Petroleum System Modelling

A petroleum system encompasses a pod of active source rock and all related oil and gas and includes all essential elements and processes needed for oil and gas accumulation to exist. The essential elements of a petroleum system are source rock, reservoir rock, seal rock and overburden rock. The processes include trap formation and generation-migration-accumulation of petroleum. All essential elements must be placed in time and space such that the processes required to form a petroleum accumulation can occur (*Magoon and Dow, 1994*).

Petroleum System Elements:Source,Reservoir and Seal

The analysis of available source rock data in the basin indicate that organic matter richness in the basin is fair to good with fair to good remaining generation potential. The organic matter of all the sequences of Bengal basin is shown to be dominated by Type-III kerogen. Source rock data indicate that the Lower Gondwana coal and coal-shale sediments are mature source rocks in the basin, developed in the shelf area. The Gondwana source rocks are not envisaged in the area around hinge and east of hinge zone. Geochemical analysis of oil from discovery well in the basin suggests that generation of hydrocarbons from source rocks of Late Cretaceous or younger age. Source rock data for Paleocene is available only in a few wells. Paleocene is deposited in shallow marine environment in shelf areas and in deeper marine conditions east of hinge. In general, this sequence shows fair organic matter richness but poor generation potential. The carbonate facies of Eocene is observed to change basin ward into shale in several wells and may be potential source rocks. Oligocene sequence shows fair to good organic matter richness in the shelfal area. Miocene sequence exhibits fair organic matter richness but poor generation potential in the basin margin and shelf areas. In deep basinal areas, it shows fair to good organic matter richness but with poor generation potential.

The oldest reservoir facies in the basin is Triassic Upper Gondwana, which is mostly sandy. Gas Indication (Patuli-1) reported from these rocks. Early Cretaceous is represented by Rajmahal volcanics and Late Cretaceous reservoir is represented by arkosic sandstone. Reservoir facies in Paleocene, Eocene, Oligocene and Mio-Pliocene sequences have proven oil and gas occurrences. Miocene sequence is having huge thickness especially towards SE part of the basin. Numerous Channel cut & fills are observed in this sequence. Pliocene sequence is present in almost entire basinal area & slopes homoclinally towards south. Numerous channel cut & fill are also observed in this sequence. These channel systems have special bearing on the hydrocarbon potentiality of this play, as the alternate, repetitive proto Damodar trend and proto Ganga may create an environment where multiple reservoir and cap rock facies would be stacked both laterally and vertically (Figure 3).

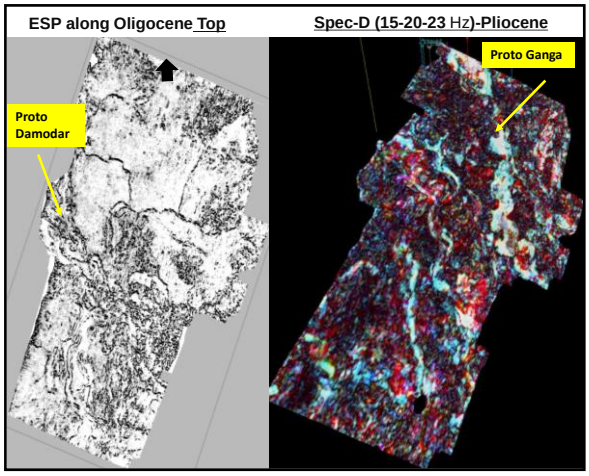

Figure 3: Channel System in Oligocene and Mio-Pliocene

Model Building: Basin and petroleum system models encompass all the geological data to constrain the elements and inherent processes to provide scenarios for petroleum system(s) to exist. An initial model geometry is built with horizon interpretations for Basement, Early Cretaceous (Rajmahal Traps), Paleocene, Eocene, Oligocene, Miocene and Pliocene. The seismic interpretation along with geological interpretation is populated in the PetroMod platform. This is followed by defining the facies, through which elements of an envisaged petroleum system are constrained and final model geometry is ready for simulations after thermal calibrations.

Four source layers (1- in Paleocene, 2 in Eocene and 1 in Oligocene), reservoir facies in almost all the

layers with intra formational seals at all levels are modelled as basic input parameters (Figure 4). Uncertainty has been studied by running multiple simulations with varying model parameters.

