Risk factor weighting

To alleviate the problem of not being able to assign an accurate storage efficiency number for each site, the initial storage potential (total pore volume) estimate needed to be discounted. This was done by multiplying the five risk factors for each site: storage capacity, injectivity potential, site details, containment, and existing natural resources. The resultant risk or ESSCI chance was rated between zero (fail) and one (complete success). The ESSCI chance allowed sites to be compared and the most viable ones to be identified, based on geotechnical, environmental and economic risk factors.

Each trap type has unique characteristics and therefore influences the risk assigned to an ESSCI (see figure 2). For example, those with hydrodynamic traps were rated low, mostly due to the perceived higher risk for containment. If CO_2 can migrate to the edge of the basin, it has a higher chance of escaping.

However, subsequent reservoir modelling* for the Petrel Basin ESSCI site has shown that over a period of 10 000 to 100 000 years, there would be complete dissolution of the CO_2 in this hydrodynamic trap. The CO_2 would move only tens of kilometres from the injection site and in that time would not migrate anywhere near the edge of the basin some 120 kilometres away.

In contrast, the depleted fields have more certainty associated with them because they have stored hydrocarbons for thousands to millions of years. The ESSCI chance for dry structures (non-petroleum bearing) is wide-ranging, which reflects the variety of geological settings that were examined.

Storage capacity

Multiplying the initial storage potential by the ESSCI chance gives a risked storage capacity (figure 3). The hydrodynamic ESSCIs represent about 43 per cent of sites studied, but more than 94 per cent of the risked storage capacity because their available pore space is enormous.

Overall the total risked capacity for the 65 ESSCIs is 740 000 Mt of CO_2, which is equivalent to Australia's total net CO_2 1998 emissions for 1600 years.

Storage costs

Storage capacity estimates allow sites to be ranked, but they do not indicate whether a site will potentially be commercially viable. Each ESSCI analysis needs to consider emission rates and project-specific economics, such as the costs of compression, transport (pipelines) and injection.

Capital costs for the ESSCIs analysed range from $US13 million to $US1300 million. This includes a suite of sites ranging from small CO_2 sources adjacent to depleted gas field facilities, to large CO_2 sources further than 1000 kilometres from an injection site.

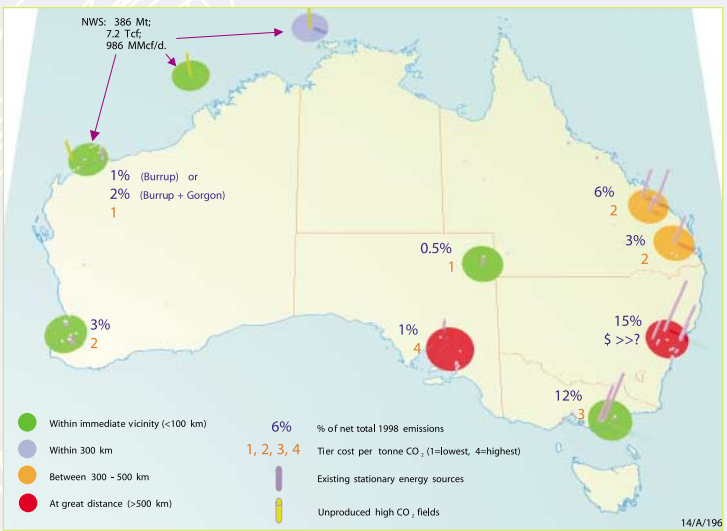

Figure 4. Major emission nodes as well as the relative percentage of total emissions that could be sequestered at Australia's net total 1998 CO_2 emission levels, the distance to the nearest viable ESSCI, and an estimate of the cost (least expensive:1 to most expensive: 4).

Source–sink matching

To estimate whether a site has the storage capacity to match the anticipated supply rate of CO_2 from neighbouring sources, the ratio of risked storage capacity to volume of CO_2 source for a 20-year period was calculated. This storage to volume ratio shows the clear dichotomy between eastern Australia (where there are larger CO_2 sources and lower storage capacity) and western Australia (where there are smaller CO_2 sources and larger storage potential).

The dichotomy is shown in figure 4. The figure attempts to merge the technical details for each site, the emission sources and the economics. It identifies all major emission sites and puts them into nodes based on distance from a technically viable ESSCI. The percentage of total emissions that each node represents in terms of Australia's total net 1998 CO_2 emissions is also shown. A ranking system for the costs ranges from one, the least expensive option, to four, the most expensive option.

Storage potential

From the data in figure 4, it is possible to make a realistic estimate of the likely volumes of CO_2 that could be stored in Australia on a yearly basis. This can be done by counting nodes that have large emission volumes, are within 300 kilometres of a technically viable ESSCI, and have a ranking of one or two for cost per tonne.

Using these criteria, Australia has the potential to realistically store up to 25 per cent of its total net 1998 CO_2 emissions, or 100 to 115 Mt of CO_2 per year. This is important data for the Australian Government, which seeks to achieve Kyoto Protocol targets (equivalent to an 8% increase in CO_2 emissions over 1990 levels) even if it does not ratify the Protocol.

* *Reservoir modelling was done within GEODISC by CSIRO and the National Centre for Petroleum Geology and Geophysics.*

For more information phone John Bradshaw on +61 2 6249 9659 or e-mail john.bradshaw@ga.gov.au, or refer to an article published on pages 25 to 46 in the APPEA Journal in 2002.

Broad study looks at *Otway's petroleum*

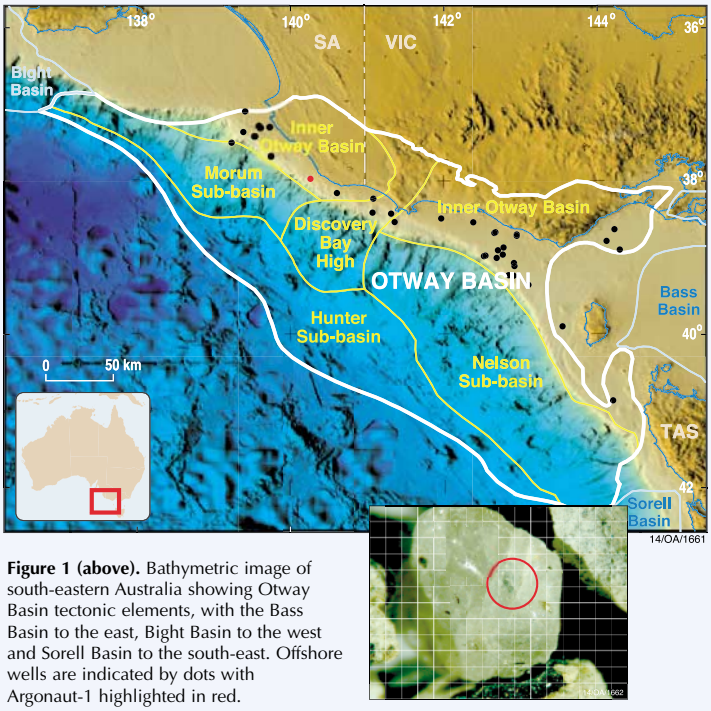

Figure 1 (above). Bathymetric image of south-eastern Australia showing Otway Basin tectonic elements, with the Bass Basin to the east, Bight Basin to the west and Sorell Basin to the south-east. Offshore wells are indicated by dots with Argonaut-1 highlighted in red.

