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AUSGEO *news*



CO₂
down under



OFFSHORE ACREAGE **RELEASED**

Also: Use of acoustic surveys probed, potential new oily sub-basin, dinocyst zones realigned...

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CONTENTS



Comment 3

Survey sounds fine in Antarctic waters 4



PETROLEUM SPECIAL...

Potential new oily sub-basin in Browse 8

Bass well data suggest a Tertiary problem 10

Big capacity to store greenhouse
gas down under 11

Broad study looks at Otway's petroleum 14



New resource estimates for Bonaparte
on GA program 15

Crustal thickness turns heat up on
sedimentary basins 16

Events calendar 18



Achieving new heights in Antarctica 18

Dinocyst zones realigned for
Shelf explorers 19

Timor Sea activity significant 20

Product news 21



On March 24 the Australian Government releases new acreage offshore for petroleum exploration. This year's opportunities are in frontier areas and in producing basins, as well as in basins known to have petroleum systems (see page 22). Geoscience Australia carries out a lot of research to support this annual release of acreage to reduce the risks for petroleum explorers. This issue of AusGeo News is devoted to reporting some of that research.

Photo: ©Lowell Georgia/CORBIS



Last December, the Commonwealth Government announced the successful bids under its 2002 Cooperative Research Centres (CRC) program. Geoscience Australia will participate in four of these successful bids: the CRC for Greenhouse Gas Technologies, the CRC for Spatial Information, and the extension bids for the CRC for the Coastal Zone, Estuary and Waterway Management and the CRC for the Great Barrier Reef World Heritage Area.

Geoscience Australia will contribute enormously to the CRC for Greenhouse Gas Technologies following its success in the APCRC – Geological Sequestration of Carbon Dioxide project (GEODISC). The main findings of this work are featured in this issue of *AusGeo News*.

Oil and natural gas account for more than 50 per cent of Australia's energy fuels. Australia has huge reserves in gas with several major developments in the 'pipeline' and recent discoveries on the North West Shelf and in the Otway Basin.

Australia has also enjoyed a high level of self-sufficiency in liquid hydrocarbon, but its reliance on imported oil is likely to increase in the future.

Geoscience Australia forecasts that annual total liquid-hydrocarbon production in Australia will decline by 40 per cent in 10 years. This outlook is exacerbated by a marked decrease in exploration over the past year. A new oil province needs to be found.

The Commonwealth Government is addressing the issues and problems associated with current levels of exploration in Australia. Minister for Industry, Tourism and Resources, the Honourable Ian Macfarlane announced a House of Representatives Industry and Resources Committee Inquiry into 'Resources exploration impediments' in May last year, which has already attracted a considerable number of submissions. Last year, 28 new areas for offshore petroleum exploration were also awarded with a total exploration commitment valued at almost \$600 million.

This month another 35 areas in basins around Australia are released for industry bidding. Geoscience Australia, in conjunction with state authorities, provided the technical and geological information for the 2003 Offshore Acreage Release.

The Government also conducted a major internal review of Geoscience Australia's pre-commercial petroleum exploration and technical advice program. This review is now being considered, and I would like to take this opportunity to thank the petroleum exploration industry for their contributions.

High-quality pre-commercial geoscientific information is crucial to maintaining Australia's competitive position in attracting petroleum exploration investment. Inside this issue of *AusGeo News* are some examples of the work Geoscience Australia carries out to provide this information, in particular in the Bass and Otway basins and off north-western Australia.

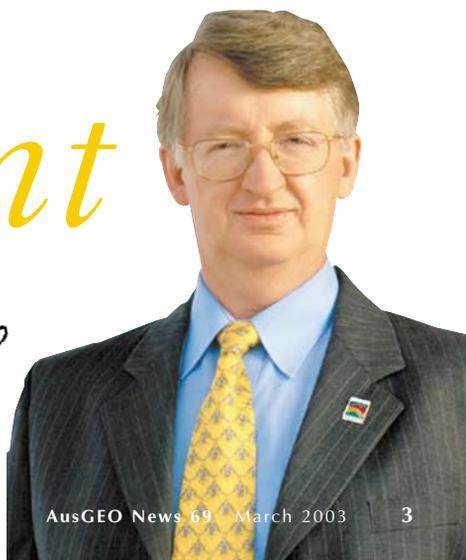
This issue also contains an article about a topical environmental issue, the impact of marine acoustic technology on whales, seals and other marine fauna. This work highlights how Geoscience Australia collaborates with scientists around the world to develop significant expertise in areas of science that are new to the organisation.



Comment

Neil Williams

NEIL WILLIAMS
CEO Geoscience Australia





SURVEY SOUNDS FINE IN

Anta

The web has many reports of whale and dolphin strandings and how some could be linked to acoustic technology used in marine surveys and naval exercises. But is there hard evidence and, if so, what practices and equipment are at fault?

Two years ago one Environmental Licensing Agency banned its scientists from using acoustic equipment in Antarctic waters. This stopped a large marine research program and prompted a review of Antarctic surveys and their potential effect on marine animals by a team of scientists from various countries involved in the Scientific Committee for Antarctic Research (SCAR).

Geoscience Australia's Dr Phil O'Brien, convenor of SCAR's ad hoc working group on marine acoustic technology outlines the group's findings, a draft of which was released in February.

The use of echo sounders, acoustic releases and seismic reflection equipment for marine surveys has been questioned because these acoustic tools may interfere with the activities of marine animals that use sound, presumably for navigation, communication and acquiring food. Overuse of these tools, particularly at close range, perhaps harms whales, seals and penguins and the animals on which they feed.

