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Expanding Exploration Frontiers of India

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Summary

Understanding the continental margins, basins evolution and their architecture is a dynamic process. Integration of new set of data coupled with regional concepts have redefined the exploration frontiers which are more complex and challenging. The frontiers of today are different from what we conceived yesterday. A revisit to the concepts of plate-tectonics in conjunction with bold ideas and innovative technology clearly suggests that deep and ultradeepwater plays are the future frontiers of Indian petroleum search. Bay of Bengal is the sediment repository of Bengal Fan and pre-collision sediments. Two tectonic elements, 90° E and 85°E ridges, positioned longitudinally, divide the sediment apron into three basins: the western basin (8 km thick), the central basin (22 km thick in the North) and the eastern basin (2 km thick). With huge thickness of sediments the abyssal plains of Bengal Ocean provide an optimistic preview of petroleum precursors for exploration. Episodic rifting of the Gondwana during the period of the Jurassic till the end of the Cretaceous, facilitated megaregional rift-drift structural superpositions in the southern tip of India i.e., deepwater Kerala basin. Various tectonic events pertaining to oceanic fracture zones/transforms generated largescale sub-basalt geological structures warranting immediate exploration attention.

Introduction

Understanding the continental margins, basins evolution and their architecture is a dynamic process. Integration of new set of data coupled with regional concepts have redefined the exploration frontiers which are more complex and challenging. The frontiers of today are different from what we conceived yesterday. Deepwater exploration globally is taking a new turn in terms of concept, technology and discovery. The past two decades which have witnessed the deeper frontiers are pushed further deep (to more than 3kms) and there is a tendency to even go beyond. The prominent expanding frontiers in Indian context, lies in deep waters of both eastern and western continental margins.

Seismic-gravity-magnetic (SGM) combination is tried out to decipher deepwater basins, unnoticed earlier. Oceanic fracture zones/transform faults, identified by SGM enhances petroleum prospectivity of deepwater and their shallow water counter-parts.

A revisit to the concepts of plate-tectonics in conjunction with bold ideas and innovative technology permitted to identify deep and ultra-deepwater opportunities to realize the estimated petroleum potential of Indian deep offshore basins. For example, long offset seismic, gravity and magnetic characterization of major tectonic elements such as 85° E ridge, Vishnu fracture zone, Laxmi ridge and Indus and Bengal fans enhanced the understanding of the megaregional tectono-stratigraphic frame-work and thereby sectorwise hydrocarbon habitats.

Bay of Bengal is the sediment repository of Bengal Fan and pre-collision sediments, characterized by its three extended arms with decreasing thicknesses stretching up to 7° S. Two tectonic elements, 90° E and 85°E ridges, positioned longitudinally, divide the sediment apron into three basins: the western basin (8 km thick), the central basin (22 km thick in the North) and the eastern basin (2 km).Curie isotherms in conjunction with oceanic transforms, when utilized as a basis for envisaging heat flow regimes, western basin appears to be a favorable situation for thermogenic hydrocarbons and central basin for biogenic hydrocarbons predominantly. In essence, the abyssal plains of Bengal Ocean provide an optimistic preview of petroleum precursors for exploration.

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The episodic rifting of the Gondwana during the period of the Jurassic till the end of the Cretaceous, facilitated megaregional rift-drift structural superpositions in the southerntip of India i.e., deepwater Kerala basin. Plate tectonic reconstruction of Late Jurassic to Early Cretaceous, demonstrates that the basin as situated on the north-eastern part of Proto-Mozambique Ocean, with Antarctica as the major provenance of sediment supply. Subsequent tectonics pertaining to oceanic fracture zones/transforms generated largescale sub-basalt geological structures warranting immediate exploration attention.

