9th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2012"

P-271

Hydrocarbon Potential of the Area on and around Ninety Degree East Ridge to the West of Andaman Islands.

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Summary

The present study area is on the northern part of the buried Ninety East Ridge between 110 to 140 latitude to the west of Andaman Islands. The areas have water depth ranging from 2700 to 3200m and yet to be explored for hydrocarbon. Available seismic data in the area is minimal. In the only well drilled in the shallow water on the accretionary prism to the west of the North Andaman Island, sediments from Late Cretaceous to Recent were encountered.

The present work is an attempt to assess the hydrocarbon potential of the area on the basis of published literature and few 2D seismic lines across northern part of the area. Regionally, the area in and around NER is tectonically less disturbed and stable compared to the accretionary prism to the east of Andaman-Sunda trench. Thickness of sediments overlying the NER shows considerable variation but is in the general range of 2.0 – 6.0 km. The trench in the east has also similar sediment thickness.

In the study area Pre-Eocene sedimentary units consisting of pelagic sediments and terrigenous materials and Eocene to Oligocene deep water shales may act as a good source rock. Higher basement heat flow in the area is expected to lead to early maturation of the argillaceous sediment. The Mio–Pliocene Bengal Fan providing coarser clastics may give rise to good reservoir facies. Cretaceous to Eocene limestone / chalks also can be expected to provide good reservoir. Structural traps in the form of large anticlines are the principal type of traps for accumulation of hydrocarbons in Miocene sediments. Stratigraphic traps like wedge outs, carbonate reefs also can provide other possible hydrocarbon plays.

Introduction

In the deep-sea areas of Indian Ocean to the south of Bay of Bengal, the Bengal fan sediments are underlain by two hotspot traces, viz., the Eighty Five Degree East Ridge, which runs in the central part of the fan and the Ninety Degree East Ridge farther east, close to the Andaman subduction zone (Sunda Trench)(Fig.1, 1A). It is approximately 5,000 km (3,100 miles) in length trending North-South and northern part of it lies to the west of the Andaman subduction system in close proximity. The ridge consists of volcanic rocks which increase in age in the northward direction. It is interpreted that a hotspot in the mantle beneath the Indo-Australian Plate has created the ridge as the Indian plate moved northward. Northern part of the ridge plunges northward and is buried under thick sedimentary column.

The area under review is tectonically less disturbed and stable compared to the accretionary prism to the east of Andaman - Sunda trench. Eastern part of the Bengal fan which comes from the north covers this area (Fig. 2). Two to more than six kms of late Paleogene-early Neogene sediment is expected over the NER and adjoining areas.

The present study has been focused on the possible play types in and around NER. The play types are mainly carbonate platform, carbonate buildups, fault closures, drape structures, wedge out/ pinch outs features etc. It is observed that the NER has acted as paleo high which has facilitated the growth of carbonates under shallow water environment. However, the same has been drowned subsequently. This paleo high and further tectonism has resulted drape structures, fault closures and wedge outs.

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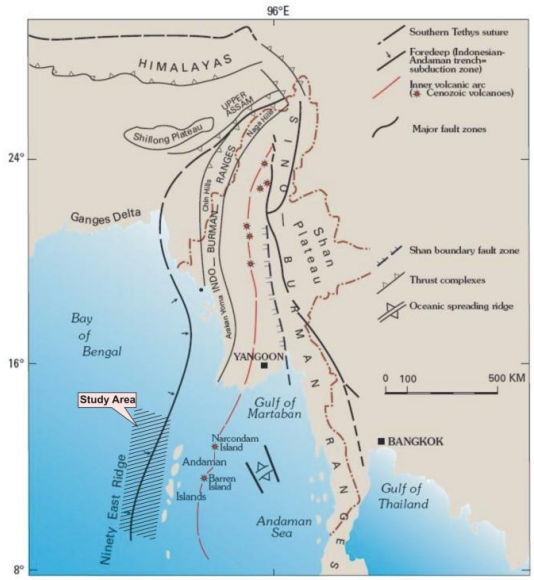

Fig.1 Regional Tectonic map of Andaman & adjoining areas (Modified from Bender, 1983 & Wandrey, 2006) .