Acoustic tools are crucial to marine research. Without these tools, very little would be known about the world's oceans and continent formation.

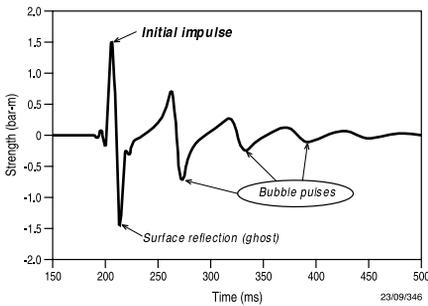
Echo sounders aid navigation, map the sea-floor, and show the distribution of fish and plankton. Seismic reflection equipment images the sediments beneath the sea-floor, which is important for determining resource potential and climate history. Acoustic releases allow seabed moorings to be placed and retrieved without the long lines that can entangle animals and icebergs.

Our task was to consider whether acoustic technology has an impact on major animal groups in the Antarctic. The SCAR working group comprised an international team of geoscience and biology experts who know about Antarctic wildlife and the acoustic response of wildlife, and the various survey equipment used.

Our biggest problem was finding definitive data because research is at an early stage. Nevertheless, the working group has come up with a few guidelines for assessing survey risks and some mitigation strategies.



Acoustic Waters



▲ **Figure 1.** Pulsed sound produced by a single airgun showing the major features of a pulsed sound wave form.

Noise levels

In the harsh Antarctic conditions, animals on pack ice and in the sea tolerate a lot of noise and make sounds that rise above the din. Sound from wind-generated waves, sea ice and sediment movement can reach 180 decibels. Whale songs, flipper slapping and breaching (some of which is not meant to be friendly) can exceed 190 decibels. Many whales can 'sing' for long periods, with baleen whales making sounds that last 16 seconds.

The thresholds of auditory damage in marine animals are difficult to assess because, for example, how do you test the hearing of a great whale? There are differences across species and within populations and, like humans at a rock concert or a club on Saturday night, some individuals may be more tolerant of sound even when they experience hearing loss. Like the human condition, safe hearing thresholds are probably lowered with repeated exposure.

The literature suggests that auditory damage in marine animals is possible from sound levels as low as 178 decibels for sensitive species, to 224 decibels for less sensitive species.

Sound pressure

In the ocean, sound travels as vibrations of water molecules that exert push-pull pressure on objects in their paths. Sound is heard by push-pull on an animal's hearing mechanism.

Sound levels are usually expressed as decibels. Decibels are actually a ratio of the sound pressure against a standard reference pressure. The reference pressures for air and water are different, so sound levels in air and water cannot be compared directly. A sound unit in water is in decibels relative to one micropascal (dB re 1µpa). Typical Antarctic surveys have source levels of about 220 decibels, which diminish rapidly away from the source.

Another important characteristic of sound is its frequency or pitch. It is measured in cycles per second or hertz. Frequency governs what can be heard by a species. For example, baleen whales use sound with frequencies as low as 20 hertz—a low rumble to humans.

Dolphins use sound up to 24 000 hertz, which is inaudible to humans.

Most acoustic devices use pulsed sound (figure 1). Outputs vary depending on the equipment, filtering, the signal, and the environment. The figure given for the energy of the sound source depends on how the energy is measured. A pulsed sound can be measured as the pressure difference from the zero to the first sound peak or between the two major peaks. It can also be measured as the total energy or as the energy in a range of frequencies. There are also many ways of expressing the sound level, and each method produces different decibel numbers.

Sound energy is lost as it spreads. In the simplest case, sound energy from a source spreads out much like light from a torch, becoming weaker with distance, halving every time the distance doubles. In shallow water, the surface and sea-floor form boundaries that channel the sound energy in a horizontal direction. In the deep ocean, layering in the water can either increase or decrease the energy reduction.

Sound is scattered when it strikes objects in the water. These objects can be the sea-floor, the shore, the surface, bubbles, particles suspended in the water, marine life and the thermal structure of the ocean. Sound reflected from the sea-floor usually loses a lot of intensity, particularly if the bottom is soft such as mud. Not as much energy is lost when the sea-floor is rock, and in some cases the energy may refract and add to noise levels if the sound strikes hard shallow shelves.

Some acoustic energy will also be converted into heat, but how much depends on the temperature, concentration of magnesium sulphate in the seawater, and the frequency of the sound wave. High frequency sound is absorbed more rapidly than low frequency sound.

Acoustic equipment

The dominant frequency determines the impact on animal hearing. Sound sources such as airguns produce more noise in the hearing range of baleen whales than mid-frequency echo sounders, which produce more noise in the ranges used by seals and toothed whales.

Acoustic devices are designed with various beam shapes. Seismic airguns that are towed behind a ship produce a much broader, almost spherical beam compared with a hull-mounted, scientific echo sounder.

The maximum sound levels from most hull-mounted scientific echo sounders are directed vertically below the ship (figure 2). Amplitude levels emitted horizontally are typically 20 to 40 decibels lower than those emitted vertically.

Baleen whales

Baleen whales use sound extensively and in the dominant frequency of seismic surveys. Their songs can degrade the quality of seismic survey data by drowning the return signals. The passing of survey vessels generally does not silence baleen whales. Some whales even change their calling patterns in response to echo sounders. They appear to avoid seismic sources and mid-frequency echo sounders, but do not react to high frequency pingers and acoustic tags.