East Coast of India

The eastern continental margin of India (ECMI) in Bay of Bengal has been evolved through multiple phase of tectonic activity and fed by abundant supply of sediments brought by prominent river systems.The ECMI has been catergorised into seven sedimentary basins namely Ganga-Brahmaputra (Bengal Basin), Mahanadi, Visakhapatnam Bay, KrishnaGodavari, Pennar-Palar, Cauvery and Gulf of Mannar from north to south based on integrated interpretation of free air anomaly, Bouger anomaly, isostatic residual anomaly and multichannel regional seismic data (Fig. 1). Seismogeological sections from three sedimentary basins namely , Bengal Basin , Krishna-godavari and Cauvery are presented in this paper to describe the various deep water play types.

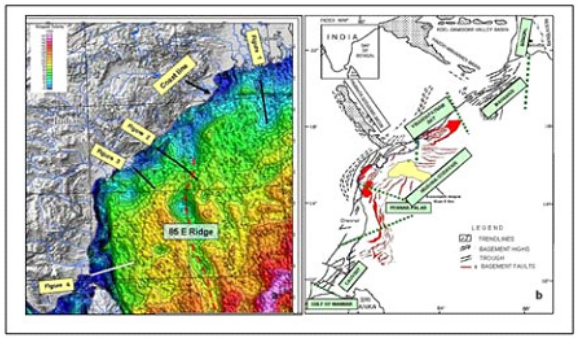

Figure 1: Maps showing basin classification in east coast of India. a) represents a bouguer gravity map with the lineaments which defines east coast basins, b)east coast basin classification based on interpretation from gravity, magnetic,seismic interpretation.

Bengal Basin

The Bengal Basin is fed by two major river systems namely Ganges and Brahmaputra. To its west are the crystalline rocks of the Singhbhum-Chotanagpur platform, while to its north lies the Shillong plateau.

The depositional elements of the basin are typically represented by numerous, repeated canyon cuts caused by mass-wasting, with intervening fills in the form of deep water to sub-aerial channels and progradational deposits as deltas. The regional seismic section (Fig. 2) depicts the shelf slope system with clear cut prograding shelf edge with time. This section also brings out the morphology of the present day channel-levee-overbank system, which possibly could act as the prominent petroleum system in the basin.

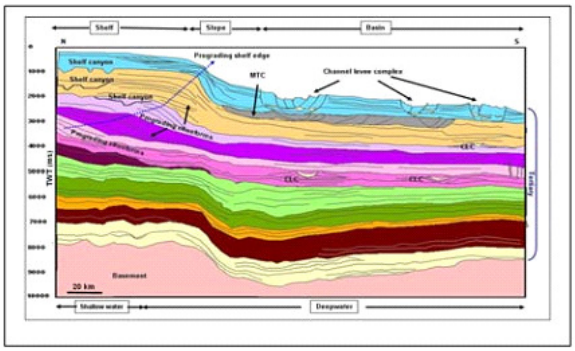

Figure 2: Regional seismo geological section representing shelf-slope system and depositional elements of GangaBrahmaputra (Bengal) basin. Various features identified on the section are Prograding shelf edge through geological time, morphology of present day channel-levee complex, shelf canyons and mass transport complex. Abbreviations used in the figures: MTC –mass transport complex,CLC-channel levee complex

Krishna-Godavari Basin

The basin has been evolved as a composite rifted horstgraben features in the Late Jurassic period. It was part of the development of the east coast divergent margin. The horsts and grabens were separated by vertical or steeply dipping faults. Since the Cretaceous period, the basin has become a pericratonic rift basin (Rao, 2001). The basin is fed by two major river systems namely Krishna and Godavari. The regional seismic section (Fig. 3) depicts

thick pile of Mesozoic and Tertiary sedimentary sequences. The Mesozoic sequence represents rifted geometry where as the Tertiary sequence exhibits very bright amplitude package suggesting numerous vertically stacked sinuous deep water channel – levee complex (Bastia, 2006) .The sand to shale ratio within these channels are very high providing an excellent reservoir facies for petroleum accumulation.

