# 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.

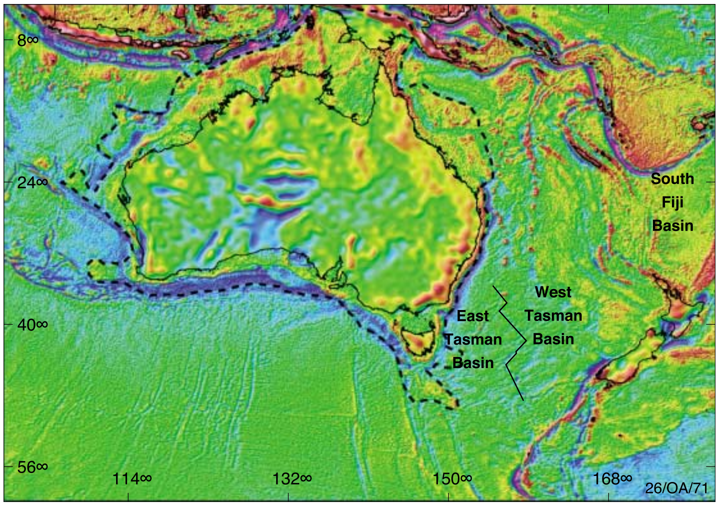


**Figure 1a.** Satellite-derived, free-air gravity (Smith WHF & Sandwell DT. 1997. Global seafloor topography from satellite altimetry and ship-depth soundings. Science, Sep 26; 277:1956–1962.)

## 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.

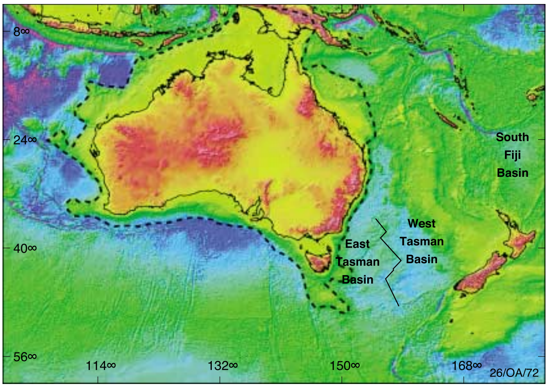


**Figure 1b.** Satellite-derived topography/bathymetry (Smith & Sandwell, 1997)

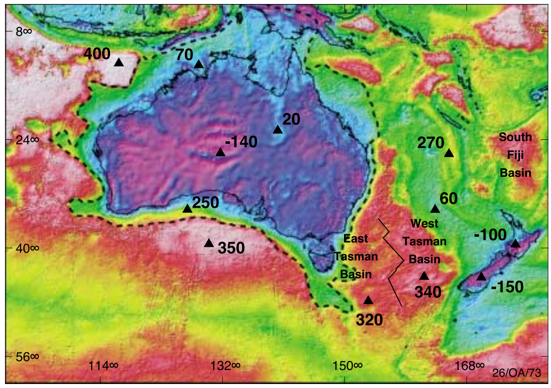


**Figure 1c.** (top right) Bouguer anomaly gravity computed from the data presented in figures 1a and 1b at reduction density 2.67 g/cm$^3$. The dashed line is the continent–ocean boundary defined on the basis of the bathymetry. Gravity values at selected locations (triangles) in milligals

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.

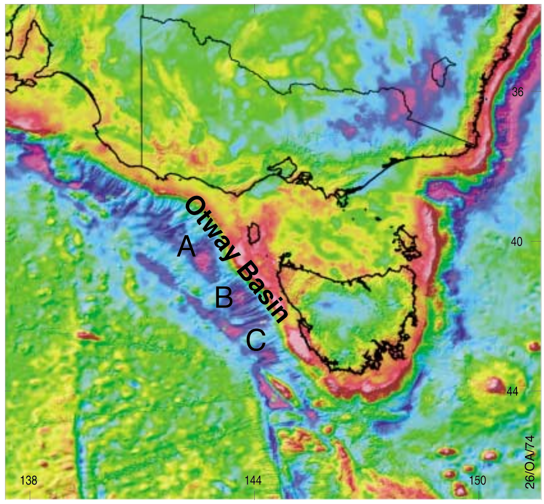


**Figure 2.** Composite image of the Bouguer gravity onshore and free-air gravity offshore draped over topography/bathymetry for south-eastern Australia

### *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**

# AROUND the divisions

## 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