

## Cretaceous and Paleogene Sequences of Indian East Coast Deep Offshore: The New Frontier for Deepwater Exploration & Development

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### Keywords

**East coast margin of India, deep water play types, Cretaceous and Paleogene sequences**

### Abstract

Deep and ultra-deep-water exploration has been rejuvenated given the progress made in deep water seismic imaging and drilling resulting in significant cost reductions and critical technological breakthroughs. The higher oil prices and diminishing reserves have given further fillip to deep-water exploration and development.

India's east coast passive margin deep offshore basins remain largely underexplored. Discoveries in the Krishna Godavari and Cauvery peri-cratonic basins demonstrate the potential for a working petroleum system in the deep-water setting.

Fundamental to a working petroleum system and basin opening discoveries are the occurrence of robust source rock intervals. Currently, exploration operations are conducted in onshore and shallow-water zones of peripheral basins. Lately oil and gas discoveries were made in Krishna Godavari, Cauvery, and Mahanadi basins. These discoveries show that deep-water areas hold vast potential for hydrocarbon occurrence.

A good regional seismic data set is fundamental to the identification of play fairways and potential leads. TGS's excellent effort at reprocessing existing 2D data resulted in the creation of a large 587,000 sq.km pseudo-3D (2D cubed) extending out into deep and ultra deep water (Fig. 1). A recent review of Seismic lines from the 2D cube highlights a thick stratigraphic succession deep offshore ranging up to 10,000 meters. The post-rift stratigraphic section deep offshore extends from the early Cretaceous to the present day. Rifting history and regional geological understanding points to the existence of multiple source rock intervals including the world class Cenomanian-Turonian source interval. The deep offshore drill wells illustrate good to excellent source

rocks in Paleocene and Cretaceous sediments (Pande et al., 2008). The seismic demonstrates that there is adequate sediment thickness to drive maturation.

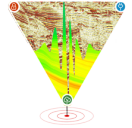
Much of the Cretaceous succession deep offshore is dominated by low stand deposits derived from hinterland drainage systems of Krishna-Godavari, Cauvery, and Mahanadi rivers (Bastia, 2007). However, in contrast, post Miocene depositional systems are dominated by the prograding Bengal Fan. Broad deep water distributary systems constitute reservoirs.

Multiple play types and potential traps are identified from the TGS-2D cubed. Hydrocarbons migration likely occurred along faults and facilitated by carrier beds to form significant accumulations. Perhaps, some of the best analogues for this margin are the giant oil fields of Equatorial Margin of Africa which is also characterized by a narrow shelf and a broad deep offshore area. This data set may play a key role in unlocking the potential of this basin.

### Introduction

The passive continental margin of east coast India developed following the breakup of India from Antarctica. The breakup occurred around 136-132 Ma (Rao., 2001). Three distinct phases of evolution marked this passive margin continental margin, which being intracratonic rift, post rift thermal subsidence and passive continental margin. From north to south the three important basins are Mahanadi, Krishna-Godavari, and Cauvery. Oil and gas discoveries occur onshore and shallow offshore within these basins (Fig. 2). Lately there have been a few gas discoveries in the deep offshore Krishna-Godavari Basin. However, much of the deep offshore is poorly explored. The focus of this paper is to





### Play Element Source

Figure 3 illustrates the plays and play elements pertinent to the deep offshore. Fundamental to a working petroleum system and basin opening discoveries hinges on the occurrence of robust source rock intervals. Rifting history and regional geological understanding points to the existence of multiple source rock intervals including the world class Cenomanian-Turonian source interval. The deep offshore drill wells also illustrate good to excellent source rocks in Paleocene and Cretaceous successions (Pande et al., 2008).

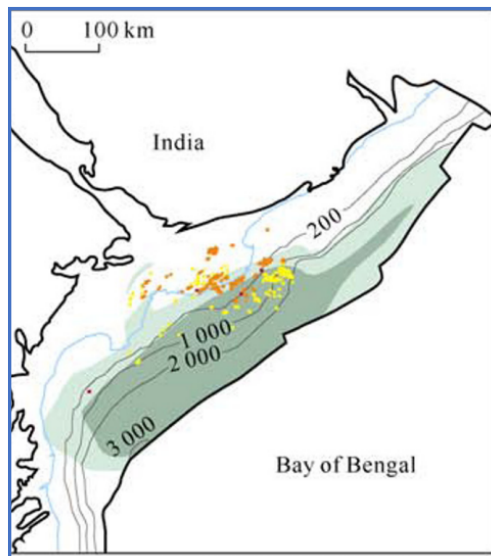


Fig. 4 Lower Cretaceous source rock distribution, Krishna Godavari Basin (Yanqun et al., 2017)

