Introduction

Of Queensland’s many sedimentary basins that are prospective for petroleum, the Cooper and Eromanga basins stand out as the largest conventional petroleum province, and exploration is currently underway to determine the region’s unconventional petroleum potential.

The Cooper Basin is an intracratonic basin containing up to 2 kilometers (km) of non-marine rocks deposited in the Permian to Middle Triassic. It covers approximately 130,000 km² in southwestern Queensland and northeastern South Australia, with approximately 95,000 km² within Queensland. The basin unconformably overlies varying basement rocks, including Proterozoic gneiss, the early Palaeozoic Warburton Basin, early Palaeozoic Thomson Orogen metamorphics and the Devonian Warrabin Trough. The Cooper Basin is subdivided into several troughs and depressions by ridges and anticlines, including the Nappamerri, Arrabury and Windorah troughs, the Yamma Yamma, Ullenbury and Thomson depressions and the Farras Syncline (Figure 1).

The Cooper Basin is unconformably overlain by the Eromanga Basin. The Eromanga Basin contains a non-marine to marine sequence of rocks deposited from the Late Triassic to Cretaceous. In Queensland, it covers 567,000 km², and overlies several older basins. The Cooper Basin is the main source for petroleum in the Eromanga Basin, with the area where the Eromanga Basin overlies the Cooper referred to as the Cooper–Eromanga petroleum system.

Figure 1: Discovery wells (drilling density), depositional centres and troughs within the Cooper Basin over the Z-horizon (basement)
Exploration history

Exploration in the Queensland section of the Cooper and Eromanga basins began in 1959, though no discoveries were made until 1969. Discoveries remained small and exploration rates remained low and focused on the Cooper Basin formations, as the overlying Eromanga Basin was considered unprospective.

Discoveries of oil and gas in the South Australian section of the Eromanga Basin encouraged exploration in Queensland and resulted in the discovery of the Jackson oil field in 1981. This discovery triggered interest in the Cooper and Eromanga basins in southwest Queensland, which was reinforced by the discovery of the Challum gas field in 1983.

Exploration soon defined a region of larger oil and gas fields, trending northwest from the Jackson oil field to the Naccowlah gas field. This trend sits on the northern rim of the Nappamerri Trough. Gas discoveries dominate the Cooper Basin, with some small oil discoveries also made. The Eromanga Basin is typically oil-prone.

Some parts of this region are mature for conventional exploration and development, though large areas remain under-explored. Exploration for conventional deposits has had a reasonably consistent rate of success, with distinct phases of exploration for oil and gas evident from discovery results. These phases are due to a combination of factors, including exploration success and market drivers. Creaming curves (Figure 2) for the Cooper and Eromanga basins highlight the relative maturity of the currently exploited plays in the basins, and the potential for new discoveries as targets change. Recent discoveries, such as oil at Cuisinier on the northern flank, represent a shift in the types of plays targeted. Contingent gas (2C) resources reported against wells drilled to target tight gas resources in deep troughs highlight that there is significant potential for tight, shale or basin-centred gas in the Cooper Basin.

Conventional petroleum system

The distribution of gas and oil reflects source rocks, maturation, reservoirs, seals, traps and hydrocarbon migration history of the two basins, with the Cooper Basin being gas-prone and the Eromanga Basin oil-prone (Figure 4).

Source rocks

The main source rocks in the Cooper Basin are the coals in the Patchawarra, Toolachee and, to a lesser extent, the Epsilon Formation. The Murteree and Roseaneath shales and the Daralingie Formation are not thought to contribute significantly as a source (Draper, 2002), though a study in South Australia found the Murteree Shale to have the highest volume of dispersed organic material (Smyth, 1983).

Boreham and Summons (1999) identified the Birkhead and Murta formations as the main source rocks in the Eromanga Basin, though they estimate that less than 25% of the oil trapped in the Eromanga Basin has come from the source rocks within the basin. The Poolowanna Formation also has source rock characteristics.

Maturation

Maturity levels are highest in the deeper troughs of the Cooper Basin, and the increase of maturity with depth results in increasingly dry gas with increasing depth within a field. In South Australia, a strong relationship exists between maturation levels and the presence of commercial gas fields. Expulsion of gas has occurred from the main depocentres in the southern basin and in the northern area.

Based on conventional maturation studies, the Eromanga Basin succession is at best only marginally mature for gas generation. The deepest areas — those overlying the Nappamerri, Windorah and Arrabury troughs — offer the best prospects for oil and gas generation because of increased maturity. However, studies of source rock potential in conjunction with vitrinite reflectance measurements suggest that some source rocks within the Eromanga Basin may generate at an earlier maturation level (Wecker, 1989).

