



## **Deep waters of Rakhine Basin - A New Frontier?**

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### **Summary**

*Offshore Rakhine Basin is a frontier basin with limited number of exploratory wells in the shallow waters. It was considered to be of low prospectivity till the 'Shwe' gas discovery in 2003. Shwe Phyu and Mya are the subsequent discoveries and all three fields are reported to contain biogenic gas within Lower Pliocene section. The deepwater area of the basin is a virgin exploratory territory. It is envisaged that significant future hydrocarbon accretions are likely to come from deepwater acreages, in the scenario of depleting resources onland and shallow offshore. As a continuing impetus in this direction, the present study attempts to analyze geo-scientific data from the deep waters of Rakhine Basin, off the west coast of Myanmar.*

*The present study posed tremendous challenges, being in an area that is rank exploratory in nature, without any well control and lack of linkages of seismic data from elsewhere in the surroundings. The study was based on the integration of available geo-scientific data, including regional data from the public domain and a viable model for the study area was conceptualized. Apart from showing the continuation of the biogenic system proved in the shallow waters, the study postulates a probable thermogenic petroleum system, within the Cretaceous sequence, hitherto undiscovered in the Rakhine offshore basin.*

### **Introduction**

The Rakhine Basin is in the eastern fringe of the Bay of Bengal and western coastal province of Myanmar. The basin is approximately 850 km long and 200 km wide. It is bounded in the east by the Indo-Burma Ophiolite Belt and continues to the north as the Chittagong Fold Belt in Bangladesh, and Tripura-Cachar Fold and Disang Flysch belts in India. It merges in the south with the Andaman-Nicobar-Sunda-Java Foredeep basins system. Four structural provinces are found within the basin from East to West; a) Rakhine (Arakan) Fold belt, b) Rakhine (Arakan) coast, c) Rakhine offshore and d) Bengal Fan part. However, the major portion of the basin is in offshore and the study area falls in the structural province of Bengal Fan part of the Basin.

The basin occupies the eastern abyssal plain of the Bay of Bengal and the youngest portion of the westward migrating accretionary wedge related to the oblique subduction of the Indian Oceanic Plate beneath the Burmese Plate, as

evidenced by the occurrence of mud volcanoes in the SE corner of the area. The basin contains thick Tertiary foredeep sediments deposited over Upper Cretaceous deep marine sediments. The Tertiary successions in the present onshore portion of the basin contain deep marine, nearshore to deltaic sediments while the offshore portion contains continental shelf, slope and basin floor sediments. The entire sedimentary succession with thickness of over 20,000 m in the accretionary wedge has been subjected to thin skin deformation in the eastern half of the basin (IHS Energy website).

The study area is located in the Rakhine Basin off Myanmar west coast where the bathymetry ranges from 1640– 2450m. The location of the Rakhine Basin vis-à-vis other Myanmar basins and the extent of study area is shown in (Fig 1). The Shwe & Shwe Phyu and Mya gas discoveries are made within the Lower Pliocene reservoirs in the neighbouring shallow water blocks. These discoveries are reported to contain predominantly biogenic gas, mainly Methane with  $\delta^{13}\text{C}$  values to be around -66‰.



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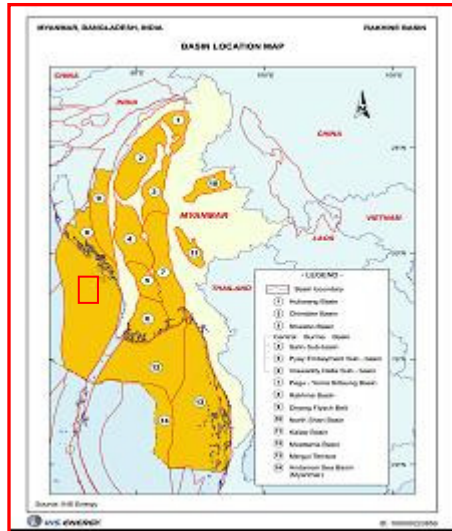


Fig.1. Study area within Rakhine basin (red rectangle)

A major portion of Rakhine basin is in offshore. The few shallow water offshore wells in the basin were drilled only upto the Lower Pliocene and the understanding of deeper stratigraphy is mostly from onland wells. The stratigraphic chart of the basin is given in Fig 2. Structural trends in Rakhine Basin are shown in Fig 3.

The subsurface information from the study area is limited to about 13000 LKM of 2D seismic data in 4x4 km grid, a subset of which is PSTM processed with 12x12 km grid (Fig 4). The area is rank exploratory in nature with the nearest wells in shallow water acreages at a distance of more than 50 km. In the absence of any other hard subsurface data, the inferences about prospectivity were drawn by integrating the results of interpretation with regional geo-scientific information available in the public domain.

