Seismic Expression of Layer Bound Polygonal Fault System: An Example from Bass Basin of Australia

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Summary

High-resolution 2D seismic data reveal presence of extremely dense normal extensional faults in the middle Oligocene to late Miocene section in the entire offshore Bass Basin. The very fine-grained Late Tertiary calcareous clay and marl-dominated succession of the basal Torquay Group exhibits a complex system of small-scale extensional faults with layer-bound deformation without displacement transfer to the underlying basement structures. The entire sequence is pervasively deformed by very small-scale normal faults with average fault spacing ranging between 60m – 500m and fault throws ranging between 10m – 40m. The stratigraphy overlying and underlying this sequence is undisturbed and is characterised by highly continuous reflection patterns. The analysis of the Yolla 3-D seismic data suggests that the layer-bound fault system is polygonal in nature. There are three units (stratigraphic tiers) within the deformed interval and the reflection characteristics vary from very low amplitude - low frequency (middle unit) to high amplitude - high frequency content (top and bottom units). Two-way time structure maps mapped for five horizons within the deformed interval from the Yolla 3-D seismic data bring out clearly the polygonal pattern of faulting in the area. The obscure nature of polygonal faulting in the middle unit is due to a dramatic loss of reflectivity, which is attributed to overpressuring in the mudstones. Though the overall geometry of the polygonal fault system is similar at all horizons, the detail of the fault pattern varies from one unit to another. This change in deformation style of various units can be attributed to lateral facies variation, if compared to studies from the North Sea basin where fault intensity correlates positively with both clay fraction and smectite content (Dewhurst *et al*., 1999).

Introduction

The existence of polygonal fault systems was first documented in the Lower Tertiary mudrocks from the North Sea Basin (Cartwright, 1994). The fault system there is characterised by densely packed, layer-bound, minor extensional faults exhibiting unique polygonal map geometry in plan view. Vertically, the polygonal fault system is organised in tiers of stratigraphically-bound layers of faults that have a distinctive structural style. Separate tiers have distinct fault spacing, orientations and fault trace shapes (Cartwright, 1996). A similar polygonal network of faulting has been observed in the Cretaceous siliciclastic sequences of the Eromanga Basin of Australia (Watterson *et al*., 2000). The regional 2D seismic data from the Bass Basin of Australia exhibit in the shallow section corresponding to the Torquay Group, a highly fractured interval with faults having very small throws and restricted to one particular layer in the stratigraphy. The detailed 3D seismic data in the Yolla area clearly bring out the polygonal system of faulting in the Early Miocene interval in this area. While the 2D seismic data is not sufficient to adequately map a fault set of this nature, it does indicate its widespread existence throughout much of the Bass Basin. Although there is still a hot debate as regards the genesis of such fault systems (Goulty, 2001), a synoptic discussion on the genesis is presented here with reference to various postulated models. Though no direct study has been made regarding the hydrocarbon implications of the polygonal fault system in this basin, the implications for reservoir geometry and seal capacity in petroleum exploration are discussed with reference to published literature from North Sea data.

Stratigraphic setting of the polygonal fault system

The polygonal fault systems as seen in the Bass Basin affect the middle Oligocene to late Miocene section of the Late Tertiary basal Torquay Group. The lithology of the deformed units is dominated by calcareous clay and marl deposited in slope and basin plain depositional environments (Williamson *et al*., 1987) in a barred marine basin setting. The region over which the polygonal fault system is developed is illustrated in Figure 1.

The Bass Basin was a large post-rift continental sag basin by the Late Eocene flanked by significant regional uplift on at least three margins: the King Island - Mornington rise in the west-NW and the Flinders Island - Bassian rise to the east-NE encompassing the basin in an elliptical fashion. The representative regional geo-seismic cross section across the central portion of the basin presented in Figure 2 shows

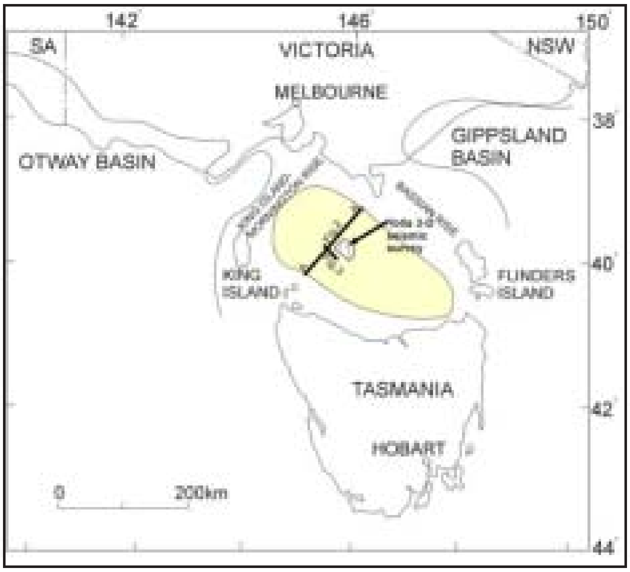

Fig.1: Regional map of the Bass Basin showing the distribution of high-density polygonal fault system over almost the entire offshore Bass Basin. The location area of the Yolla-3D seismic survey is also shown along with the locations of figures 2 and 3.

that by Late Eocene, the basin went into passive thermal stage subsidence. The regional section (Figure 2) shows that there have been no major tectonic movements in the basin since the Late Eocene except for minor reactivation along the pre-existing normal extensional faults. The basin has largely undergone passive subsidence since the Late Eocene as a response to thermal relaxation after the initial rifting events formed the basin.

