AUSGEO news ISSUE 81 March 2006

Australian Government
Geoscience Australia

The northern Arafura Basin

—a shallow water frontier

New research, along with previous exploration data, provides strong evidence for an active Palaeozoic petroleum system in this underexplored potential hydrocarbon province.

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The Australian Government's 2003-04 Budget included $25 million to assist the petroleum exploration industry in the search for a new oil province by generating new geoscience data in offshore frontier areas and preserving Australia's seismic data archive. As part of this Big New Oil Program, Geoscience Australia is undertaking a program of seismic acquisition, geological sampling and oil seep detection studies in a number of Australia's frontier basins, including the Arafura.

Geoscience Australia, in consultation with Industry, identified the northern Arafura Basin as a promising shallow-water frontier and has recently undertaken a regional geological framework study and a seepage survey (figure 1). Together with previously published results and data, these studies suggest that the undrilled northern part of the basin has favourable conditions for the preservation of hydrocarbon accumulations, despite many risk factors.

Arafura Basin framework study

The goal of the framework study was to investigate the region's geology, which will underpin future petroleum exploration. This involved a comprehensive review and interpretation of all available existing well and seismic data. Outcomes of this new work will be published in two new Geoscience Australia records:

- 'New datasets for the Arafura Basin' is a compilation of a range of analyses by Geoscience Australia and collaborating agencies, and includes the results of new geochemical, organic-petrological, biostratigraphic and geohistory studies.
- 'Petroleum geology of the Arafura Basin' presents the interpretive results of the framework study, focusing on our new understanding of the evolution of the Arafura Basin and its petroleum potential.

Both will be available in mid-2006. In addition, the recently published audit of wells in the Arafura Basin (GA Record 2006/02) analyses petroleum exploration drilling in the basin to date, and summarises the available information on petroleum systems in the basin.

Arafura seepage survey

The Arafura seepage survey was conducted by Geoscience Australia in collaboration with the National Oceans Office in April and May 2005. This survey was part of Geoscience Australia's Seeps & Signatures project, which was initiated to identify and characterise features and signals of natural hydrocarbon seepage by integrating remote sensing and seabed and underlying geology with sampling and analytical programs (figure 1).

The survey collected a variety of acoustic datasets (multibeam swath, echo sounder, side-scan sonar, sub-bottom profiles, seismic) and included an extensive sampling program of sediments, rocks, biological material, conductivity–temperature–depth (CTD) profiles, and video imagery. The acoustic dataset was used during the survey to map out appropriate sites for sampling using dredges, gravity cores, benthic sleds and sediment grabs.

The survey collected over half a terabyte of digital data, over 100 cores, 90 grabs and 50 camera deployments. Details of the survey, with initial interpretations of selected datasets, are presented in a post-survey report to be available in mid-2006.