Figure 2 (insert). Argonaut-1 cuttings sample at ~6500′ illustrating oil inclusion in a quartz grain (red circle) targeted for GOI analysis

Interest in the Otway Basin picked up recently with significant gas discoveries including major offshore finds at Thylacine (600 billion cubic feet) and Geographe (500 bcf). These finds, together with earlier discoveries offshore and onshore, confirm that the Otway Basin is a major hydrocarbon province. Commercial quantities of liquid hydrocarbons however have not yet been discovered.

Geoscience Australia is assessing the geological risks of petroleum occurrences and the potential for further economic development in the Otway Basin, in consultation with industry and South Australian and Victorian government departments. The study incorporates interpretations of seismic, biostratigraphic, lithologic and geochemical data, and geohistory models.

Basin analysis

The Otway Basin is a north-west to south-east striking, divergent margin rift and drift basin. It is approximately 500 kilometres long, from Cape Jaffa in South Australia to north-west Tasmania (figure 1).

Seismic data used in the study include recently reprocessed Geoscience Australia surveys in-filled with multi-vintage industry data (grid spacing 15–20 kilometres) incorporating most offshore and selected onshore wells. Interpretation is under way to provide a revised tectonostratigraphic framework for the entire basin.

The major unconformity-bounded accommodation cycles will be identified and mapped. Events that shaped the basin (timing, orientation and distribution) and their impact on the timing and style of trap formation will be assessed. Deposition systems and the regional distribution of major source, reservoir and seal units will be linked to the chronostratigraphic framework.

Sampling program

Samples from onshore and offshore wells were obtained for palynological and source rock (Rock Eval, TOC and isotope) analyses. The sampling program covers the Early Cretaceous, largely non-marine and Late Cretaceous mixed marine/non-marine sections. Stratigraphic discontinuities will be identified using University of Utah Integrated Palaeontological System software, which manipulates and compares disparate stratigraphic data (e.g. biostratigraphy and lithology).

Oil pathways

In collaboration with CSIRO Petroleum, traces of oil retrieved from offshore wells (figure 2) are being studied to track the oil migration and charge history in the basin. A mix of techniques (Quantitative Grain Fluorescence, Quantitative Grain Fluorescence–Extract and petrographic examination for grains containing oil inclusions or GOI) are being used to detect palaeo-oil columns and oil migration fairways. Samples have been selected to test the relationships among mature source rock, reservoir, seal and trap integrity. The region's oil prospectivity will be assessed using results of these analyses incorporated into the regional basin framework.

Oil families

The organic geochemistry work is focusing on gas-gas, gas-oil, oil-oil and oil-source correlations in the Otway Basin. Already, open-file source data for the Late Jurassic–Cretaceous succession has been assessed, and sampling has occurred to target potential source rocks.

Samples from recent discoveries in the region will complement previous analyses in the 'Oils of Eastern Australia' study by Geoscience Australia and GeoMark Research (USA).

Geochemical findings will be compared with the known oil families from the Bass, Gippsland and Taranaki (NZ) basins. This will provide the basis for refining the petroleum system/oil family nomenclature for south-east Australia. Synthesis with recently completed studies in the Bight and Bass basins will improve what is known about the tectonostratigraphic evolution and petroleum geology along the Southern Margin.

The Otway Basin is strategically located should future discoveries occur. It is close to growing south-eastern energy markets with recent investment resulting in gas pipelines linking Victoria, New South Wales and Tasmania and a proposal to link South Australia.

For more information phone Andrew Krassay on +61 2 6249 9309 or e-mail andrew.krassay@ga.gov.au

New resource estimates for Bonaparte on GA program

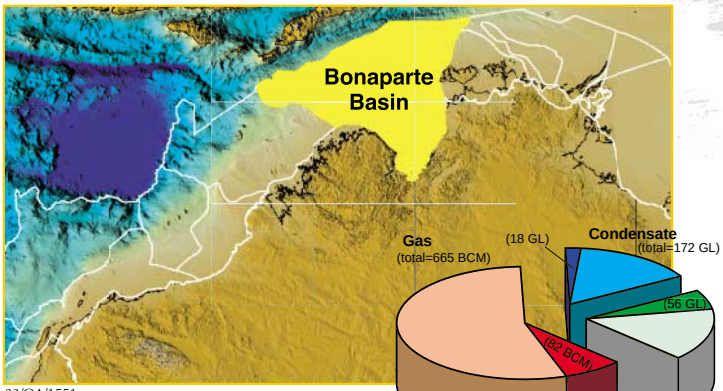

Figure 1. Location of the Bonaparte Basin

Figure 2 (pie graph). Bonaparte Basin USGS assessment results showing proportions of resources in oil equivalent units (1 barrel of oil is approximately equal to 6000 cubic feet of gas). The darker portions are AUSTPLAY assessment results showing how much of the ultimate potential is likely to be discovered in the next 10 to 15 years.

Geoscience Australia is carrying out research to estimate the volumes of hydrocarbons likely to be discovered offshore in such basins as the Bonaparte over the next 10 to 15 years to forecast petroleum production in Australia.

Forecasts suggest that by 2005 Australia's level of production will drop about 33 per cent, and by 2010 production will be down about 50 per cent.[1] This forecast includes production from already developed and soon to be developed fields, and a component from fields yet to be discovered.

Only 50 per cent of Australia's current liquid hydrocarbon reserves are oil. The rest is condensate associated with gas fields, of which very little is presently being developed.[1]

Oil exploration companies primarily have developed the science of undiscovered resource assessment so that they can rank competing investment opportunities. There is no simple way of making this estimation. Over many decades a variety of quite simple to relatively sophisticated techniques have been used (see list in table 1).

Geoscience Australia uses a relatively sophisticated 'extrapolation of discovery rate' technique to estimate undiscovered resources. It attempts to model the explorers' ability to discover the largest fields early in their exploration efforts. A detailed analysis of past exploration is made, which is then projected forward in time to estimate the likely amounts to be discovered in the next 10 to 15 years. Like all forecasting techniques, many assumptions have to be made. Providing one is aware of what assumptions are made, the forecast can be evaluated.