Expression of the fault system in the 2-D seismic data

Figure 3 shows a 2-D seismic line from the central Bass Basin illustrating the key features of the seismic expression of the Late Tertiary succession in the basin. The middle Oligocene to Late Miocene section of the Late Tertiary has been pervasively deformed by minor extensional faulting characterised by fault spacing ranging between 60m-500m and with fault throws between 10m-40m.

The deformation is limited to a particular stratigraphic interval with the overlying and underlying intervals showing highly continuous reflections. The wide spacing of 2-D seismic lines may not be suitable to fully resolve the small-scale extensional faulting as many of the faults may be oblique to the line orientation and may not be imaged properly. The close spacing between the individual faults may mask the reflection image of these small-scale fault structures by spatial aliasing problems. There are three units A, B and C, distinguished by amplitude-frequency characteristics of the reflection packages. Units A and C are of high amplitude and high frequency content whereas the middle unit B is characterised by low amplitude, low frequency reflections. The deformation style of all the units may be similar but the loss of frequency in the middle unit B may be the reason for lack of clear definition of the style of faulting. The lower unit seems to have been intensely faulted at central and right hand side of the section with the reflection patterns exhibiting continuous reflections on the left of the

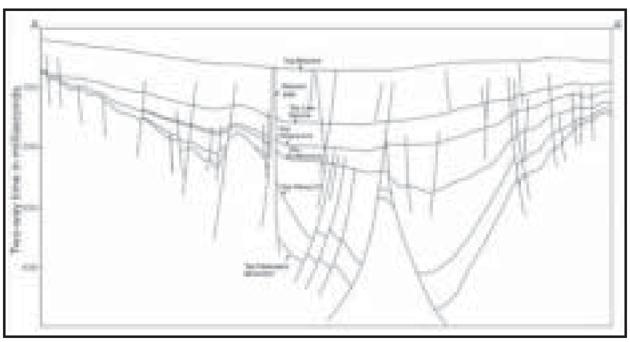

Fig. 2: Regional geo-seismic cross-section across the central portion of the Bass Basin (for location see Figure 1) showing the major sequence boundaries and their two-way time depths. Only the major tectonic faults are shown not the polygonal faulting which has affected the Middle Oligocene - Late Miocene succession

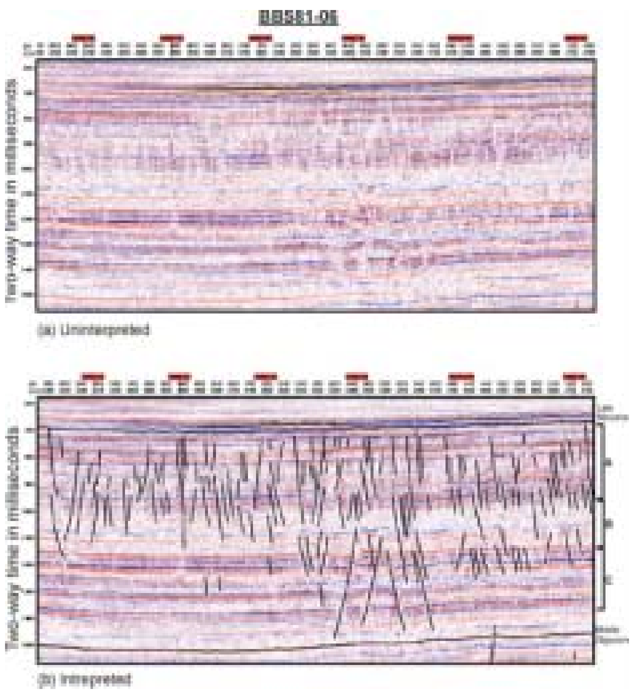

Fig. 3: 2-D seismic expression of the Middle Oligocene – Late Miocene interval showing highly discontinuous pattern of reflections, bounded above and below by continuous reflection intervals. The seismic line is from the central Bass Basin (for location see Figure 1).

section. This may be related to the variation in the grain size distribution and the mineralogical composition of the corresponding lithology that directly correlates with existence or non-existence of polygonal faulting (Dewhurst *et al.*, 1999).

Analysis of the fault system in the Yolla 3-D seismic data

The Yolla 3-D seismic survey was designed to cover specifically the area around the first major oil/gas discovery well in the basin, Yolla-1, in order to define the structural closure of the Yolla Field in greater detail. It covers an area of approximately 260 km^2. The survey was conducted with a 12.5m × 25m bin size and comprises 30-fold data (Lennon *et al*., 1999). For the present study, an area equivalent to 10km × 8km has been considered for horizon mapping (Figure 4).

Though the high-resolution 2-D seismic data show the type of faulting in the deformed interval in cross section, it is almost impossible to map the fault pattern consistently from conventional 2-D seismic data. However, the 3-D seismic data show the faults to be much more clearly resolved and interpretation is much easier with less chance of spatial aliasing. Figure 5 is an inline seismic section showing the 7 horizons that have been mapped for the present study. The horizons 2-6 represent the polygonally-faulted horizons at successively shallower levels whereas horizons 1 and 7 represent undeformed layers, one underlying and the other overlying the deformed interval. The faults displacing the horizons in a normal extensional style are clearly seen.

