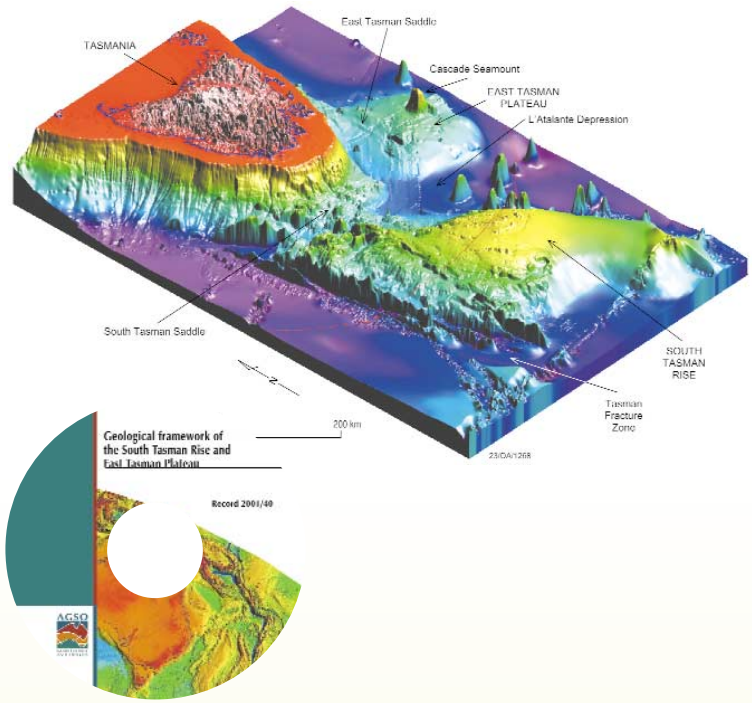
In-depth view of remote TASMAN REGION on record



For insights into the geology of the South Tasman Rise and East Tasman Plateau, a remote region off southern Tasmania, grab a copy of Geoscience Australia's record 2001/40 that was released in March.

Since 1994, the region has been the focus of a number of major geoscientific investigations including seismic surveys, seabed swath-mapping, geological sampling and deep-sea drilling.

The South Tasman Rise and East Tasman Plateau are large, submerged continental blocks that abut southern Tasmania. They cover an area of approximately 230 000 square kilometres and are separated from Tasmania by 3000 metre deep saddles underlain by transitional crust. Elsewhere they are surrounded by oceanic crust of Campanian to Palaeogene age.

The region evolved in the Late Cretaceous as this part of eastern Gondwana began to fragment, creating a number of microplates. Structural development has been dominated by wrenching associated with the Tasmanian–Antarctic Shear Zone, Tasman Basin rifting and break-up, break-up at the southern margin of the South Tasman Rise, and movement along the north–south Tasman Fracture Zone.

Sedimentary basins on and adjacent to the South Tasman Rise and East Tasman Plateau contain at least four kilometres of section consisting of Late Cretaceous to Eocene siliciclastics, overlain by Oligocene and younger pelagic carbonates. The siliciclastics, where drilled, comprise deltaic and shallow marine silty claystones, often rich in organic carbon.

Volcanic activity has been widespread and appears to be related to two main phases, Campanian (initial break-up) and Eocene (mantle plume/lithospheric tensile stress).

The region is a deep-water frontier, prospective for petroleum in the medium to long term. Very little industry exploration has occurred, but this could change as existing oil and gas fields become depleted, and as technological advances permit drilling and production in deeper water.

On the South Tasman Rise, narrow wrench basins with several kilometres of fill lie in water depths as shallow as 1400 metres. There was moderately high terrestrial heat flow in the region, and gradients suggest oil maturation at less than two kilometres depth. Palaeogene claystones provide a regional seal.

Bottom simulating seismic reflector (BSR)-like horizons have been identified over parts of the South Tasman Rise and adjacent areas. But further work is needed to establish the presence of gas hydrates. If proven, gas hydrate accumulations in the upper few hundred metres of the sedimentary section may have long-term resource potential.

Extensive fields of manganese nodules have been identified in deep water (>2400 metres depth) on the South Tasman Rise and adjacent abyssal plains. The nodules are commonly large (5–10 cm diameter), but their metal grades are sub-economic. Thick ferromanganese crusts are abundant on rocky substrates. Those recovered from within the oxygen-minimum zone (<2000 metres depth) are high in cobalt.

