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DEEP CRUSTAL STRUCTURE OF EAST JAVA SEA BACK-ARC REGION FROM LONG-CABLE 2D SEISMIC REFLECTION DATA INTEGRATED WITH POTENTIAL FIELDS DATA

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ABSTRACT

A new 2D regional reconnaissance survey, JavaSPAN, has been acquired and processed by ION-GXT covering the eastern Java Sea east to the Bone Basin and north as far as the North Makassar Basin. Over 9800 km of data were acquired using a maximum offset of 9000 m and a 18 second record length. The data are being processed to PSDM level thus imaging the lower crust and MOHO. Geological highlights of the interpretation of the data include the crustal scale relationships between the basins and intervening highs as well as the deep structural relationships of some key elements of Southeast Asian tectonics. The survey puts the petroleum systems of this large area into context, and highlights some potentially overlooked potential in the early and pre-Tertiary.

INTRODUCTION

In the past six years ION-GXT has been at the forefront in the acquisition of regional 2-D seismic reconnaissance surveys to image the deep crustal structure of basins and continental margins interesting to the petroleum industry. Most of these surveys have the purpose to better understand the tectonic history of the subject area, through imaging transects across a basin or passive margin adjacent to open oceans, and to more accurately interpret basin architecture, the evolution of the petroleum systems, and the timing of trap development. To date "SPAN" surveys have been conducted or are planned adjacent to all the continents except Antarctica. At the time of writing in early 2008 ION-GXT just finished acquisition on such a regional 2-D survey of the Java Sea back-arc region from east Java to Flores Island in the south, and extending northward between Kalimantan and Sulawesi in the Makassar Straits (Figure 1). Processing is underway, with remarkable brute stacks currently available for most of the lines, and full PSDM (pre-stack depth migrated) lines across the Java Sea from SE of Madura Island to the mouth of the Bone Basin. The survey has been called "JavaSPAN" in a similar fashion to preceding surveys.

ACQUISITION DETAILS OF THE SURVEY

The survey is comprised of 9800 line kms of 2D data. Acquisition parameters include a 25 m shot interval, 12.5 m group interval and maximum offset of 9,000 m. The record length is 18 sec and the data are being processed to pre-stack time image of 16 sec and pre-stack depth image of 40 km record length. Integration through modeling of gravity and magnetics data gathered simultaneously with the seismic is being used to constrain deep crustal structure imaging and interpretation: such an approach places limits on the velocities of the deeply buried sedimentary and non-sedimentary rocks that are critical to the seismic PSDM processing workflow.

GEOLOGICAL HIGHLIGHTS OF THE SURVEY

Makassar Straits

Five lines image the North Makassar Basin (Figure 1C), one long line running down the center of the basin from the foot of the Paternoster Platform northward, one paralleling that on the east side of the basin skirting the foldbelt offshore West Sulawesi, and two lines across the basin deployed from the NE and SE corners of the Mahakam delta southeastward into the center of the basin to the foot of the foldbelt on the east side. For logistic reasons the shallow water of the delta itself was avoided, but the outer fringes of the delta including the delta top are well imaged with deep well control. The

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north-trending line on the east side of the Straits skirts the NE corner of the Paternoster Platform and runs southward into the center of the South Makassar Basin (Figure 1A). It shows both the Taku Talu (Figure 2) and Paternoster Faults to be deep seated and fringed well out into the basins with impressive debris fans. The center of the North Makassar Basin is filled with 6 seconds of remarkably flat-lying sediments underlain by another 2 seconds of apparently sedimentary section. The South Makassar Basin shows considerably more dramatic structure at the late Cretaceous level (Figure 3), and the center of the basin is buried in a 6 seconds of Tertiary fill. It is however more variable with thinner section developed over some 2 seconds of relief in the pre-Tertiary surface. As these are brute stacks as this stage, detailed interpretations have not as yet been carried into the basin.

Sangkarang Basin

Line 4900 (Figure 1D) stretches from the base of the scarp of the Paternoster Platform at the Taku Talu Fault across the South Makassar Basin and crosses into the Sangkarang Basin, where it parallels the basin-bounding fault for some 200 km toward the Flores Basin. The floor of the basin is filled with 2-3 seconds of normal faulted sediment overlying a mildly structured basement.

