



Integrated assessment of the Capel and Faust basins, offshore eastern Australia

New insights into the prospectivity of remote frontier basins

Takehiko (Riko) Hashimoto, Nadege Rollet, Karen Higgins, Peter Petkovic, Ron Hackney and Geoff Fraser

A recent assessment carried out by Geoscience Australia has provided new insights into the geological evolution and petroleum prospectivity of the Capel and Faust basins. These remote deepwater basins, located about 800 kilometres off the east coast of Australia in water depths of 1300 to 2500 metres (figure 1), have previously seen little scientific or petroleum exploration effort. This assessment was carried out under the Australian Government's Offshore Energy Security Program as part of Geoscience Australia's continuing efforts to identify a new offshore petroleum province and deliver pre-competitive geoscience information (*AusGeo News* 84).

“The analysis of geological relationships from the basement through the basin sediments to the seafloor was facilitated by 3D visualisation and geological modelling.”

Regional setting

The Capel and Faust basins are located within a large continental fragment that extends about 1600 kilometres from the southwest of New Caledonia to the Bellona Trough west of New Zealand (figure 1). Most of this fragment is located within the limits of the Australian Exclusive Economic Zone and Extended Continental Shelf as defined by the United Nations Convention on the Law of the Sea (UNCLOS).

Previous work in the region (including Willcox et al 2001; Staggs et al 2002; Willcox & Sayers 2002; van de Beuque et al 2003) was based mainly on a sparse coverage of 2D regional seismic data. This data included acquisitions by the Shell RV *Petrel* (1971) survey and the Australian Geological Survey Organisation (AGSO) surveys s177 (1996) and s206 (1998). The only well in the Capel and Faust basins is the Deep Sea Drilling Program (DSDP) drill-hole 208 (figure 1), which terminated at 594 metres below the seabed in Late Maastrichtian nannofossil chalk. There are no petroleum exploration wells in the area.



These early surveys indicated the existence of multiple large sedimentary depocentres in the region. Tectonic reconstructions (such as Norvick et al 2001, 2008; Willcox et al 2001) suggested that these basins were formed initially during the Early Cretaceous rifting of the former eastern Gondwana margin. This was followed by further rifting during the Late Cretaceous leading up to the opening of the Tasman Sea (Hayes and Ringis 1973; Gaina et al 1998). As such, the basins shared a common origin with other Cretaceous eastern Gondwanan basins, including some that are petroleum producers such as the Gippsland and Taranaki basins. However, the lack of seismic imaging and well control in the deeper sections of the basins precluded an assessment of the total sediment thickness. This is a key determinant of the region's petroleum prospectivity.

Data acquisition

To fill some of the data gaps, Geoscience Australia completed a series of marine surveys over the Capel and Faust basins during 2006 and 2007 (figure 1). The joint French–Australian

AUSFAIR survey in 2006 used the French Polar Institute (IPEV) vessel RV *Marion Dufresne*. The AUSFAIR survey collected shallow sediment cores to test for indications of gas hydrate deposits, and obtained rock samples to investigate the solid geology of the Capel, Faust, Fairway and New Caledonia basins (Colwell et al 2006). The survey did not yield conclusive evidence for gas hydrates. However it resulted in the recovery of volcanic and volcanoclastic rock samples that have provided invaluable information on the timing of deposition and geological setting.

The Capel–Faust GA-302 survey in 2006–2007 acquired approximately 6 000 kilometres of high-quality 2D seismic data along 23 lines with a typical spacing between 15 and 35 kilometres (*AusGeo News* 86). This survey filled a significant seismic data gap in an area where the occurrence of large sedimentary depocentres was indicated on regional satellite gravity imagery and the few existing seismic lines (Kroh et al 2007). Data were recorded to 12 seconds two-way time (TWT) which enabled, for the first time, the imaging of the entire thickness of the basin sediments. The survey also acquired shiptrack gravity, magnetic and sonobuoy refraction data.

