7th Biennial International Conference & Exposition on Petroleum Geophysics

"HYDERABAD 2008"

P -407

Dovetailing Macro and Micro Tectonics for Prospect Level Structural Synthesis, Kerala Konkan Basin

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Summary

Evaluating the area in terms of its tectonic architecture involves a visualization of the very number of deformation episodes, their overprints and scale of deformation. Kerala Konkan basin being a passive volcanic continental margin inherited complex geology characterized by a number of tectonic episodes starting from late Jurassic Karoo rift to KT Seychelles India rift, hotspot-volcanism related tectonic inversions and finally compressional imprints pertaining to the Himalayan orogeny. Consequently, understanding tectonic architecture of the area becomes an essential component for prospect generation and evaluation. An iterative and systematic approach developed through integration of regional gravity, 2D seismic and prospect level 3D seismic attributes (coherency and spectral decomposition) in conjunction with concept based paleo-tectonic reconstruction models has resulted in proposing the regional and local scale tectonic architecture of the basin.

Introduction

Delineating tectonic architecture is one of the challenging tasks along the south western continental margin of India. It has been a tradition practice in the industry to use gravity-magnetic and seismic data sets to explain the structural geometry of any region. Present study concentrates on realization of deformation pertaining to various tectonic episodes, their scales and relationship.

Having been classified as complex volcanic passive margin, Kerala Konkan basin (Fig 1) shares same geologic history with the contiguous Bombay offshore basin in the north and Mannar Basin to the south. Basin came into existence during the breakup of Madagascar-India-Sri Lanka-Antarctica continental assembly from East Africa undergone multi-episodic rifting viz., Permo-Triassic Karoo (Al Danforth et al, 2007), Late Cretaceous Madagascar-India (Alan Collins, 2006) and KT Seychelles rift (Biswas et al., 1982), each associated with localised volcanism overprinting the deformation events punctuated by hotspot trails viz., Marion (Anil Kumar et. al., 2001) and Reunion. Dominant structural trends in the area are NW-

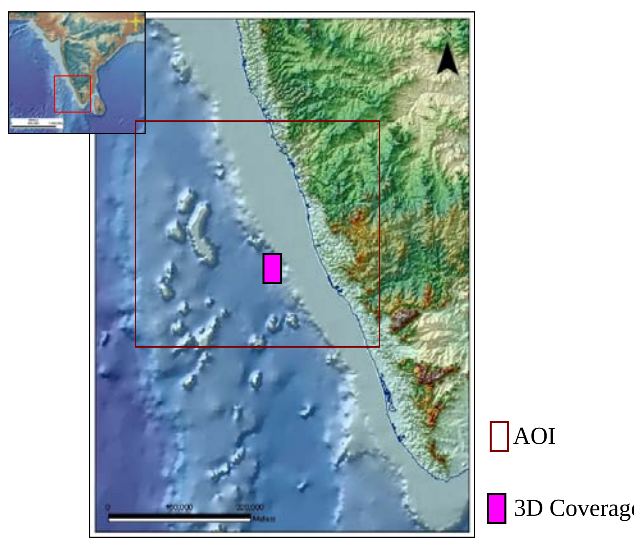

Figure 1: Location Map of Kerala Konkan Basin

SE to NNW-SSE and NE-SW. The nature of separation is an important topic of debate as the structural imprints along the margin are represented by vertical to sub-vertical faults with regional depressions separated by basement arches. This paper discusses briefly about a comprehensive geophysical approach integrating geologic data to explain the tectonics at various scales and unravel at micro level.

Theory and Methodology

Evaluating the area in terms of its tectonic architecture is the function of identifying the number of tectonic events the area has undergone, deformation overprints and visualizing the scale of deformation. A regional approach has been adopted to analyze the structural architecture integrating regional seismic, gravity-magnetic and prospect level 3D seismic attributes.