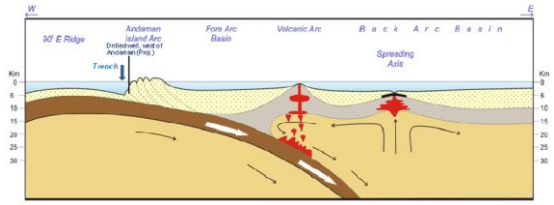

Fig.1A. Schematic Geological cross-section across Andaman Subduction Zone .

Fig.2 A regional map showing extent of Bengal fan sediments. (see the extent of Bengal fan sediments)

Ninety East Ridge (NER)

The bathymetric expression of the Ninety East Ridge (NER) is visible up to Lat. 10°N (**Fig.3**) but seismic reflection data indicate that it extends up to about Lat. 17°N. The gravity anomalies are strongly positive over the exposed segment of the ridge but are subdued over the buried portion **(Fig.4).** Towards north there is a prominent break in the continuity of the trench gravity low, where the NER seems to impinge upon the island arc. Seismic reflection data indicate that the NER is very close to the trench (C. Subrahmanyam et. al.,2008**).**

NER is a major aseismic ridge, which extends from 30°S northwards into the Bay of Bengal where it is buried beneath the Bengal fan sediments. The ridge forms the eastern limit of the Bengal fan against the Andaman arc. The NER is a complex zone of deformation within the Indian plate and part of the ridge experienced intense seismic activity in the past (Petroy and Wiens, 1989). The NER displays en-echelon block structure between 5°S and 10°N. Further north, continuity of the NER is mainly inferred from single and multichannel seismic data as the ridge is buried under the thick pile of Bengal fan sediments (e.g. Curray et al., 1982; Gopala Rao et al., 1997). East of the NER, the Andaman trench looks prominent till about 10°N, but further north, similar to the NER, the trench signature is totally lost as the Bengal fan sediments fill the trench.

To get a clear picture of the relief of the NER and its proximity to the trench and also some indication of the sediments over and adjacent to the NER, Curray et al and Gopala Rao et al have examined six multichannel and single channel seismic reflection sections which are shown in Fig.4**.** The line drawings of the six interpreted seismic sections are shown in **Fig.5**.

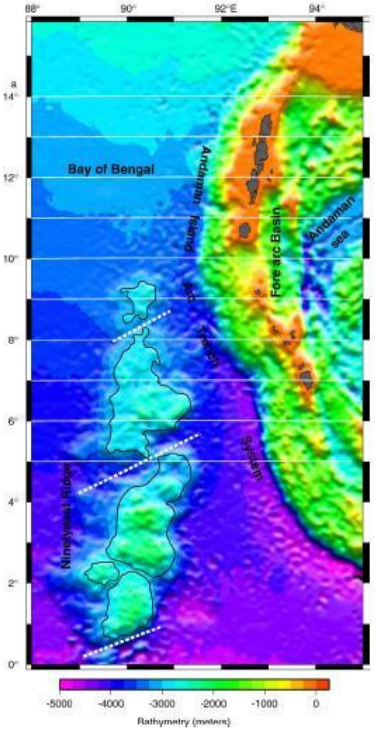

Fig 3. Bathymetry Map over Ninety East Ridge & Andaman. (After C. Subrahmanyam et. al.,2008)