In late 2007, the GA-2436 survey, using the New Zealand vessel RV *Tangaroa*, acquired approximately 24 000 square kilometres of multibeam bathymetry and 11 000 line kilometres of shipboard gravity and magnetic data with a line spacing of three to four kilometres over the central part of the Capel and Faust basins (*AusGeo News* 89). The survey improved geophysical data coverage over the largest basin depocentres imaged by the GA-302 seismic survey. Sediment and rock samples as well as video footage were also collected as part of a joint marine reconnaissance survey mapping seabed environments and habitats (Heap et al 2009).

Assessment methodology

The key datasets for the geological and petroleum prospectivity assessment included 2D seismic reflection, seismic refraction (sonobuoy), gravity, magnetic, multibeam bathymetry and rock sample data. Given the sparse data coverage of the Capel and Faust basins and the lack of geological constraints (to help a better understanding) an integrated workflow was developed to maximise information output from the available data sets.

The analysis of geological relationships from the basement through the basin sediments to the seafloor was facilitated by 3D visualisation and geological

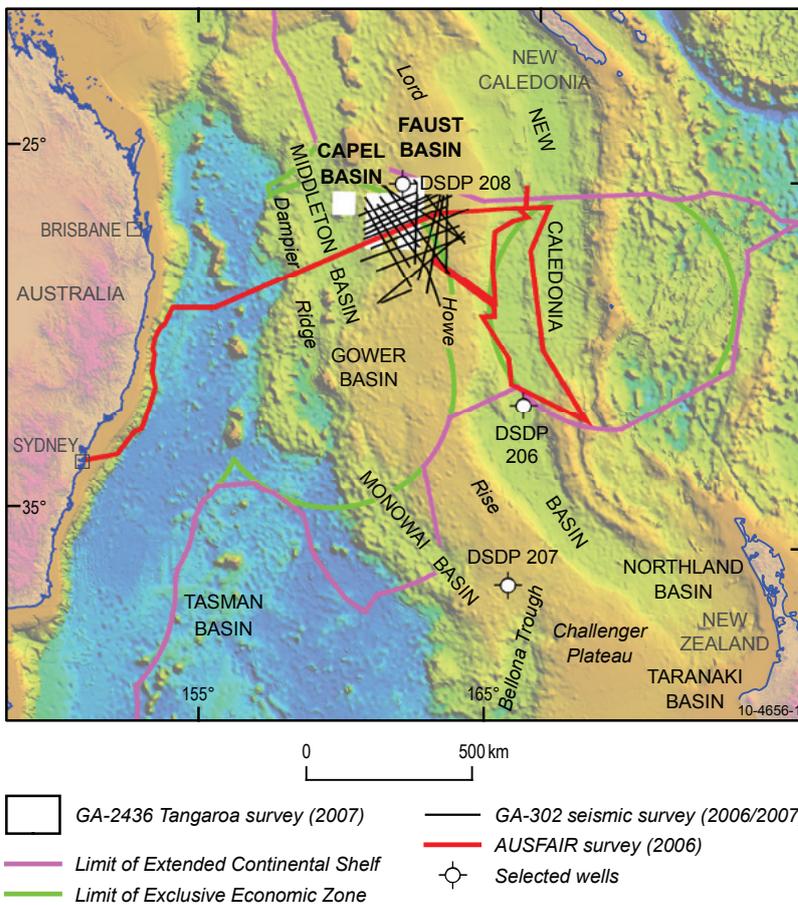


Figure 1. Location of the Capel and Faust basins, recent Geoscience Australia data acquisition surveys, DSDP drill holes and maritime boundaries.

modelling. In particular, the use of 3D analytical space assisted interpolation between the widely spaced seismic lines and in testing hypotheses regarding the complex basin architecture. Gravity data was found to be a reliable indicator of basement topography within the study area. Using this relationship, the sediment thickness distribution as interpreted from seismic data was tested by 3D gravity modelling. This provided a quality-control mechanism for the seismic interpretations.

