Mystery beneath the 85° East Ridge

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Keywords

90° East Ridge; Petroleum System; Carbonate Mound; Paleo-tectonic; Seismic Velocity.

Summary

85° East Ridge is a near-linear, aseismic, age-progressive ridge situated in the north eastern part of Indian Ocean. For last few decades lots of exploration efforts have been carried out to decode its mystery of evolution and hydrocarbon potential. Seismic and other geophysical studies have revealed that the ridge remained as an elevated structure till Paleocene and since Oligocene onward it has been buried beneath sediments. The ridge is associated with complicated gravity and magnetic signatures which draws the attention of geo-scientists. With the help of available seismic data and pre-drilling conceptual model, it was believed that, 85° East Ridge is a favorable structural feature for hydrocarbon accumulation with all the essential elements of petroleum system. Thick shales sequences of Cretaceous Formation on both sides of ridge may provide the favorable condition for hydrocarbon generation and maturation and can acts as good source rock. Eocene and Oligocene carbonates as well as onlaping sediments of Cretaceous and Paleocene on either side of the ridge are the possible reservoir rocks and overlying shales as well as the carbonates will provide the vertical and lateral seals for hydrocarbon accumulation.

Only one well has been drilled on the 85° East Ridge till date. Though, this well was devoid of any hydrocarbon but it reveals the mystery beneath the 85° East Ridge and the earlier conceptual model is no longer holds true. The post-drill study tries to dig out the possible reasons of non-occurrence of hydrocarbon below the ridge. The drilling result shows that the ridge is devoid of any hydrocarbon mainly due to poor reservoir and source facies. The expected reservoir rock i.e. Oligocene carbonate deposits are reworked and impure. They are recrystallized and very tight. The proposed source rock i.e. Cretaceous shales contain very poor organic matter and have poor source potential of type IV.

Introduction

Eastern offshore of India is characterized by presence of two aseismic ridge systems namely 85° East and 90° East Ridge. While the 90° East Ridge is having expression on present day sea bottom, the 85° East Ridge is buried under huge thickness of Bengal sediments, expect in the southern part. The feature extends from the Mahanadi Basin in the north, off the

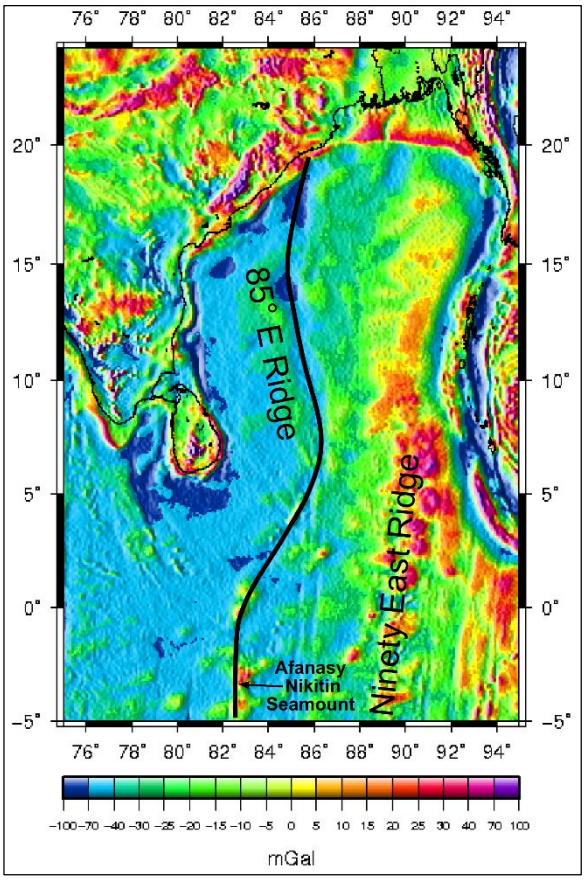

Figure 1: Free-air gravity map of north eastern Indian Ocean showing location of 85°E Ridge.

north eastern coast of India, shifts westwards by about 250 km around 5°N, southeast of Sri Lanka and