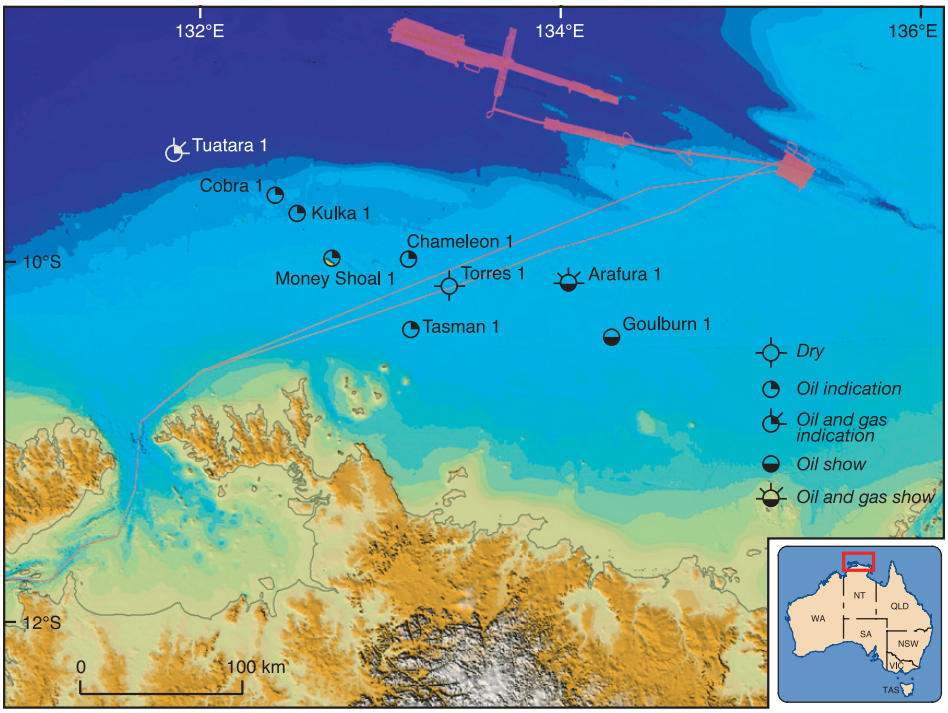
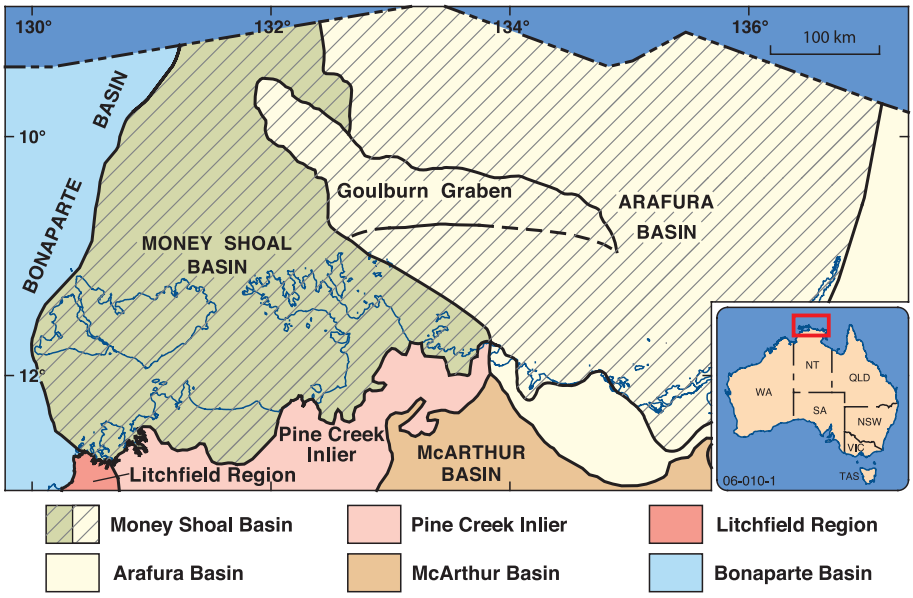


Figure 1. Location map of study area and seepage survey tracks. Wells drilled previously in the Arafura region are shown.

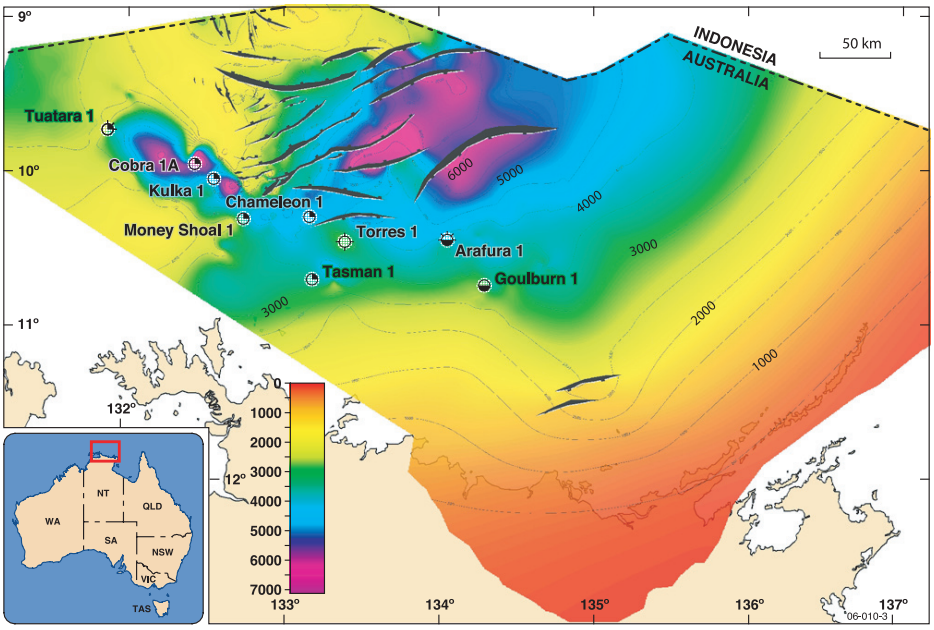
Arafura Basin geology

The Arafura Basin is a Neoproterozoic to Palaeozoic basin, extending in shallow waters (< 220 m) from onshore northern Australia into Indonesian waters. It is in a structurally complex region with an underlying Proterozoic basin (the McArthur Basin) and an overlying Mesozoic to Recent basin (the Money Shoal Basin; figure 2).