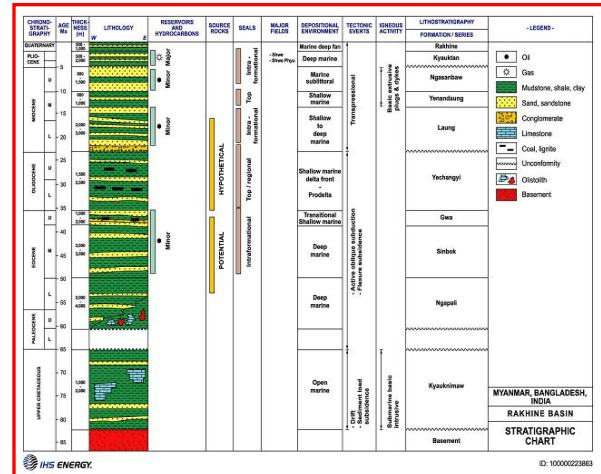


Fig.2. Stratigraphy of Rakhine basin

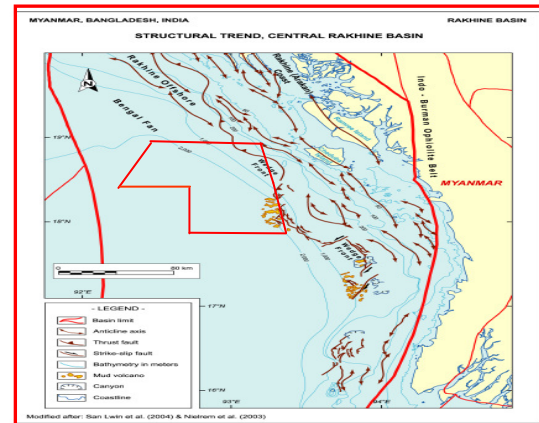


Fig.3. Structural trends in Central Rakhine basin

## Regional Tectonic Setup and Basin Evolution

The geological history of the basin dates back to the initial breakup of the Gondwana land during Early Cretaceous. The oceanic crust inherited from the breakup of the Gondwana constitutes the basement. It is exposed in the Indo-Myanmar range to the east as obducted ophiolitic mélangé. It also occurs as olistoliths in the lower Tertiary sedimentary successions in the Arakan coast and islands.



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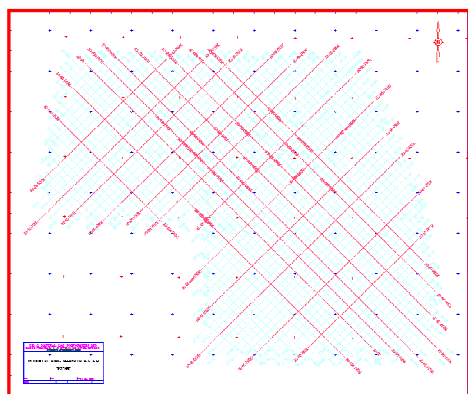


Fig.4. Seismic 2D coverage (PSTM lines in red)

During the long northward drift of the Indian plate in the Late Cretaceous, an open marine environment prevailed in the region which received distal sediments from Indian hinterland. The initial collision of the Indian plate and the Southern Asia occurred in the late Paleocene time approximately 55Ma (Curry & Moore, 1974). Plate motion accelerated in a slightly different direction in the Early Oligocene time approximately 35Ma with Indian plate converging towards Asia in a more north easterly direction. Towards the end of the Oligocene, the region suffered a marine regression and parts of the area are believed to have subjected to sub-aerial exposure and erosion. This could mark the initiation of an active tectonic period in the basin. During Early Miocene, transgression and tectonic down-warping of the basin led to rapid subsidence within the basin and at the end of the Late Miocene, a major structuration phase within the basin was initiated due to opening up of the Andaman Sea to the south east. In the eastern half of the Basin, N-S striking narrow elongated anticlines were formed. The Arakan-

Yoma range emerged, leading to further west ward shift of the depocentre from the Arakan coastal area into the Bay of Bengal.

In the Early Pliocene, a slope floor depositional system was established immediately west of the accretionary wedge front, which progressively migrated west wards into the Bay of Bengal. By Early Pleistocene times, most parts of the Arakan Coastal area were emergent and the Brahmaputra river joined the Ganges river, further west and the present day configuration where the Rakhine Basin forms the eastern fringe of the Bengal basin system was established (Alam et al., 2003). The fine Bengal fan clastics, blanketing the older successions in the basin are informally grouped into the Rakhine series.