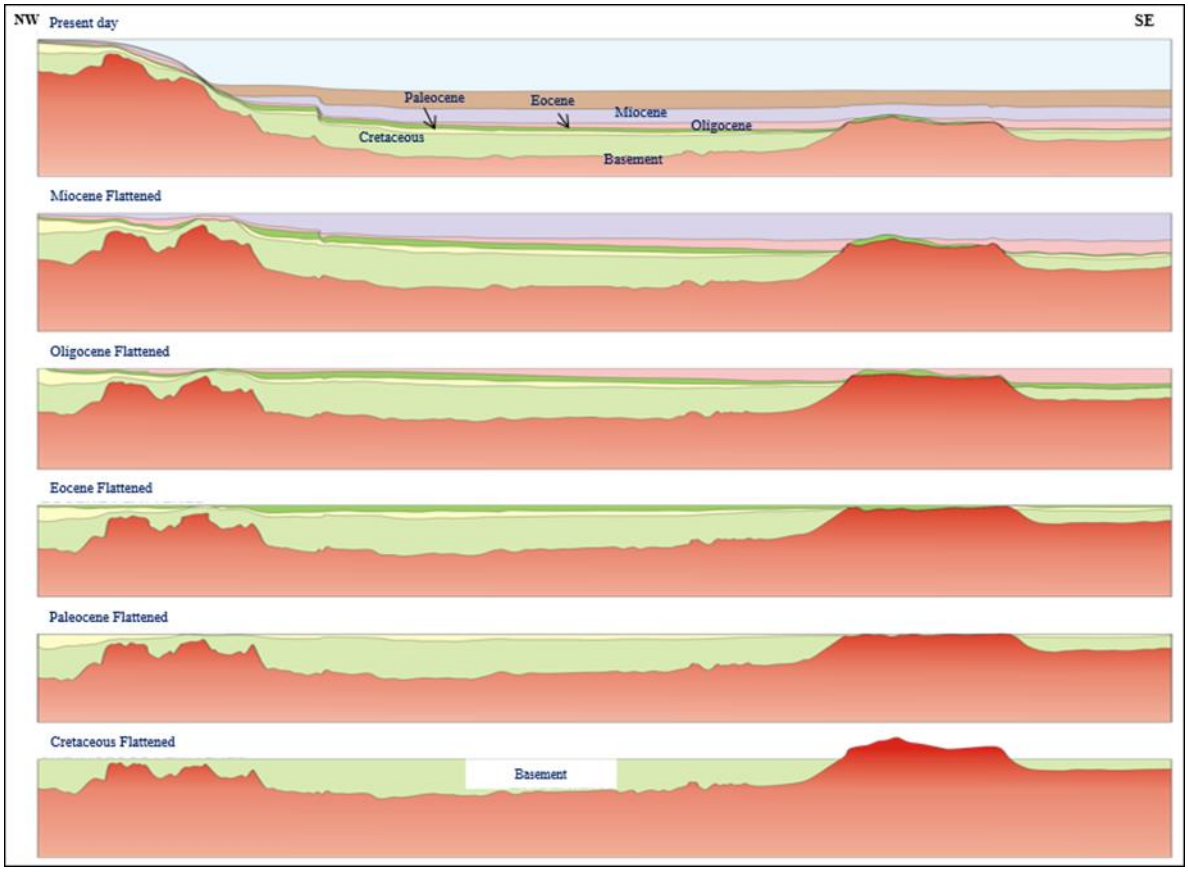

Figure 2: Paleo-tectonic Analysis of 85°E Ridge.

continues south to the Afanasy Nikitin Seamount in the Central Indian Basin (Figure 1) (Nayak et al., 2011; Michael and Krishna, 2011; Sar et al., 2009 and Sreejith et al., 2011). For the last two decades there has been on-going debate on the evolution and hydrocarbon prospectivity of the 85° East Ridge. As per Curray and Munasinghe (1991), the evolution of the ridge is related to plume whereas according to Sar et al., 2009, the ridge is of continental origin. Whatever may be the origin of the ridge, seismic and other geophysical studies have shown its hydrocarbon prospectivity time to time (Nayak et al., 2011; Michael and Krishna, 2011; Sar et al., 2009 and Sreejith et al., 2011) and there was a strong belief that 85° East Ridge is a favorable structural feature with all required elements of petroleum system for hydrocarbon generation and preservation.