The structure of the Arafura Basin is dominated by the northwest-trending, highly deformed Goulburn Graben. All exploration drilling in the basin has been restricted to this area, where large structures combined with a thick sedimentary section (up to about 10 kilometres of Arafura Basin sediments) provided exploration targets. Geoscience Australia's study has revealed that the area to the north and east of the Goulburn Graben (the 'Northern Platform') also contains thick sediments (figure 3), but is less deformed. This area offers a wide range of different play types for exploration.



▲ **Figure 2.** Regional setting of the Arafura, McArthur and Money Shoal basins.



◀ **Figure 3.** Sediment thickness map (in milliseconds two-way time) of the Arafura region, showing well locations in the Goulburn Graben and the distribution of Neoproterozoic faults.

Goulburn Graben prospectivity

Exploration in the Goulburn Graben began in the early 1970s, with the drilling of Money Shoal-1. Since then, there have been two other main periods of exploration—the early 1980s, and late 1980s to early 1990s—with a total of nine wells drilled to date (figure 1). A recent audit of wells by Geoscience Australia (GA Record 2006/02) attributed the lack of commercial success in the Goulburn Graben to a combination of poor-quality reservoirs and/or restricted fluid movement, hydrocarbon charge, timing of events and breach of structure.

Despite these exploration risks, hydrocarbon generation and migration in the Goulburn Graben is evidenced by oil and gas shows at Arafura-1 (figure 4) and an oil show at Goulburn-1. These shows have been linked geochemically to a potential Cambrian source rock. Other potential source rocks are present throughout the Palaeozoic and Mesozoic succession. Palaeozoic reservoirs intersected in the Goulburn Graben area are generally of poor quality, but may improve laterally with changes in sediment facies and secondary porosity development. Irrespective of this, the overlying Mesozoic sediments of the Money Shoal Basin contain high-quality reservoirs that are well placed to receive charge from Palaeozoic source rocks. Both the Arafura and Money Shoal basins contain a number of potential seals. The Bathurst Island group forms a laterally and vertically extensive regional seal and generally overlies the high-quality Mesozoic reservoirs.

Many of the petroleum system elements recognised in the Goulburn Graben are likely to be present in the undrilled northern region of the basin.

Northern Arafura Basin prospectivity

The northern part of the Arafura Basin is characterised by a series of large Neoproterozoic half grabens, bounded by generally northeast-trending planar normal faults (figure 3). The overlying Palaeozoic section seems structurally conformable, despite the long hiatuses indicated by unconformities at the base of the Cambrian, Devonian and Carboniferous–Permian sections (figure 5). Compared with the Goulburn Grabens, which was the focus of extensional tectonism in the Late Carboniferous – Early Permian and was subsequently highly deformed during a mid-Late Triassic compressional episode, the Northern Platform has undergone only minor deformation (figure 5). Mild reactivation of the Neoproterozoic faults during Triassic compression resulted in the formation of both small and large-scale inversion anticlines and uplift of the basin margins. As a result, many of the risk factors for the accumulation of hydrocarbons identified in the Goulburn Graben are reduced in this region. Trap breach and reservoir degradation in the Goulburn Graben is largely associated with the Triassic structuring and erosion event. There, erosion of up to 3.5 kilometres of Palaeozoic sediments breached early formed traps, and hydrothermal alteration reduced reservoir quality. However, in the northern part of the basin, early formed traps are likely to have remained intact, negating trap breach and timing issues, and reservoir quality is probably much higher, with less hydrothermal alteration and shallower burial.

Recent geohistory studies by Geoscience Australia model hydrocarbon generation and expulsion; it was not limited to the Palaeozoic era, but also occurred in the Late Cretaceous to Cenozoic. This implies that traps in the region may have accumulated oil and gas at various stages of basin development.