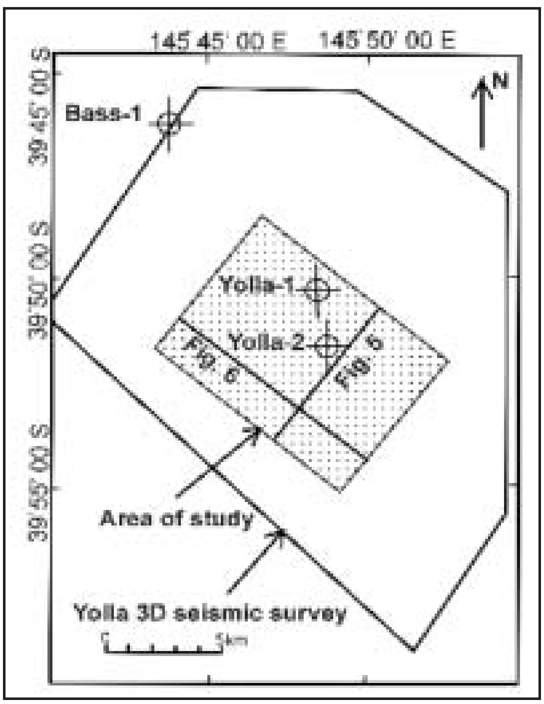

Fig 4: Location map of the Yolla-3D survey and the area considered for mapping of the polygonal fault system in the Bass Basin in the present study is indicated

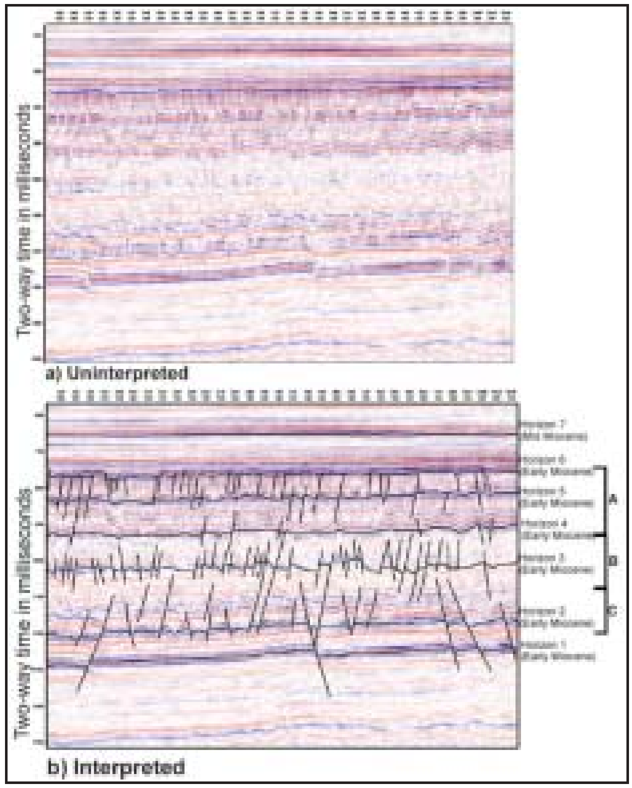

Fig. 5: Interpreted inline section (for location, see Figure 4) showing the 7 horizons mapped (3 in Unit A, 1 each in Unit B & C of the deformed interval) and 2 in undeformed intervals. The polygonal faults have affected all the three Units defined in the deformed interval and the lowermost horizon 1 has only tectonic faulting and no polygonal faulting (refer to Figure 13) whereas the uppermost horizon 7 does not have any signs of faulting activity (Figure 12). The faults have affected the three Units differently although there are some common faults between the Units A & B and also between Units B & C.

The crossline presented in the Figure 6 also clearly shows the structural style of the polygonal fault system. The faults are all extensional with small throws 10-40ms (approximately equivalent to 10-40m). Many of the faults dip in one direction, giving the appearance of rotated domino fault blocks. Some faults dip in the opposite direction and, when combined, give an impression of mounded reflection geometry. Individual faults are generally restricted in vertical extent to only a part of the entire deformed interval while some faults crosscut most of the interval. The pattern of faulting is seen to vary from one stratigraphic level to the

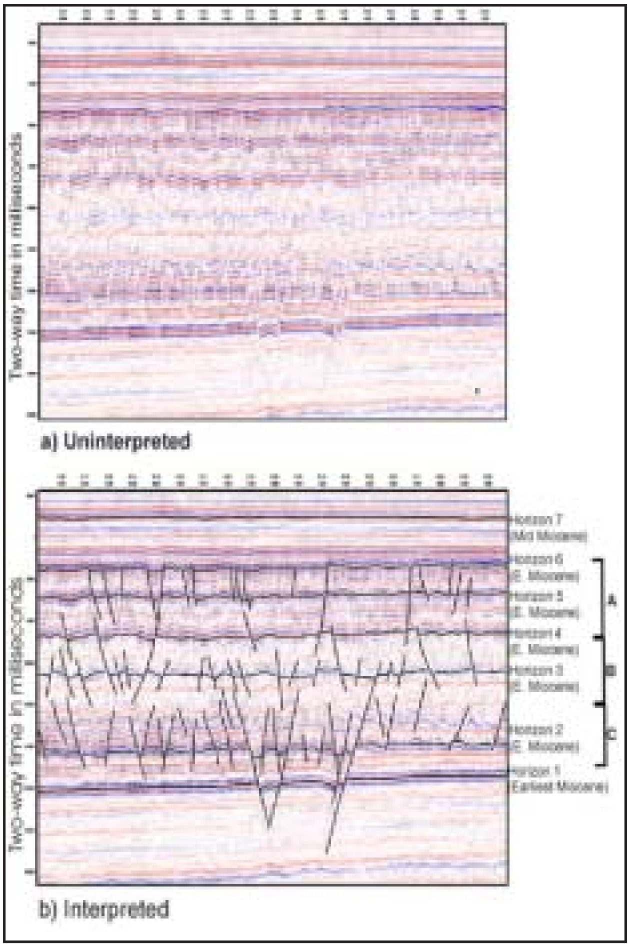

Fig. 6: Interpreted crossline section (for location, see figure 4) showing the 7 horizons mapped. The polygonal faults have affected all the three units defined in the deformed interval and the lowermost horizon 1 has got only tectonic faulting. The uppermost horizon 7 does not show any faulting activity. The faults have affected the three units differently. There are some faults in common between units A & B and between units B & C.

next, but the extent of mechanical coupling between different sets of faults is not clear, since changes often occur within the low reflectance intervals.