Integrating all the geo-scientific data a conceptual model is build and one well has been drilled in 2014 on 85° East Ridge. But unfortunately the well was devoid of any hydrocarbon. Hence, the earlier conceptual model is failed and a new model is required to reveal the mystery beneath the 85° East Ridge.

Objective

In the present study, an attempt has been carried out to showcase the pre and post-drill conceptual models to dig out the mystery beneath the ridge.

Pre-drilled conceptual model

Paleo-tectonic evolution of 85° East Ridge is shown in the Figure 2. The study suggests that 85° East Ridge was a basement high which remained exposed till Paleocene. During Eocene it was submerged with the

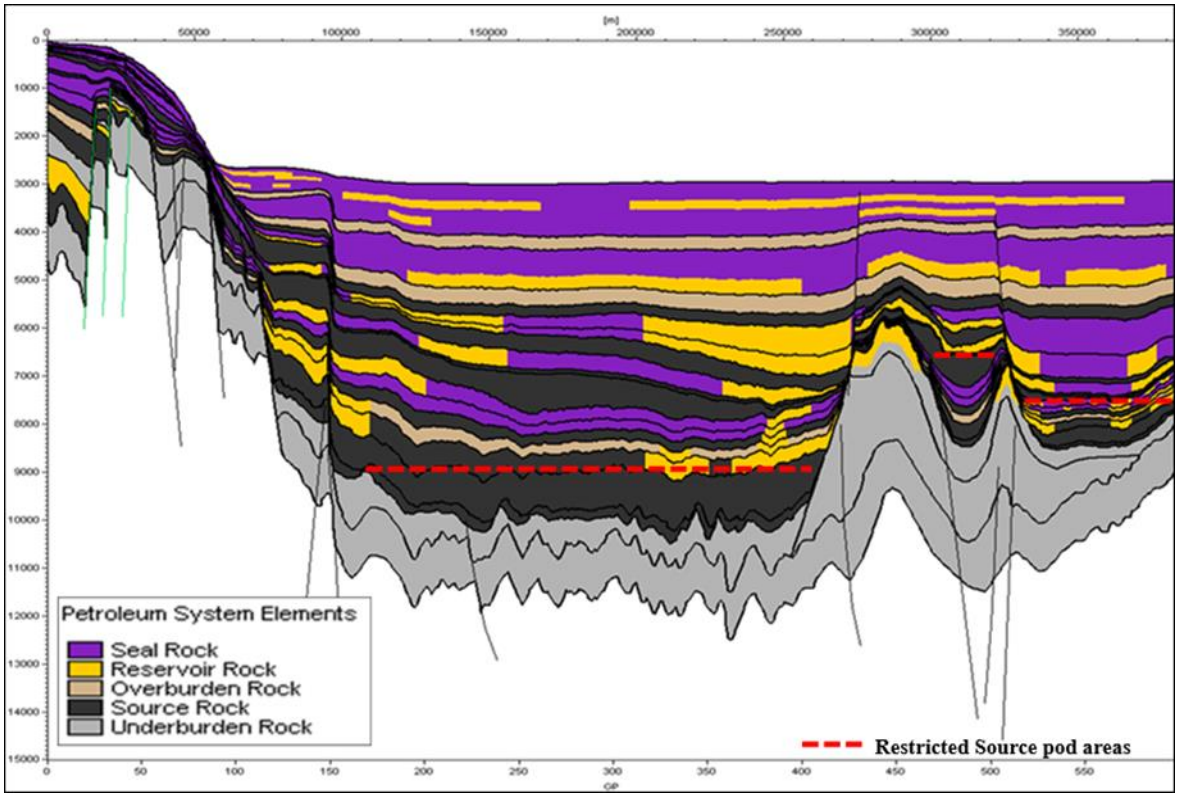

Figure 3: Pre-drill Conceptual Petroleum System Elements over 85° East Ridge.

global sea level rise and remained at shallow water up to Oligocene. This created a suitable condition for carbonate build up above the structural high. Since Miocene onward sea level raised and it was under the deep sea.

The pre-drilled conceptual petroleum system modeling is shown in Figure 3. The figure 3 shows that all the required elements for hydrocarbon generation and preservation are present over the 85° East Ridge. A brief description of each element of the earlier conceptual petroleum system model is included for the sake of completeness.