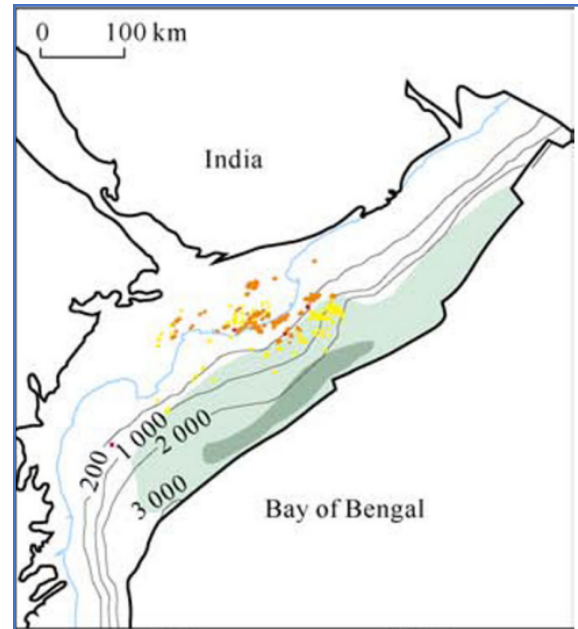


Fig. 5 Paleocene source rock distribution, Krishna Godavari Basin (Yanqun et al., 2017)

In addition to the two proven source rock intervals (Figs 4 & 5), there is the potential for the existence of world class Cenomanian-Turonian source interval that is ubiquitous within passive margin settings. Perhaps one of the best global analogues for this source intervals existence is the Equatorial Margin of Africa and its conjugate along the south American margin. Plate restoration (Fig. 6) for the east coast margin passive margin development illustrates the potential. The seismic demonstrates that there is adequate sediment thickness to drive maturation (Fig 7.). The thick stratigraphic succession (Fig. 8) in the deep offshore drives maturation which is in many ways may be similar to the deep Gulf of Mexico and the Atlantic margin basins. Understanding the maturation and migration story may well be fundamental to unlocking the potential in the deep offshore setting.

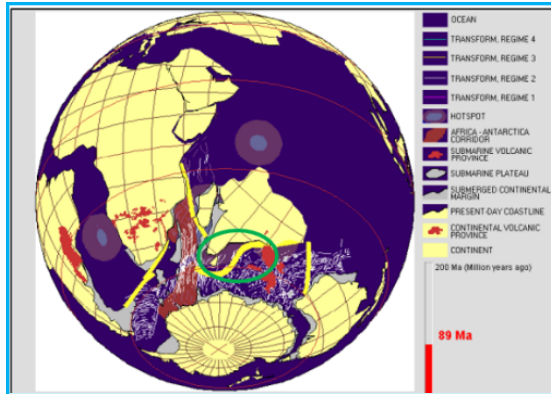
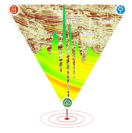


Fig. 6 90 Ma India's rapid drift initiated. Plate restoration highlights the potential existence of the C-T source interval deep offshore Reeves & Witt., 2000.

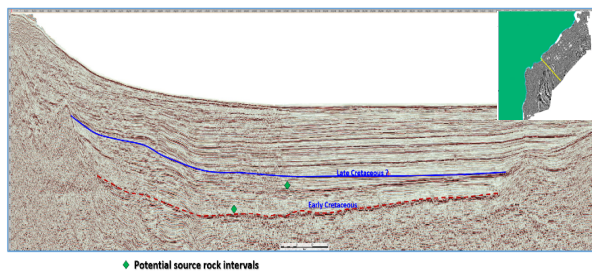


Fig. 7 TGS 2D cube illustrates the potential for the existence of post upper Cretaceous (C-T) source interval and sufficient sediment column to drive maturation.

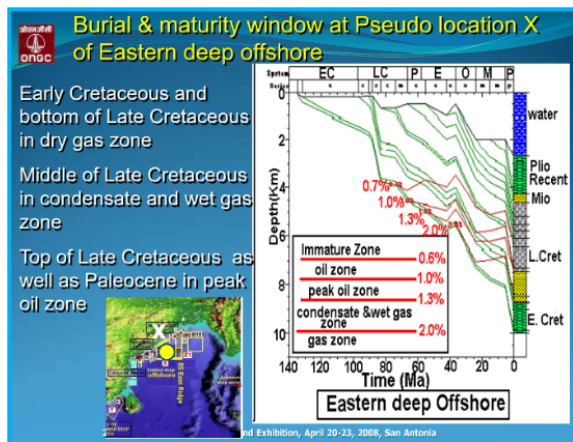


Fig. 8 Burial and maturity window deep offshore Pande et al., 2008

### Play Element Reservoir

Much of the Cretaceous succession deep offshore is dominated by low stand deposits derived from hinterland drainage systems of Krishna-Godavari, Cauvery, and Mahanadi rivers (Bastia, 2007). However, in contrast Post Miocene depositional systems are dominated by the prograding Bengal Fan. Broad deep water distributary systems likely constitute reservoirs. The example in Figure 9 illustrates the development of shelf edge delta and the associated low stand fan complex in deep water.