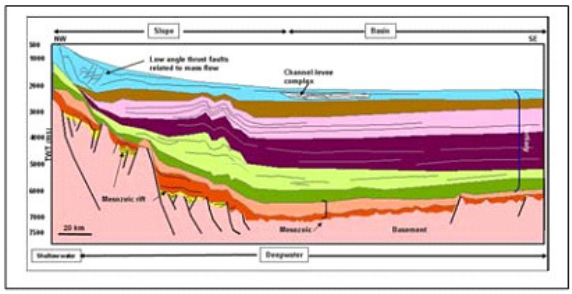

Figure 3: Regional seismo-geological section of the Krishna-Godavari basin depicting Mesozoic and Tertiary sedimentary sequences. Interpreted faults in the Mesozoic section forms well defined half grabens. Tertiary section is characterized by channel levee complex and mass transport complex

This basin represents a series of horst-graben features that are oblique to the coast like the Palar basin in the north (Balakrishnan & Sharma, 1981). The grabens are filled with Mesozoic rocks. Thick Tertiary sediment pack mostly contributed by Cauvery river system is accumulated as a thick wedge on the uniformly eastward sloping platform.

The regional seismic section (Fig. 4) shows the prominent basement highs and the Mesozoic sediments abutting against the highs. The Tertiary high amplitude packages are suggestive of channel fill sediments.

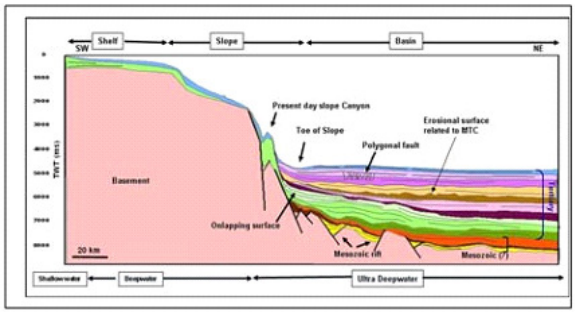

Figure 4: Regional seismo-geological section of Cauvery basin showing prominent basement highs and associated Mesozoic-Tertiary sequences. Sediments abutting against the basement can be a good target for hydrocarbon exploration

85^{o} East Ridge

Another important tectonic element in the eastern offshore of India is 85^{o} East Ridge.The east coast deep sea basins are limited to the east by the prominent ridges . 85^{0} East Ridge is the most conspicuous tectonic features amongst them which played a significant role through geologic times in confining and distributing the sediments from the coast to deep sea (Ramana et al., 1997; Mukhopadhyay et al., 1991). The ridge is an aseismic one which has evolved through geologic times (128 Million years ago).The expression of 850 E ridge below the Bengal fan sediment is shown in the regional seismic profile (Fig. 5).Free air anomaly .bouger anaomaly and isostatic residual anomaly maps of east coast margin of India coherently bring out the disposition of this important ridge.

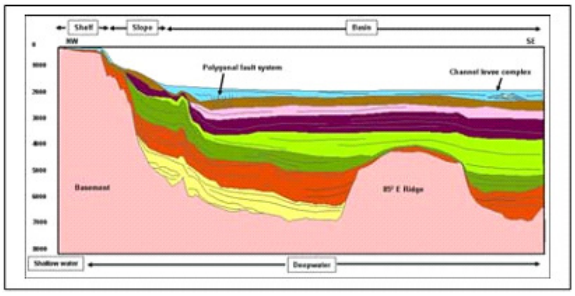

Figure 5: The seismic section depicting the expression of 85^{o} E ridge. Two lows flanking the ridge can be a good place for source rock generation. Channel levee complex & polygonal faults are also seen.

West Coast of India

Deep water exploration in the western offshore of India is mostly focused to the Kerala-konkan basin.The frontier Kerala deepwater basin is bounded by prominent north-south oriented oceanic fracture zone (Vishnu FZ) in the west and Comorin ridge in the east. Vishnu Fracture Zone (VFZ), which extends from the Kerala shelf southward to the Carlsberg-Ridge, over a length of more than 2500 km, has a strong bearing on the the sedimentation as well as structural fabric of the basin.