Flores Basin

Toward the south, line 4900 crosses an area of as-yet poorly understood but more structured basement before it drops into the Flores Basin. The sediment load thins over this margin to the Flores Basin, water deepens, and the line enters an area of rough normal faulted oceanic crust in the back arc environment. Shallow graben and half-graben fill lies above what appears to be relatively young basaltic crust. These brute stacks are plagued with multiples so an age estimate for the crust from the sedimentary fill of the graben, and the thickness of the crust cannot be estimated. Line 4900 emerges on the south side of the Flores Basin into a deep-water basin with gentler topography and complex reflection sets before it climbs onto the north flank of Flores Island itself. This is Hamilton's (1979) Flores Trench, and it appears to shoal to the west, being pinched off between the rise onto Sumbawa Island and rough terrain to the north. We have entertained the idea at this early stage of processing that there is an area of Tertiary back arc spreading nested in a trapped piece of older (Mesozoic) oceanic crust in the Flores Basin, an interesting idea we plan to follow up with on the final PSDM processing of this data set.

Bone Basin

The area surrounding and including the southern extremes of the Bone Basin, outside the mouth of the two arms of Sulawesi is imaged by three lines, one of which (3700, Fig. 1D) has been processed to PSDM level (Figure 4). It clearly shows young normal faulting off the west arm of Sulawesi that isolates Pulau Selayar on a narrow north-south trending horst block. Several horst systems punctuate the mouth of the Bone Basin, and the SPAN lines to the south promise to illuminate the relationship of the Bone Basin to the Flores Basin.

Java Sea

Inversion structures have drawn the main exploration interest in the Java Sea portion of the data set. This part of the survey covers territory that ranges in water depth between 200 and 2000 m, and is flanked by ultra-deep water to the SE. It is punctuated by a number of carbonate platforms and flanked to the NE by the Paternoster Platform. The basement is generally believed to be the Sunda craton toward the western edges of the survey, Meratus-related Mesozoic accretionary arc that stretches offshore from Kalimantan, and the back-arc underpinnings of the Sunda Arc itself. Ten lines stretch from 111º E in central Java and merge with the imaging over the South Makassar, Sangkarang and Bone basins in the east, one of which, line 3700 has been processed to the PSDM stage. This collection of lines images the Bawean Arch and Trough, the Madura Island structural trend, Madura Basin, and the Massalima Trough. Of particular interest are some depocenters that have been imaged south of Kalimantan north of the Bawean Arch. These appear to be nested basins containing early Tertiary and Mesozoic sedimentary sections beneath the rather uniform younger Tertiary cover that may have developed on and around the edge of the Sunda craton in the Mertus foreland. They are only imaged in brute stack form at the moment, but promise to open an interesting new play seaward of the Meratus fold belt.

The basement-involved fold and thrust faulting is well imaged by the JavaSPAN dataset (Figure 5). One of the authors (Emmet, 1996) studied a portion of this area using data from an older (1982) 2D grid, which are now supplemented by the regional 2D lines from the 2008 ION-GXT SPAN survey. More recently, the regional geology was reviewed by

Sribudiyani et al. (2003). Following shutdown of the Meratus subduction, extension during Middle Eocene to Late Oligocene formed half-grabens, which were inverted during the Neogene. Simultaneous regional subsidence prevented, except in a few cases, uplift and erosion of the structures so that most of the record of their growth was preserved. The evolution of some Paleogene extensional structures was strongly controlled by the structural fabric of the basement, which is the low-grade pelitic schist of the Meratus accretionary complex that flanked the Sunda craton during the Cretaceous. The top of that accretionary basement is a profound angular unconformity. Mapping of intra-basement reflections allows recognition of faulted synclines which preserved Cretaceous thrust-fold structures. In the two cases in which basement synclines were mapped, Paleogene half-graben basins appear to have nucleated on existing faults or to have developed new faults parallel to bedding surfaces in basement. Should shortening continue in the East Java Sea, it will eventually involve the nearby platforms and may emplace thrust sheets that nucleated on basement synclines in deep water many km landward.