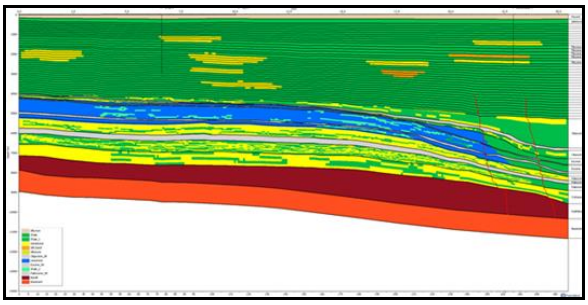

Figure 4: Final model geometry

Processes: Generation

Maturity: Rock maturity overlay indicate that modelled viz. Paleocene, Eocene and Oligocene formations have attained peak oil generation window only in the areas on the hinge or to the east of shelf break, whereas in the shelf area, except for Gondwana and to some extent Paleocene formation, no other formations have attained adequate maturity(Figure 5).

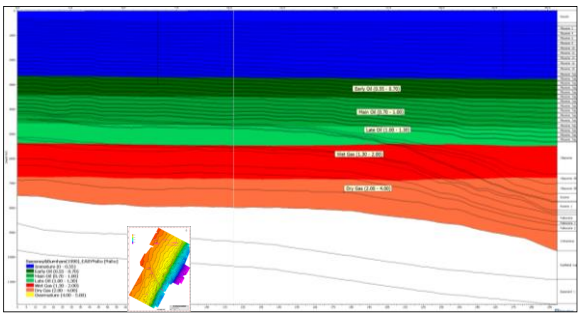

Figure 5: Rock maturity overlay

Transformation Ratio (TR): The transformation ratios for Paleocene source rock are more than 50% in the modelled area and other source rocks achieve 50% transformation ratio near hinge zone only. A transformation ratio (TR) of 50% is used to define the Critical Moment (CM).The analysis of critical moment is essential as it is the time that best depicts the generation-migration-accumulation of hydrocarbons in a petroleum system (Magoon and Dow, 1994).

The Paleocene source rock achieves more than 50% TR on the shelf and hence critical moment. The other source rocks in Eocene and Oligocene achieve more than 50% transformation near or beyond hinge zone only(Figure 6).

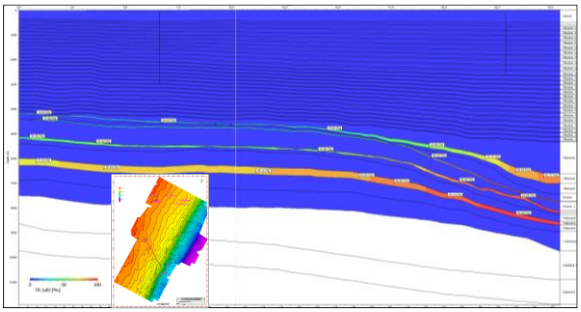

Figure 6: Transformation Ratios of modelled source rocks

The critical moment for the Paleocene source rocks in the modelled area is 14Ma, Eocene source rocks 10Ma and Oligocene source rocks is 4 Ma. Thus, effective source rocks are developed east of hinge zone. The Paleocene which has higher transformations throughout the basin is likely to be the major contributor to the accumulations in the basin (Figure 7).

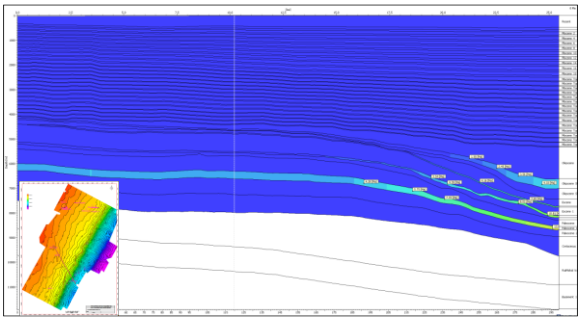

Figure 7: Critical Moment of modelled source rocks

Migration: From the discussion in the pre para, it is safe to assume that major contribution of hydrocarbon charge will be from east of hinge zone and minor contribution from shelf. This is also observed in the 3D migration modelling (Figure 8).