Record 2001/40 titled *Geological framework of the South Tasman Rise and East Tasman Plateau* by Hill and Moore is a very visual product with 34 text pages, 12 figures and 14 plates. All text and images are also on a CD that sits in a sleeve on the inside back cover.

Record 2001/40 can be purchased from the Geoscience Australia Sales Centre for $44 (includes GST) plus postage and handling. To obtain a copy please complete the enclosed order form and return it to the Sales Centre.

For further information phone Peter Hill on +61 2 6249 9292 or e-mail peter.hill@ga.gov.au

PETREL GEOHISTORY CD *coincides with offshore* ACREAGE RELEASE

In May, Geoscience Australia releases a new interactive CD-ROM on the geohistory of the Petrel Sub-basin, titled 'Petrel on WebBury'.

'Petrel on WebBury' presents interactive geohistory models of the regional burial, thermal and hydrocarbon maturation and expulsion history of the Petrel Sub-basin, Bonaparte Basin, north-west Australia. The models are based on a comprehensive geohistory analysis undertaken by Geoscience Australia and BuryTech.

The package is very timely with the recent discovery of gas at Blacktip-1 in the Petrel Sub-basin and the April 2002 acreage release of four offshore exploration areas east of Blacktip-1.

About the package

The geohistory models are generated by the WinBury 1D burial and thermal geohistory modelling software. The thermal history models are constrained by conventional vitrinite reflectance, thermal alteration index, spore colour index, conodont colour alteration index, and limited fluorescence data, together with limited apatite fission track analysis.

The burial and thermal models are applied to potential Carboniferous–Cretaceous source units within each well to constrain the timing and relative volumes of expelled liquid/gaseous hydrocarbons. New kerogen kinetic data for these source facies are used in the expulsion models.

The modelling package is divided into five sections:

- wells—geohistory models for 24 wells and 11 depocentre sites;
- x-sections—cross-section geohistory models;
- multi-well—multiple-well geohistory curves and basin-wide maps for three-source units;
- seismic—interpreted seismic lines showing structural setting of the wells; and
- petroleum system—a schematic summary of the active petroleum systems.

Users can select multiple views within each section (e.g. temperature, heatflow, subsidence, maturity and expulsion time-plots/contoured maps) by point and click buttons and drop-down windows. They can make temporary modifications or add new data to the well models, and view corresponding maturity, generation and expulsion models based on these changes. Revised models can be printed directly from the screen views, but will not be saved on exit from the well.

Current users of WinBury modelling software can copy well data files from the package directly to their WinBury working directories.

The package requires 30 MB of hard disc space, and Windows 95/98 or NT operating systems. It uses a standard web browser (Internet Explorer or Netscape Navigator).

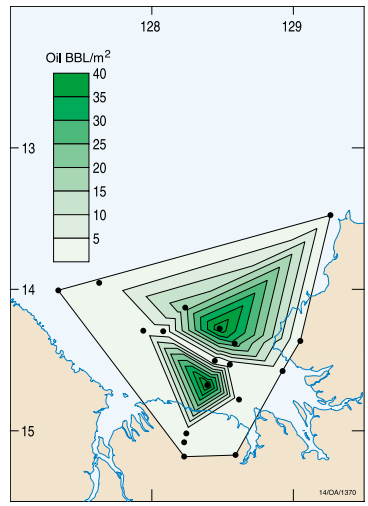
Hydrocarbon expulsion models

Expulsion models have been generated for three basin-wide source rock units: Lower Carboniferous Milligans Formation, Lower Permian Keyling Formation and Upper Permian Hyland Bay Formation.

Milligans source unit

Modelled oil and gas expulsion from postulated oil-prone source units within the Lower Carboniferous Milligans Formation is restricted to two offshore depocentres immediately north and south of the Turtle–Barnett High (Petrel Deep and Cambridge Trough, respectively; figure 1).

Oil expulsion from the northern depocentre commenced in the Late Carboniferous (ca 315–300 Ma), and reached its peak in the Early Permian (300–290 Ma). Minor expulsion continued throughout the Permian and Early to Mid-Triassic, prior to the onset of regional uplift associated with the Late Triassic Fitzroy Movement.