Reservoirs

The main conventional reservoirs in the Cooper Basin are in the Patchawarra and Toolachee formations, though gas is also reservoired in the Epsilon Formation, and in the Nappamerri Group. More fields have gas and gas liquids reservoired in the Patchawarra Formation, though the Toolachee Formation has larger gas reserves in total.
In the Eromanga Basin, hydrocarbons have been discovered in all units below the Wallumbilla Formation, with approximately half the fields having more than one pool. The widespread braided fluvial deposits of the Hutton, Adori, and Namur Sandstones and the lower Poolowanna Formation, form the best reservoirs within the Eromanga Basin, but sandstones in the Birkhead, Westbourne, Murta and Cadna-owie formations have also produced hydrocarbons in this region.

Seals
Internal seals are common in the Cooper Basin succession, though regional seals are also present. The Murteree Shale provides a regional seal to the Patchawarra Formation, the Roseneath Shale to the Epsilon Formation and the Nappamerri Group to the Toolachee Formation. The percentage of shale in the Nappamerri Group is variable, providing areas of both excellent and poor seal characteristics.

The early Cretaceous marine strata form a widespread regional seal over the Eromanga Basin reservoir formations. Local seals are present in the finer-grained formations.

Traps
Exploration in the Cooper and Eromanga basins has been mainly directed towards drilling anticlinal traps with four-way dip and three-way dip closures with fault control, with some focus on exploring for stratigraphic traps. In several fields, commercial hydrocarbons have been produced from both the Cooper and Eromanga basins on the same structure.

Recent and future exploration targets

**Shale gas play**
Initial interest in a shale gas play in the Cooper Basin, consisting of the Roseneath Shale, the Epsilon Formation and the Murteree Shale (REM), spurred explorers to examine the petroleum potential of the deep Cooper Basin. Exploration focus has gradually shifted to examine the broader Gidgealpa Group, which comprises sandstones, shales and coals that together form a hybrid type play, with multiple stacked shale gas, tight gas and deep coal seam gas targets. The regional seal to this play is the Nappamerri Group.

**Basin-centred gas play**
Exploration drilling within the Nappamerri Trough in the Queensland portion of the Cooper basin has intersected over 1.3 km of gas-saturated Gidgealpa Group rocks. Recent exploration has examined the Windorah Trough in the northern part of the Cooper Basin where the REM is absent and the Patchawarra and Toolachee formations are thinner. In this part of the Cooper Basin, the main exploration targets are likely to be either tight or basin-centred gas plays. Previous exploration in this region has focussed on structural highs, resulting in this exploration play being largely untested.

**Other exploration targets**
While the main shale and tight gas targets are found within the Cooper Basin, the Birkhead Formation, Toolebuc Formation and Winton Formation in the Eromanga Basin may present other exploration targets.
The Birkhead Formation has been identified as a possible source rock formation within the Eromanga Basin. Maturity modelling by Deighton et al. (2003) identified areas of the Birkhead Formation that had reached maturity, though gas or oil expulsion has only occurred over a very limited area.

The Early Cretaceous marine Toolubuc Formation is present within the Carpentaria and Eromanga basins in Queensland, the Northern Territory and South Australia. It comprises laminated calcareous and kerogenous mudstones, with minor coquinite and labile sandstone. Indications of gas and oil are common in mud logs from conventional drilling, and a study by the GSQ has outlined an area in the central Eromanga basin where the Toolubuc Formation may represent a possible shale-oil play. Samples taken from the Toolubuc Formation in GSQ Julia Creek 1 have been sent for kinetics analysis. For more information on this project, see the brochure specifically relating to the GSQ’s work on the Toolubuc Formation.

The Winton Formation is the shallowest formation in the Eromanga Basin. Examination of mudlog gas readings from coals in this formation suggest that they may be prospective for coal seam gas, though coal thickness could be a limiting factor in this exploration play.

**Land availability**

Authorities to Prospect (ATP) for petroleum in Queensland are released under a competitive tendering process. These areas are released as Calls for Tenders, with the next release planned to coincide with the APPEA Conference in May 2015. Currently available land is shown in Figure 3.

**Data availability**

Data for the Queensland section of the Cooper Basin is available from the Geological Survey of Queensland.

- Exploration reports, including well completion reports and studies conducted as part of petroleum exploration in Queensland are available online from the QDEX Reports system.
- QDEX Data provides access to a wide variety of geophysical and geochemical data with larger file sizes. Currently this includes wireline log data (including LAS and DLIS) packaged by well, 3D geological and geophysical models, airborne and ground geophysical data, geochemical data and seismic survey processed and field data.
- The Queensland Petroleum Exploration Database (QPED) contains geological, geophysical and geochemical data derived from the drilling of petroleum and coal seam gas wells, and stratigraphic bores. This data includes general well history, company and GSQ stratigraphy, analytical data and hydrocarbon indications. QPED can be downloaded from QSpatial.
- MinesOnlineMaps can be used to view spatial information relating to the petroleum industry, such as the location of exploration and production tenures, wells, and seismic surveys. There is a link between MinesOnline Maps and QDEX Reports so that reports relating to displayed layers can be readily displayed. Shape files for the layers displayed in MinesOnlineMaps are downloadable from QSpatial.

**References**


**Further information:**

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