In the absence of direct evidence, regional tectonic reconstructions and analogue basin studies were integrated with seismic interpretations. These were used to infer the composition and age of the basin sediments and the basement as well as the likely presence of petroleum system elements. Multibeam bathymetry and seismic data were integrated to map seafloor geology and fluid migration pathways. This provided an indication of seal integrity and the relationship between seafloor features and subsurface geological processes. Basin modelling, which was carried out in collaboration with GNS Science (Geoscience Australia's New Zealand equivalent), tested for the hydrocarbon generation and expulsion potential of the basins.

Basin structure and stratigraphy

The study has confirmed the existence of several large basin depocentres (or areas of thick sediments) within the Capel Basin and the western part of the Faust Basin, some of which measure up to 125 kilometres by 35 kilometres. The basin structure is complex, featuring a series of fault-bounded depocentres separated by basement highs (figure 2). The total thickness of sediment filling the depocentres increases westward, attaining a maximum of over six kilometres in the western part of the Capel Basin.

Seismic, gravity and magnetic data indicate a heterogeneous pre-rift basement underlying the Capel and Faust basins, including sedimentary, volcanic and intrusive rocks (figure 3). Regional tectonic reconstructions suggest that the sedimentary rocks may include the offshore extensions of the Mesozoic Clarence-Moreton and/or Maryborough basins of eastern Australia, both of which are known to contain potential petroleum source rocks.

The depocentres of the Capel and Faust basins evolved through two phases of rifting during the Early and the Late Cretaceous. Gravity, magnetic and fault modelling data suggest that a pre-existing NW–SE structural trend within the basement interacted with an E–W extensional vector to initially form NNE–SSW trending depocentres during the Early Cretaceous. This phase (Syn-rift 1) is likely to be part of a regional volcanic rifting event that affected much of the former eastern Gondwana margin during the Early Cretaceous. It resulted in widespread volcanoclastic deposition, such

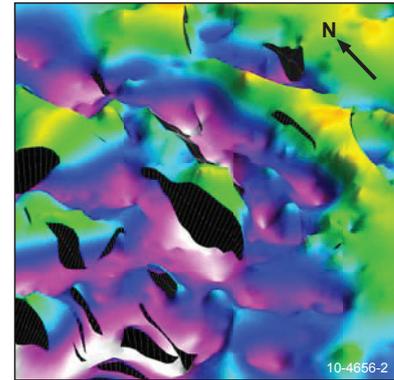


Figure 2. 3D geological model of the basement surface beneath the Capel and Faust basins, showing the compartmentalised, fault-bounded depocentres. The areas shown in violet to white colours indicate the depocentres while areas in yellow to green colours show the surrounding structural highs. The depocentres in the middle section are approximately 120 kilometres long.

as the Grahams Creek Formation in the Maryborough Basin (Hill 1994), Strzelecki Group in the Gippsland Basin and Eumeralla Supersequence in the Otway Basin (Norvick et al 2001, 2008; Krassay et al 2004). Seismic character and analogue basin studies suggest that widespread volcanics, volcanoclastic and fluvial sediments, localised coal and lacustrine sediments, were probably deposited in the Capel and Faust basins (figure 3). Syn-rift 1 deposition ended with regional uplift and erosion, probably correlating with a similar Cenomanian event in eastern Australia, attributable to a major reorganisation of the Australia–Pacific plate boundary (Veevers 2000; Norvick et al 2001, 2008; Willcox et al 2001; Schellart et al 2006; Rey & Müller 2010).