Assessment results are typically presented as probability distributions. The values typically reported are P_{90}, P_{50} (the median) or the mean (average) and P_{10} where P_x indicates that there is an 'x per cent' probability that at least this amount will be discovered. These three categories are sometimes reported as the minimum, most likely and maximum values. Unless the distribution is purely symmetrical, the P_{50} and mean values are sometimes significantly different.

Geoscience Australia's in-house resource assessment program is called AUSTPLAY. The fundamental input data are the pre-drill area of closure and the volumes of discovered hydrocarbons related to a discovery well. The basic unit of assessment is a petroleum system.

A recent update of the Bonaparte Basin (see figure 1 for location) estimates that in the next 10 to 15 years, 56 gigalitres (350 million barrels) of oil, 82 billion cubic metres (2.9 trillion cubic feet) of gas and 18 gigalitres (115 million barrels) of condensate will be discovered. These numbers are the average values from the probability distributions produced by the assessment process.

Table 1. Methodologies to calculate undiscovered hydrocarbon resources

- Geologic analogy
- Areal yield
- Geochemical material balance
- Summary of prospects, plays
- Delphi (panel opinion)
- Volumetric yield
- Field number and size
- Extrapolation of discovery rate

The Bonaparte Basin is also one of four Australian basins that have been assessed by the United States Geological Survey. The USGS forecasts that 205 gigalitres (1286 million barrels) of oil, 665 billion cubic metres (23.49 trillion cubic feet) of gas and 172 gigalitres (1080 million barrels) of condensate will be discovered in the Bonaparte Basin.[2]

Obviously, the USGS methodology significantly differs from AUSTPLAY. They used the 'field number and size' methodology in table 1, where the primary input parameters are the number of fields to be discovered, the size of the undiscovered fields and the probability of adequate geological conditions. As well, the forecast period for the USGS assessment is nominally 30 years compared to 10 to 15 years for Geoscience Australia's forecast.

Figure 2 compares the assessment results from AUSTPLAY and the USGS. Geoscience Australia has adopted the USGS assessment as the ultimate potential for the Bonaparte Basin. The AUSTPLAY assessment can be considered a subset of the USGS assessment.

Details of Geoscience Australia's Bonaparte Basin resource assessment will be presented at the Timor Sea Symposium in June (see www.dbird.nt.gov.au/ntgs/).

References

1. Powell TG. 2001. Understanding Australia's petroleum resources, future production trends and the role of frontiers. APPEA Journal; 41(1):273–287.
2. US Geological Survey. 2000. [CD-ROM]. US Geological Survey world petroleum assessment 2000—description and results. USGS digital data series DDS-60 4.

For more information about Geoscience Australia's resource assessment phone Andrew Barrett on +61 2 6249 9502 or e-mail andrew.barrett@ga.gov.au

Crustal thickness TURNS HEAT UP *on* sedimentary basins

Australia and Antarctica were parts of the single continent Gondwanaland some 140 million years ago. Before the super continent broke into parts, there was much crustal extension. As the crust thinned, huge amounts of sedimentary rock were deposited along Australia's Southern Margin. In some places the total sediment thickness is 15 kilometres (e.g. Ceduna Sub-basin).

Geoscience Australia's Basement and Crustal Studies (BCS) project is trying to determine the crustal thickness of Australia–Antarctica before break-up. The research is assisting plate tectonic reconstructions of the two continents. But it also provides thoughts on how crustal extension may have affected hydrocarbon maturation in deposited sediments along Australia's Southern Margin.

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Crustal thickness

Most reliable estimates of crustal thickness come from refraction seismic measurements that define the depth to the Moho boundary, where seismic velocity increases to eight kilometres or more per second. These measurements were used by the BCS project for Australia, but there are insufficient seismic measurements of crustal thickness for Antarctica.

Seismic measurements for Antarctica therefore were supplemented by predicted values using the regression between seismically defined crustal thickness and upwardly continued gravity. Upward continuation emphasises the effects of variations in crustal thickness in the total gravity signal.

Reconstructions

Once crustal thickness data were compiled, points on the Australian continent were reconstructed to their pre- break-up position. Reconstructions are accomplished through rotations with respect to Euler poles. (Euler's theorem says that the motion of rigid bodies along the surface of a sphere is equivalent to a rotation.) For this process, Dr Dietmar Müller of the University of Sydney supplied the most up-to-date finite rotation parameters defining the movement of Australia relative to Antarctica.

Points on the Australian and Antarctic margins with crustal thickness values of less than 30 kilometres were excluded from subsequent gridding. Based on global data compilation, it was thought that such crust would have been affected by pre- break-up extension. The reconstructed crustal thickness of part of Gondwanaland prior to the pre- break-up extension is shown in figure 1. This diagram assumes that geological processes on both continents (excluding margins) have not significantly affected crustal thickness since then.

Separation

Crustal thickness along the zone of subsequent Australia–Antarctica separation is clearly reduced and its width (as highlighted by black arrows in figure 1) varies substantially. Thin crust is generally weaker than thick crust, so it is not surprising that the continents broke apart along this zone.

Another obvious feature on the diagram of pre-extensional crustal thickness is a distinct zone of thick crust, which spans Australia–Antarctica from the Eastern Highlands in Australia to the Trans-Antarctic Mountains. This may explain why the break-up of the continents between Tasmania and Northern Victoria Land occurred as the last stage of the separation process.

Thick crust in this region essentially served as a lock. After this lock was broken, final separation occurred.

These results have several important implications, but only two will be discussed here.

Thick sediment

The thickest sediment accumulated where the width of the zone of pre-extensional thin crust was minimal—in the Ceduna Sub-basin (figure 1). This may be due to the higher rate of subsidence in the zone with the steepest slope on the Moho. The rheology of the crust and sediment supply also contributed. How they contributed is the subject of a future study.

Sediments of the Otway, Sorell, Bass and Gippsland basins to the north and west of Tasmania, unlike other basins on the Southern Margin, commenced in a thick crust environment. All four are located within the Eastern Highlands–Trans-Antarctic Mountains zone (figure 1). Although crustal thickness immediately underneath the basins is not much different from the western part of the Margin, clearly there are two prominent (up to 45 km) Moho lows to the north and south of them (blue colours in figure 1).

Heat flow

Onset of pre- break-up crustal extension within the zone was probably different compared with the western part of the Southern Margin, because thicker crust is harder to break. Thicker crust also generally means higher heat flow. For example: under high heat flow conditions, temperature at 45 kilometres depth is an estimated 1200° C, while at 30 kilometres depth (more typical for the western part of the margin), it is 800° C. Corresponding surface heat flow would also vary greatly. These differences may have affected the style of crustal extension and hydrocarbon maturation in deposited sediments.