Regional Gravity Interpretation

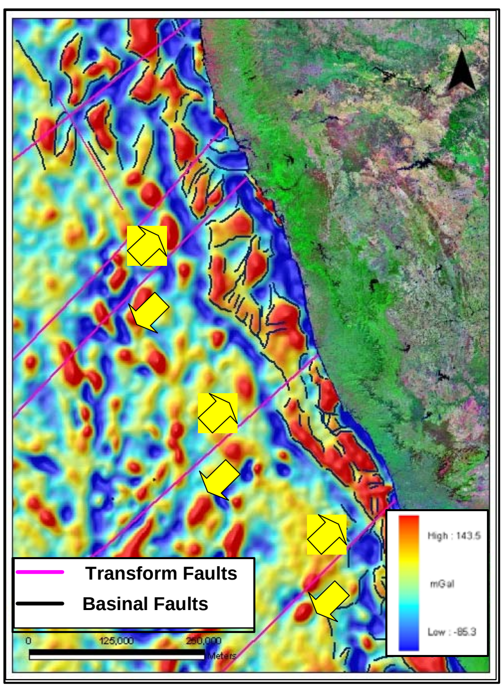

Figure 2: Bouger Gravity Anomaly Bandpass 10-200 km Map with Regional basin level, major transform and their relative movement. (Rao, et. al., 2007)

Gravity data is one of the important tools for analyzing the regional fault geometry and basement tectonic trends (Dale Bird et al., 2001). Initial reconnaissance was carried out at regional as well as prospect level to determine tectonic architecture, major structural trends and sediment thickness. Gravity enhancements (Rao et al, 2007) from satellite derived free-air anomaly field (Sandwell and Smith version 15.1) to improve desired anomaly features were used to evaluate the area to unravel the evolutionary history of the basin. Bouger gravity Bandpass 10-200 km map (Fig. 2) (Rao, et. al., 2007) show three major structural trends in the region viz. NW-SE, NNW-SSE and NE-SW cross trend related to the major continental rifting episodes.

Interpretation from gravity data shows right stepping nature of the shelf margin fault defining the basin geometry intersected by major transforms extending to deeper offshore. Structural disposition and stepping of the shelf margin fault is interpreted to be the result of the movement along these major transforms governing the width of the shelf in the western offshore basins. In addition to the major structural trends, signatures of the volcanic activity representing the Marion and Reunion hotspot were successfully tracked.

Regional Seismic Interpretation:

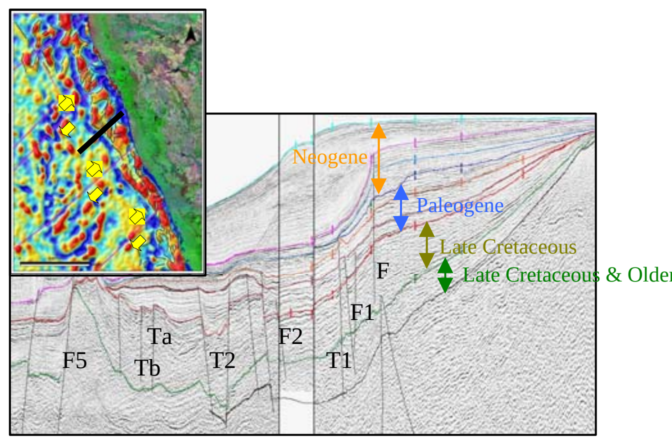

Figure 3: Regional Seismic section showing the structural architecture of the basin trending high angle shear faults and NE-SW cross trends inducing the compressional element at the locales of intersection

Regional seismic interpretation from offshore Kerala region and adjoining areas, integration with regional gravity-magnetic data, calibration from the wells drilled in the area by different operators and DSDP information, tectonic reconstruction, structural modeling studies, regional geophysical studies by National Research Institutes (NIO and NGRI) and published literature has brought out a new dimension to the geologic history of the region. Regional seismic (Fig. 3) shows a typical passive continental margin basin architecture dictated by the NW-SE and NNW-SSE.