CONCLUSIONS

As is the case with all the SPAN programs, the JavaSPAN data set affords the industry an unparalleled synoptic overview of the main structural features within the Java Sea and Makassar Straits as well as the crustal setting and relationships between the basins.

ACKNOWLEDGEMENTS

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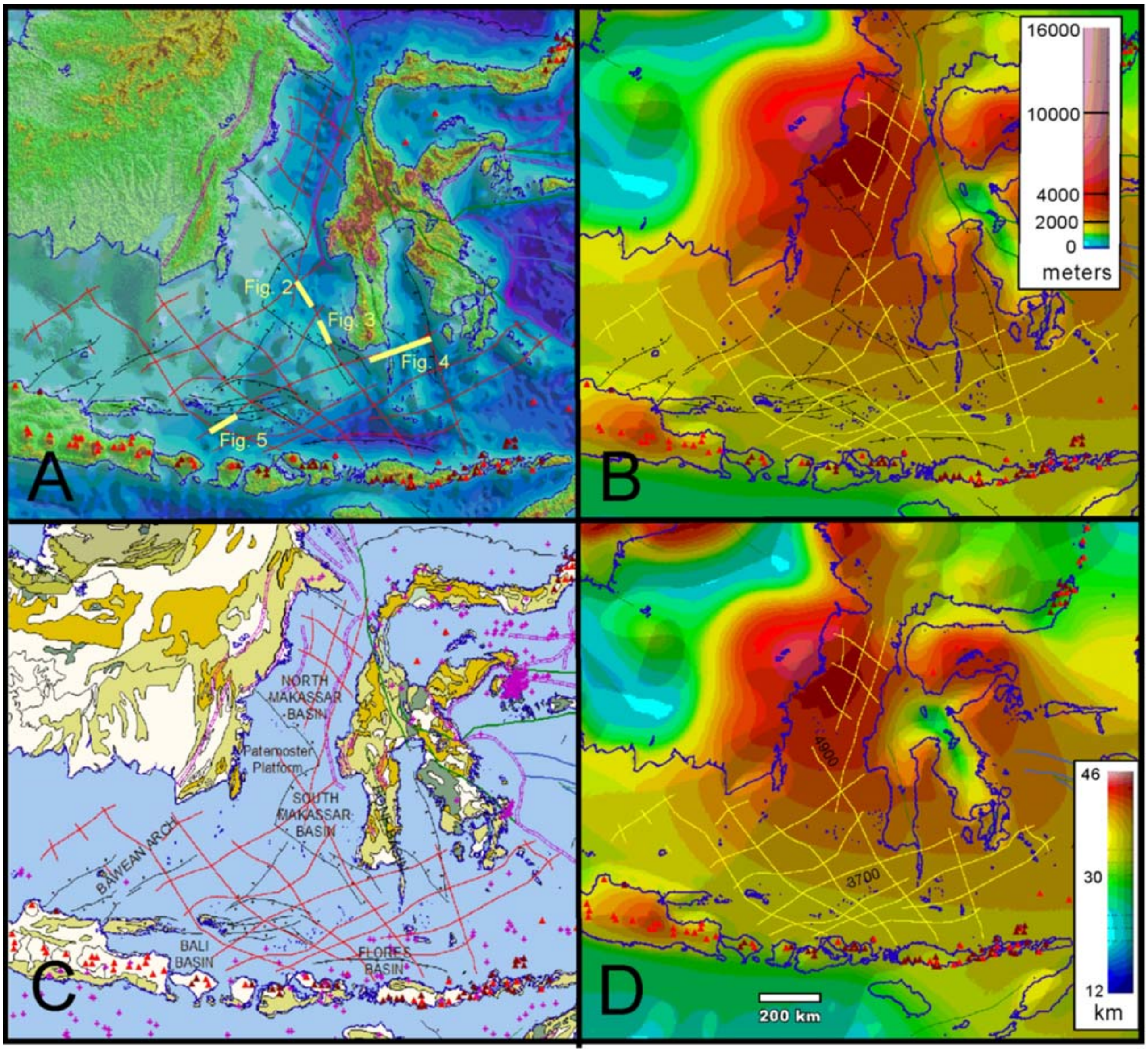