This packaging of sets of faults within stratigraphic units represents the tier structure (Cartwright, 1994 & 1996). A similar structural style is also seen in the orthogonal lines (Figure 6). It is obvious from the two representative 3-D seismic sections shown here that each of the faulted units (A, B & C) has different faults affecting the layers in characteristic fashion though some of the faults crosscut from one unit to another.

Although it is much easier to interpret faults on the 3-D data than the 2-D data, the structure is so complex that it is difficult to make consistent fault interpretations on a section-by-section basis. Two approaches to mapping complex networks of small faults are possible using 3-D seismic data (Cartwright and Lonergan, 1996). One approach is to take time slice images and identify faults from offsets in the strike of bedding. Faults interpreted as time slice lineaments can be calibrated with the cross-sectional data to verify the interpretation. The second approach is to conduct a full manual horizon interpretation and to map closely-spaced horizons and to use these to analyse the 3-D structure in the 3-D seismic dataset. In the present study, 400 inlines were used for horizon picking using an 'autotrack' correlation technique while interpreting each line one by one.

Figures 7-11 show the horizon maps for the five successively deeper but polygonally-faulted horizons correlated within the Early Miocene deformed interval.

The polygonally-organised faults are clearly recognisable as discontinuities in the two-way travel time values (colour gradations) to the horizon. Irregularities in the fault traces and width are a reflection of the resolution accuracy in interpreting fault plane positions. As is seen in each of these maps, the fault pattern contains many triple and quadruple fault intersections typical of polygonal fracture networks. To give a total picture for the area, two horizon maps, one for a horizon immediately overlying and the other immediately underlying the deformed interval are also presented (Figures 12 & 13). Some of the tectonic fault pattern is obvious from Figure 13 and this pattern penetrates

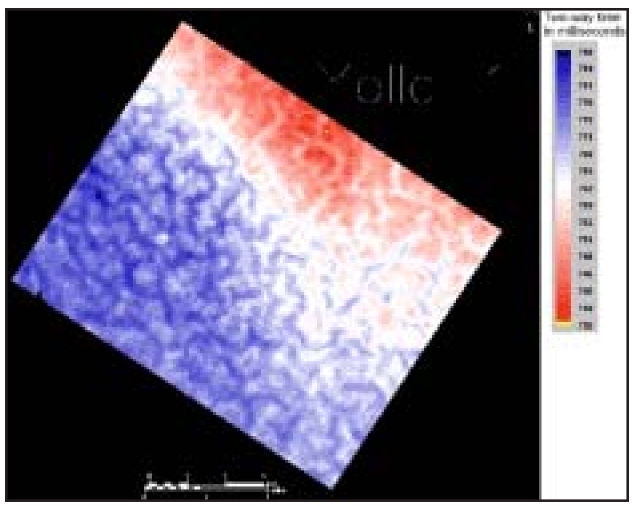

Fig.7: Two-way time structure map of horizon 6 within the Early Miocene (Unit A) interval. The horizon is deformed by small extensional faults that are organised in a polygonal pattern. Fault intersections are a mixture of orthogonal and non-orthogonal types involving 3, 4 and occasionally 5 fault segments.

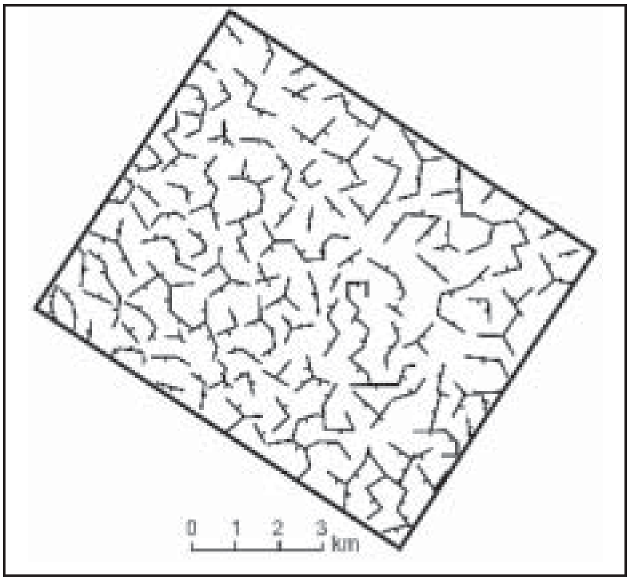

Fig. 7a: Fault trace map constructed from the two-way time structure map of horizon 6 within the Early Miocene (Unit A) interval (Figure 7). The fault map shows typically 'irregular' type polygonal fault geometry involving orthogonal and non-orthogonal fault intersections with up to 5 fault segments.

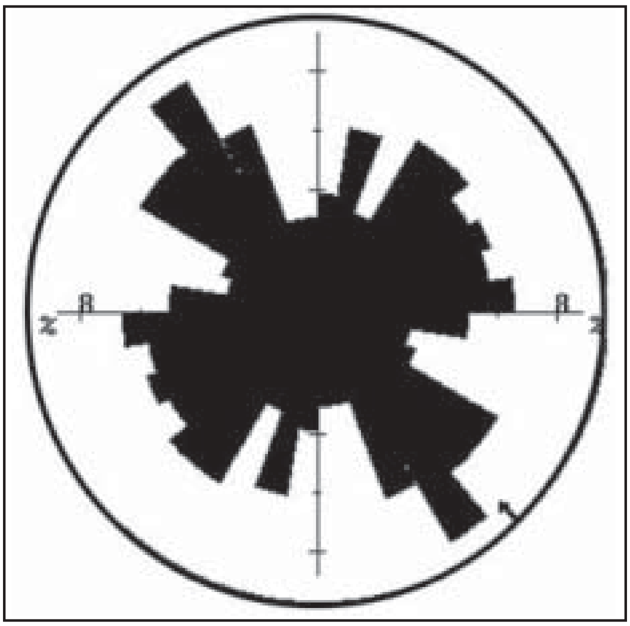

Fig. 7b : Rose diagram showing the fault strike distribution for all the faults (total 216 faults) as observed in figure 7a. Random distribution of fault strike is clearly seen.