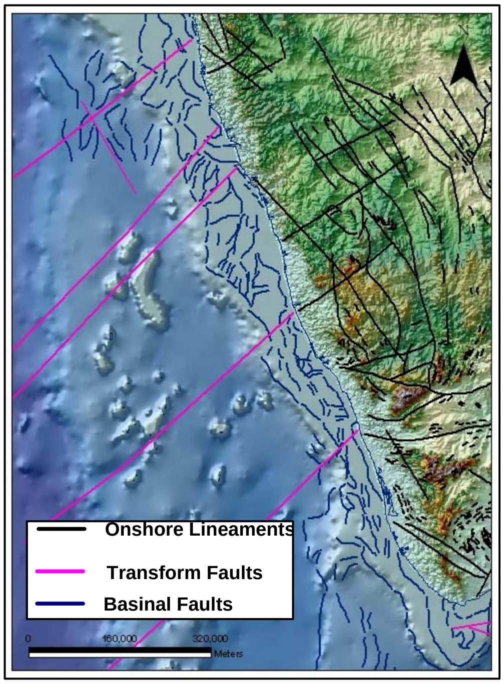

Figure 4: Regional tectonic map integrating onland and offshore lineaments.

Area has experienced two major episodes of deformation viz., a. trans-tensional separation between India and Madagascar and b. cross trend deforming the pre-existing structures due to change in the regional stress regime. Regional composite tectonic map (Fig. 4) thus generated from integrating onshore and offshore tectonic elements after crucial analysis and synthesis of geologic and geophysical datasets shows three major structural trends viz. NW-SE to NNW-SSE trend related to Permo-Triassic (Karoo) rift between East Africa and Madagascar-India-Sri Lanka-Antarctica continental assembly initiated by transtentional movement along Davies Fracture Zone (NW-SE), NNW-SSE trending Late Cretaceous rift between Madagascar and India followed by KT India-Seychelles rift. It is evident that southern margin of India has been witnessing and was an integral part of tectonic events starting from Pan-African orogeny – Permo Triassic – Jurassic – Cretaceous rifting episodes.

3D Seismic Interpretation:

Semblance attributes are very effective tools for visualizing the reflection continuity and Spectral decomposition applied along horizon is quiet helpful in identifying the reflection breaks on the events. First pass 3D interpretation has shown the three generations of regional faults trending NW-SE, NNW-SSE and NE-SW (Fig. 5). Coherency attribute was calculated with 20, 40 and 100 ms windows consistent along the interpreted time structure horizon to enhance the visibility of the minor geometric elements associated with the dominant structural trends in the area. It has been noticed that the coherency attribute extracted with the minimum time window (20 ms) consistent with the horizon is very efficient in tracing the cross trends and minor discontinuities across the horizon in great detail (Fig. 6).

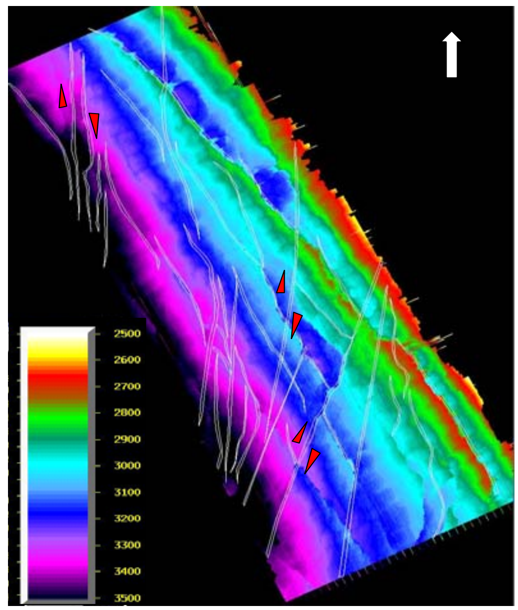

Figure 5: Time Structure map showing the relative block movement, fault geometry and structural disposition.