Whale response to sound depends on their activity at the time. Studies of humpback, bowhead and grey whales show they are less responsive when migrating or feeding than when suckling and resting. Individual reaction also varies. About 10 per cent of migrating grey whales avoided noise at 163 decibels and about 50 per cent at 173 decibels, by diverting around a sound source in their migratory path.

Studies of humpbacks along Australia's North West Shelf (when they were not migrating) show humpback cows with young calves move away at sound levels of 126–129 decibels. Some whales however swim directly towards an airgun source up to a certain stand off distance, sometimes circle it, and then swim off. Maybe the similarity of the sound level and frequency content of the airgun to a breaching event makes humpbacks inquisitive.

There are humpback whale populations on both sides of Australia. Those in the west have been exposed to intense industry seismic activity for several decades. The eastern population has not. The annual growth rate is about the same for both populations, suggesting that the seismic activity off Australia to date has not threatened humpback whales.

The closer an animal is to a loud sound source, the more likely it is to be injured. In many jurisdictions, seismic surveys are required to gradually increase gun numbers and pressures so animals can swim away before sound reaches dangerous levels. There are no studies to verify that this works, though, and it assumes that the animals will avoid the noise and swim away.

Most baleen whales breed in temperate waters to the north of Antarctica and migrate to the krill-rich summer feeding grounds in the Antarctic. Calves are older and stronger by the time their pods reach Antarctic waters. They arrive

from October to December and depart by late February. They concentrate along the retreating ice edge in spring and early summer. Later in the season they move to a 60 nautical-mile wide krill belt seaward of the continental shelf edge.

Toothed whales

Toothed whales vary in size, body shape and possibly hearing apparatus. They produce whistles, pulsed sounds and echo-location clicks. Their general sounds reach maxima of 180 decibels, and echo-location clicks reach 228 decibels.

Airguns produce enough high-frequency noise to be heard by toothed whales, even though most of the energy in airguns is in frequency ranges below their optimum hearing. Continuous pulsing from an echo sounder seems to produce less reaction than short sequences of sound pulses followed by longer pauses. Antarctic killer whales will approach and swim alongside vessels operating echo sounders.

Reaction thresholds in dolphins and porpoises can be as low as 110–140 decibels, but responses diminish with time even for levels as high as 170 decibels. Dolphins exposed to sound pressure levels of 192–201 decibels demonstrate temporary decreased sensitivity. In humans, similar but prolonged exposure would produce permanent hearing impairment.

Deep-diving sperm and beaked whales may be more vulnerable, because their physiological needs limit their avoidance options and make it hard for them to move laterally to avoid an approaching source. The well-documented cases of whale stranding involving military echo sounders and seismic equipment have mostly involved beaked whales.

In Antarctica, sperm and beaked whales are found in deep water and along the continental slope near squid, their main food source.

Penguins

Not much is known about penguin hearing, but they seem less likely to be disturbed by marine acoustic surveys than whales. Their susceptibility is probably comparable to humans.

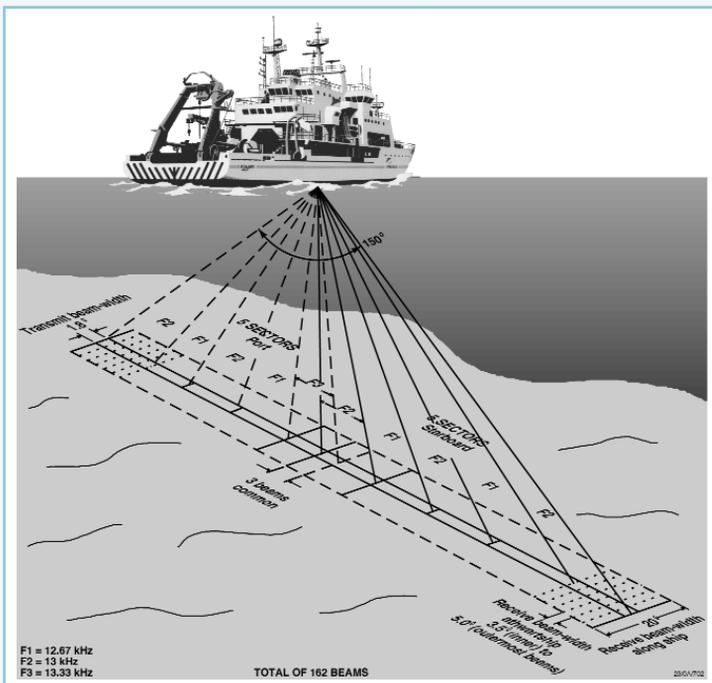


Figure 2. Beam pattern for a hull-mounted, multibeam echo sounder

It is not known whether Antarctic penguins communicate under water. But on land, they use sound extensively for mate and chick recognition. Contact calls can be heard up to a kilometre from the originating bird.

Virtually the entire Antarctic continental margin is within foraging range of penguins, with large colonies in the northern Antarctic Peninsula and western Ross Sea. Breeding birds generally arrive later and depart earlier at southerly colonies than at northerly colonies. All penguins moult annually and this typically occurs at the end of breeding season.

Seals

Seven species inhabit the Antarctic and sub-Antarctic. All are quite vocal, even under water, and their calling rates peak in spring. Weddell seals, for example, produce a variety of calls with source levels of 153–193 decibels.

Australian fur seals have colonised oil production facilities in Bass Strait, showing that seals get used to sound. They can also be quite inquisitive. Airguns have been ineffective in scaring South African fur seals away from fishing gear and, like Australian fur seals, they are often reported near operating seismic equipment and consistently damage it by biting.

