TRAPS

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Chapter 11

INTRODUCTION

Most of the oil trapped in the Eromanga Basin has migrated to the attics of low amplitude, dip-closed anticlines or domes. These structures are numerous although small and require dense seismic grids for accurate delineation. Seismic structural definition is good over the Cooper region but, west of the Birdsville Track Ridge, only a few individual structures are well defined. Armstrong and Barr (1986) described several attributes of Eromanga oil discoveries including their small size, simple structural closure and low fill factor, and also emphasised the importance of accurate seismic modelling in view of the thin oil columns. Such comments still apply to the western Eromanga Basin where, in an area approaching 300 000 km^2, there is < 0.25 line km of seismic per square kilometre, or about one-seventh of the seismic line density in the Cooper region.

A three-fold classification was related by Lavering *et al*. (1986) to the distribution of Eromanga oil discoveries. The first category constituted ‘shallow-pool discoveries’ above existing Cooper Basin oil and gas fields, exemplified by the Dullingari Field, Murta Formation and Namur Sandstone oil pools. The second category, ‘single field discoveries’ included isolated wildcats which Lavering *et al.* (1986) suggested may lie on yet to be discovered trends, and the third, ‘multi-field discoveries’ comprised fields with separate closures clustered on major structural trends.

Heath *et al*. (1989, p. 406) noted further that the trends in the third category ‘display structural growth from pre-Permian to Recent’ and producing fields are often surrounded by dry wildcats drilled on valid structures with similar growth histories. The distribution of Eromanga Basin discoveries in relation to major Cooper Basin faults is shown on Figure 10.2. A structure contour map of the base Eromanga west of the Birdsville Track Ridge (Fig. 11.1) indicates the size and distribution of potential structural traps in an area of low seismic coverage. At low seismic density trap size is exaggerated as shown in contrast to the lower panels of the figure which depict Limestone Creek – Biala and Dirkala Fields in the Cooper region. Dirkala Field is delineated by 3D seismic (Mackie and Gumley, 1995) and is discussed below with Limestone Creek – Biala Field under Stratigraphic Traps.

STRUCTURAL TRAPS

TRAP GEOMETRY AND DISTRIBUTION

Seismically well-defined traps are simple domes typically 1–3 km across with 20–30 milliseconds (msec) vertical closure at the ‘C’ horizon (near top Cadna-owie) structural level. Structural dip on the flanks of the domes exceeds 1° and hence traps are not flushed by artesian water (Bowering, 1982; Williams and Moriarty, 1986). Clusters or chains of domes with a common lowest closing contour occur on ridges up to 30 km long and 10 km wide, and groups of these ridges form the major structural elements of the Cooper and Eromanga Basins (Fig. 4.4).

The ridges are asymmetric with deep-seated faults on one or both margins, many of which are ascribed to compression during the Alice Springs Orogeny (Gravestock *et al*., 1995). These faults rarely propagate through the Jurassic where the Eromanga Basin is underlain by thick Permo-Carboniferous strata of the Cooper and Pedirka Basins. However, where the Eromanga succession rests directly on early Palaeozoic or older ‘basement’ rocks, and especially where the latter are shallow, steep reverse faults propagate into the Hutton or Algebuckina Sandstones and may produce marked flexures at the Cadna-owie structural level (e.g. Mulapula structure; Martin, 1987).

Effects of faulting

Faults on the margins of structural ridges have had a long history of reactivation (Moore and Pitt, 1984; Kuang, 1985; Heath *et al*., 1989; Shaw, 1991). However, study of the Warburton ‘basement’ strata beneath the Cooper Basin suggests that the major arcuate northeast structural trends are superimposed on the north–northwest Warburton rift and are oblique to it. Similarly, Tertiary fault reactivations resulting from east–west compression are superimposed on the Cooper–Eromanga sag basin and are oblique to it. As Shaw (1991) has pointed out from a study of Tertiary faulting in southwestern Queensland, the integrity of domes on the tops of ridges has been left intact because major deformation was accommodated by the flank faults. In some cases closure has been enhanced by Tertiary reactivation e.g. at Jackson (Hunt *et al*., 1990) and Tintaburra (Newton, 1986). Tintaburra represents an interesting case because in this field the Eromanga section rests directly on basement and pre-Jurassic structural growth cannot be identified (Newton, 1986).