Spectral decomposition although known for its crucial frequency measurement, is also utilized as a wavelet measurement tool. Assumptions made during interpretation that, if tuned events across the faults get highlighted on a particular frequency, then discontinuities across that event will also get highlighted. In the current study, spectral decomposition was run on a 80 ms window centered at the Early Eocene level using Discrete Fourier Transform (DFT) with Gaussian taper. Slices prepared at varying tuning cube frequencies ranging from 8 to 64 Hz with 4 Hz sampling interval were analyzed for the wavelet continuity. It has been noticed that, tuning frequencies in the range of 8 to 16 Hz (Fig. 7a) brought out the finer fault distribution in great detail. Integrating the output from the semblance and spectral decomposition attributes with time structure maps has enhanced the clarity of the fault trends, their mutual relation and control on the facies distribution in the study area.

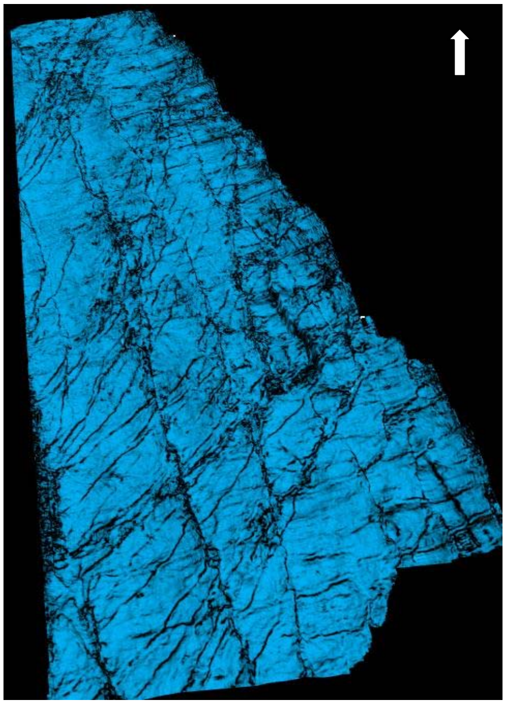

Figure 6: Horizon consistent semblance at Ely Eocene level extracted with 20 ms window showing the fault geometry with in 3D area.

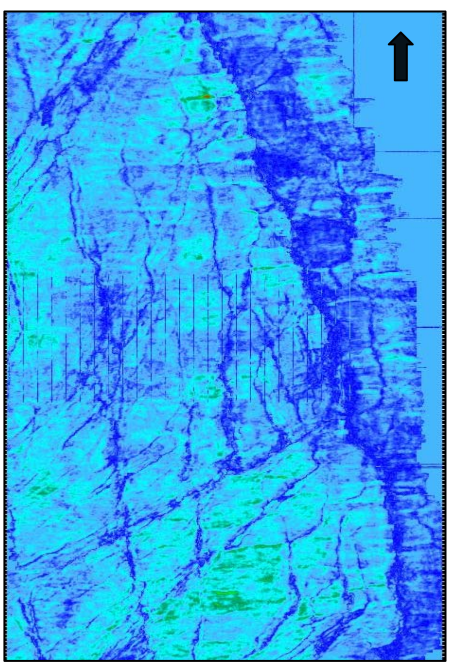

Figure 7a: Spectral Decomposition slice at 8Hz tuning frequency at Ely Eocene Level

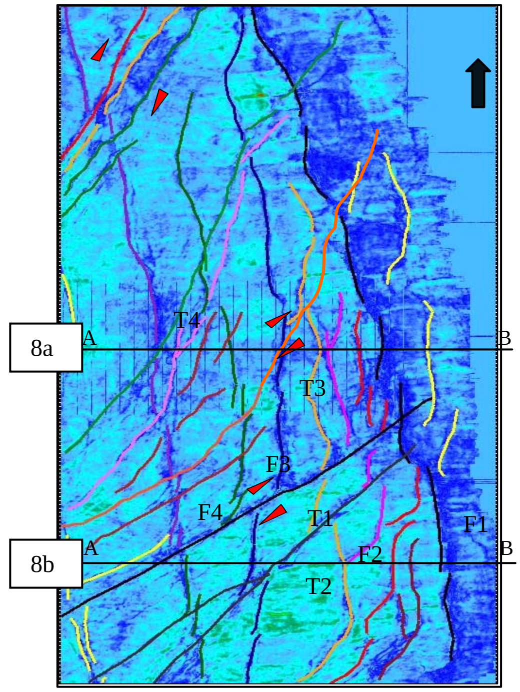

Figure 7b: Spectral Decomposition slice at 8 Hz tuning frequency at Ely Eocene Level with interpreted faults and block movement.