Figure 1 - Area of the 2008 ION-GXT JavaSPAN survey. **A** DEM and bathymetry with the locations of Figs. 2-5 shown; major tectonic elements: triangles are volcanos, extensional fault systems in barbed lines, traces of foldbelts in double purple line, strike-slip systems in green, and leading edge of upper plate in subduction system in barbed lines. **B** Isopach of sedimentary fill in basins, **C** Geology, purple crosses are earthquakes in year 2000, pale color Quaternary, browns Tertiary, Paleozoic and lower Mesozoic in gray outcrop **D** Depth to Moho, with numbers of specific seismic lines mentioned in text. **B** and **D** are inversions of potential fields data. Underlying images in **A**, **B**, and **D** are licensed from the non-exclusive SEATIGER project, with permission from DIGs (Dickson International Geosciences) and GrizGeo (Grizzly Geosciences); **C** is from the USGS Worldwide Resource Assessment Project (1997-present).

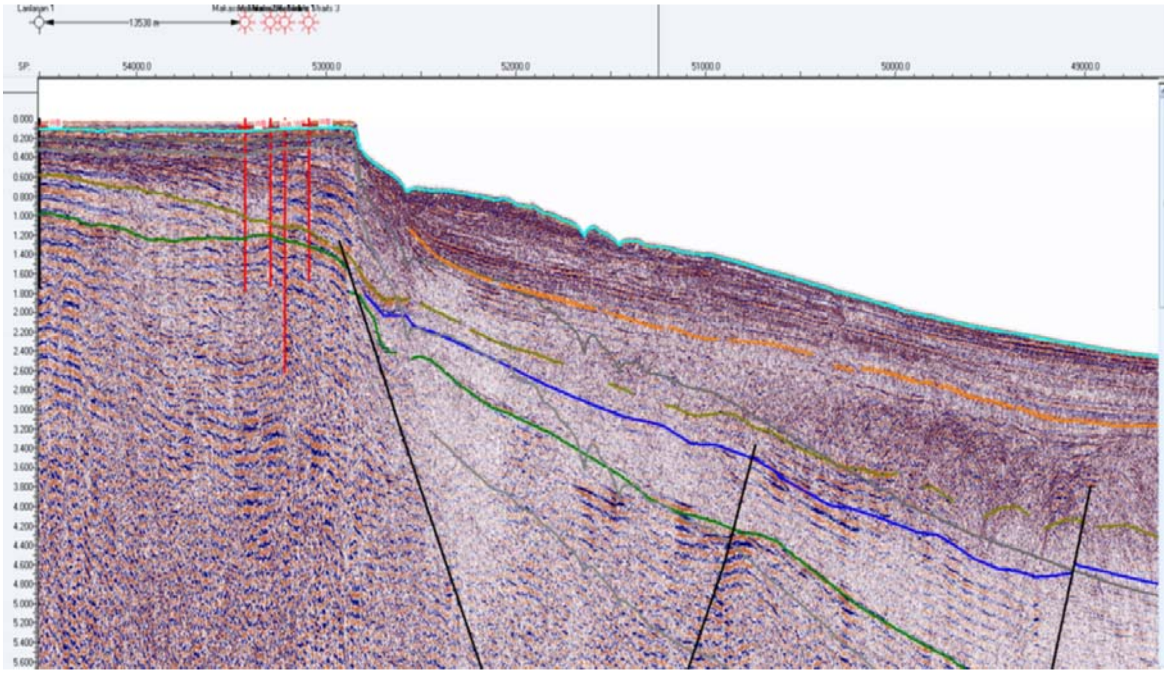

Figure 2 - Eastern margin of the Paternoster Platform (location shown in Fig. 1A) showing the Taku Talu fault front. Brute stack time section. Horizontal scale along top of image-each division is 1000m. Total section 5.6 seconds. Water bottom in pale blue and multiples thereof denoted with gray highlight. Orange and olive colored reflectors are early Oligocene picks, blue late Eocene, green top Cretaceous 'economic' basement. Wells at the north end of the line are the Larilarian (dry) and Makassar Straits (discovery) wells.