Evidence that hydrocarbon generation and expulsion have occurred in the northern Arafura Basin is provided by Infoterra's 2003 Global Seeps study of the region, which suggests the possible presence of oil seeps. Additionally, bright amplitudes imaged by seismic data at various stratigraphic levels may indicate hydrocarbons in the section (figure 6).

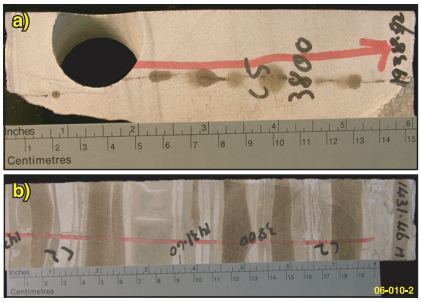


Figure 4. Evidence for oil generation at Arafura-1: oil staining in Ordovician (a) and Devonian (b) rocks.

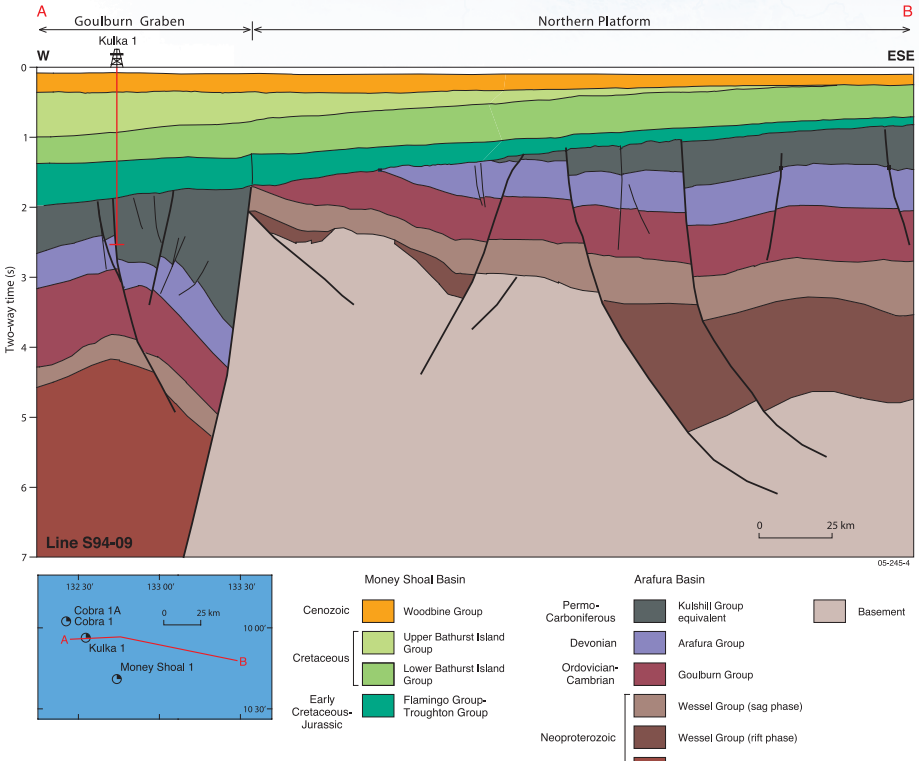


Figure 5. Regional cross-section from the Goulburn Graben (Kulka-1) to the Northern Platform.

Initial results from interpretation of a range of geophysical attributes within the sub-bottom profile data (collected during Geoscience Australia's seepage survey) and deep seismic data show a range of features that are indicative of the presence of hydrocarbons in the northern and northeastern basin. For example, high amplitudes near the tips of Cenozoic reactivation faults that affected Palaeozoic strata correspond to low frequencies in seismic data and nearby synthetic aperture radar (SAR) anomalies. Numerous enhanced reflectors with reversed polarity and low frequency indicative of shallow gas were observed on sub-bottom profiles (figure 6). Echosounder data revealed a possible active gas plume similar in character to a confirmed plume on the Yampi Shelf in the Browse Basin. Sidescan sonar data showed extensive pockmark fields coincident with an areally extensive 'poor seismic data zone' that may be due to the presence of shallow gas (figure 6).