The second rifting event (Syn-rift 2) during the Late

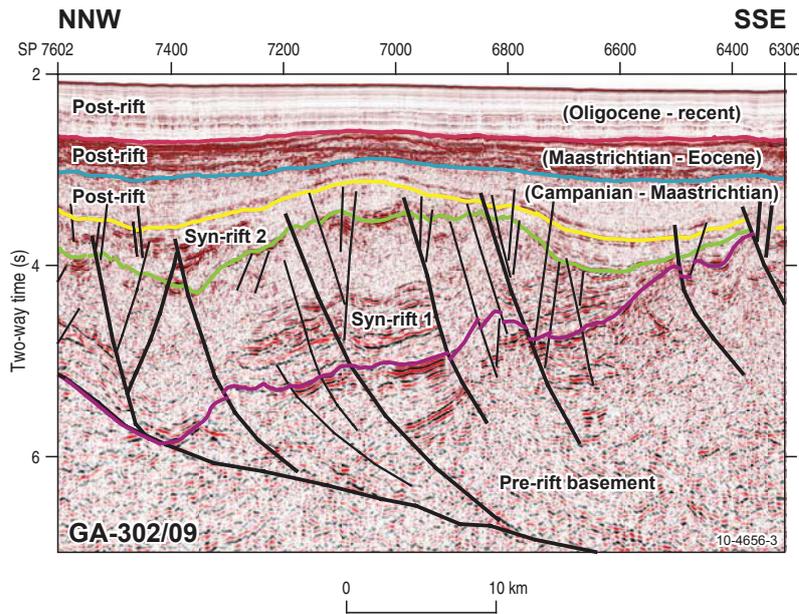


Figure 3. Seismic stratigraphy of the Capel and Faust basins.

Cretaceous appears to be related to the opening of the Tasman Sea to the west (Hayes and Ringis 1973; Gaina et al 1998). In the Capel and Faust basins, rifting was focused in the westernmost areas, where the earlier formed NNE–SSW rifts were overprinted by NW–SE trending depocentres. Sediments deposited during this phase are likely to be predominantly fluvial, with deltaic, shoreline and shallow marine sediments in the uppermost part of the succession (figure 3). It is likely to correlate with the Emperor and Golden Beach subgroups of the Gippsland Basin (Bernecker & Partridge 2001; Bernecker et al 2001; Norvick et al 2001), and the Taniwha and Rakopi formations of the Taranaki Basin (King & Thrasher 1996; Norvick et al 2001, 2008; Uruski & Baillie 2004). Volcanism appears to have been common during the Syn-rift 2 phase. Ion microprobe (SHRIMP) dating of trachyte and latite samples recovered during the AUSFAIR survey (Colwell et al 2006; Purvis & Pontifex 2006) to the southeast of the Faust Basin yielded Late Cretaceous ages. Rhyolite from the DSDP 207 drilling site on the southern Lord Howe Rise was previously dated at around 94 million years (van der Lingen 1973).

Thermal subsidence of the region from the Late Cretaceous to the present resulted in marine deposition under progressively deepwater conditions. In the earlier part of this post-rift phase (figure 3), shallow to deep marine clastic sediments were deposited. Seismic data have revealed features that may be deltaic, shoreline and turbidite sand bodies. Since the Late Maastrichtian, deep marine conditions have dominated, resulting in the deposition of chalk, marl and calcareous ooze. The lateral continuity and thickness make these fine-grained sediments a potential regional seal for petroleum traps. Cenozoic

igneous activity, fluid migration and tectonism have extensively affected the post-rift sediments, as discussed below.

Seafloor and shallow sub-surface geology

The high-resolution multibeam bathymetry data acquired during the GA-2436 survey has revealed a variety of seafloor features over the Capel and Faust basins, including mega-pockmarks, slumps, polyforms, domes and volcanoes. Integrated analysis of bathymetry and seismic data has revealed that the occurrence of seafloor features is strongly controlled by the basin structure and subsurface processes originating within the basins. Many seafloor features are related to fluid flow from the subsurface. They are commonly underlain by older, buried fluid migration features such as mud volcanoes and polygonal faults and by deeper igneous intrusions. Other seafloor features are related to post-intrusion subsidence and fault reactivation associated with the collapse of magma chambers in the subsurface.