Tertiary structures are the youngest and largest in the basin e.g. the Innamincka Dome (80 x 25 km) and Dalhousie Anticline (80 x 35 km; Krieg, 1986), and they also have surface expression. The lack of commercial success on drilling such structures is attributed to the young age of trap formation relative to hydrocarbon migration (e.g. Gilby and Mortimore, 1989). Tertiary crestal and listric faults which

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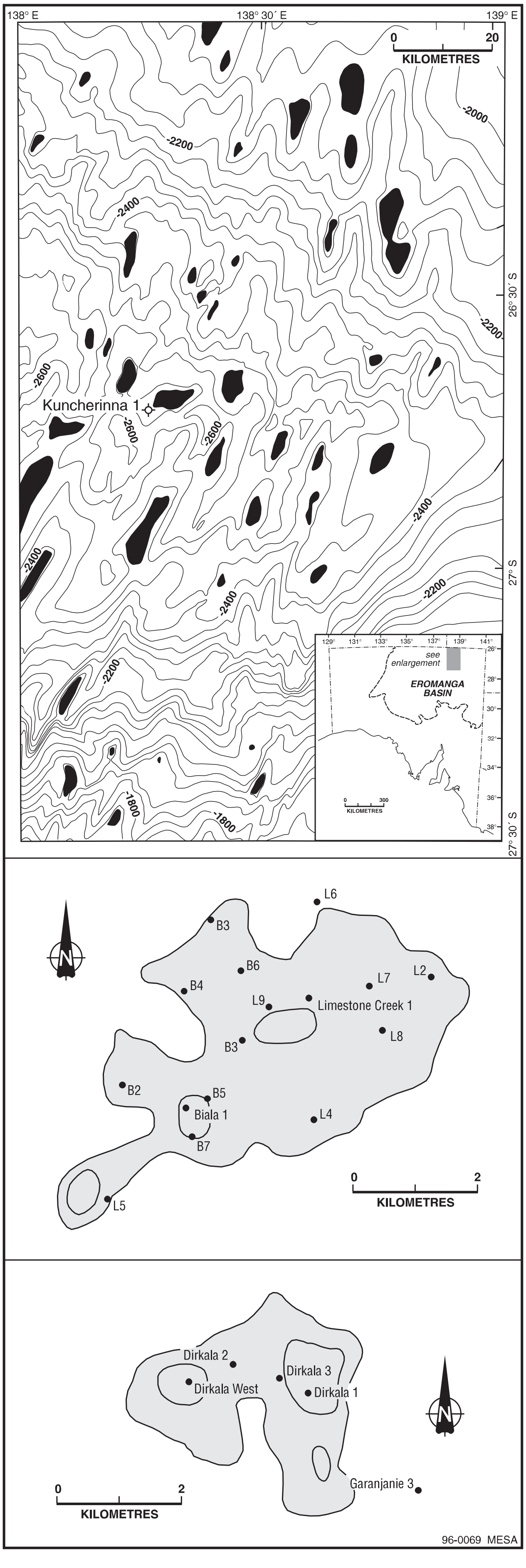

ropagate downward through the marine Cretaceous succession are relatively common. With the exception of Tintaburra where a listric fault has controlled closure of the Wyandra Sandstone Member pool (Newton, 1986), such faults have not affected trap integrity. However, commercial pools have not been discovered at this stratigraphic level in South Australia and such faults may need to be taken into account when discoveries are made.

Mesozoic and Permian structures are commonly coaxial. Individual Eromanga Basin domes are relatively uniform in size regardless of whether they are isolated or in groups, and regardless of whether they overlie late Palaeozoic infrabasins or basement (Fig. 11.1, bottom). They are interpreted to originate from flexure associated with the interference of three major structural trends, north–northwest, north–northeast and northeast as recognised by Wopfner (1985) and Gilby and Mortimore (1989) among others. All three structural trends are evident on the base Eromanga Basin depth map (Fig. 4.6) with the north–northeast trend enhanced by selective illumination. Gilby and Mortimore (1989, p. 394) made the interesting observation that in Queensland northwest structural trends ‘appear to be more favourable in terms of recognition of Permian and Triassic growth’. In the Cooper region of South Australia the north–northwest structural trend (parallel to the Wonominta Fault in New South Wales) is interpreted as a Cambrian rift trend (Boucher, 1991; Gravestock *et al.*, 1995) and is interpreted here as the oldest of the three. The arcuate northeast trend is younger than the north–northwest trend, having been superimposed by the Alice Springs Orogeny prior to cratonic sag and inception of the Pedirka and Cooper Basins. The north–northeast trend appears to be youngest and Tertiary in age, but it could be a reactivated older feature since it parallels the G8 gravity corridor. The Cambrian rift trend is parallel to G2 (Campbell and O’Driscoll, 1989; O’Driscoll, 1983).