From what is known about their hearing, seals are relatively insensitive to sound below one kilohertz. Ringed and Weddell seals are apparently unaffected by acoustic tags fixed to them. But there is a report of harbour and grey seals avoiding small airguns at ranges of about two kilometres. These seals returned to the area soon after shooting ended, however. The equipment with most potential risk for seals would be lower frequency echo sounders used for sub-bottom profiling.

The seals' sensitive periods are pupping, post-pupping and implantation, and when weaners leave breeding beaches to forage. Most Antarctic marine surveys take place from late December to March and so avoid the breeding seasons of pack ice seals. As well, any risk to pack ice seals from seismic surveys is reduced because seismic equipment trails behind the vessel and cannot operate easily in ice.

Food sources

Krill and fish attract predators that could be adversely affected by acoustic equipment, and there is also concern that survey tracks through swarms could cause them to separate and coalesce, making them more vulnerable to predators.

Fish can be displaced by large airgun arrays. The injury radius for eggs and juvenile fish will be a few metres around large airguns, with lethal effects at about 220 decibels. Krill will be affected in a similar way to fish eggs and juveniles. But with the low level of activity in Antarctica, the effect of acoustic surveys on krill and fish will be very small compared with fishing and predation.

Squid hearing is less sensitive than most fish, but they show alarm at about 156–161 decibels and will eject ink at about 174 decibels. Squid spawn and hatch from April to early November, which is outside the optimum weather conditions for seismic surveys in Antarctic waters. Squid also would only be killed within a few metres of individual, large airguns.

Crustaceans are thought to be insensitive to sound because they detect it through mechanoreceptors.

Survey impact

Despite the unknowns about acoustic propagation and animal hearing and behaviour, there is insufficient evidence to justify a ban on marine acoustic technology in the Antarctic. But there is also insufficient evidence to say that all equipment and surveys are safe.

Survey equipment with an output of less than 190 decibels produces sound levels similar to natural sources. Once sound levels go beyond 210 decibels, they can be above natural levels for a large area.

Mitigation

Surveys should use the minimum source level possible to achieve the required result. For powerful sources, increase the output slowly at the start of a line, because these 'ramped' starts theoretically allow animals to avoid equipment. There also should be shut-down zones around the source to minimise the exposure of animals that do not avoid the sound.

Continuous noise has more potential to disrupt animal communications than pulsed or intermittent signals. It is also more damaging to human hearing than pulsed sounds, so a similar effect is possible in animals.

Ship speed, line spacing, beam shape of the equipment, and survey duration influence the degree of impact. This is multiplied when there are several ships producing high sound levels in a region, making it hard for animals to avoid exposure.

The sea-floor and any adjacent coast can also restrict an animal's ability to avoid high source levels. There may be a choke point in the migration path, or the ship's progress may herd animals into a bathymetric restriction or an embayment in fast ice. Provide an escape route for the animals, particularly for whales that cannot haul out to avoid sounds.

Close proximity to a colony during breeding season is likely to expose more animals to a sound source, as will a survey in the path of migrating animals. Time surveys relative to important stages in annual cycles. Seals should not be disturbed when pupping and bonding, and when young begin to forage.

Even though the level of surveying in Antarctica is very low compared with many other parts of the world, the best way to avoid long-term disturbance and displacement is to minimise repeat surveying and ensure that areas are not surveyed in consecutive years. This requires the full use of SCAR's international coordination of surveys and data sharing arrangements.

Records of the locations, timing, frequency and nature of hydroacoustic activities need to be maintained to allow retrospective assessment of likely causes of any future observed changes in the distributions, abundance and productivity of Antarctic species. As well, the effectiveness of mitigation strategies needs to be investigated, and these strategies should be regularly reviewed.

Information on the survey history of the Antarctic is available from SCAR.

For more information phone Phil O'Brien on +61 2 6249 9409 or e-mail phil.obrien@ga.gov.au The draft report is available at www.geoscience.scar.org/geophysics/acoustics_1_2.pdf

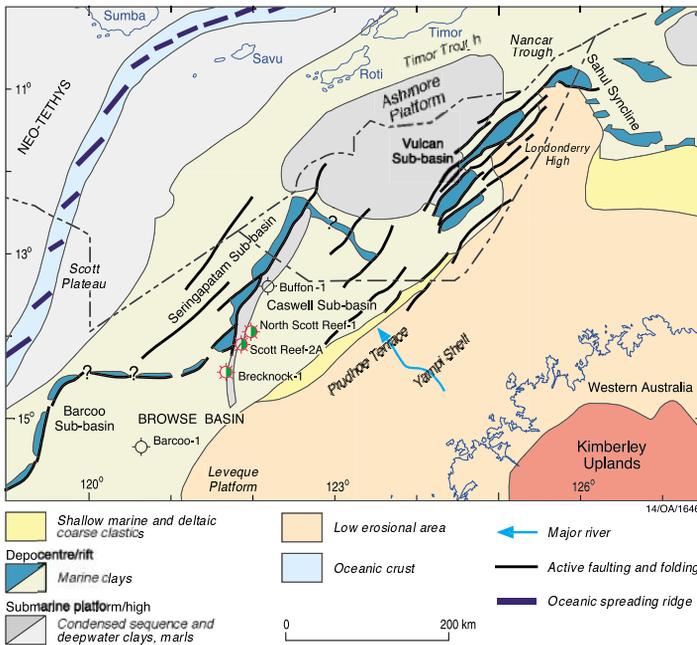


Potential *new oily sub-basin* in Browse

A forecast of declining future Australian oil production has Geoscience Australia involved in four studies to help identify new potential oil-prone sub-basins off north-western Australia. The studies suggest potential in the deepwater Browse Basin, which BHP Billiton is currently testing by drilling a well. It will be the first deepwater test in the outer Browse Basin.