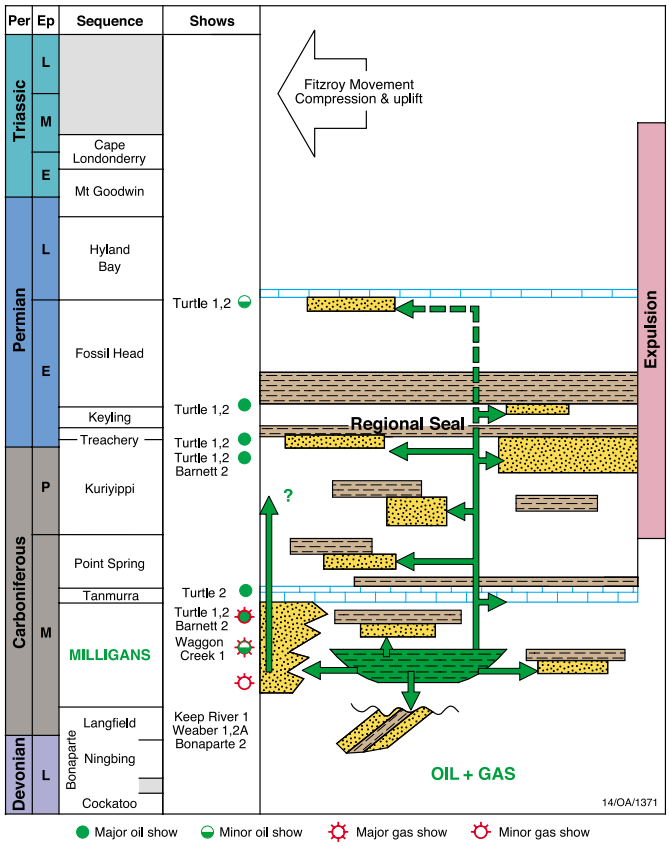


▲ **Figure 1.** Modelled oil expulsion from postulated oil-prone source units within the Lower Carboniferous Milligans Formation

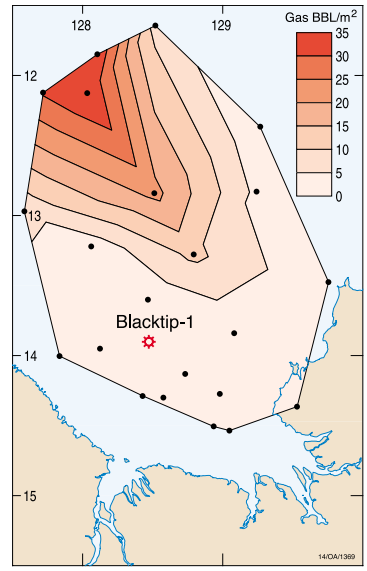
Oil expulsion from the Cambridge Trough to the south commenced in the latest Carboniferous (300 Ma). It rapidly increased to peak expulsion in the Early Permian, and then continued at reduced levels until the onset of the Fitzroy Movement.

Separate phases of oil migration are thought to have caused the biodegraded and non-biodegraded oils within several Carboniferous–Early Permian formations in the Turtle-1 and Turtle-2, and Barnett-1 and Barnett-2 wells (figure 2).[1] These phases were prior and subsequent to the emplacement of the regional Treachery Shale seal in the earliest Permian (Asselian, ca 295 Ma). The initial phase of oil migration (now biodegraded) probably was sourced from the north. The subsequent oil phase(s) (non-biodegraded) could have been sourced from either the northern or southern depocentre.

Limited gas expulsion from the Milligans Formation extends onshore to the Carlton Sub-basin. The unit is sufficiently mature in this area to have generated oil, but the models suggest that generated volumes are insufficient for expulsion of oil. Gas discoveries in the Keep River-1, Weaber-1, 2A and Bonaparte-2 wells are attributed to this system, as well as gas and minor oil recovered from Early Carboniferous sandstones in Waggon Creek-1.