Non-uniform pre-extensional crustal thickness along the Australian Southern and conjugate Antarctic margins, as well as implied differences in heat flow distribution, must be considered in modelling crustal extension and the formation of sedimentary basins. This means more complex but more realistic starting conditions in such modelling than conventionally used.

Future research

The results of this study open up new avenues for research. For example, rotation of points, the fundamental process driving the plate tectonic reconstruction, needs to be supplemented by rotation of attributes with the points.

Crustal thickness was used as an attribute in this study. In future gravity and magnetics values will be used as attributes.

The process of upward continuation of potential fields can account for varying depths to the sources of gravity and magnetics anomalies. As a result, the 'frozen-in component' of gravity and magnetics anomalies, which was not overprinted during the extension and break-up, may be defined more accurately compared to the 'frozen-in component' of crustal thickness.

To improve gravity and magnetics grids in Antarctica, the BCS project is working closely with Russian scientists from the VNIIOkeangeologia in St-Petersburg. This relationship is arguably the most extensive in Australian–Russian geoscience cooperation. The first results of this work will be available in April.

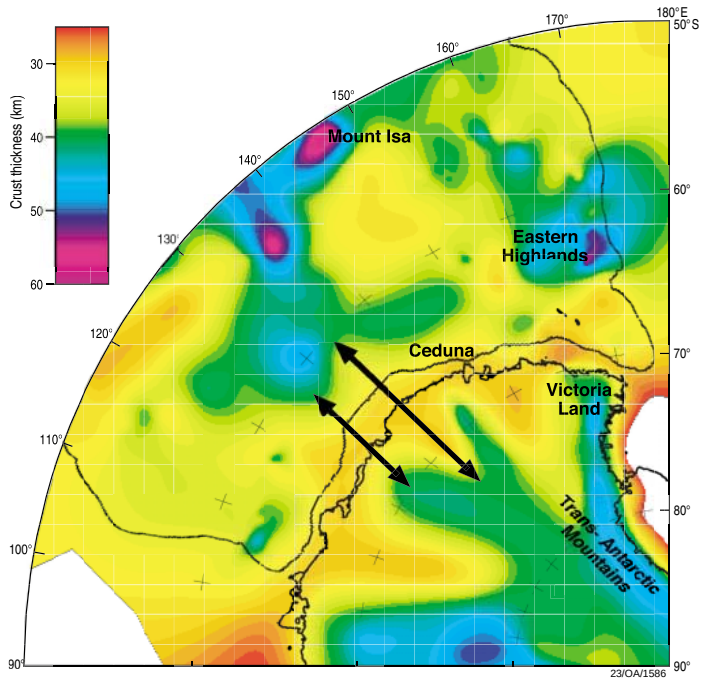

Figure 1. Reconstructed pre-extensional crustal thickness in Australia–Antarctica prior to the onset of pre- break-up extension at 140 Ma. Crustal thickness values less than 30 kilometres on both continental margins were excluded from gridding. The 300-metre isobath approximates shelf break around Australia. Both the ice coast and true coast are shown for Antarctica. Black arrows highlight width variation in the zone of thinned crust along the zone of subsequent break-up.

Achieving new heights in ANTARCTICA

Mt Shinn, the third highest mountain in Antarctica, is 140 metres lower than its height recorded on maps and atlases.

Early on December 1, Australian mountaineer Damien Gildea sent data from the summit of Mt Shinn to Geoscience Australia to accurately measure the peak's height.

Gildea used a satellite phone to send data from his GPS (global positioning system) receiver and lap-top computer to AUSPOS, Geoscience Australia's on-line GPS processing system. When Gildea descended to his base camp, AUSPOS e-mailed him the correct height of Mount Shinn.

Mt Shinn is 4660.5 metres above sea level, which is only slightly higher than nearby Mt Craddock at 4650 metres.

To reach the summit, Gildea and his Chilean climbing partner Rodrigo Fica had a seven-hour trek in 10–15 knot winds and a temperature of minus 30° C. Towards the end of their ascent, they climbed a 50–60° slope with unstable ice near the summit. They spent seven hours at the summit to record signals that fix the peak's height.

Gildea made a similar attempt 12 months earlier. His expedition was within 100 metres of the summit when it had to descend because of bad weather and dangerous ice conditions.

Mt Shinn is in the Sentinel Ranges, adjacent to Antarctica's tallest peak Vinson Massif. Mt Tyree is Antarctica's second highest mountain.

The height of Mount Shinn was last measured in the 1960s.

AUSPOS is a free on-line GPS processing service that computes coordinates within centimetre accuracy from data submitted via the internet.

For more details phone John Dawson on +61 2 6201 4344 or e-mail johndawson@auslig.gov.au

TIMOR SEA Petroleum Geoscience *Symposium*

19–20 June 2003 Carlton Hotel, Darwin, Australia

Petroleum geology of the Bonaparte Basin and surrounds

The symposium is a forum for industry, government and academia to discuss:

- 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;
- Structure and tectonics.

Abstracts of symposium papers will be available on CD. There will also be a trade display.

For more details phone Greg Ambrose on +61 8 8999 5342.

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

EVENTScalendar

Compiled by Steve Ross

Petroleum Core Workshop Events
Primary Industries & Resources South Australia

7 April to 10 April, Adelaide

Contact: Peter Boult, Primary Industries & Resources South Australia, GPO Box 1671, Adelaide SA 5001

phone +61 8 8463 3243

e-mail boult.peter@saugov.sa.gov.au

GeoHab 2003
Geoscience Australia & CSIRO

30 April to 2 May, CSIRO Marine Research Auditorium, Hobart

Contact: Linda Thomas, University of Tasmania

phone +61 3 6226 7467

fax +61 3 6226 2973

e-mail linda.thomas@utas.edu.au

www.ngu.no/geohab/

AAPG 2003—Energy: Our Monumental Task
American Association of Petroleum Geologists

11 to 14 May, Salt Lake City, Utah, USA

Contact: American Association of Petroleum Geologists, PO Box 979, Tulsa Oklahoma 74101-0979 USA

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NSW Mineral Exploration & Investment Conference
NSW Department of Mineral Resources

22 & 23 May, Sydney

Contact: Lindsay Cohen, Department of Mineral Resources, PO Box 536, St Leonards NSW 1590

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Australian Science Festival
Australian Science Festival Ltd

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Dinocyst zones realigned for Shelf explorers

Exotic, italised names such as *Wanaea spectabilis* and *Dingodinium jurassicum* (figure 1) appear on countless charts in petroleum exploration offices throughout Australia and in many parts of the world. And there is a good reason.