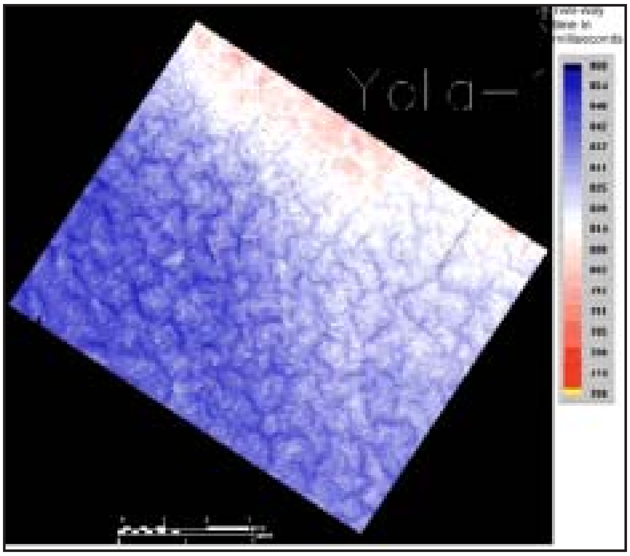

Fig.8 : Two-way time structure map of horizon 5 within the Early Miocene (Unit A) interval. The horizon is deformed by small extensional faults organised in a polygonal network. Fault intersections are a mixture of orthogonal and non-orthogonal types involving 3, 4 and occasionally 5 fault segments.

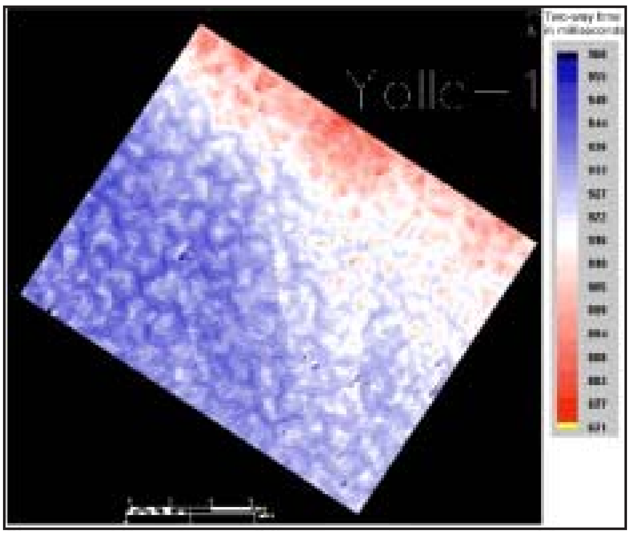

Fig. 9 : Two-way time structure map of horizon 4 within the Early Miocene (Unit A) interval. The horizon is deformed by small extensional faults organised in a polygonal network. Fault intersections are a mixture of orthogonal and non-orthogonal types involving 3, 4 and occasionally 5 fault segments

into the lowermost polygonally-faulted horizon (Figure 11) that bears a strong resemblance with Figure 13 in so far as the tectonic fault pattern is concerned. It is seen clearly that the undeformed layer (horizon 7) represented by Figure 12 shows that absolutely no faulting activity has affected this layer.

The 3-D seismic data in the Yolla area (Figures 5 and 6) show Unit A and Unit C have a marked high reflectivity. Unit A has a much higher frequency content than Unit C. Unit B in the middle suffers from poor reflectivity which directly indicates that the acoustic contrast necessary for good reflections does not exist. The two-way time structure map for the horizon 3 within the middle unit B (Figure 10) shows that the auto-tracking method of horizon

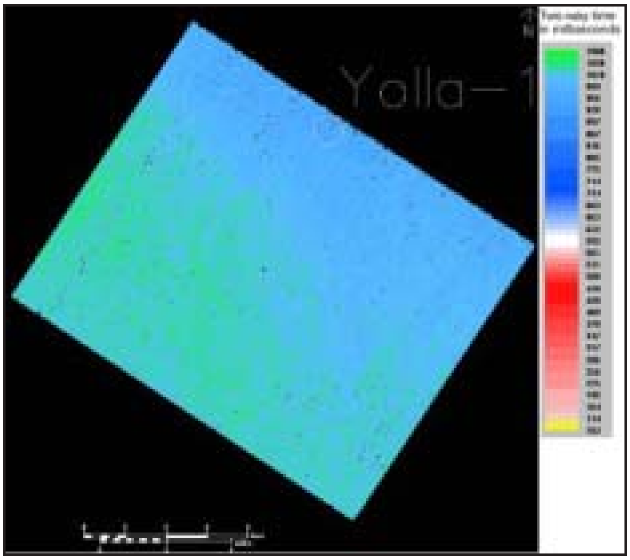

Fig. 10 : Two-way time structure map of horizon 3 corresponding to the Early Miocene (Unit B) interval. The polygonal faulting is seen in the entire map except near Yolla-1 and its close surroundings. The polygonal fault pattern is not very sharp in this map since the very low reflectivity of the Unit B has made the auto-tracking method of horizon picking much less efficient