Plate reconstructions

In the first study, a series of plate tectonic reconstructions and palaeogeographic maps were compiled for the entire north and north-west Australian margin. The 19 maps show the structural and tectonic evolution of the region from the Early Permian (290 million years ago) to the present-day, including the distribution and type of sedimentary rocks deposited during each 10–20 million year interval. An accompanying report documents the tectono-stratigraphic evolution of each area, and discusses the stratigraphic controls on the region's petroleum systems.



▲ **Figure 1.** Mid Oxfordian (155 Ma) plate reconstruction of the Browse and southern Bonaparte basins (modified after Norvick, 2002)

The palaeogeographic maps show the distribution of Jurassic rift basins that have sourced the major oil accumulations discovered in the region (Exmouth, Barrow and Dampier sub-basins in the Carnarvon Basin, and Vulcan Sub-basin and Sahul Syncline in the Bonaparte Basin). The palaeogeographic reconstruction for the Oxfordian (155 million years ago) shows that the oil-prone rifts of the NW-trending Sahul Syncline and NE-trending Vulcan Sub-basin most likely step westward into the deepwater Browse Basin. They form a graben complex in the Seringapatam Sub-basin, immediately outboard of the Brecknock–Scott Reef–Buffon High (figure 1).

Martin Norvick, University of Melbourne, compiled the plate reconstructions.

Transect restoration

To evaluate the structural and stratigraphic evolution of this unexplored deepwater Browse graben, Geoscience Australia's regional seismic profile across the basin has been back-stripped and structurally restored. The work indicates that the graben was filled with a thick syn-rift section of interpreted Early–Middle Jurassic and Late Jurassic–Berriasian age sediments (figure 2).

The sediments are likely to contain organic-rich rocks deposited within a restricted marine environment and are expected to be oil prone, based on similar facies within the other actively explored Jurassic rifts of the North West Australian margin. The graben also probably received an influx of coarse clastic sediments deposited within sub-marine fans that were transported across a fault-steepened slope between the Brecknock–Scott Reef–Buffon High and the Seringapatam Sub-basin. This may have allowed a favourable juxtaposition of hydrocarbon source and reservoir rocks.

The depth-converted section also shows a large Early Cretaceous inversion with several hundred metres of relief that is overlapped and draped by deepwater Valanginian–Aptian sediments. These sediments are likely to provide an effective regional seal for any hydrocarbons generated within the graben.

Kevin Hill and Nick Hoffman, University of Melbourne, carried out the structural-stratigraphic restoration work.

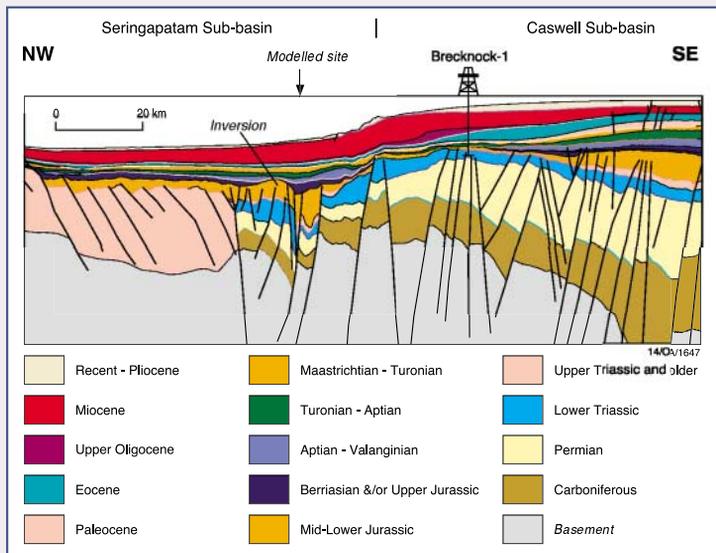


Figure 2. Cross-section based on Geoscience Australia's seismic lines 119/6 and 128/1 across the outer Browse Basin showing a thick Jurassic section in the Seringapatam Sub-basin. Note the large inversion structure of the Middle-Lower Jurassic section.

Hydrocarbon modelling

A geohistory analysis has involved assessing the geographic distribution and timing of hydrocarbon expulsion from identified source units in the Browse Basin. It incorporates a number of modelled depocentre sites derived from regional interpretations of Geoscience Australia's seismic surveys in the basin, including several sites within the Jurassic graben of the deep-water Seringapatam Sub-basin.

A maturity model for a site 35 kilometres north-west of Brecknock-1 indicates that the Upper Jurassic section straddles the immature to early mature oil zone, and that the very thick Middle-Lower Jurassic section spans the oil, wet-gas and dry-gas maturity zones (figure 3). Modelled oil expulsion from the deeper portions of the Middle-Early Jurassic section (Plover Formation equivalent) commenced at the end of the Cretaceous, and expulsion from successively shallower portions occurred in the early to mid and late Tertiary, respectively. Expulsion models for the Upper Jurassic section (Vulcan Formation equivalent) suggest no hydrocarbon expulsion, unless these sediments contain exceptionally high-quality source units at this site.