Source Rock

A close analysis of the available seismic and other geological data reveals the presence of well-developed and restricted lows between western and eastern mound of the ridge (Figure 3). The depression was filled with thick Cretaceous Sediment of more than 1.5 km thickness (Nayak et al., 2011). These sequences were deposited in low energy confined environment (Nayak et al., 2011) hence, these confined lows are believed to act as a good source kitchen area for generation of hydrocarbon (Nayak et al., 2011).

Reservoir Rock

A numbers of important geophysical features like canyon cuts, onlaps and carbonate build ups are observed in various seismic sections. As for example, in figure 4, a prominent canyon cuts have been observed which may have originated due to emergence of the ridge (Nayak et al., 2011). Similarly, in figure 5, low amplitude seismically blank zone is observed which is similar to that of a carbonate buildup (Nayak et al., 2011).

The seismic velocity analysis (Figure 6) also shows the existence of low velocity sediment below the carbonate sequences and they are flaking against the ridge creating pinch out. As per Nayak et al., 2011, these sediments are of Cretaceous and Older Tertiary

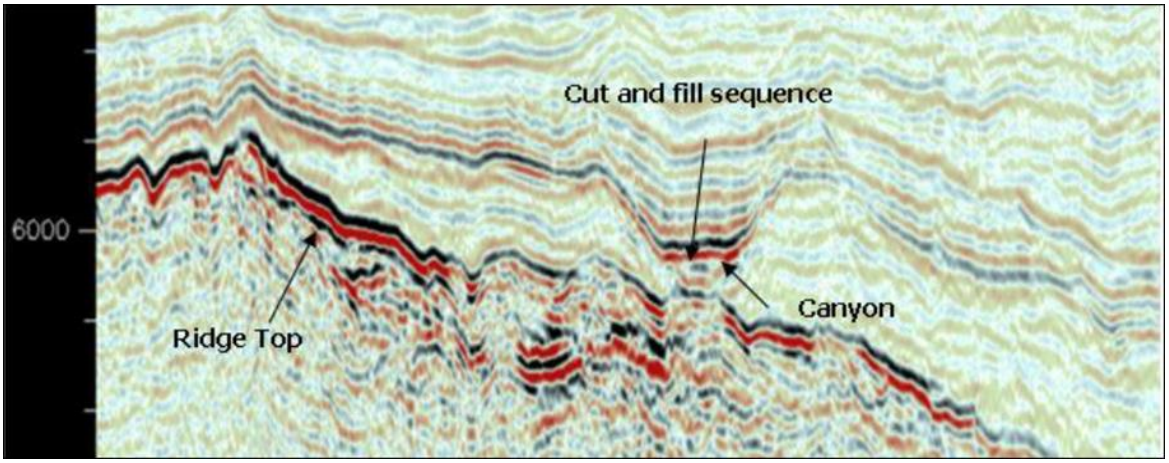

Figure 4: Well developed canyon cut seen in seismic section.

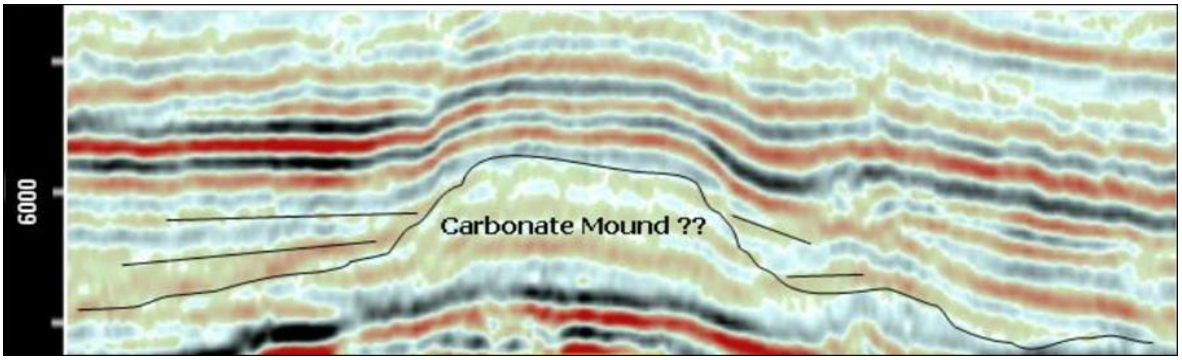

Figure 5: Carbonate build up like feature identified on top of ridge.