STRATIGRAPHIC TRAPS

Structural traps, particularly at the Hutton Sandstone – Birkhead Formation and Westbourne Formation levels, have a stratigraphic component related to reservoir–seal interfaces (Capillary seal traps, see below). Considering the seismic coverage required for accurate structural definition (≤ 1 x 1 km grid), stratigraphic traps related to facies changes or pinchouts in the Eromanga Basin are too subtle to warrant stand-alone delineation.

Facies traps

Stratigraphic traps related to facies changes can emerge during appraisal drilling or infill seismic recording. Mount (1981) concluded longshore distribution of bar sands delineated the Murta Formation oil reservoir at Dullingari.

Fig. 11.1 Depth structure map of base of Eromanga Basin in a poorly explored region west of Birdsville Track Ridge (40 m contours; shading indicates areas of closure). Lower panels show, as a comparison for scale, Limestone Creek – Biala and Dirkala oilfields delineated by dense seismic and drillholes in the Cooper region. Dirkala overlies Permian

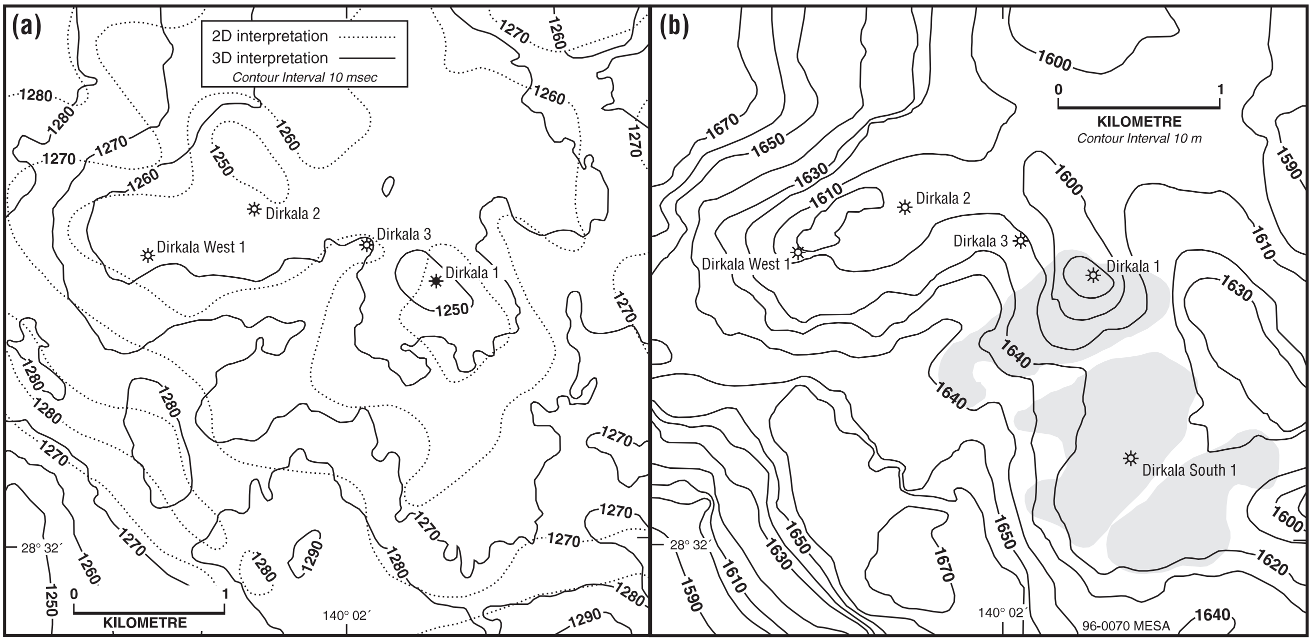

*Fig. 11.2 Dirkala Field: **(a)** time structure map of top Namur Sandstone showing structural definition after 2D and 3D seismic surveys **(b)** depth structure map of Birkhead Formation with shaded outlines of seismically delineated sand bodies (after Mackie and Gumley, 1995). Figure reproduced by kind permission of APPEA Ltd.*

Without elaborating Hunt *et al*. (1990) noted that structural closure on part of the Jackson Field was enhanced by localised sand development in the basal Birkhead Formation.