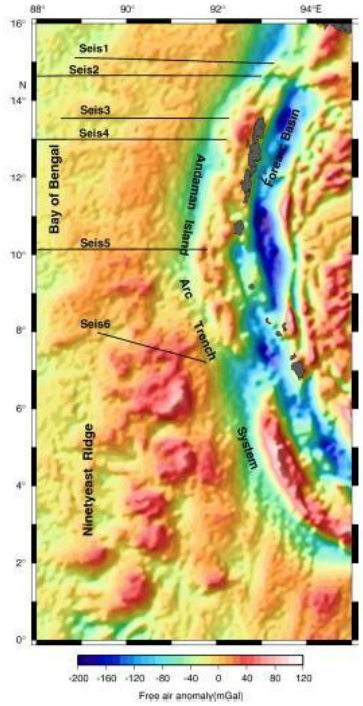

Fig.4 Free air gravity map with location of seismic lines. (After Sandwell & Smith, 1997)

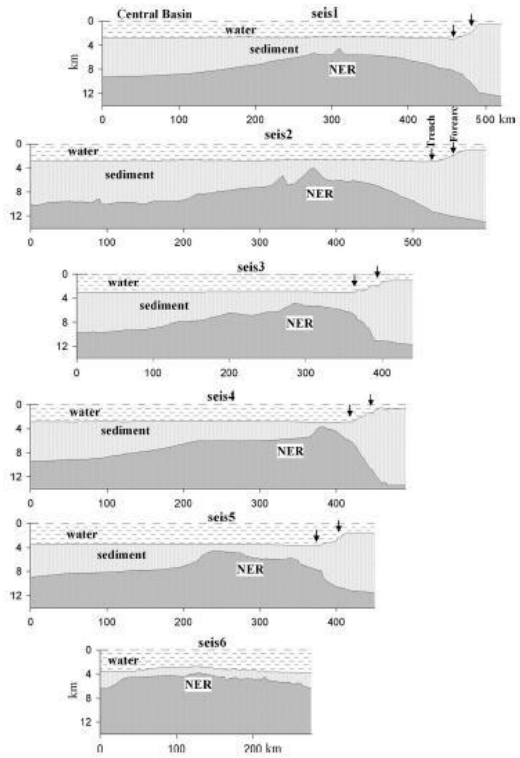

Fig. 5 Sections showing the geomorphology along different seismic lines shown in Fig. 4 over NER (After . Curray et. al., 1982 and Gopala Rao et. al., 1997)

A notable feature of all these sections is the gentle gradient of the western flank of the NER compared to the steep slope of its eastern flank. With the exception of section Seis5, the NER has great widths of 300 km and over. The ridge rises by at least 2 to 3 km above the adjoining oceanic volcanic layer 2 reflecting its strong paleo-topographic relief. Thickness of the sediments overlying the NER shows considerable variation but is in the general range of 1.5 – 2.0 km. Similarly, the trench sediments are in the range of 2 to 6 km. Curray et. al. and Gopala Rao et. al. has brought out the velocity structure of the sedimentary sequences over the ridge and inferred presence of Pre-Paleocene to Quaternary sediments over the ridge and its western flank (**Fig. 6**).

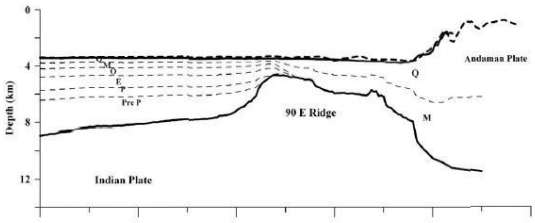

Fig. 6 An E-W section showing the Paleogene & Neogene sediments on the western flank and Neogene sediments on its eastern side of NER. (After Curray et. al., 1982 and Gopala Rao et. al., 1997)

The study by Curray et al and Gopala Rao et al have revealed that the combination of strike-slip and normal thrust mechanisms for earthquakes in the convergent zone suggesting partial subduction and partial shearing of the NER near the Andaman arc-trench system. The en- echelon block structure of the NER may owe its existence due to these complex tectonic forces.

Hydrocarbon potential

In a well drilled to the east of NER in the shallow water to the west of the North Andaman Island, sediments from Late Cretaceous to Recent were encountered. A litho-column of the well is presented in Fig. 7. The subduction zone is lying to the west of the well.