Fault Interpretation and Regional Tectonics:

Faults interpreted from spectral decomposition slice shows two generations of dominant fault trends viz., NNW-SSE and NE-SW, co-relatable with those interpreted from regional gravity and seismic data. Further, clues for the nature of deformation and style of separation can also be predicted based upon the results of seismic attribute studies. Vertical to sub-vertically dipping, left stepping, NNW-SSE to NW-SE trending faults (F1, F2, F3 & F4) (Fig. 8a&b) are interpreted to have been resulted from the initial sinistral transtension between India and Madagascar. The structural disposition and sense of plate movement resulted in the formation of sheared extensional basins separated by basement arches.

Cross cutting the first generation shearing extensional faults is another set trending NE-SW. Spectral decomposition slice at 8 Hz tuning frequency (Fig. 7a&b) shows a wider deformation zone indicating intense shearing with minor extension. These faults T1, T2, T3 & T4 are at an angle of approximately 45^o to 50^o and are dipping at steeper angles than those trending NNW-SSE. These faults are left stepping normal faults with dextral rotational component, creating compressional regime at the point of intersection with pre-existing faults. Figure 8a & b show that these faults although have formed at initial phase of separation between the eastern gondwana continental assembly, were repeatedly rejuvenated during the evolutionary history of western continental margin of India.

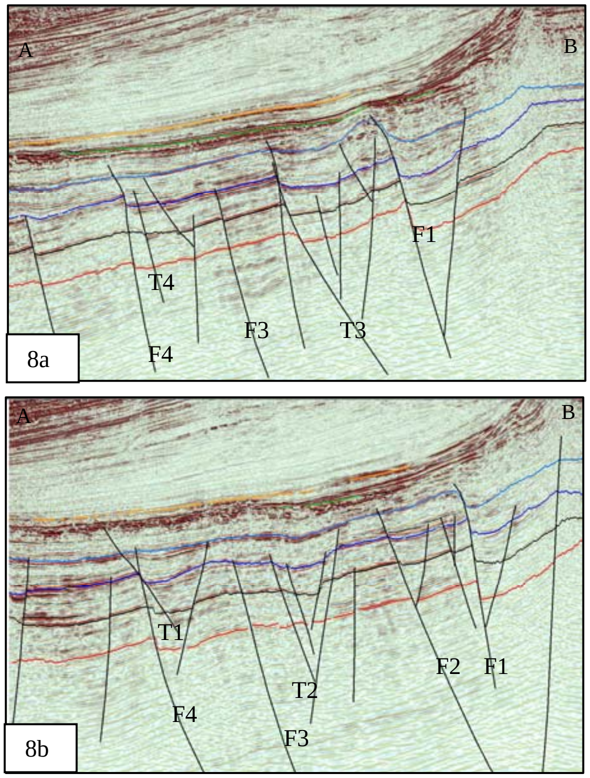

Figure 8a & b: Seismic section showing faults related to different deformation episodes. (F: Faults related to basin forming tectonics and T: related to basin modifying tectonics)

Conclusion

Interpretation from regional gravity and 2D seismic data in conjunction with prospect level 3D seismic attribute analysis has successfully delineated the basin controlling tectonic elements from macro to micro level. Definitive approach to analyse the regional data set is very essential in understanding the basin level tectonics leading to finer detailing of multi-episodic deformation controlling the structration at prospect level.

Acknowledgements

The authors would like to express their gratitude to Reliance Industries Limited for supporting the publication of this work. We thank our colleagues for their critical views and suggestions.

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