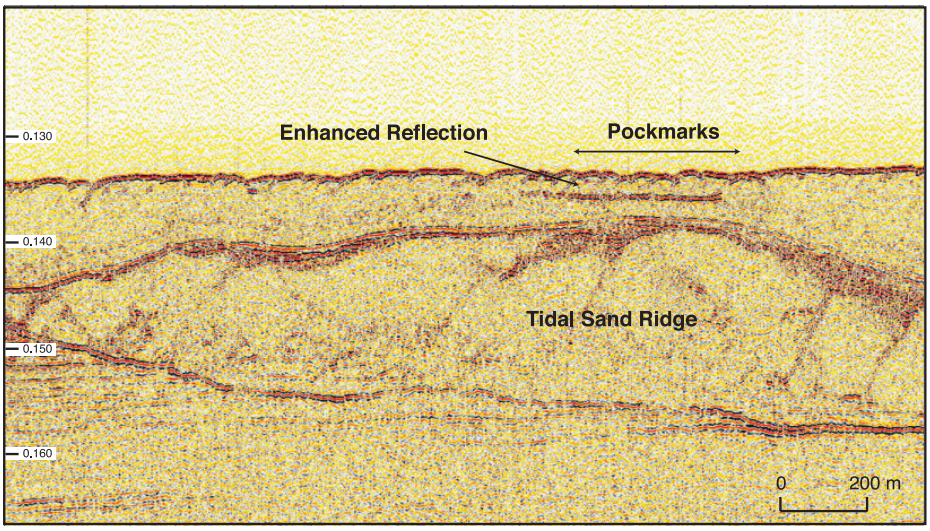
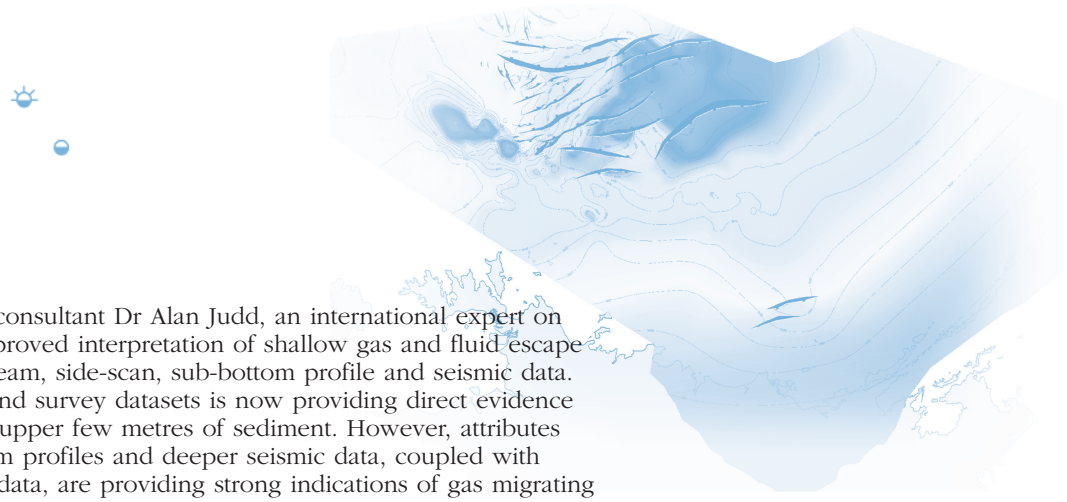


Figure 6. Tidal sand ridge with an enhanced reflector (reversed polarity) above the highest point. This, together with the pockmarked seabed above, is a possible indication of vertical gas migration.



Collaboration with UK consultant Dr Alan Judd, an international expert on shallow gas, is allowing improved interpretation of shallow gas and fluid escape features observed in multibeam, side-scan, sub-bottom profile and seismic data. The integration of sample and survey datasets is now providing direct evidence of microbial gas within the upper few metres of sediment. However, attributes observed in both sub-bottom profiles and deeper seismic data, coupled with remote-sensing and survey data, are providing strong indications of gas migrating throughout the upper 100 metres of sediment, likely sourced from much deeper within the stratigraphic section. This supports interpretations for the existence of an active petroleum system and the existence of hydrocarbons in the northern Arafura Basin.

Results of Geoscience Australia's framework study and seepage survey support the claim that the underexplored frontier region of the northern Arafura Basin has exciting new opportunities for the exploration industry.

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