For the past 250 million years, remains of organic-walled dinoflagellate cysts (or 'dinocysts') have been deposited in marine sediments. Their distribution in time and space, as with other fossil groups, form biozones. Biozones are one of the primary tools used by the petroleum industry for correlating strata.

For many in the industry, the biozone standard is Helby, Morgan and Partridge's text, known as HMP 87*.

Biozones are refined as more and more samples and their assemblages are studied and recorded by various oil and gas companies and their external consultants, or by researchers. Often initial subdivisions are broken into two or three informal subzones, designated simply as lower, middle or upper. Sometimes the basis of a refined correlation is not defined. This becomes a problem when the same name does not always apply to the same time span.

If biozones are developed without communication among the various specialists, there is the potential to confuse users who can access the information freely under the *Petroleum (Submerged Lands) Act* (see www.ga.gov.au/oracle/apcrc).

Special meeting

This problem was recognised by several major Australian explorers, including Santos and Woodside Petroleum. As members of the Virtual Centre of Economic Micropalaeontology and Palynology (VCEMP), they asked for a special-purpose meeting for relevant consultants and industry specialists to consider dinocyst zones spanning the Late Triassic to Early Cretaceous on Australia's North West Shelf.

A two-day meeting was held at Santos in December, during which biozonal criteria were reviewed and compared with definitions given in HMP 87. Consequently, consultant Dr Robin Helby has been contracted by Geoscience Australia (for the VCEMP) to provide definitions for dinocyst zones used on the North West Shelf. This work also involves palynological consultants Drs Roger Morgan and Alan Partridge.

New standard

The work by Helby and others will provide a new industry standard for a section of the geologic column (in effect HMP 2003). It will be completed by May and, although HMP 2003 will provide a stable zonal reference for the North West Shelf for some years, the biozones will continue to be refined by researchers elsewhere.

The doctoral studies being undertaken at the University of Western Australia on dinocyst assemblages from the North West Shelf, for example, should further refine the biozones.

A key issue in providing a new standard is linking the North West Shelf biozones to the geologic timescale and numeric ages. Numeric ages are important to the exploration industry because they are essential inputs for geological/geohistory modelling.

Another issue since HMP 87 was developed is the growth in use of other fossil groups (particularly nannoplankton and foraminiferids) for correlations with the standard geologic stages. The VCEMP is supporting studies of Cretaceous nannoplankton at the University of Western Australia. The university's Dr John Backhouse is reviewing these new data concurrently with HMP 2003.

A chart showing relationships among biozones defined initially by HMP 87, and used in extensive studies on the North West Shelf by Helby and Morgan should be available at APPEA at the end of March. Details of HMP 2003 are expected to be available next year.

* *Helby R, Morgan R & Partridge AD. 1987. A palynological zonation for the Australian Mesozoic. Memoir of the Association of Australasian Palaeontologists; 4:1–94.*

A special-purpose VCEMP meeting held at Santos in December reviewed criteria for dinocyst zones relevant to petroleum exploration on Australia's North West Shelf. Key contributors included (back row, l-r) Jeff Goodall, Geoff Wood, Clinton Foster and Neil Marshall, and (front row, l-r) Eric Monteil, Robin Helby and Roger Morgan.

	HMP 1987, 2003	Sub-zones	Morphed concept
140		4biii	
	Pseudoceratium iehiense	4ci	*Pseudoceratium iehiense*
141		4cii	*U. Dingodinium jurassicum*
142	*Dingodinium jurassicum*	5a	
143			*L. Dingodinium jurassicum*
144		5b	
145	*Omatia montgomeryi*	5c	*Omatia montgomeryi*

20/OA/27

Figure 1. Excerpt from HMP 2003, a zonal reference for correlating strata on the North West Shelf

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Timor Sea activity significant

The Timor Sea has been tectonically active for at least the past six million years where the Australian and Eurasian plates converge. Although the level of tectonic activity decreased about two million years ago, hundreds of earthquakes have been recorded in the region since the mid-1970s.

Geoscience Australia's Kriton Glenn and former staff member Dr Geoff O'Brien have been carrying out a series of studies on the development of the Timor Sea for 10 years. The area is important because of its unique eco-systems and hydrocarbon potential.

Some work has focused on the distribution of active sea-floor fault scarps and earthquake activity. The purpose is to see whether crustal failure in the region has any potential implications for the petroleum industry, and the management of marine reserves. There are also safety issues for coastal communities that potentially could be affected by geohazard-related events in the region.

Earthquakes

Geoscience Australia uses its database of earthquake activity to determine the locations, magnitudes and depths of earthquakes in the region, and to identify the most tectonically active areas.

Many earthquakes in the Australian sector of the Timor Sea are relatively low in magnitude. They occur around the edges of Late Miocene–Pliocene depocentres such as the Cartier and Timor troughs (figure 1). Many faults around these depocentres extend to the sea-floor. Some faults at depth and at sea-floor have displacements in excess of 100 metres, and extend for many kilometres along strike. Numerous earthquakes have occurred close to, or even within, marine reserves such as Ashmore Reef (figure 1).

Earthquake activity within the central Timor Trough and the island of Timor is much more intense. Here the earthquakes are more frequent and generally of greater magnitude, with many being large (>7 on the Richter scale).

Related events

Clearly, there is the potential for significant geohazard-related events in the region. Earthquakes at times produce large oceanic waves. They can also cause sea-floor subsidence, tsunamis, seiche and liquefaction.

Sudden sea-floor subsidence occurs where large amounts of sediment slide down the continental shelf because of either fault movement or slope failure. Slope failures are a concern in the Timor Sea region near such Neogene depocentres as the Cartier and Timor troughs.

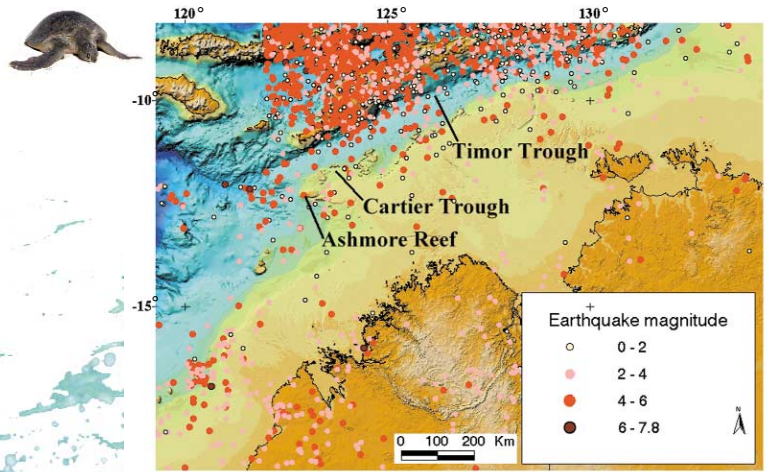


Figure 1. Hundreds of earthquakes have been recorded in the Timor Sea region since the mid-1970s.