The Browse Basin geohistory analysis was undertaken in conjunction with BuryTech. Full details will be presented at the Timor Sea Petroleum Geoscience Symposium.

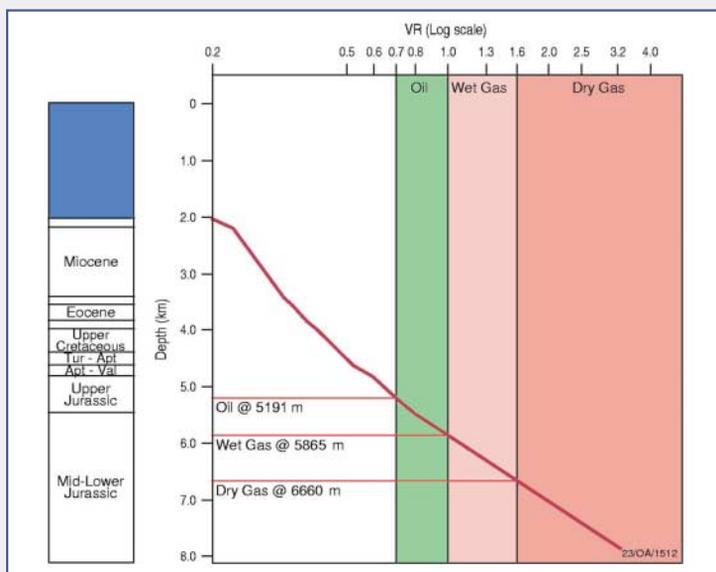


Figure 3. Modelled maturity plot for a depocentre site within the Seringapatam Sub-basin, 35 kilometres north-west of Brecknock-1

Fluid inclusion

A third study, in conjunction with CSIRO Petroleum, provides a basin-wide assessment of hydrocarbon charge history and oil migration pathways within the Browse Basin using the grains containing oil inclusion (GOI) technique. A focus of this work is looking for evidence of oil migration in wells on the Brecknock-Scott Reef-Buffon High that lies immediately inboard of the Jurassic graben identified in the adjacent Seringapatam Sub-basin. Jurassic sandstone cuttings in these wells were analysed for oil-bearing inclusions.

Elevated GOI values (1.1–1.3%) provide evidence for early oil migration prior to gas charge at the North Scott Reef-1, Scott Reef-2A and Brecknock-1 wells. No evidence of oil migration was detected by the GOI technique in Buffon-1 to the north, or Barcoo-1 to the south. The source and migration pathway of this inclusion oil has yet to be determined, but the early oil charge may have migrated from the newly identified Jurassic graben in the adjacent Seringapatam Sub-basin.

Details of the Browse Basin fluid inclusion study will be presented at the Timor Sea Petroleum Geoscience Symposium to be held in Darwin in June (see www.dbird.nt.gov.au/ntgs).

New deepwater well

The four studies provide support for a potential new oil-prone sub-basin in the deepwater Browse Basin. This potential is currently being tested by the Maginnis-1, 1A well (BHP Billiton Permit WA-302-P), the first deepwater well in the outer Browse Basin. This well and the recent deepwater Wigmore-1 well in the outer Beagle Sub-basin (Kerr McGee, Permit WA-295-P) herald a significant new phase for exploration of the deepwater North West Shelf.

For more information contact John Kennard on +61 2 6249 9204 or e-mail john.kennard@ga.gov.au

Bass well *data suggest* a Tertiary problem

Petroleum exploration in the Bass Basin began in 1965 and although 32 wells have been drilled to test the basin's potential, only the Yolla field is being considered for commercialisation*.

As part of the Western Tasmanian Regional Minerals Program, Geoscience Australia has taken a closer look at data from the drilled wells to find reasons for explorers' limited success.

An audit shows that about one-third of the wells in the basin were invalid tests. The drilling has been off-structure and poor data quality has led to geological misinterpretations.

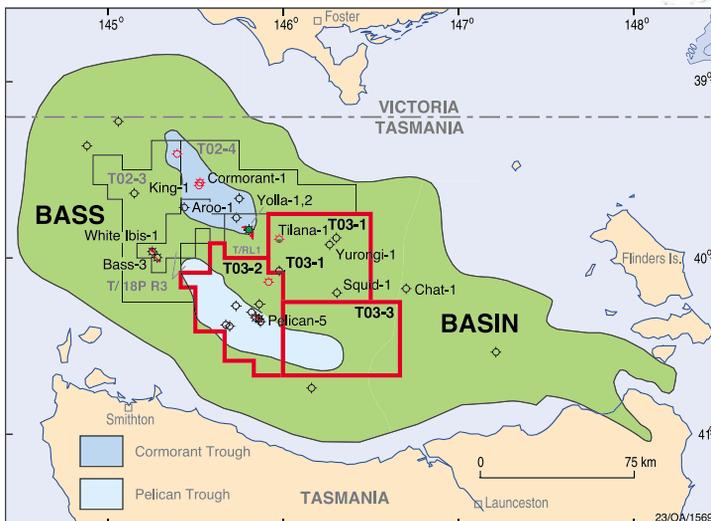
Of the remaining wells, the primary reasons for failure were lack of effective seal, timing of hydrocarbon charge, trap validity, lack of access to mature source rocks or reservoir problems.