(Paleocene and Eocene) coming from Godavari and Mahanadi-Ganges systems.

Therefore, carbonates buildup of Eocene and Oligocene as well as onlaps of sediments on either side of the ridge within Cretaceous and Paleocene are the potential reservoir rock. Figure 7 shows the existence of a number of carbonate sequences over the ridge. These carbonate sequences are of Eocene to Oligocene age and build the favorable conditions for hydrocarbon preservation and act as the reservoir.

Cap Rock

Shales overlying and juxtaposing the reservoirs as well as carbonates may constitute the cap rock (Figure 3).

Trap

Structural closure with associated faults and pinch-out on either side of the ridge and carbonate build ups may create structural as well as strati-structural entrapment (Figure 4 & 5).

Seal

Lateral facies variation along with faults and overlying shales may provide the vertical and lateral seals for the sand and carbonates reservoirs (Figure 3).

Migration/Charge

The normal faulting/fissures flanking the ridge may create the migration path. The assumed critical

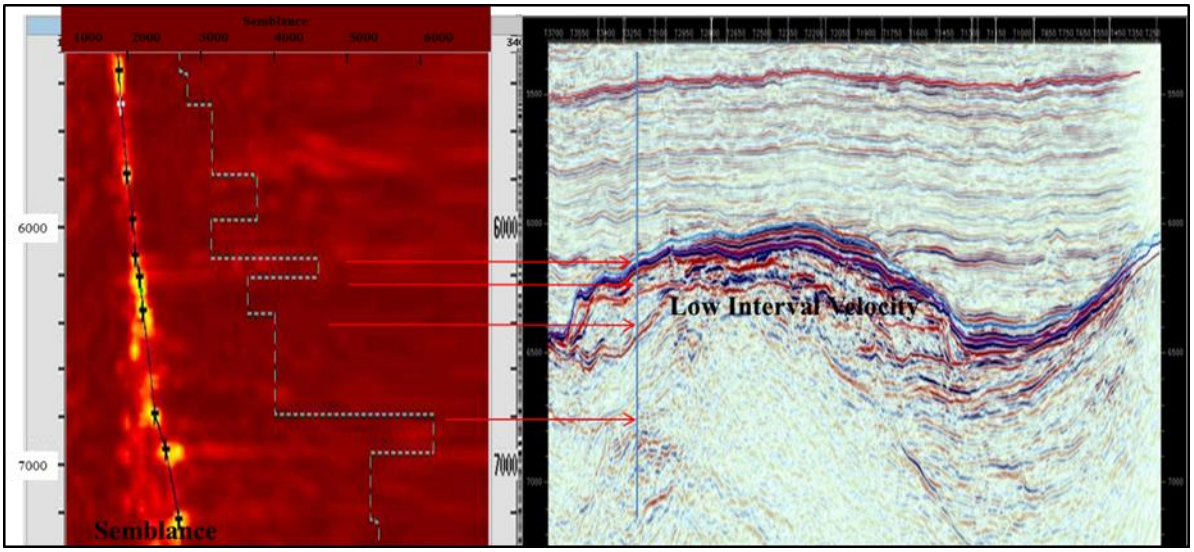

Figure 6: Interval Velocity profile showing low velocity sedimentary package over the 85° East Ridge.