Tsunamis occur when the water column is vertically displaced, and a wave forms as the water mass attempts to regain its equilibrium. A series of rocking waves, or seiche, creates changes in water level that may pose serious threats to maritime communities as the water mass sloshes back and forth.

Liquefaction is a physical process where, in response to the ground shaking, water-saturated, well-sorted sediments behave as fluids rather than as solids. The sediment fabric collapses, increasing pore space water pressure, which decreases the sediment shear strength.

Several types of sea-floor structural failure are caused by liquefaction. These include mud volcanoes, lateral spread of large blocks of sediment, slope failure and the loss of bearing strength.

The potential for liquefaction and allied geohazards on Australia's North West Shelf are yet to be fully determined, but these natural occurrences may have significant implications for ecosystems on low-lying islands, sea-floor pipelines and petroleum platforms.

In the Timor Sea, events related to liquefaction are most likely to occur within and around the Neogene depocentres that subsided rapidly and contain significant thicknesses of poorly consolidated sediments. They are also potentially associated with some of the large carbonate banks and shoals—especially those composed principally of Halimeda-type algae.

Ongoing research

Geoscience Australia continually captures data about tectonic activity in the Timor Sea region to better understand geohazards and identify areas of greatest risk (where they are most likely to occur or be generated, and what communities and resources are most likely to be affected). Identifying areas that were affected by such processes in the past is an important part of the research.

Geoscience Australia's Dr Mark Leonard provided the earthquake data used in this article.

For more details phone Kriton Glenn on +61 2 6249 9379 or e-mail kriton.glenn@ga.gov.au. Geoff O'Brien can be contacted at the National Centre for Petroleum Geology and Geophysics, University of Adelaide.

Basins database in PROTOTYPE, on-line soon

Geoscience Australia is gathering what is known about the geology of Australia's offshore sedimentary basins in a new Oracle database that should be accessible on-line next year. The prototype will be on show at the APPEA trade exhibition from March 23 to 26.

The database provides basic information such as basin size, water depth, tectonic setting, age, sediment thickness, rock types, depositional environments, main resources and key references (figure 1). It also includes an overview of the geology, exploration status and petroleum system elements of each basin. Information on stratigraphy, geological events, and petroleum systems and other resource information will be added later.

Basin boundary information is being captured also. Boundaries are compiled as polygons and individual attributed line segments that are useable in a GIS. Attributes include boundary type, basis of interpretation, confidence level, positional accuracy and source reference. The database is capable of holding multiple versions of basin definitions.

The primary purpose of the database is to provide advice on the petroleum potential of Australia's sedimentary basins. But it will also be useful for evaluating other sub-surface resources (e.g. sediment-hosted mineral deposits, coal, coal-seam methane and groundwater, and geological sequestration).

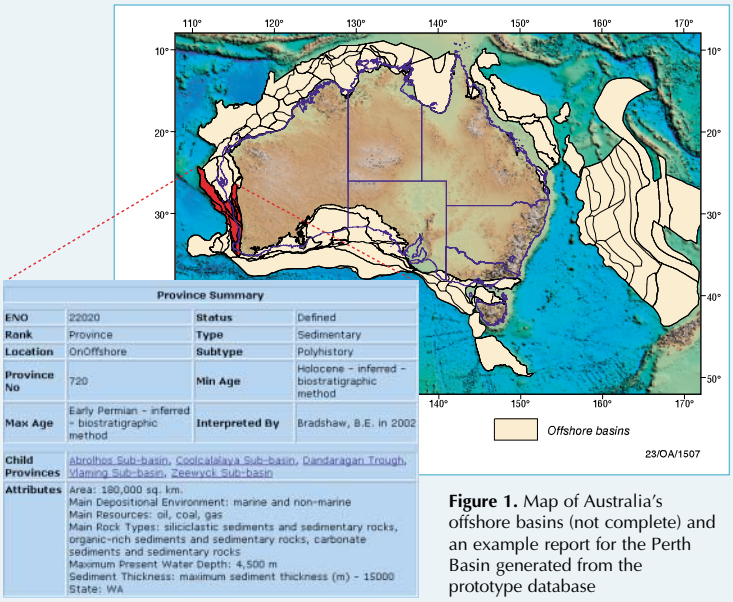


Figure 1. Map of Australia's offshore basins (not complete) and an example report for the Perth Basin generated from the prototype database

The database is part of a program that began several years ago to capture knowledge about all Australian geological provinces in the PROVINCES database. The work is occurring within two Geoscience Australia projects: the Australian Basins Information Management Systems (AusBIMS) project which is concentrating on the offshore basins, and the National Maps project which is concentrating on onshore geological provinces. Geoscience Australia works closely with state authorities and industry to include the most up-to-date interpretations.

For those interested in providing feedback on the prototype of the offshore basins database, visit Geoscience Australia's booth at the APPEA trade exhibition. The full database should be available via the web in 2004.

For information about the offshore basins component phone Barry Bradshaw on +61 2 6249 9035 or e-mail barry.bradshaw@ga.gov.au. For information about the onshore provinces component phone Ollie Raymond on +61 2 6249 9575 or e-mail oliver.raymond@ga.gov.au

GEOHAB 2003

April 30 to May 2
HOBART

Abstracts & registration due MARCH 30

For further information and a registration form visit www.ngu.no/geohab/ or contact *Linda Thomas:* phone +61 3 6226 7467 e-mail linda.thomas@utas.edu.au

'Geological Mapping of Habitats for Marine Resources and Management'

GEOHAB Marine Geological and Biological Habitat Mapping

GeoHab is an annual meeting designed to:

- Maintain awareness of technological developments and survey standards
- Identify existing metadata sources relevant to marine habitat mapping
- Develop new thematic maps useful for fisheries management, biodiversity management, and the assessment of future Marine Protected Areas
- Encourage standardisation of maps through the creation of a habitat mapping glossary and building links to marine mapping agencies worldwide
- Apply and evaluate habitat classification systems using real-world examples.

The focus of this year's meeting is the application of marine geological mapping emphasising the interaction between managers and researchers.

GeoHab was established in 2001. Meetings have been held in Canada (2001) and the United States (2002). Geoscience Australia and CSIRO Division of Marine Research will host this year's meeting in Tasmania, Australia.

New acreage offshore open to exploration

Australia's petroleum Offshore Acreage Release for 2003 will be formally announced on March 24. Thirty-five areas in 13 regions are proposed for release (see figures 1–3).

Closing dates for the release areas will be September 2003 and March 2004, depending on the area's size and exploration maturity. Many of the proposed release areas have proven plays in Mesozoic and/or Palaeozoic petroleum systems.