Deepwater Kerala being a frontier, regional studies are pertinent to provide a geological basis for understanding the very existence of sub-basalt Mesozoic sedimentary basin, tectonics, plausible petroleum systems and the over-all hydrocarbon prospectivity. Studies on the conjugate margins viz., Gulf of Mannar, Madagascar, Seychelles and Mozambique basins provided a regional geological framework to envisage the petroleum potential of the Mesozoics in the study area (Fig. 6)

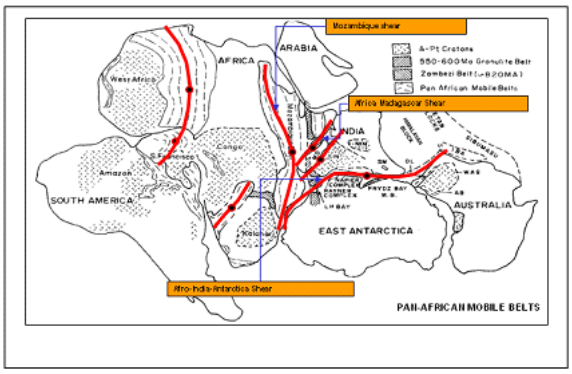

Figure 6: Gondwanaland showing the distribution of Archaean-Proterozoic cratons and Pan-African and other older mobile belts, during Early Mesozoic.

Regional study correlating the geology, tectonics and stratigraphy from sedimentary basins along East Africa, Western Madagascar, Western India and Sri Lanka to establish conjugate continental margin relationship and evaluate the regional petroleum system has been tried out to decipher the petroleum prospectivity of Kerla-Konkan basin (Fig. 7).

Long offset data acquired in the basin have helped in better imaging of the sub surface geology. Another challenge faced in this frontier basin is below basalt imaging (Fig.8). Advance cutting edge processing have really brought out many sub basalt events .

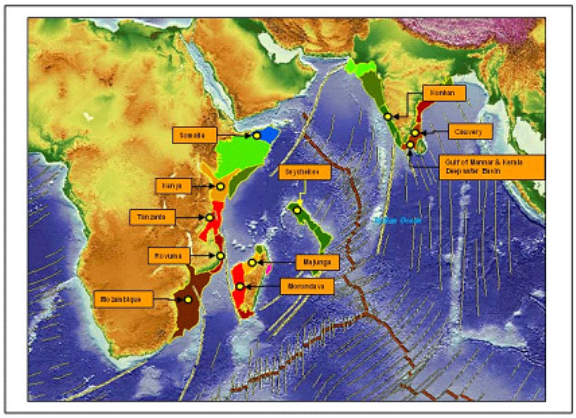

Figure 7: Eastern Gondwana conjugate continental margin basins along east Africa, Western Madagascar, western continental margin of India and southern tip of India

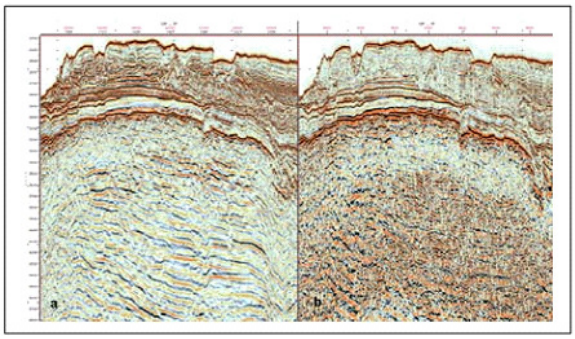

Figure 8: A representative seismic section from KeralaKonkan basin showing improvement due to processing.a) advance processing b) conventional processing.

Conclusion

New frontiers for hydrocarbon exploration lie in both east and west coast of Indian deep waters. Although commendable efforts have been made by various companies in the East coast of India, a lot more are waiting to be exploited. Ultra deep region around 85° E ridge needs more attention in the near future. Further another

challenging regime exists in Kerala-Konkan basin of west coast of India . Application of cutting edge geological and geophysical technology with focus on better imaging and interpretation would be the key to address the above frontiers.

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