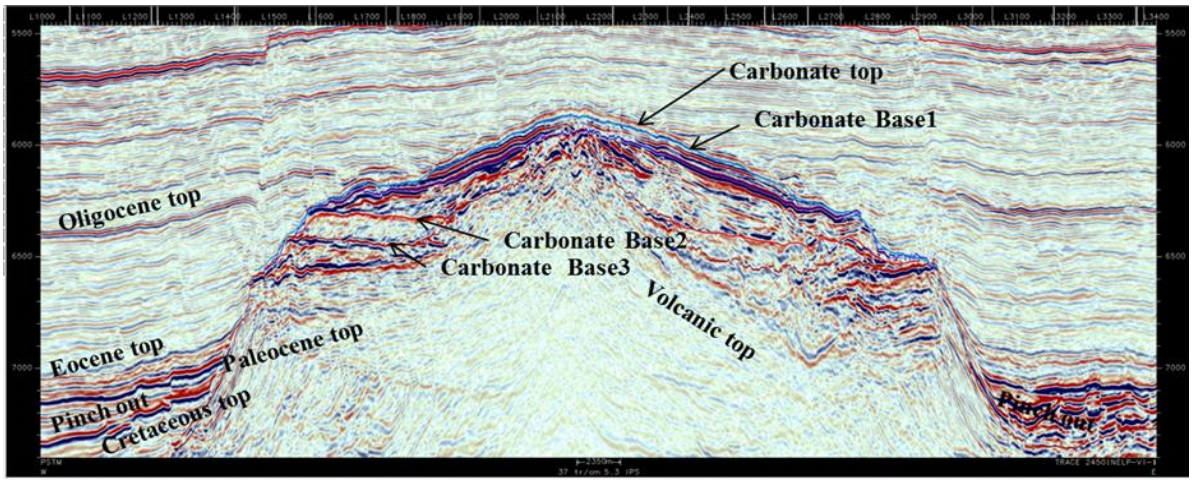

Figure 7: One representative seismic profile showing different packages of carbonate deposition over the 85° East Ridge.

moment of migration is the Late Cretaceous (Figure 3).

Based on the above conceptual model, it was thought that 85° East Ridge may act as a favorable prospect for drilling and in 2014 one well has been drilled for the first time over the ridge to test its prospectivity.

Post-drill Analysis

The drilling results show that the well is dry. Therefore, all the earlier assumptions are no longer hold true and hence a modification of the earlier conceptual model is essential to satisfy the drilling results. The litho-column of the drilled well is shown in Figure 8. A post-drill analysis has been carried out to build the modified petroleum system model over the ridge. Based on the detailed analysis the following observations have been drawn-

- The well encountered sufficient thickness of Pliocene, Miocene and Oligocene sediments including more than 50 m thick limestone at Oligocene level.

- Oligocene carbonates are reworked, impure, recrystallized and tight.
- Eocene sediments seem to be absent over the 85° East Ridge at drilled position as Oligocene Limestone is overlain on volcanic rock.
- Post drilling analysis confirms the presence of seal and cap rock. But the source rock evaluation indicates presence of very poor type IV organic matter with very poor source potential of post mature stage.

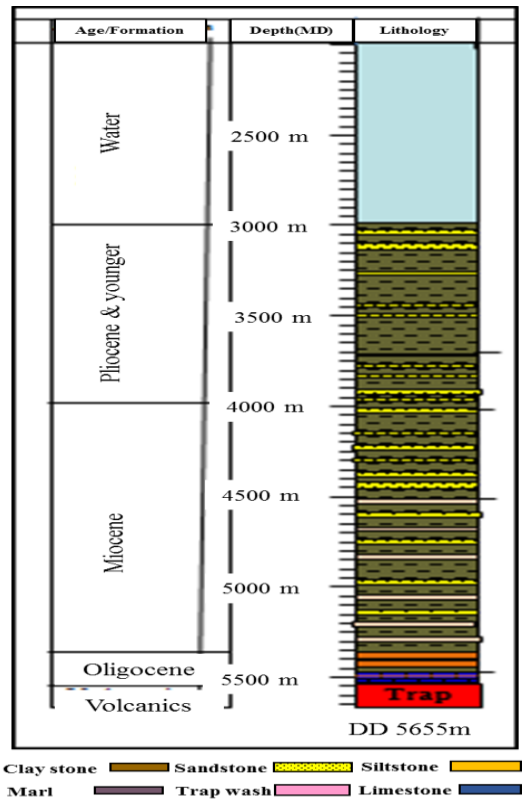

Figure 8: Litho-column of the drilled well on 85° East Ridge.

Conclusion

Based on the post-drill analysis, it is clear that the pre-drilled conceptual model is no longer valid over the ridge. Due to the presence of tight carbonate rock, very poor organic matter and source potential and non-charging of hydrocarbon from deeper horizons to available shallow reservoir facies appear to be most important factors for non-accumulation of hydrocarbon in 85°East Ridge. Thus, it reveals the mystery over the ridge and ascertains the probable reasons of non-accumulation hydrocarbon beneath the 85°East Ridge.

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