Volcanic build-ups and intrusions, evident at the seafloor and revealed in the subsurface on seismic data, indicate widespread post-rift igneous activity during the Maastrichtian–Paleocene/Eocene, the Late Oligocene–Miocene and the Pliocene. The close spatial association between igneous intrusions and fluid-migration features indicates that these Cenozoic igneous pulses



were the major driver of fluid migration. Consequently they drove the development of most seafloor and fluid migration features in the Capel and Faust basins. The occurrence of expulsion-related features at the present-day seafloor, several million years after the last major igneous pulse, suggests that fluid migration is an ongoing process that continues to affect basin evolution long after the cessation of igneous activity.

Petroleum prospectivity

The main type of potential petroleum source rocks expected in the Capel and Faust basins are coaly sediments that may be present in the pre-rift and the Early Cretaceous syn-rift successions. Lacustrine sediments may also be significant as potential source rocks. Multi-1D basin modelling, carried out in collaboration with GNS Science, has indicated that these rocks would be capable of generating and expelling oil and gas. These results have alleviated long-held concerns that sediment thicknesses in the depocentres were insufficient for active petroleum systems. Potential reservoir rocks may be found in fluvial sandstones within the syn-rift succession and the deltaic, shoreline and shallow marine sandstones in the upper syn-rift and lower post-rift successions. The upper post-rift deep marine sediments may act as a regional seal. Expected major trapping styles include fault-related plays, stratigraphic pinch-outs, unconformity plays, and drape and anticlinal structures. 3D geological modelling indicates the existence of several large potential anticlinal structures with likely four-way closure. Much of the petroleum generation and migration is expected to have occurred before most trapping structures and the potential regional seal were in place by the Oligocene. However, a significant amount of generation is also likely after this time. Cenozoic igneous activity, if sufficiently extensive, has been shown to potentially have a positive effect on late-stage petroleum generation. On the other hand, the widespread fluid migration triggered by the Cenozoic magmatism is a major risk for seal integrity of the upper post-rift sediments.

Implications

The recent assessment by Geoscience Australia has significantly advanced current knowledge of the Capel and Faust basins and regional tectonic evolution. The study has also indicated that, if source rocks are present, these remote offshore basins may contain petroleum systems that are capable of generating and accumulating oil and/or gas. These findings will guide future scientific and resource exploration in the vast frontier region to the east of continental Australia and assist in reducing exploration risk.

For more information

phone Riko Hashimoto on
+61 2 6249 9141

email riko.hashimoto@ga.gov.au

References

- Bernecker T & Partridge AD. 2001. Emperor and Golden Beach Subgroups: the onset of Late Cretaceous sedimentation in the Gippsland Basin. In: Hill KC & Bernecker T (eds), Eastern Australasian Basins Symposium: a refocused energy perspective for the future. Petroleum Exploration Society of Australia Special Publication 391–402.
- Bernecker T, Woollands MA, Wong D, Moore DH & Smith MA. 2001. Hydrocarbon prospectivity of the deep water Gippsland Basin, Victoria, Australia. *APPEA Journal* 41: 91–113.
- Colwell J, Foucher J-P, Logan G & Balut Y. 2006. Partie 2, Programme AUSFAIR (Australia–Fairway basin bathymetry and sampling survey) Cruise Report. In: Les rapports de campagnes à la mer, MD 153/AUSFAIR–ZoNéCo 12 and VT 82/GAB on board R/V Marion Dufresne. Institut Polaire Français Paul Emile Victor, Réf: OCE/2006/05.
- Gaina C, Müller DR, Royer J-Y, Stock J, Hardebeck J & Symonds P. 1998. The tectonic history of the Tasman Sea: a puzzle with 13 pieces. *Journal of Geophysical Research* 103(B6): 12413–12433.
- Hayes DE & Ringis J. 1973. Seafloor spreading in the Tasman Sea. *Nature* 243: 454–458.
- Heap AD & others. 2009. Seabed environments and subsurface geology of the Capel and Faust basins and Gifford Guyot, eastern Australia: Geoscience Australia survey TAN0713 post-survey report. Geoscience Australia Record 2009/22.
- Hill PJ. 1994. Geology and geophysics of the offshore Maryborough, Capricorn and



northern Tasman Basins: results of AGSO Survey 91. Australian Geological Survey Organisation Record 1994/1.