The most comprehensive account of the deliberate search for a stratigraphic trap is provided by Mackie and Gumley (1995). Production from oil drillhole Dirkala 1 indicated a resource greater than that mapped, and seismic amplitude anomalies in the lower Birkhead Formation suggested sand development within the mudrock-dominated formation. A small 16 km^2 3D seismic survey was recorded to try to determine the geometry and characteristics of the sand. A comparison of the 3D and earlier 2D (1 x 0.5 km grid) seismic interpretation at the top Namur Sandstone is shown on Figure 11.2. Mackie and Gumley noted a time shift of 5–10 msec associated with superior seismic resolution and migration, leading to better structural definition. In addition, these workers noted a split seismic wavelet related to an intra-Birkhead shale–sand interface. Mapping of this sand from its seismic attributes defined an inferred fluvial channel south–southeast of the crestal producing drillhole. The thickest sand was drilled at Dirkala South 1 (Fig. 11.2) and tested at 171.7 kL of oil per day. A new oil pool was also discovered in the Murta Formation.

Capillary seal traps

The stratigraphic distribution of Eromanga oil pools led Heath *et al*. (1989) to conclude a Permian origin for the oil. Some characteristics they pointed out are:

- Eromanga pools have not been discovered in the deepest (hence most mature) section of the basin
- multiple, vertically-stacked pools are common
- few pools occur where Permo-Triassic seals are thick
- Heath *et al*. (1989) thus drew attention to migration pathways from Permian source rocks and vertical migration of hydrocarbons through the Eromanga aquifers and leaky seals

A transition from the quartz-dominated Hutton Sandstone of cratonic provenance to lithic Birkhead Formation of volcanic arc provenance was documented for Bodalla South and other Queensland fields by Watts (1987). The provenance switch led Boult (1993) to an investigation of potential seals in this field using mercury injection techniques. Capillary pressure data indicated that the ‘weak link’ (terminology of Boult, 1993) is a membrane seal characterised by low entry pressure. If the capillary pressure of such a seal is exceeded, then oil migrates through it as a result of buoyancy [oil is considered to migrate as a separate liquid phase]. The quartzose–lithic transition has been documented as far west as Gidgealpa Field in South Australia (Boult *et al*., in prep.) but it is unlikely to extend west of the Birdsville Track Ridge where quartz-dominated facies have been drilled.

The Eromanga Basin succession on the Murteree Ridge overlies the Warburton Basin with no intervening Permian strata. Oil is produced from a very thin (~ 0.3 m) but areally extensive high permeability shoreface sand in the Murta Formation. Production history has been suggested by Williams *et al*. (1994) to indicate water influx from the underlying McKinlay Member and Namur Sandstone and that such connection to the underlying aquifer explains how oil got into the Murta sand in the first place. Fine grained lacustrine and lake-marginal facies make up the bulk of the Murta Formation beneath the oil reservoir. The seal capacity of sands within these units was found by Williams *et al*. (1994) to be low and, assuming shales were not laterally continuous, the sands formed the ‘weak link’. Oil could have found tortuous pathways around shales and through sands of these units into the reservoir. Although admittedly hypothetical, the authors raise an important question regarding Eromanga Basin seal efficiencies. Several studies have shown that shales composed predominantly of clay minerals are minor contributors to the fine-grained facies of the Poolowanna, Birkhead, Westbourne and Murta Formations. A continuous porosity–permeability trend from reservoir to non-reservoir rock was illustrated by Gravestock and Alexander (1986) and related to percolation thresholds and tortuosity by Korvin (1992). Effective capillary seal may be largely independent of the thickness of the formations mentioned above, thus hydrocarbons could be more likely to break through, rather than migrate laterally around them. Ultimately, the last effective regional seal could be the marine Bulldog Shale and its equivalents.