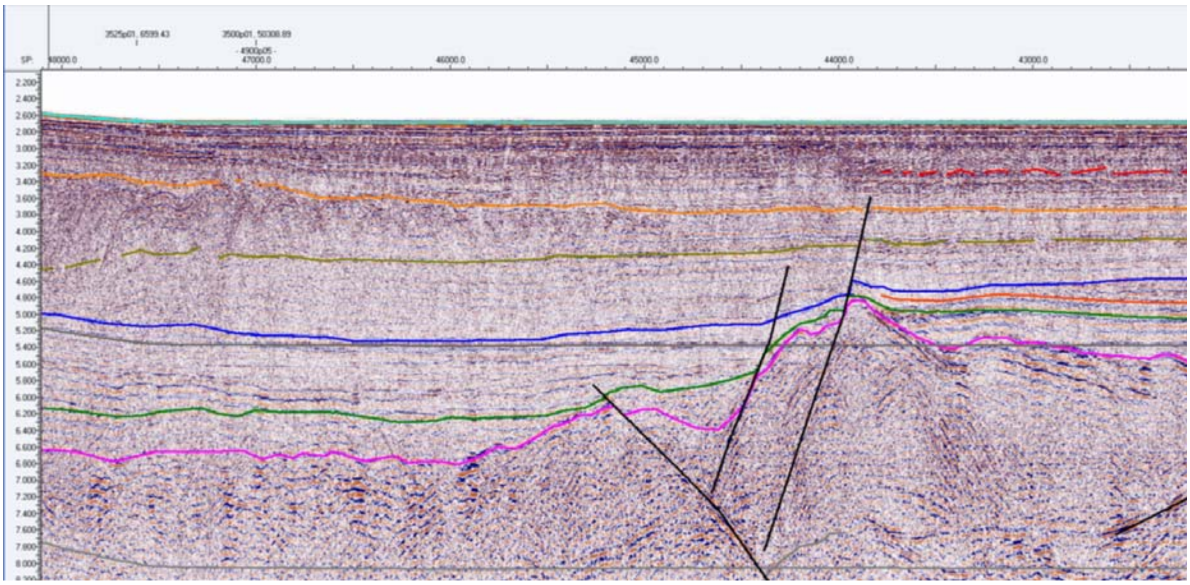

Figure 3 - Southeast margin of the South Makassar Basin (location shown in Fig. 1A) showing large structural relief on pre-Tertiary section. Horizontal scale along top of image-each division is 1000m. Total section 8.2 seconds. Water bottom in pale blue and multiples thereof denoted with gray highlight. Red a Miocene pick; orange and olive colored reflectors are early Oligocene picks, blue late Eocene, green top Cretaceous 'economic' basement, bright pink crystalline basement.