King PR & Thrasher GP. 1996. Cretaceous–Cenozoic geology and petroleum systems of the Taranaki Basin, New Zealand. Institute of Geological & Nuclear Sciences Monograph 13.

Kroh F, Morse MP & Hashimoto T. 2007. New data on the Capel and Faust basins. Preview 130: 22–24.

Krassay AA, Cathro DL & Ryan DJ. 2004. A regional tectonostratigraphic framework for the Otway Basin. In: Boulton PJ, Johns DR & Lang SC (eds), Eastern Australasian Basins Symposium II. Petroleum Exploration Society of Australia Special Publication, 97–116.

Norvick MS, Langford RP, Rollet N, Hashimoto T, Earl KL & Morse MP. 2008. New insights into the evolution of the Lord Howe Rise (Capel and Faust basins), offshore eastern Australia, from terrane and geophysical data analysis. In: Blevin JE, Bradshaw BE & Uruski C (eds), Eastern Australasian Basins Symposium III: Energy security for the 21st century. Petroleum Exploration Society of Australia Special Publication, 291–310.

Norvick MS, Smith MA & Power MR. 2001. The plate tectonic evolution of eastern Australasia guided by the stratigraphy of the Gippsland Basin. In: Hill KC & Bernecker T (eds), Eastern Australasian Basins Symposium: a refocused energy perspective for the future. Petroleum Exploration Society of Australia Special Publication, 15–24.

Purvis AC & Pontifex IR. 2006. Mineralogical Report No. 8881. Pontifex & Associates Pty Ltd.

Rey PF & Müller RD. 2010. Fragmentation of active continental plate margins owing to the buoyancy of the mantle wedge. *Nature Geoscience* NGE0825, DOI:10.1038.

Schellart WP, Lister GS & Toy VG. 2006. A Late Cretaceous and Cenozoic reconstruction of the Southwest Pacific region: tectonics controlled by subduction and slab rollback processes. *Earth-Science Reviews* 76: 191–233.

Stagg HMJ, Alcock MB, Borissova I & Moore AMG. 2002. Geological framework of the southern Lord Howe Rise and adjacent areas. *Geoscience Australia Record* 2002/25.

Uruski C and Baillie P. 2004. Petroleum potential of New Zealand's deepwater basins. In: Hill KC & Bernecker T (eds), Eastern Australasian Basins Symposium: a refocused energy perspective for the future. Petroleum Exploration Society of Australia Special Publication, 151–158.

Van de Beuque S, Stagg HMJ, Sayers J, Willcox JB & Symonds PA. 2003. Geological framework of the northern Lord Howe Rise and adjacent areas. *Geoscience Australia Record* 2003/01.

Van der Lingen GJ. 1973. Correlation of seismic reflectors. In: Burns RE, Andrews JE & Shipboard Party (eds), Initial Reports of the Deep Sea Drilling Project, 21: 523–539.

Veevers JJ. 2000. Billion-year Earth History of Australia and Neighbours in Gondwanaland. GEMOC Press, Macquarie University.

Willcox JB & Sayers J. 2002. Geological framework of the central Lord Howe Rise (Gower Basin) region. *Geoscience Australia Record* 2002/11.

Willcox JB, Sayers J, Stagg HMJ & van de Beuque S. 2001. Geological framework of the Lord Howe Rise and adjacent oceanic basins. In: Hill KC & Bernecker T (eds), Eastern Australasian Basins Symposium: a refocused energy perspective for the future. Petroleum Exploration Society of Australia Special Publication, 211–225.

Related websites/articles

AusGeo News 84: Extra \$75 m for offshore work

www.ga.gov.au/ausgeonews/ausgeonews200612/offshore.jsp

AusGeo News 86: Promising results from Capel and Faust basins seismic survey

www.ga.gov.au/ausgeonews/ausgeonews200706/seismic.jsp

AusGeo News 89: Survey of eastern frontier basins completed

www.ga.gov.au/ausgeonews/ausgeonews200803/survey.jsp