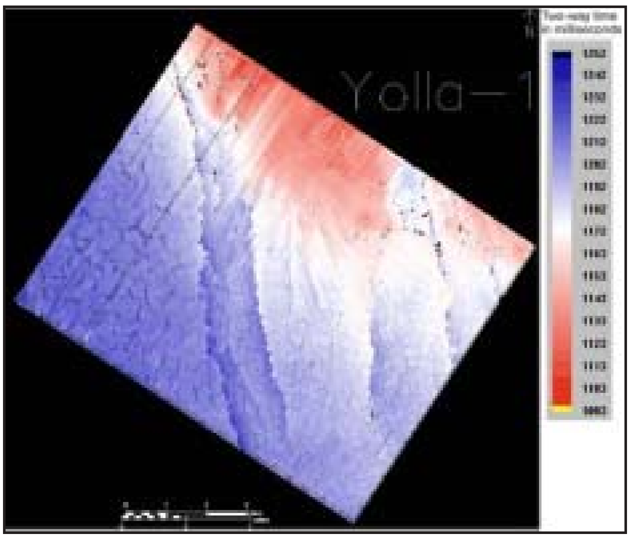

Fig.11: Two-way time structure map of horizon 2 corresponding to the Early Miocene (Unit C) interval. There is no polygonal faulting near Yolla-1 or to its immediate west, south and southeast. The broad tectonic fault pattern is quite evident in this map similar to the Figure 13 in the eastern half of the map.

picking in this case has been very less efficient because of the very poor reflectivity of the Unit B. The sharpness of the polygonal fault pattern as seen in this map (observed all through the area except near Yolla-1 and its close surroundings) is lost compared to all the other polygonally faulted horizons (horizon 2, 4-6).

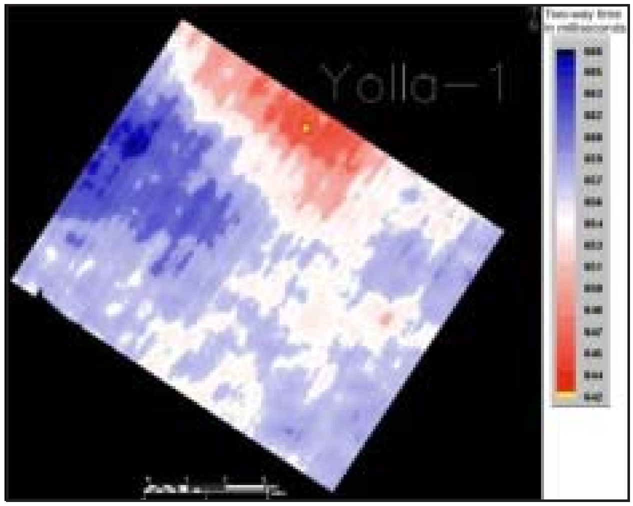

Fig.12 : Two-way time structure map of horizon 7 corresponding to the zone above the Mid-Miocene deformed interval. Note the absence of any polygonal faulting in the horizon map. There is also no sign of any tectonic faulting at this horizon level.

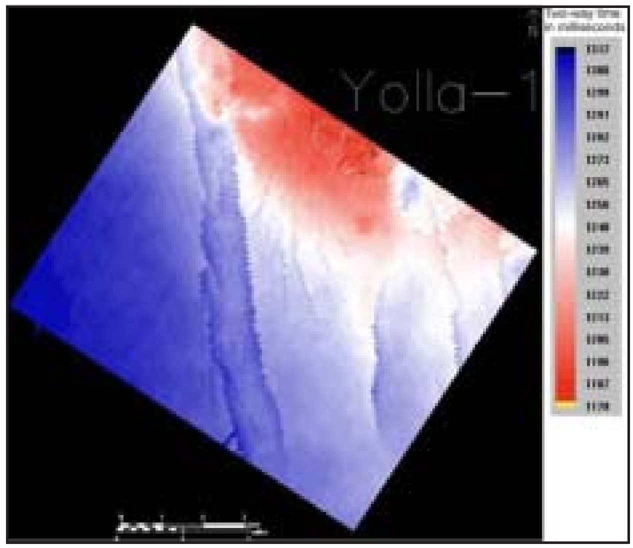

Fig.13: Two-way time structure map of horizon 1 corresponding to earliest Miocene, below the deformed interval. Note the absence of any polygonal faulting in the horizon map while the broad tectonic fault pattern is quite clear in the central and eastern part of the map with N-S fault trend. Note the similarity of the tectonic fault pattern between this figure and the figure 11.

It is suggested here that the middle unit B is overpressured. It is believed that dewatering of the upper unit A should be facilitated through polygonal faults into the unit above while the bottom unit C might use a similar escape route to dewater into the underlying unit. The middle unit perhaps does not have access to escape routes for dewatering, leading to overpressure in that mudstone layer. Though there has not been any investigation into the nature of the middle unit in terms of lithofacies, mineralogy and pressure state etc, it is suggested that this middle unit is overpressured. Some of the examples shown in literature from the North Sea also indicate a similar lack of reflectivity in the middle unit surrounded by intervals with better reflectivity.

The interval velocity log for Yolla-1 shows a dramatic decrease of velocity against the stratigraphic interval corresponding to the one showing polygonal fault development. It is perhaps because the low velocity clay-dominated section in the lower part of the Torquay Group which exhibits polygonal faulting is less consolidated in general than the underlying Demons Bluff Formation and also because the upper part of the Torquay Group is more carbonate-rich than the lower clay-dominated section. The interval velocity curve right against the middle unit shows an abrupt decrease of velocity that is indicative of the fact the unit is perhaps overpressured. Although no pressure study of this interval has been made, these indirect geophysical observations point to the fact that the development of polygonal fault system is intricately related with overpressure development (Cartwright, 1994).