▲ **Figure 2.** Early Carboniferous Milligans petroleum system



▲ **Figure 3.** Modelled gas expulsion from shales and coaly shales of the Early Permian Keyling Formation

Keyling source unit

Modelled gas expulsion (figure 3) from shales and coaly shales of the Early Permian Keyling Formation is restricted to the central and outer portions of the Petrel Deep (to the north and north-west of Penguin-1 and Bougainville-1). Modelled expulsion from the outer Petrel Deep occurred in the Late Permian–Early Triassic. Expulsion from the central Petrel Deep (e.g., below total depth of the Petrel wells) commenced and peaked in the Early Triassic (250–240 Ma). Subsequent phases of minor expulsion occurred in the Late Triassic–Early Jurassic, Late Jurassic and mid-Cretaceous. To date, no oil accumulations have been discovered that are likely to have been sourced from the Keyling or underlying Treachery Shale and Kuriyippi Formation.

Structural traps at the Petrel, Tern and Penguin gas accumulations predominantly formed in the Late Triassic (ca 230 Ma). This is indicated by erosion of the Early Triassic Cape Londonderry Formation and marked onlap and thinning of the Late Triassic–Early Jurassic Malita Formation across these structures. These structures post-date the main phase of modelled oil expulsion from any oil-prone source units within the Keyling Formation, Treachery Shale and Kuriyippi Formation. They are unlikely to have received the main phase of oil charge from these sources.

Hyland Bay source unit

Modelled gas expulsion from the Upper Permian Hyland Bay Formation is limited to the outboard portion of the Petrel Sub-basin adjacent to the Malita Graben. It occurred in the Jurassic–Cretaceous, with peak expulsion in the mid- to Late Cretaceous. This unit is considered too lean to expel significant quantities of oil. The Petrel, Tern, Penguin and Fishburn gas accumulations are most probably sourced from the Hyland Bay or Keyling formations.

Oil migration

Oil expelled from the oil-prone source units within the Keyling Formation, Treachery Shale and Kuriyippi Formation may have migrated to older structures and stratigraphic traps on the flanks of the Petrel Deep. To date the only possible indications of such an oil charge are interpreted, low-confidence, synthetic aperture radar (SAR) oil slick anomalies east and south-east of the Petrel Field (perhaps re-migrated oil).

The major risk of this modelled oil charge is the net effective thickness and basinward distribution of thin, oil-prone shales and coaly shales (immature–marginally mature) in the Flat Top-1 and Kinmore-1 wells on the Eastern Ramp of the sub-basin. If these facies extended basinward as far west as the Petrel Field, then some evidence of oil migration and charge during the subsequent phases of minor expulsion in the Late Triassic to Early Jurassic, Late Jurassic and mid-Cretaceous would be expected at the Petrel, Tern and Penguin fields. However, none is known.

Exploration, recent discoveries

There has been no commercial hydrocarbon production from the Petrel Sub-basin, despite the discovery of numerous oil or gas accumulations onshore and offshore. The discovery of gas at Blacktip-1 (figure 3) last July, however, is likely to change the exploration–development history of the sub-basin. It is currently being evaluated for development opportunities via a pipeline to nearby onshore areas. The development proposal and the April 2002 release of four offshore exploration areas east of the Blacktip-1 permit are expected to stimulate exploration interest in the sub-basin.

Integration of the Petrel Sub-basin hydrocarbon expulsion models with the known distribution of hydrocarbon accumulations, shows and SAR anomalies suggest that the recent Blacktip-1 gas accumulation was probably sourced from Late Carboniferous to Early Permian units (Kuryippi, Treachery, Keyling formations). These source units are prospective for gas throughout a large portion of the sub-basin. The occurrence of interpreted SAR oil slicks east and south-east of the Petrel Field may indicate oil migration pathways from local oil-prone coaly facies within these units. These SAR anomalies occur within or adjacent to the new 2002 offshore release areas.

The recent Sandbar-1 well (September 2001) drilled in the western portion of the Cambridge Trough failed to intersect significant hydrocarbons. Details of this well have yet to be released, so the implications for source-rock distribution and quality cannot yet be assessed.

Reference

1. Jefferies PJ. 1988. Geochemistry of the Turtle oil accumulation, offshore southern Bonaparte Basin. In: Purcell PG & RR, eds. The North West Shelf, Australia. Proceedings of Petroleum Exploration Society Australia Symposium, Perth; 563–570.

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GOVERNMENT RELEASES *new acreage* FOR PETROLEUM EXPLORATION

In April, the Commonwealth Government formally announced the 2002 Offshore Acreage Release, which comprises 41 areas in 13 different regions (figures 1–3). Closing dates for the release areas are in October 2002 and April 2003, depending on the size and exploration maturity of the areas. Many of the release areas have proven plays in Mesozoic and/or Palaeozoic petroleum systems.