The opportunities include:

- large deepwater blocks in frontier areas—Exmouth Plateau on the North West Shelf and Perth Basin (figure 2), Ceduna Sub-basin on the Southern Margin, and the Sorell Basin along the western Tasmanian margin (figure 1);
- large shallow water blocks over the Palaeozoic Arafura Basin and Eastern Bonaparte Basin in northern Australia (figure 3);
- moderate sized blocks under various water depths in immature to sub-mature basins, which have known petroleum systems operating (Bonaparte, Otway, Bass and Perth basins, figures 1–3); and
- smaller blocks in shallow water in producing basins (Carnarvon and Gippsland basins, figures 2 & 3).

The regular coordinated release of offshore acreage by the Commonwealth and state governments offers new entrants the chance to establish an acreage position in Australia.

Good signs offshore

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 the Bight, Duntroon and Otway basins.

There were discoveries such as Exeter and Stybarrow in the Carnarvon Basin, and Casino in the Otway Basin. These combined with the success of the Cliff Head appraisal wells in the Perth Basin and Apache's successful 'String of Pearls' around Varanus Island in the Carnarvon Basin resulted in a successful year for petroleum exploration in Australia.

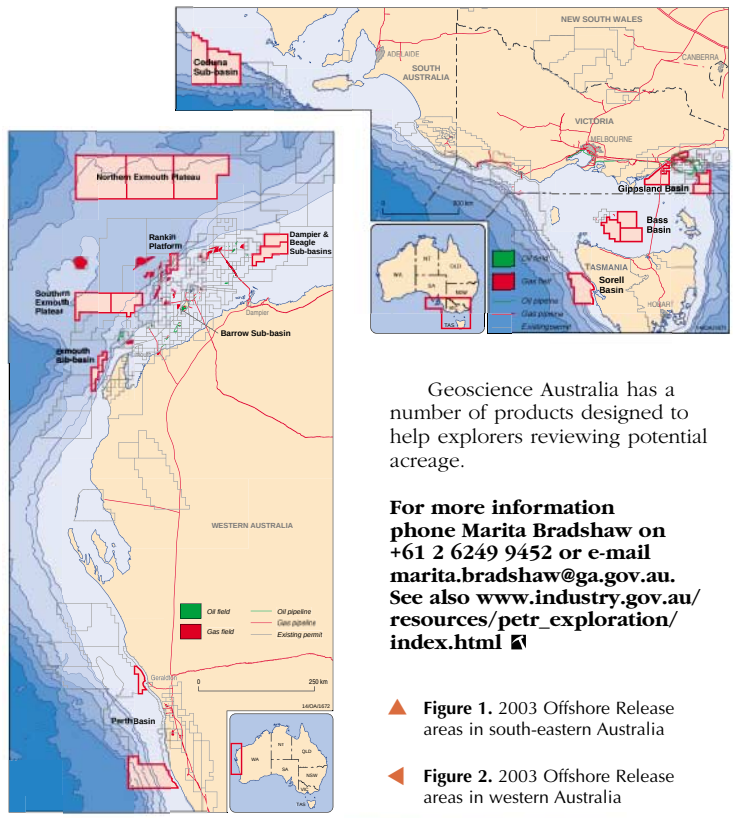
Australia is optimistic about increased offshore exploration in 2003. There was strong bidding for offshore areas in the 2002 release, including the new frontiers of the Otway and Perth basins. New seismic surveys are planned in these frontier areas, which will improve what is known about the regions.

High hopes are held for the results of two, deepwater drilling vessels currently working in Australia, the *Atwood Falcon* and the *Glomar Jack Ryan Drillship*. Wildcat wells in the outer Browse, offshore Canning and Bight basins have the potential to dramatically alter how industry perceives deepwater Australia.

The Great Australian Bight is remote deepwater frontier acreage in every sense, but early seismic results look promising.

On the company scene second tier companies, including a number of US independents such as Apache and Kerr-McGee, are now exploring successfully in Australia. Companies that have returned to Australia after several years include UNOCAL and Marathon Petroleum.

Australia offers a very low risk corporate environment for international exploration. It has internationally competitive regulatory and tax regimes including security of title, a highly educated workforce, and is politically stable.

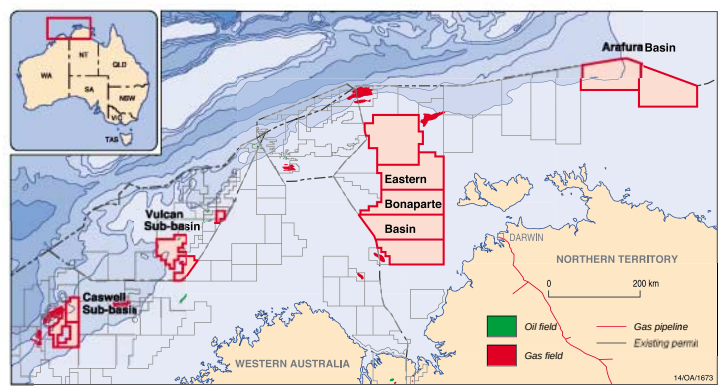


Geoscience Australia has a number of products designed to help explorers reviewing potential acreage.

For more information phone Marita Bradshaw on +61 2 6249 9452 or e-mail marita.bradshaw@ga.gov.au. See also www.industry.gov.au/resources/petr_exploration/index.html

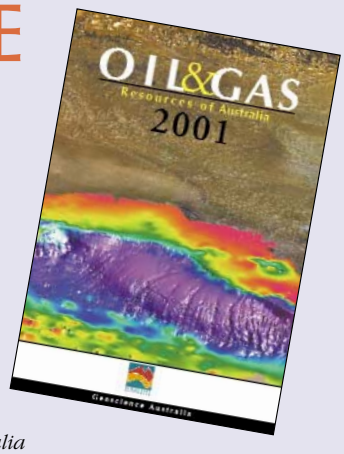
▲ **Figure 1.** 2003 Offshore Release areas in south-eastern Australia

◀ **Figure 2.** 2003 Offshore Release areas in western Australia



▲ **Figure 3.** 2003 Offshore Release areas in northern Australia

INCREASE
in Australian gas and condensate reserves reported



Australia's commercial and non-commercial gas and condensate reserves continue to increase because of further discoveries and a revision of reserve estimates.

This information is published in the latest *Oil and Gas Resources of Australia* (OGRA 2001), which was released by Geoscience Australia at the end of last year.

OGRA 2001 is an important reference about Australia's oil and gas production. It provides a forecast of Australia's crude oil and condensate production from 2002 to 2015, an estimate of undiscovered oil and gas potential, and sustainability indicators for petroleum resources. There is also a section about coal-bed methane and shale oil resources, production and developments, and lists of petroleum pipelines, offshore discoveries, and producing platforms and fields.