### Present Study

**Seismic interpretation:** Thorough scanning of the seismic data revealed that the stratigraphic section could be divided into two broad, distinct zones – a shallower section devoid of any structures and not affected by many faults and a deeper section showing a few structures and affected by faulting activity.

The seismic event corresponding to the biogenic gas discovery in the adjoining shallow water block is brought into the study area and correlated. A high amplitude anomaly is observed close to this event in the north-western parts of the area and was mapped as Horizon A. Geometry of this high amplitude reflection indicates that this is a fan body. AVO analysis at different locations over the geobody has shown a sporadic class III response (Fig 5). This could be indicative of a pay similar to the one encountered in the shallow waters. However, the anomaly is shallow and the inherent risk is that the AVO response could also be caused by very fine, unconsolidated clastics, as evidenced by two recent wells in the shallow waters.

Two reflections, which are close to each other but are consistent seismo-facies boundaries, were identified at deeper levels and mapped over the whole area as Horizons B and C. Their maps exhibit two big structural closures, with areas exceeding 250 sq km each, which hold lot of exploration promise (Fig 6). The PSTM processed data has shown the presence of a thick sedimentary section below horizon C. The geometry of reflections is diagnostic of a



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half graben architecture indicating a rift fill play, capped by horizon C (Fig 7). This rift fill play, hitherto unknown, may be the key in establishing a thermogenic petroleum system in the Rakhine offshore. The bottom of this rift fill sequence shows a typical basement response and is interpreted as Horizon D.

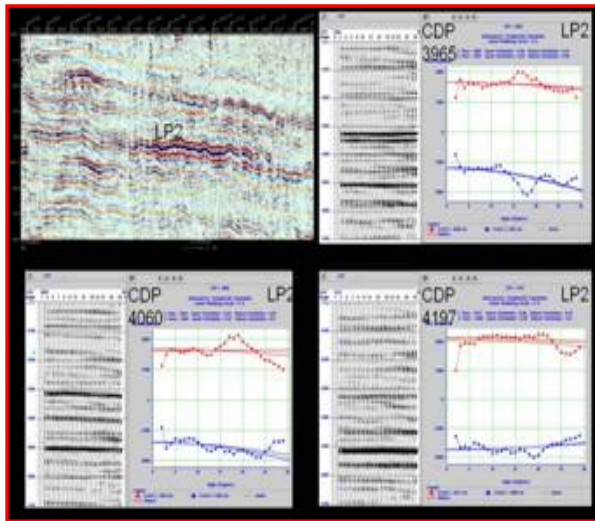


Fig.5. High amplitude reflection with its AVO response

Depth maps for horizons A, B, C & D and isopach map for the rift fill sequence were prepared using seismic velocities. A sedimentary thickness in excess of 5.0 km in the study area is observed.

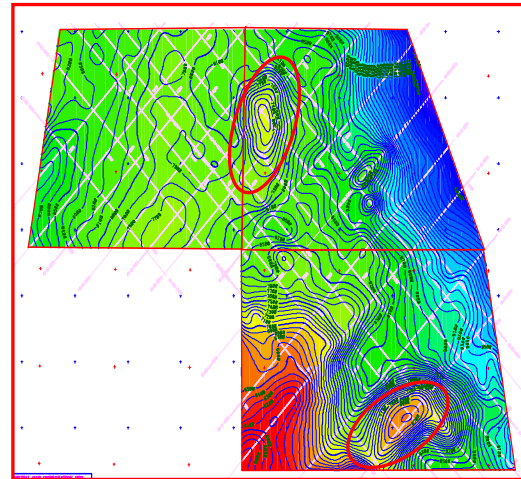


Fig.6. Structure map at rift fill top with two big closures

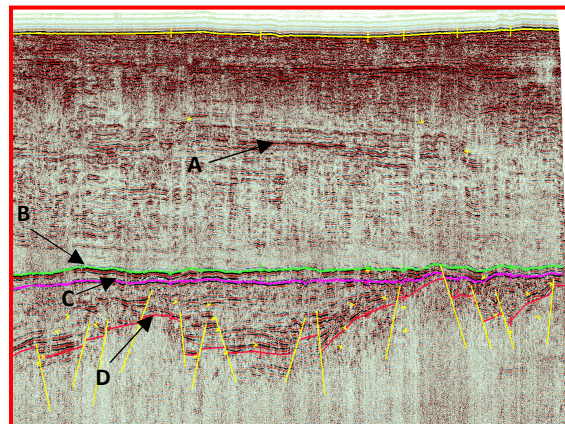


Fig.7. Section showing rift fill play with half grabens

### Integration with regional data

**Tertiary section:** Geological understanding developed from the information available in the public domain and the results of exploration in the shallow waters indicate that (i) the study area, being mostly away from the provenance and in open marine / deep water conditions, had predominantly received finer clastics in the post Late Cretaceous period





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(ii) there was no active drainage system from the Myanmar coast which could have supplied sediments to this area (iii) the sedimentation rates till Oligocene time were very low and active sedimentation in this area started only after the input from Bengal fan commenced.