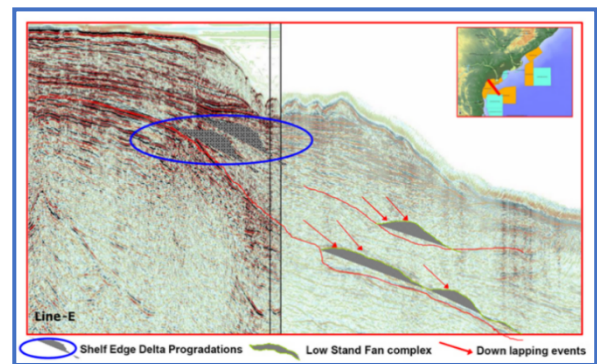
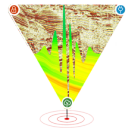


Fig. 9 Seismic line showing shelf edge delta and deep-water low stand fan complex, Bastia et al., 2007.

### Play Types

The stratigraphic succession and geological history of Eastern Continental Margin of India is genetically analogous in overall set up to the south American margins as seen in the Sergipe Alagoas basin Brazil offshore as well as in the Guyana-Surinam basin where the recent giant discoveries are reported (Fig.10). It is also genetically comparable to the Rakhine Basin Offshore Myanmar, which form the complimentary rift shoulder to Indian Margin. In the recently processed 2D cube, we can identify strong leads, multiple play types and potential traps (figs 11 & 12). However, full 3D may be required to identify the detailed geometry and map them. We can identify multiple play types and potential traps from the TGS-2D cubed (Fig.11). Trap types include both structural and stratigraphic traps (Fig.12). Hydrocarbons migration likely occurred along faults and facilitated by carrier beds to form significant accumulations.



Low stand up-dip pinch outs, paleo structural/volcanic drapes sitting adjacent to the older grabens having embedded source sequences, low stand fans and faulted bypassed sand complexes would be the likely plays in the Paleogene–Cretaceous succession. Newly processed 2D cubed seismic does indicate initial signatures of such features providing strong leads for follow up 3D campaigns in high potential corridors to translate these leads into drillable targets.

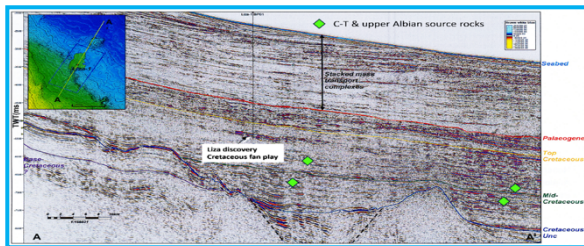


Fig. 10 Seismic line passing through Liza-1 discovery showing the play type Price et al., 2021.

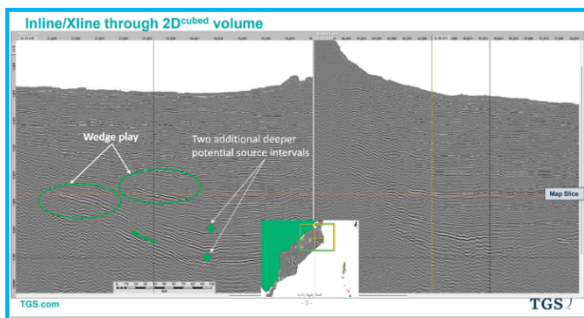


Fig. 11 the wedge play illustrated here has rejuvenated deep water exploration & development in Atlantic margin basins.

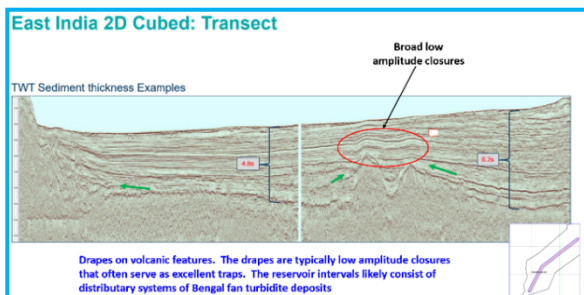


Fig. 12, Broad low amplitude drape like features on volcanic highs. Differential subsidence around the highs creates structural closures.

## Conclusions

Deep offshore east coast India is likely characterized by robust play elements. Shallow water oil and gas discoveries and a few deep offshore discoveries highlight the existence of a working petroleum system in the deep offshore. The east coast passive margin with its narrow shelf and a broad slope and abyssal setting is analogous to the Equatorial Margin of Africa and its conjugate that are characterized by giant oil and gas discoveries. The stratigraphic succession in terms of source rock development is significantly identical. The thick stratigraphic succession in the deep offshore likely drives maturation which is in many ways may be like the deep Gulf of Mexico and the Atlantic margin basins. Understanding the maturation and migration story may well be fundamental to unlocking the potential in the deep offshore setting.

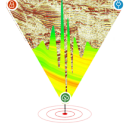
We can identify multiple play types and potential traps from the TGS-2D cubed. This data set will likely play a key role in unlocking the potential of this basin.

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