The Bass Basin is an intra-cratonic rift basin between northern Tasmania and southern Victoria (figure 1). Hydrocarbon discoveries and shows occur in Late Paleocene to Early Eocene sandstones of the Eastern View Group. Intraformational shales seal these accumulations. Oil and gas shows also occur higher in the stratigraphic succession below the regional sealing facies of the Middle Eocene Demons Bluff shale.

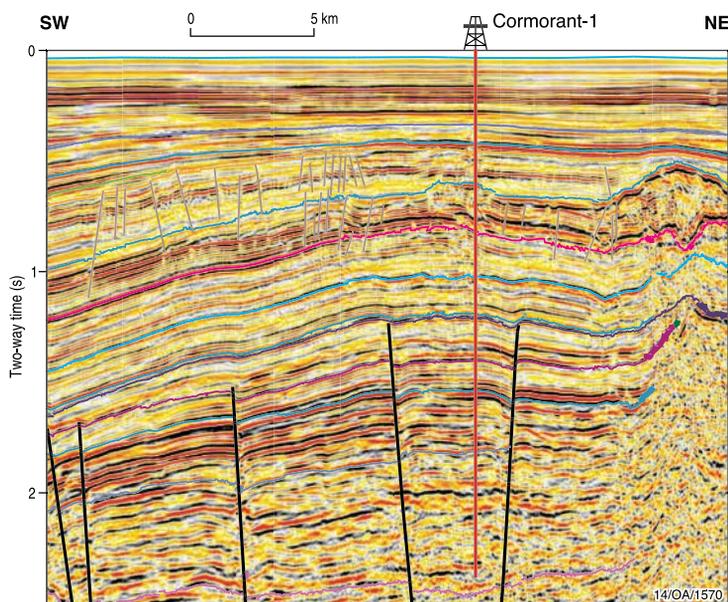
In parts of the basin, the regional seal has undergone a period of structural inversion during the late Tertiary resulting in trap and seal breach (figure 2). This process particularly affected anticlinal closures of Eocene age. Structures on fault-bounded basement highs were less affected.

Recent fluid inclusion studies by CSIRO and Geoscience Australia identified palaeo-oil zones at Yolla-1, Cormorant-1 and Bass-3 along with suspected zones at Aroo-1, King-1 and Pelican-5. Several potential palaeo-hydrocarbon zones were also identified at Yurongi-1, Chat-1, Tilana-1 and Squid-1.

The basin's pattern of hydrocarbon distribution shows that hydrocarbons were generated in the Cormorant and Pelican troughs with migration into structures within the depocentres and on the adjacent flanks. In the Yolla and White Ibis fields, access to mature source rocks was provided by large-displacement faults that linked the upper Eastern View Group reservoirs with deeper mature source rocks.



▲ **Figure 1.** Location map of the Bass Basin showing wells, fields, current permits and the 2002 and 2003 Release Areas



▲ **Figure 2.** Seismic section showing the Cormorant-1 well situated over an inversion-related anticlinal structure in the north-western Bass Basin

In part, future exploration successes in the Bass Basin will mean explorers need to find traps that were in place prior to the generation of hydrocarbons, but did not undergo significant Tertiary inversion.

The Bass Basin study is a Commonwealth and Tasmanian government initiative coordinated by Mineral Resources Tasmania. Some results of the study will be presented at the 2003 APPEA conference.

For more information phone Jane Blevin on +61 2 6249 9818 or e-mail jane.blevin@ga.gov.au

* Origin Energy-operated BassGas project

B

Australia has the potential to sequester a quarter of its annual total net carbon dioxide (CO₂) emissions, or about 100–115 million tonnes (Mt) of CO₂ a year, in underground reservoirs.



ig CAPACITY to store greenhouse gas *down under*



The Australian Petroleum Cooperative Research Centre's GEODISC program has been examining the issue of geological storage of CO₂. Within GEODISC, Geoscience Australia and the University of New South Wales recently completed an analysis of Australia's potential for the geological storage of CO₂. More than 100 sites were assessed, of which 65 are potentially Environmentally Sustainable Sites for CO₂ Injection (ESSCIs).

Worldwide case

Attempts to assess the potential for storage of CO₂ in geological formations are mostly at a regional scale or global level. The amount of detail and assessment methods vary substantially, from counting storage volume in sedimentary basins to more simplistic approaches that try to estimate the potential worldwide.

Worldwide volume assessments are often quoted as 'very large' with estimates ranging from 100s to 10 000s gigatonnes (Gt = 10⁹ tonnes) of CO₂. The huge volumes of CO₂ that can be stored geologically compared with many other sequestration methods have been relied upon to guide policy directions and decide future research proposals. However as knowledge has increased about the technical issues of geological storage of CO₂, so has the uncertainty about details used in the assessment methods.

To decide future viable injection sites, especially where capital costs range from less than \$US50 million to more than \$US1000 million, it is essential to use more sophisticated means to make storage potential assessments.

In GEODISC, the initial deterministic approaches are being closely integrated with mapping emission sources and economic modelling. The huge numbers that can be generated for storage potential are being realigned to take account of the reality of economic and geological viability.

Australian case

Estimates of storage potential and a deterministic risk assessment provide an idea of the enormous geological storage potential of CO₂ in Australia. But they do not account for various factors in CO₂ source to sink matching (emission location to storage site matching). A more realistic analysis can be derived if preferences due to CO₂ source to sink matching are incorporated, and it is assumed that some economic imperative will apply to encourage geological storage of CO₂.