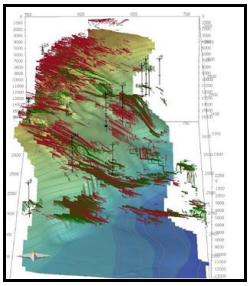

Figure 8: Depicting 3D migration model

In view of the lack of structuration in the study area the long distance migration towards shelf has greater chance of migration losses. For hydrocarbons to migrate into shallower traps, vertical migration pathways (faults) are imperative. From the modelled section, it is evident that the expelled hydrocarbons have migrated towards the shelfal parts from deep basin through regional fault systems related to hinge zone (Figure 9). Micro faults present in the Oligocene and younger Neogene sequence can further help in migrating the hydrocarbons to the shallower levels. The same is further supported by the modelled accumulations shown in the Figure 9. Migration pathways are complex and are generally vertical along faults and fractures and lateral through porous layers.

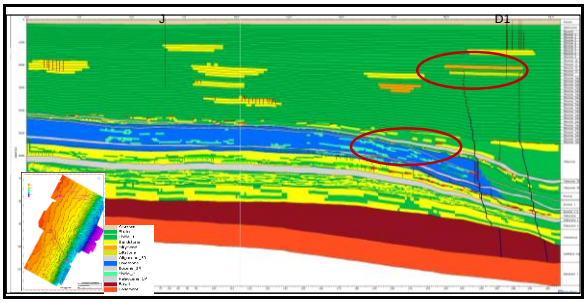

Figure 9: Migration pathways from hinge to shelf

Entrapment: There is absence of major structuration in the study area. The strati-structural traps have proved to be hydrocarbon bearing in the basin. Channel-levee complex of two distinct river systems (Proto Damodar and proto Ganga) and their alternate stacking may provide good locales for stratigraphic hydrocarbon entrapment. During Mio-Pliocene Hinge zone area was in marginal marine setup leading to possibility of stratigraphic traps. The migration pathways suggest that strati-structural prospects near hinge zone are the most favourable locales for charging. 3D Petroleum System study suggested possibility of stratigraphic entrapment near the Hinge Zone area of Bengal Basin. The 3D PSM could suggest possible migration pathways into multiple reservoirs & demonstrate earlier established oil accumulation in Basal Oligocene sands near the hinge zone (Figure10).

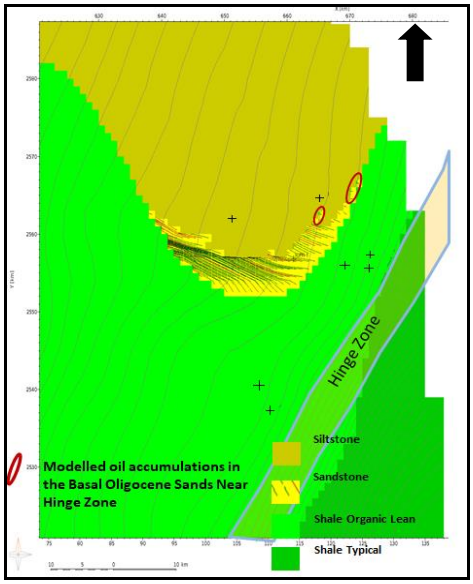

Figure 10: Modelled accumulation in basal Oligocene sands

Charge Model:

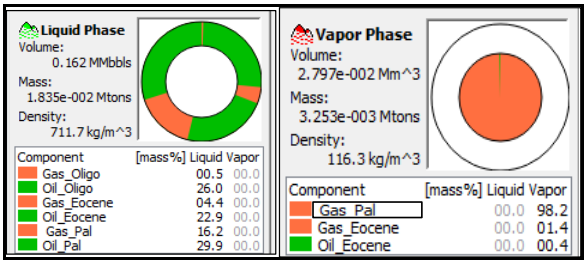

Figure 11: Charge analysis through source rock tracking

From the above Figure 11, depicting source rock tracking in the modelled area, it can be observed that reservoirs are getting charged by multiple source rocks. Therefore chances of existence of multiple petroleum systems remain high. Although in view of the lack of oil to source correlation all the petroleum systems remain hypothetical.

Conclusions:

1) The Paleocene source rocks are the effective source rocks in the basin
2) Eocene and Oligocene are the potential source rocks in the basin.
3) The Paleocene source rocks attain critical moment on the shelf as well beyond the hinge zone, whereas Eocene and Oligocene source rocks attain critical moment east of hinge zone only.
4) The migration pathways are from east of hinge zone to shelf and then further westwards towards basin margin.
5) Most promising area for the hydrocarbon accumulation is the hinge zone and area around it, in view of better migration & entrapment conditions.
6) In absence of major structuration in the study area, strati-structural prospects emerge as the main hydrocarbon entrapment mechanism.
7) In view of the lack of oil to source correlation all the petroleum systems remain hypothetical in the basin.

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