The outstanding feature of the fault pattern seen in the Figures (7-11) is the polygonal geometry of the fault system with polygons, on average, 400m across. The fault trace map (Figure 7a) has been prepared for the horizon 6 within Unit A (Figure 7) by tracing each fault from the two-way time map. This map clearly suggests the random distribution of the fault strike orientations. The pattern does not resemble typical tectonic fault systems. There is no systematic offset of one fault trend by another nor there is any particular bias towards any fault strike orientation that is typical of a general tectonic fault system. There is a much broader range in fault orientations than would be expected for a tectonic fault set and the fault strike distribution is almost uniform in all directions. A rose diagram has been constructed on the basis of 216 small faults in the Figure 7a and has been presented in Figure 7b.

It can be seen that the fault strike distribution has a very broad range although a small bias in the NW-SE direction could be seen. This small bias may be due to the general NW-SE strike of the Basin in post-rift time. It can be seen that the fault strike distribution has a very broad range although a small bias in the NW-SE direction could be seen. This small bias may be due to the general NW-SE strike of the Basin in post-rift time.

The closest analogue for the randomly oriented polygonal fault pattern is desiccation cracks on mud flats (Cartwright, 1996) but these are usually much smaller structures (cm- to m- scale) rather than the km-scale structures seen in all these maps. Mud cracks are vertical tensile fissures, open at the surface, whereas the structures in Figure 7-11 are normal faults in cross section with dips ranging from 20º - 50º. Though the polygonal fault patterns on each of these horizons (Figures 7-11) look to be similar in terms of fault trace length, spacing, intersection style and orientations, the entire deformed interval appears to have three different tiers that are independent of each other (Figure 5 & 6). The tiers have been marked by separate styles of faulting though some faults cross cut from one tier to another. The 3-D geometry of the complex fault networks recognised in this area can be described as sets of interlocking skewed prisms, pyramids and cones.This polyhedral geometry is summarized in the Figure 14.

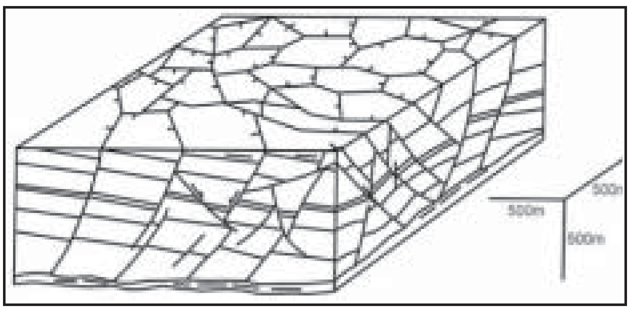

Fig.14 : Block diagram showing the three-dimensional fault geometry typical of individual tiers in the Late Tertiary of the Bass Basin. Any orientation of cross-section through this polyhedral fault network would comprise sets of minor-displacement faults with extensional sense offsets of stratal reflections.

The bottommost horizon (horizon-2) seems to have not been affected by polygonal faulting in the area close to Yolla-1 well and to its immediate vicinity in the southeast.

Genesis of the layer-bound polygonal fault system

Cartwright (1994) was the first to propose a hydrofracture mechanism model for the genesis of layer-bound fault system in the lower Tertiary mudrocks of the North Sea Basin by through the process of episodic collapse of basin-scale overpressured shale compartments. Faulting is linked to movements induced by density inversion between under-compacted and normally compacted shale layers. From detailed strain analysis on the 3D seismic data from North Sea, Cartwright and Lonergan (1996) found that the apparent extensional strain on any given polygonally-faulted horizon was approximately uniform in all directions with random fault strike distribution.The large apparent extensional strain (6% to 19%) affecting 250,000 square km area in the North Sea Basin would have required the basin margins to extend appreciably (almost 20 km along any line of 100km length) to accommodate the apparent extensional strain observed along the seismic sections. There is, however, no evidence of such basement faulting showing contemporaneous basement extension. These observations made them conclude that the fault system was not tectonic in origin. They proposed a layer-parallel volumetric contraction model for the development of polygonal faulting (Figure 15).

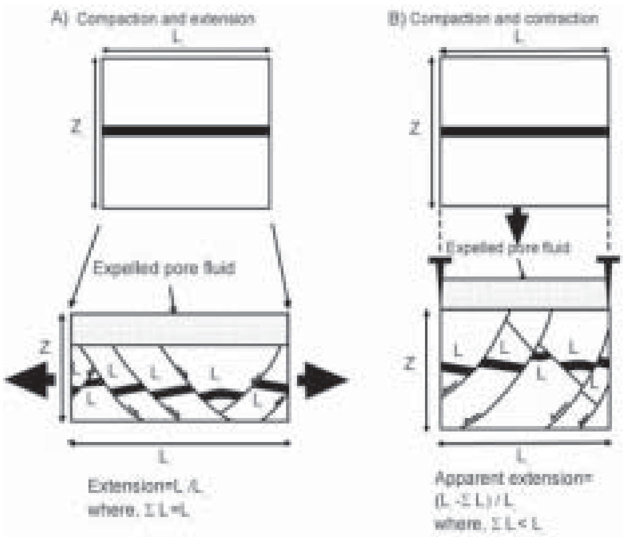

Fig.15 : Alternative strain paths to explain the bulk strain observed in polygonal fault system (After Cartwright and Lonergan, 1996).