**Cretaceous section:** A view of reconstruction of the plate motions through geologic past shows that the study area came into existence about 100 -110 Ma. The area always remained a part of the Indian plate, occupying the distal portion of the Bengal-Mahanadi basin. The region experienced a two episode rifting history – the first phase in the Early Permian times (intracratonic rifting) when the Son-Narmada, Pranhita -Godavari, Mahanadi and other rift systems were formed and the second phase in Early Cretaceous time (pericratonic rifting) during which Kutch, Cambay, Narmada and other rifts came into existence (S.K. Biswas,1999). It is difficult to associate the rifting seen in the study area, being far away from the then land mass, with this pericratonic rifting. We believe that the observed phenomenon in our area is an “active rifting” as against the passive rifting experienced by the Indian peninsula. The rift system so envisaged in the area was probably caused by mantle upwelling and thinning of crust owing to the plate’s passage over the Kerguelen hot spot during the northward drift of the Indian plate in the Early/Mid Cretaceous. This correlation of the rifting event has led us to designate the timing of seismically mapped horizons B and C as top of rift fill (Mid Cretaceous) and Cretaceous top respectively. The abrupt change in the seismic character above horizon C also supports it to be Cretaceous top.

The 90° East ridge manifests itself on the bathymetry map south of 12°N but becomes submerged towards north. The ridge is primarily composed of Ocean Island Tholeiites (OIT), a subset of basalt which increases in age from approx 43.2 +/- 0.5 Ma in the south to 81.8 +/- 2.6 Ma in the north. Analysis of regional gravity data (Fig 8) suggests that the submerged portion of the 90° East ridge runs into the study area (Thomas Maurin, Claude Rangin, 2009). The southern high appears to be an offshoot of the ridge which itself continues in a NNW-SSE trend along the western margin of the area.

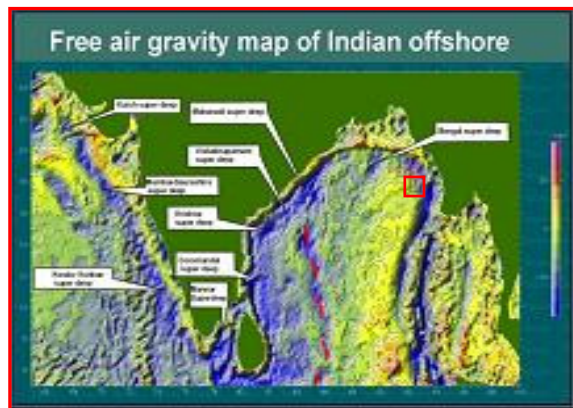


Fig.8. Free air gravity map showing extension of 90° East ridge

In the absence of any deep wells for predicting the age of basalt and likely lithology of the Cretaceous section, we had taken recourse to the information provided by DSDP wells drilled over the 90° East Ridge (Fig 9). Data from the three wells (DSDP website) at sites 214, 216 (which ended in basalt of Paleocene and Cretaceous age respectively) and 217 (which terminated in Paleocene without touching basalt) indicates that the basalt in the study area will be about 80-82 Ma old. Using the lithology information from site 217, we estimate that the reservoirs in the Cretaceous section in the study area will be primarily composed of chalk and chert.

A regional sedimentary thickness map of the area (Subrahmanyam V et al., 2008) estimates a 5-8 km sedimentary column in the study area. The depth map prepared by converting the correlated basement horizon using seismic velocities predicts a basement depth in the range of 7.5-11 km (including water column) which fairly corroborates with the regional map.

Based on the data integration as outlined above, a thermogenic petroleum system within the Cretaceous sequence is postulated with the pelagic shales within the rift sequence as the source, the chalk and chert as reservoirs and Upper / post Cretaceous shales as the seal.