Source rock : The Baratang Formation Late Cretaceous-Late Eocene in the well drilled on the inner slope, west of Andaman Islands is more than 1000 m thick with large amounts of sands in the lower part, shale in the middle and again sands near top.. This is a thick argillaceous sequence associated with greywacke and algal limestone. The Inner slope has been the locale for Palaeogene turbidite deposition that is known as collector of rich organic matter. Baratang Formation and its equivalent sequence will act as the most favorable source rock in the area. Higher basement heat flow due to the mantle hot spot is expected to lead to early maturation of the argillaceous sediments.

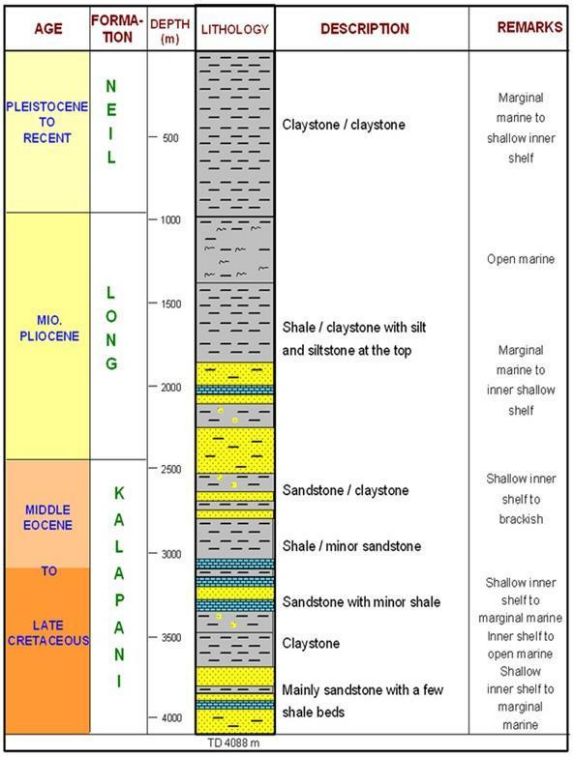

Fig 7. Litho-column the well to the west of Andaman Island

Reservoir : Mio–Pliocene Bengal delta Fan providing coarser clastic inputs in the Neogene sediments are expected to provide a reservoir facies. Cretaceous to Eocene limestone / chalks also can provide reservoir facies. Shallow water reefal limestone facies has also been reported from DSDP dredging samples.

Seal : Plio-Pleistocene pelagic claystones/shales will act as regional seals in the area. Moreover the claystones/shales within Miocene will also provide local seals.

Entrapment Conditions : Anticlinalal structures are the principal type of traps for accumulation of hydrocarbons in Miocene sediments. Stratigraphic traps like wedge outs, reefs etc. also can be expected **(Fig. 8).**

Play Types

Based on the study of few regional seismic sections**,** play types have been observed in and around NER. These are mainly:

1. Anticlinal traps

Structural traps in the form of large anticlines/ drape structures are the principal type of traps for accumulation of hydrocarbons in Miocene sediments. 2D seismic sections show development of large anticlinal reversals which are expected to form anticlinal closures for sizable hydrocarbon accumulations.

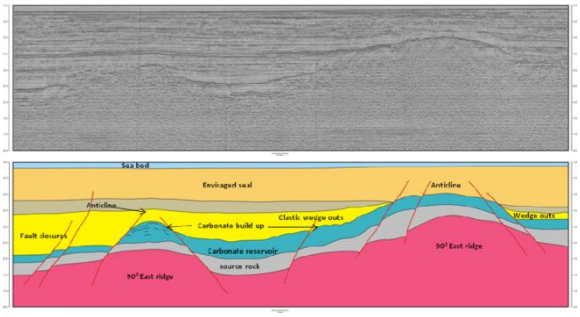

Fig. 8 An E-W seismic section and its line drawing showing the geological model with different play types in and around NER