On offer is acreage adjacent to the recent Blacktip gas discovery in the Petrel Sub-basin (figure 2) and to the Thylacine and Geographe gas discoveries in the Otway Basin (figure 3).

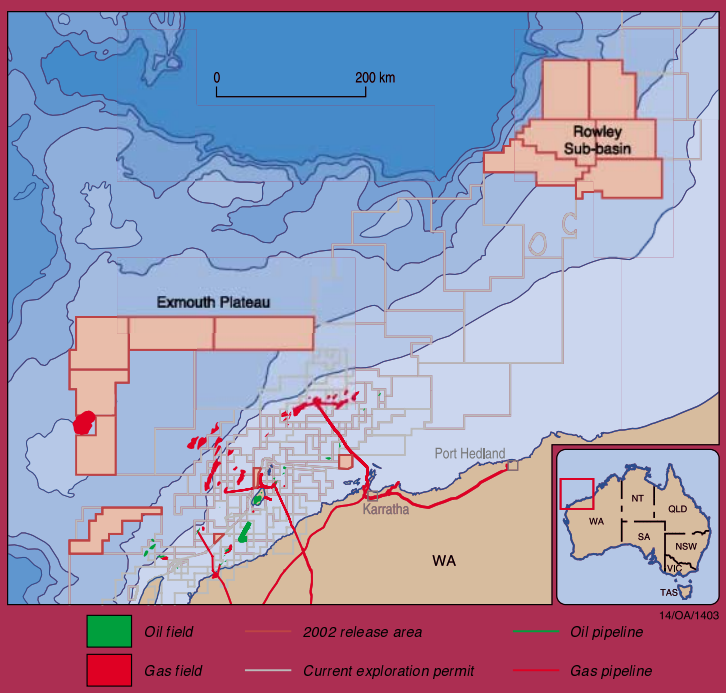
More information about this year's offshore acreage release areas is available via www.industry.gov.au/petexp.

Good signs offshore

The year started on a high note for Australia's offshore oil exploration when Roc Oil announced the Cliff Head discovery over Christmas–New Year. Cliff Head 1 and 2 were drilled in the shallow waters of the offshore Perth Basin, a few kilometres from the fishing port of Dongara (figure 4). Reports indicate that Cliff Head may be a substantial oil discovery.

Oil and gas have been produced from the onshore Perth Basin since the 1970s, but there were no commercial hydrocarbon discoveries offshore. This discovery has changed perceptions of the offshore Perth Basin. It indicates the potential for oil accumulations in good-quality reservoirs. This should have a positive impact on the assessment of the adjacent acreage areas (W01-16 to 26) gazetted in 2001, which closed for bidding on April 11.

The Cliff Head discovery is also significant because it was made by a team of junior Australian companies—a segment of the industry that has increased in importance with the consolidation of the 'super major' oil companies in recent years (Exxon–Mobil, BP–Amoco, TotalFinaElf and Chevron–Texaco).



▲ **Figure 1.** 2002 offshore release areas in western Australia

Exploration companies involved

Second-tier companies, including a number of United States independents, already operate successfully in Australia. Apache, the most notable of these, has been involved in dozens of discoveries since 1994. New entrants that have had discoveries in recent years include:

- major US independents (Kerr McGee)
- Japanese companies (Cosmo, Nippon)
- Canadian companies (PanCanadian and AEC, recently merged as EnCana; and Nexen)
- European companies (OMV, AGIP), and
- small Australian explorers (Tap, Strike and Roc).

After Australian companies, Japanese explorers represent the largest number of new entrants since 1995. Japanese companies have long been part of the exploration industry in Australia, but are increasingly taking on the role of operator.

They have met with startling success in the Browse and Bonaparte Basins, with major gas/condensate discoveries by Inpex (Dinichthys, Titanichthys and Gorgonichthys) and Nippon (Crux). Idemitsu also participated with the operator Santos in the Corowa oil discovery in the Carnarvon Basin, and Cosmo with OMV in the Audacious oil discovery in the Timor Sea. Mitsui via Wandoo Petroleum is a partner in the offshore Perth discovery at Cliff Head.