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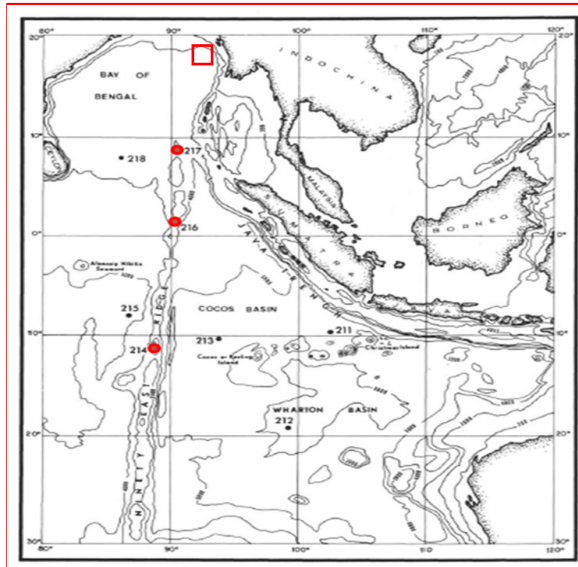


Fig.9. DSDP well sites over 90° East ridge

**Basin modeling:** 1D Maturation modeling using IES-Petromod software was carried out for the area assuming kerogen of Type-II, TOC- 2%, HI-500, thermal gradient 29°C/km and HF-60 mW/m<sup>2</sup> with source rock mainly carbonates mixed with very fine clastics with an average thickness of approximately 300m throughout the area. The results of the maturation modeling (Fig 10, 11) suggest that the mainly carbonate facies reservoirs within the Cretaceous rift fill sequence fall within the 'Late oil to Wet gas' window.

Also, geological history of the area indicates likely deposition of source facies in Paleogene section. Though, very few deep seated faults, connecting the likely Cretaceous source within rift fill sequence to the Tertiary section are visible in the present data set, the maturity modeling shows that Paleocene and Eocene sources will be mature enough to fall within 'Oil window'.

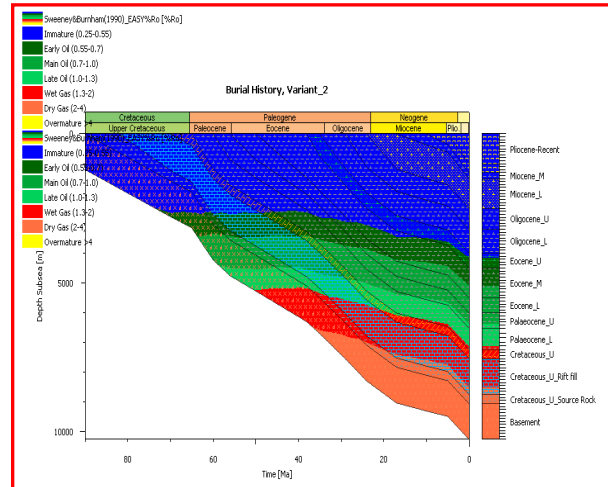


Fig.10. Burial history from IES Petromod

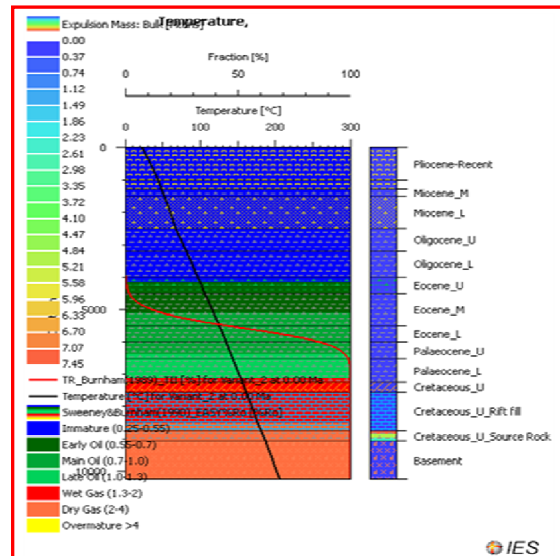


Fig.11. Maturation model

**Prospectivity perception:** Though the mapped Cretaceous structures in the area are very attractive in size, the risk of reservoir is palpable. The risk of source and seal is minimal compared to the reservoir. However, even with a very



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conservative net to gross ratio for the reservoir, a run of techno-economics has returned quite a favourable outcome.

### Conclusions

The study establishes the likely continuation of the shallow biogenic system and postulates a probable thermogenic petroleum system, hitherto undiscovered, within the Cretaceous sequence in Rakhine deep offshore. Combination of shallower biogenic system and a deeper thermogenic petroleum system opens a promising new exploration frontier. Coupled with recent advances in our geological knowledge, subsurface mapping techniques and deep water drilling techniques, the area could become the focus of exploration in the years to come.

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