2. Carbonate platform

In the study area, carbonate platform like feature has been envisaged with topographic relief. Spectacular examples of present-day carbonate platforms are the Bahama Banks under which the platformal carbonate is roughly 8 km thick, the Yucatan Peninsula where it is up to 2 km thick, the platform of the Great Barrier Reef, the Maldive atolls etc. All these carbonate platforms and their associated reefs are confined to tropical latitudes where the carbonate precipitation is biotically controlled by organisms (such as corals) present that exploit carbonate dissolved in seawater to build their calcitic or aragonitic skeletons. Thus they may develop hard reef structures. Similar set up is expected in the study area.

3. Carbonate buildups

There are few carbonate build-up like features observed in the seismic sections. These may be biologically influenced carbonate accumulation which was large enough to have developed topographic relief above the sea floor. Most, but not all, build-ups are features of positive relief on the sea floor at the time of their formation. Others may have been at sea floor level, and kept pace with surrounding sedimentation. Here the carbonate build up may be Bioherms as they are mound- or lens-shaped. These may be in-place organic structures (reefs), others may be banks of loose, transported carbonate sediment consisting largely of shells or skeletons. The geomorphology, extent and size of the carbonate build-ups reveal that their location is controlled by the underlying bathymetry and/or faults.

4. Fault closures

The interpretation of available seismic sections has revealed the presence of few deep seated faults which may give rise to fault aided entrapment for hydrocarbons.

5. Pinch outs / Wedge outs

These are different types of stratigraphic trap which are likely to be present in the study area. Older sedimentary sequences wedge out against the paleo-high. These wedge outs are expected to provide important entrapment for hydrocarbons.

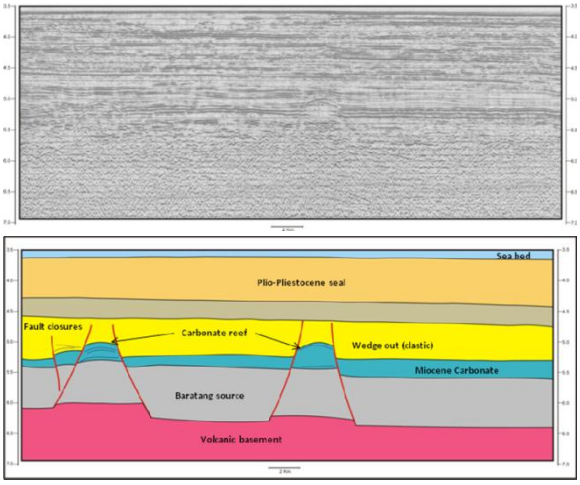

Fig. 9 An E-W section showing the Paleogene & Neogene sediments and different play types in and around NER.

Discussion & Conclusion

The present study has been focused on the possible play types in and around NER. The play types are mainly anticlinal closures/drape structures, carbonate platform, carbonate buildups, fault closures, wedge outs features etc. It is observed that the NER has acted as paleo high which has facilitated the growth of carbonates under shallow water

environment. However, the same was drowned subsequently. This paleo high and further tectonism has resulted drape structures, fault closures and wedge outs. Both thermogenic and biogenic petroleum systems are expected. Ninety East Ridge is interpreted to have been created by mantle hotspot in the mantle beneath the Indo-Australian Plate as the Indian plate moved northward. Therefore, higher basement heat flow leading to early maturation of the argillaceous sediment is expected.

New seismic and geological data in the area will give new insight into the geology, tectonic evolution vis-a-vis hydrocarbon prospectivity of this part of the Indian Ocean.

Acknowledgments

The authors would like to thank the management of Oil & Natural Gas Corporation Ltd., India for permission to publish this work. We express our sincere thanks to D. P. Sahasrabudhe, Basin Manager for his encouragement and guidance in the R & D activities in the basin. Thanks are also due to R. K. Paul and Ujjal Mukherji for drawing outputs of figures in the paper.

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