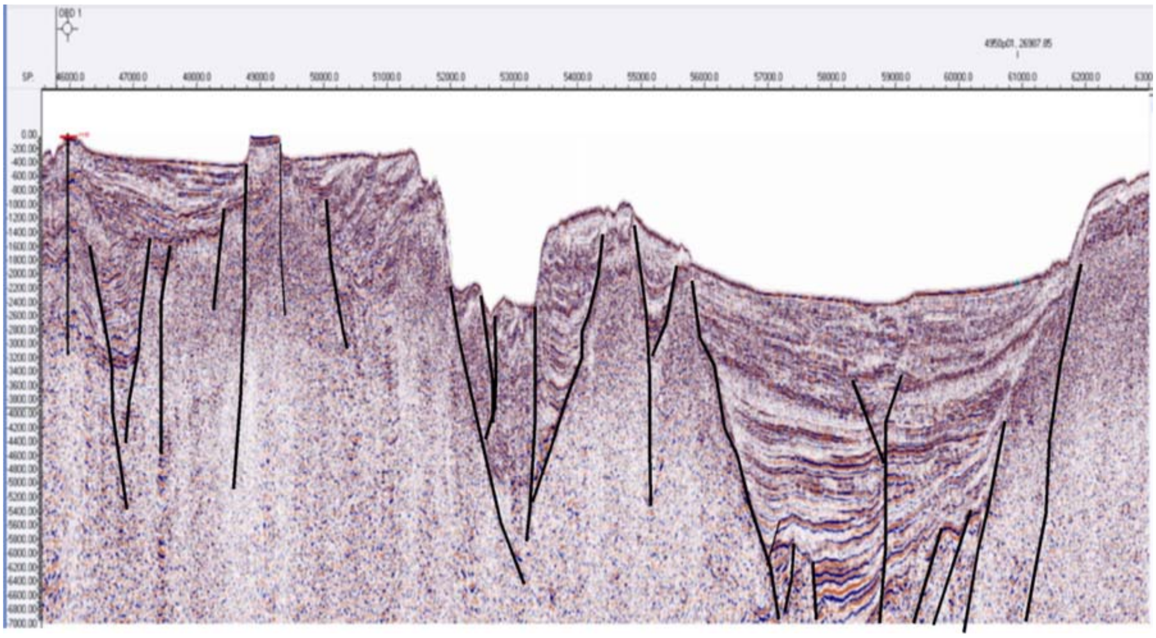

Figure 4 - PSDM transect across the southern Bone Basin (location shown in Fig. 1A). Vertical scale highly exaggerated. Well at the west side of the line is the ODB-1 well.

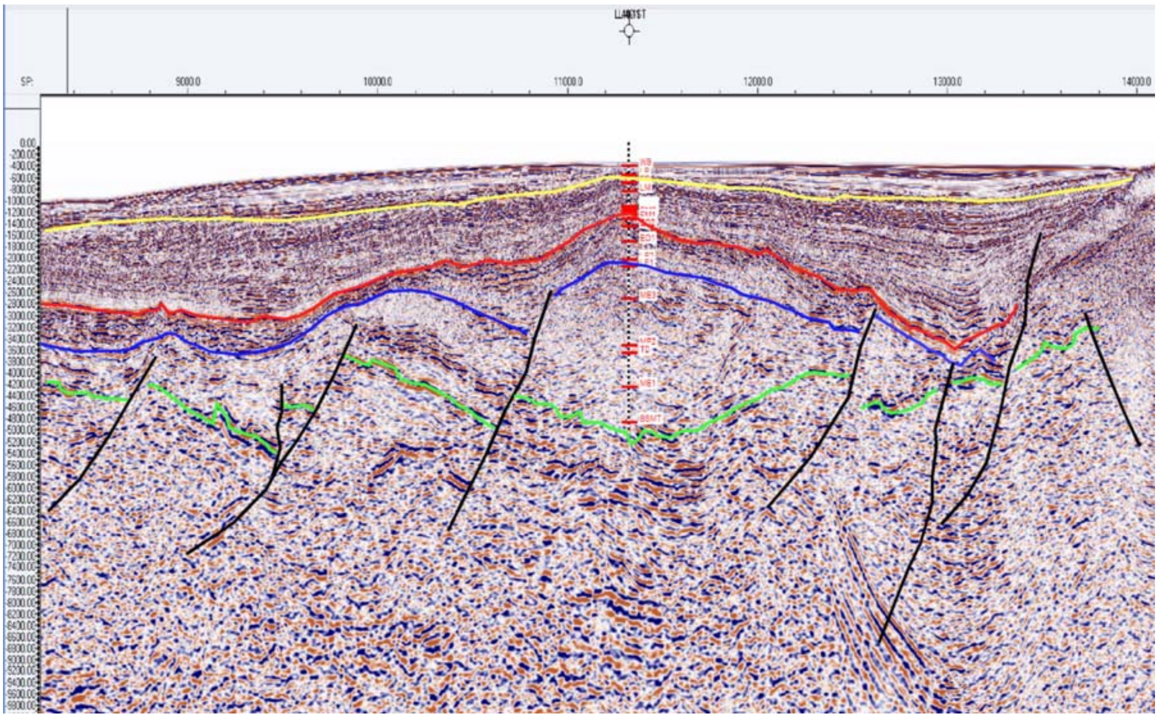

Figure 5 - PSDM image across an inversion structure in the Madura structural trend. (location shown in Fig. 1A). Total vertical section is 9800 m. Well is the L-40-1 well. Yellow-colored reflector is a Lower Pliocene surface tied to the well, red and blue Eocene surfaces, and the green is top Cretaceous 'economic' basement.