Emission maps

The National Greenhouse Gas Inventory calculated that Australia's net greenhouse gas emissions for 1999, not including emissions from land clearing, were 458.2 Mt of CO₂ equivalents. Stationary energy emissions, primarily produced through electricity generation, represent 56.7 per cent of national emissions or 259.8 Mt. These stationary sources are the most likely to be considered suitable for sequestration.





GEODISC made maps of the location of all major, stationary energy emission sites, and estimated the likely supply rates of CO₂ for a 20-year period (figure 1). The emissions mapping shows that the top 35 point sources represent 90 per cent of the emissions that can be potentially sequestered (the top 50 point sources represent 96%). It also shows that the major emission sources are concentrated into nodes. The presence of nodes means it will be possible to reduce the set-up costs of establishing injection sites, provided there are viable injection sites in neighbouring regions.

Basin screening

GEODISC screened all sedimentary basins in Australia to identify where CO₂ storage might be viable. This included assessing all sedimentary basins that were adjacent to known, major emissions sources, or which might in the future require potential injection sites to store CO₂ emissions.

About 300 known sedimentary basins were screened, of which 48 were considered viable based on their geological characteristics. More than 100 sites within these basins were examined, resulting in the identification of 65 potential ESSCIs.

Storage efficiency

Total pore volume assessments (i.e. space in rock that can hold CO₂) were calculated for each site based on their reservoir conditions, as well as their possible CO₂ capacity. This required making a preliminary assumption (although incorrect) that 100 per cent of the pore volume could be filled with CO₂.

The total pore volume for the 65 ESSCIs was 7 x 10¹² cubic metres, or a potential CO₂ storage capacity of 3.9 x 10¹² tonnes. This estimate makes no adjustment for the storage efficiency of CO₂ in the pore space.

Storage efficiency varies with each ESSCI because of different trap types (geological structure that can store CO₂) and geological characteristics.

A detailed reservoir model is needed to accurately assess a site's storage efficiency. Continuing research in the GEODISC program aims to model the most likely sites for future storage of CO₂.

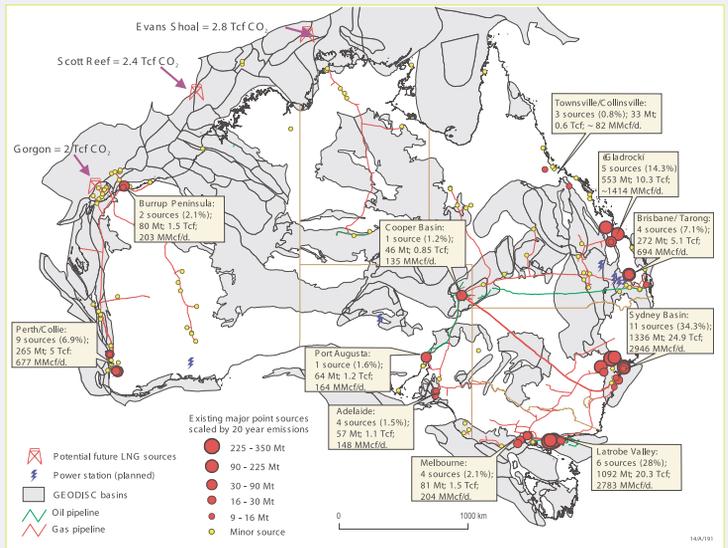


Figure 1. Major CO₂ point sources and percentage of total emissions estimated for a 20-year period. Volume of CO₂ for each node of point sources is shown in million tonnes (Mt) and in trillion cubic feet (Tcf). Expected emission rates are in million cubic feet per day (MMcfd).

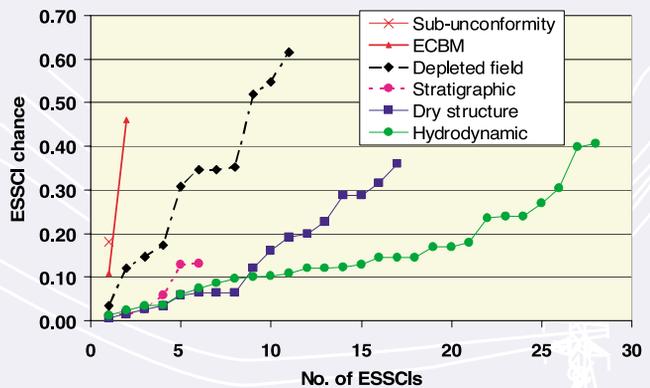


Figure 2. Graph showing the ESSCI chance (product of risk factors) plotted against the number of ESSCIs for different ESSCI types.

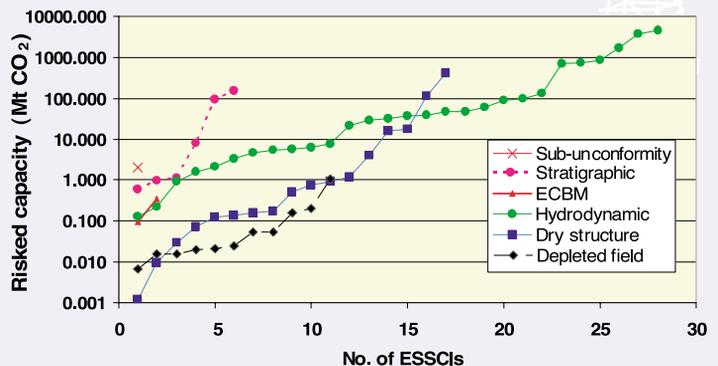


Figure 3. Graph showing the ESSCI capacity (ESSCI chance multiplied by total pore volume) plotted against the number of ESSCIs for different ESSCI types.