New entrant opportunity

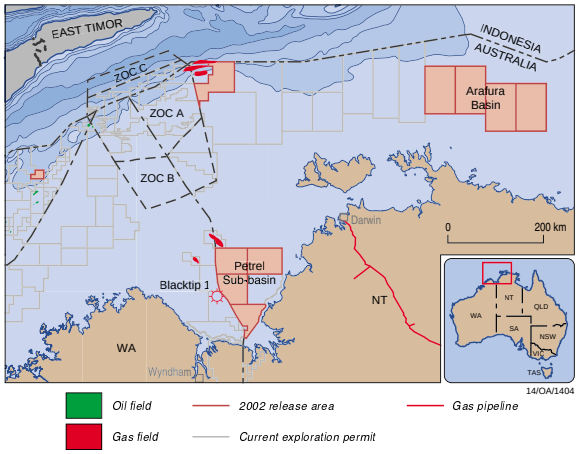
The regular, coordinated release of offshore acreage by the Commonwealth, State and Territory governments provides an opportunity for new entrants in Australia. In the past year there has been significant uptake of acreage in basins outside the main producing regions including areas well beyond the North West Shelf and into deep water. New comers have been well represented in the potential new petroleum provinces.

Kerr-McGee and Antrim were recently awarded exploration permits in the Browse Basin. New licences were awarded in the Great Australian Bight, where a consortium of Woodside, Anadarko and PanCandian has permits covering Late Cretaceous delta systems. Acreage has also been taken up in the Gulf of Carpentaria.

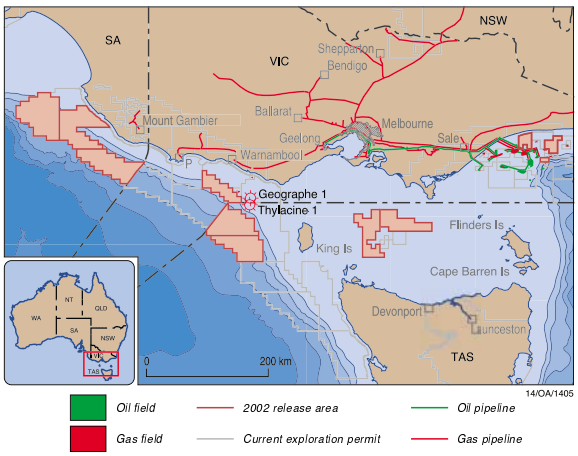
Australia's competitive regulatory and fiscal regimes (including security of title), its highly educated workforce and political stability, provide a very low-risk corporate environment for international exploration companies.

OPPORTUNITIES IN THIS YEAR'S RELEASES

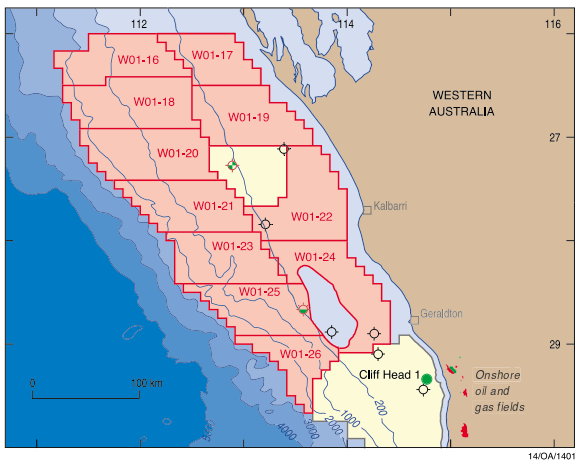
- Large deepwater blocks in frontier areas: Exmouth Plateau and Rowley Sub-basin on the North West Shelf (figure 1, on page 31) and Ceduna Sub-basin on the Southern Margin
- Large shallow water blocks over the Palaeozoic Arafura Basin in northern Australia (figure 2)
- Moderate-sized blocks under various water depths, in immature to sub-mature basins which have known petroleum systems operating (Bonaparte, Otway and Bass basins, figure 3)
- Smaller blocks in shallow waters in producing basins (Bonaparte, Carnarvon and Gippsland basins)



▲ **Figure 2.** 2002 offshore release areas in northern Australia



▲ **Figure 3.** 2002 offshore release areas in south-eastern Australia



▲ **Figure 4.** Offshore Perth Basin showing 2001 acreage and Cliff Head oil discovery

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