The latest petroleum titles map showing the 2002 Offshore Release areas is also included.

Reserves

Condensate reserves increased by more than 15 per cent in 2000 to the beginning of 2001, despite a small fall in production during 2000. Condensate now represents 61 per cent of Australia's commercial and non-commercial crude oil and condensate resources. But growth is constrained by gas production and the timetable for developing major gas fields.

Remaining commercial and non-commercial gas reserves have increased more than 23 per cent in one year from 115 trillion cubic feet in 2000 to 141 trillion cubic feet at the beginning of 2001. This figure should be larger when recent discoveries are assessed. The increase is mainly due to large discoveries in the Carnarvon Basin and appraisals of the Brewster and Brecknock South fields in the Browse Basin.

Remaining commercial and non-commercial crude oil reserves however declined by five per cent (from 1664 million barrels to 1587 million barrels), because of increased levels of production. This level of production cannot be sustained in the medium term. The mean expectation production rates are expected to drop by nearly 37 per cent in 2005 and possibly 55 per cent by 2015.

Estimate revision

OGRA 2001 includes a revised assessment for the Bonaparte Basin, namely a 41 per cent decrease for oil and a 30 per cent increase for gas. An assessment of undiscovered resources based on the United States Geological Survey methodology provides an ultimate potential estimate for undiscovered resources, and allows the prospectivity of Australian basins to be benchmarked against international petroleum basins.

Availability

OGRA is produced annually because it is an important reference for energy analysts, petroleum engineers and geologists, petroleum exploration companies, stockbrokers and share investors. It is available in hard copy and from Geoscience Australia's web site.

Copies of OGRA 2001 and the Petroleum Exploration and Development Titles Map and Key can be purchased from Geoscience Australia Sales Centre for $55 (includes GST) plus postage and handling.

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

Access to petroleum data *free and easy*

Public access to exploration and production data (E&P) is a key issue for attracting petroleum investment to Australia.

Australian legislation requires that petroleum E&P data be lodged and made available publicly. The data ranges from digital seismic tapes to core and cutting samples from wells. It also includes information in relational databases such as organic geochemistry, biostratigraphy, and reservoirs and shows.

Seismic information available publicly is being progressively consolidated to high-density media.

To reduce exploration costs and in line with its spatial data policy, the Commonwealth Government makes company data available at the cost of transfer after a relatively brief confidentiality period. As well, any government pre-competitive regional studies, databases and spatial information relating to petroleum prospectivity can be accessed for free over the internet.

Additional information about access to E&P data can be found on the Geoscience Australia web site (www.ga.gov.au) and in an article in the 2003 APPEA Journal titled 'Access to Australian exploration and production data: A critical factor in attracting investment' by Williamson and Foster.

Key contacts for E&P data at Geoscience Australia are listed below.

Contacts for petroleum data

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New information about southern basins

Two new publications highlight recent results from Geoscience Australia's Southern Australia Regional project. One provides new information about the distribution of potential source rocks in the Bight Basin. The other helps delineate the main structural elements of basins along Australia's southern and south-western margins.

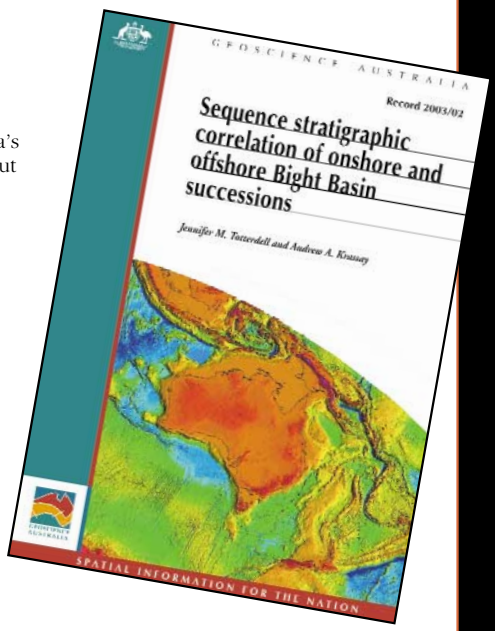
Record 2003/02—*Sequence stratigraphic correlation of onshore and offshore Bight Basin successions* focuses on Cretaceous sedimentary rocks found in petroleum exploration wells, stratigraphic holes and water bores along the southern Australian coast in South Australia and Western Australia. The Cretaceous succession is interpreted within the Bight Basin sequence stratigraphic framework, and is correlated with the thicker section farther basinward. The correlation is based on existing and recently commissioned biostratigraphic studies (included in appendixes) and the interpretation of seismic data on the continental shelf.

The sedimentary section preserved in the onshore wells records the evolution of depositional environments near the northern margin of the Bight Basin. This includes localised non-marine deposition in the Early Cretaceous, through increasingly marine (although shallow and anoxic) conditions, to the local development of a small deltaic complex in the Late Cretaceous.

Organic-rich non-marine shales of Early Cretaceous age and Late Cretaceous organic-rich facies of marine affinity have been identified in wells. This provides new information about the nature and extent of potential source rocks in the Bight Basin.

Record 2003/03—*A revised structural framework for frontier petroleum basins on the southern and south-western Australian continental margin* provides a revision of the structural framework of the Bight, Mentelle and Perth basins. Each basin is defined by component structural elements that relate to different stages in their evolution. Details of the structural style, fabric and evolution of each basin element are presented.

This revised structural framework of basins along the southern and south-western margin will benefit petroleum explorers by more clearly delineating the main structural elements and potential petroleum provinces in this frontier region.



Both records can be purchased from the Geoscience Australia Sales Centre. Record 2003/02 costs $33 and Record 2003/03 costs $44 (including GST) plus postage and handling. They are not available electronically.

For more information phone Jennifer Totterdell on +61 2 6249 9407 or e-mail jennifer.totterdell@ga.gov.au

ACRES products delivered *on-line*

Geoscience Australia now offers on-line delivery for its ACRES remote sensing data products. This service was launched on December 16 to add to other delivery options offered through Priority Processing and STAR services.

On-line delivery is available for a range of data products currently available on a single CD-ROM from the Landsat, RADARSAT, ERS and JERS satellites.

On-line delivery gives customers faster access to standard products and reduces delivery costs by regular freight. A product delivered on-line is $50 less than its recommended retail price. The normal retail price applies, however, if the product is requested on CD-ROM at the same time as/in addition to on-line delivery.

More information about on-line delivery is available via the web at www.auslig.gov.au/acres/prod_ser/onlinedelivery.htm.

For more details phone Medhavy Thankappan on +61 2 6201 4130 or e-mail medhavythankappan@auslig.gov.au