The faulting develops in response to fluid expulsion from the mudrocks during its early burial and compaction history. The conditions for failure may be achieved through increased pore-fluid pressure or through tensile stresses generated as a result of pore-fluid loss, or a combination of these two processes (Cartwright and Lonergan, 1996). It results from lateral contraction of stratal surface during faulting. As pore fluid is expelled, the sedimentary particles contract inwards as well as compact vertically, and this lateral contraction creates a space problem controlled by the lateral basin margin constraints. Since it is not mechanically feasible for large voids to be open at depth, the space problem is instead solved by the development of polyhedral arrays of normal faults, allowing lateral contraction to proceed. Dewhurst *et. al*., (1999) suggested a suitable physical mechanism to explain why certain sedimentary units would contract volumetrically during compaction. They proposed a colloidal mechanism called syneresis for the development of a layer-bound polygonal fault system. They also found a positive correlation between high smectite content and ultra fine grain size with development of polygonal faulting. Studying a number of wells from different locations in terms of depositional setting, they pointed out that when the lithofacies is clay-rich with a high smectite content, the faulting is intense and when it is relatively coarse-grained and smectite poor, the faulting activity diminishes.

Watterson *et al*. (2000) studied the Lake Hope 3-D survey in the Eromanga Basin and found that polygonal cell boundaries coincide approximately with the downward termination and near convergence of conjugate pairs of normal faults. The faults there have a systematic geometric relationship with folds, with anticlines in the mutual hangingwalls of fault pairs and broader footwall synclines. They proposed density inversion mechanism beneath the faulted sequence wherein a diapiric process was initiated but ceased while still at an embryonic stage, possibly due to depletion of the low-density layer.

There is currently ongoing research into this relatively new type of fault system and its genesis. However, the debate is still continuing (Goulty, 2001) about the exact mechanism by which these fault systems have developed.

Implications in petroleum exploration

Lonergan and Cartwright (1999) published a classic case study of the intricate relationship between the reservoir sand development and polygonal fault structure in the Lower Tertiary Alba Field in the North Sea. They noted large-scale modification of reservoir geometry through sand remobilisation and sand withdrawal during early burial by analysing 3-D seismic time slices and horizon maps over the field. On a mapped marker horizon in the mudrocks 80-120m above the reservoir, there is a marked decrease in polygonal fault density compared to areas away from the reservoir. On a horizon in mudrocks within 5-50m of the base of the reservoir, there is an increase in horizon disruption by small faults directly below the sand body. Thus changes in polygonal fault density and pattern in the hemipelagic mudstones may indicate the presence of a sandstone reservoir and may prove a useful exploration tool in the search for subtle sand bodies.

Conclusions

The very fine-grained Late Tertiary calcareous clay and marl-dominated succession of the basal Torquay Group exhibits a complex system of small-scale extensional faults with layer-bound deformation without displacement transfer to the underlying basement structures. The analysis of the Yolla 3-D seismic data suggests that the layer-bound fault system is polygonal in nature. The polygonal fault system exhibits tier structure consisting of three units, individual units showing somewhat different fault pattern and characteristics. The present study has brought out for the first time the details of this relatively new fault system in the Bass Basin. Further research needs to be done to study the exact nature of variation in the intensity of faulting and its style in response to different lithofacies variation, clay mineralogy, depositional setting and grain-size variation from detailed XRD and SEM work on either core or cutting samples. Similarly, the role of the polygonal fault system influencing the reservoir geometry and seal capacity in the basin is yet to be studied. The controversies regarding genesis of the fault system is likely to be resolved with more research into this relatively new type of fault system.

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Views expressed in this paper are that of the author(s) only and may not necessarily be of ONGC.

References

Cartwright, J. A., 1994. Episodic basin-wide hydrofracturing of overpressured Early Cenozoic mudrock sequences in the North Sea basin. *Marine and Petroleum Geology*, 11, 587-607.

Cartwright, J. A., 1996. Polygonal fault systems: a new type of fault structure revealed by 3D seismic data from the North Sea basin. *AAPG (American Association of Petroleum Geologists) Studies in Geology*, 42, 225-230.

Cartwright, J. A., and Lonergan, L., 1996. Volumetric contraction during the compaction of mudrocks: A mechanism for the development of regional-scale polygonal fault systems. *Basin Research*, 8, 183-193.

Dewhurst, D. N., Cartwright, J. A., and Lonergan, L., 1999. The development of polygonal fault systems by syneresis of colloidal sediments. *Marine and Petroleum Geology*, 16, 793-810.

Goulty, N.R., 2001. Polygonal fault networks in fine-grained sediments - an alternative to the syneresis mechanism. *First Break*, 19.2, February, 2001.

Lennon, R. G., Suttill, R. J., Guthrie, D. A., and Waldron, A. R., 1999. The renewed search for oil and gas in the Bass Basin: Results of Yolla-2 and White Ibis-1. *APPEA (Australian Petroleum Production and Exploration Association) Journal*, 39, 248-261.

Lonergan, L., and Cartwright, J. A., 1999. Polygonal shrinkage faults and their influence on deepwater reservoir geometries in the Alba Field, UK Central North Sea. *AAPG (American Association of Petroleum Geologists) Bulletin*, 83, 410-432.

Watterson, J., Walsh, J.J., Nicol, A., Nell, P.A.R. and Bretan, P.G., 2000. Geometry and development of a polygonal fault system. *Journal of the Geological Society, London*, 157, 1261-1264.

Williamson, P.E., Pigram, C.J., Colwell, J.B, Scherl, A.S., Lockwood, K.L. and Branson, J.C., 1987, Review Of Stratigraphy, Structure, And Hydrocarbon Potential Of Bass Basin, Australia. *AAPG (American Association of Petroleum Geologists) Bulletin* 71, 253-280.