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Thick Skinned Tectonic and Entrapment of Hydrocarbon in Fractured Basement and Overlying Tertiary Reservoirs in Borholla-Changpang Field, Dhansiri valley, A&AA Basin.

Ram Krishna Singh*, Pratim Bhaumik+, Chiranjit Singh, Md S Akhtar, H J Singh and Sanjive Mayor, *ONGC*

Summary

Borholla-Changpang field falls in Dhansiri valley of Assam and Assam Arakan Basin and represents classical example of Paleogene multiple sandstone reservoirs overlying fractured basement reservoirs of Pre-Cambrian age. The Tertiary sandstone reservoirs range in age from Paleocene-Eocene in Paleogene section and Miocene Pliocene in Neogene section. The Borholla field was discovered in the year 1969 and commercial oil was established from sandstone reservoirs in Paleogene and gas from Neogene section. Later in the year 1973 first time, commercial oil was established from fractured basement of Borholla field. Since then Borholla field is producing from Paleogene sandstone reservoirs as well as fractured basement reservoir.

The thick-skinned tectonic has resulted horst and graben structure of Borholla-Changpang structure oriented in North-South direction. The horst part of the fractured basement contains the hydrocarbon and is juxtaposing Kopili shale forming ideal seal for entrapment of hydrocarbon. The inverted overlying Paleogene section forms ideal entrapment conditions for Paleogene reservoirs. The sandstone reservoirs in Paleogene section are within Basal sandstone, Sylhet and Kopili Formations. The reservoirs within Basal sandstone are continental origin whereas the reservoirs within Sylhet and Kopili Formation are lenticular sand bodies and resulted from regressive deposition cycle during deposition of Sylhet Formation and Kopili Formation. These sand bodies in the horst are cut by the North-South trending fault and are juxtaposing Kopili shale and forming ideal entrapment condition for accumulation of hydrocarbon.

The source rock studies indicates maturity of source rock increases towards Schuppen belt and a number of oil shows are reported from Schuppen belt by different field Geologists also supplements the prospectivity of Schuppen belt and adjacent area. The Borholla-Changpang field falls in the proximity and have proven hydrocarbon reservoir in fractured basement and within Paleogene and Neogene reservoirs. Chasing of similar thick-skinned horst and graben structures in the proximity of Schuppen belt areexpected to be rewarding from hydrocarbon point of view.

Keywords*: Dhansiri valley, Borholla-Changpang, Fractured basement, Schuppen belt.*

Introduction

The Borholla-Changpang field falls in Dhansiri valley of Assam shelf. The Borholla field represents relatively plain topography than the Changpang field which constitutes part of Naga Hill and falls in Schuppen belt of Assam Arakan Fold Belt (AAFB). The west hadding Naga thrust brings major topographical changes at the surface and separates Changpang field from Borholla field.

The subsurface sedimentary records obtained from drill wells indicate a poly tectonic history and sedimentation in Dhansiri valley. The initial rift phase is characterized by the Pre-Tertiary sediments restricted in graben are overlain by the Tertiary sediments. The Tertiary sediments in horst are directly resting over basement. In Borholla-Changpang area also the fractured basement is directly overlain by Paleogene and successively by Neogene and quaternary

Basin Research Group, KDMIPE,ONGC-Dehradun.
E-mail: rks1660@gmail.com
+Forward Base ONGC AGARTALA, TRIPURA.

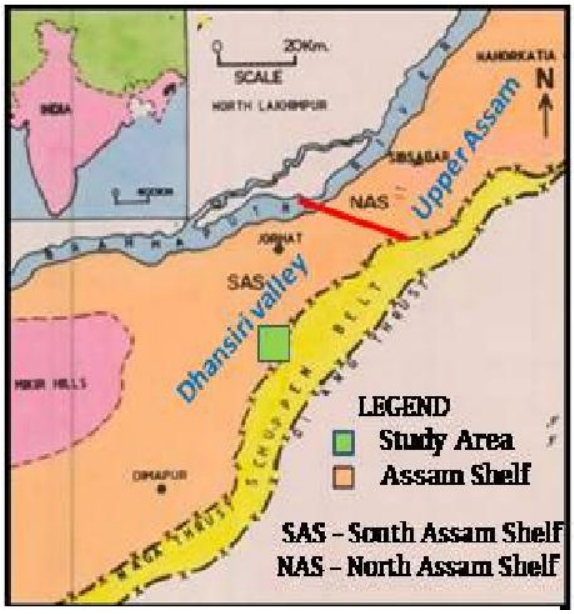

Fig. 1. Index Map

sediments. The Borholla field was discovered in the year 1969 and commercial oil was established in multi layered Paleogene sandstone reservoirs and gas in Neogene sandstone reservoirs. Later in the year 1973 first time in India, commercial oil was established from fractured granitic basement of Borholla field and later its continuity in Changpang area. Since inception, the field is producing from fractured granitic basement and overlying multilayered sandstone reservoir within Basal sandstone/Tura, Sylhet and Kopili Formations (Paleogene sandstone reservoirs). The commercial viability of gas established in Miocene and Pliocene sandstone reservoirs are yet to realize (Fig.1).

Geological settings, Generalized Stratigraphy and Tectonics

Geological settings

Dhansiri Valley constitutes southern part of Assam shelf. The E-W trending Jorhat fault separates it from Brahmaputra valley. The Dhansiri valley represents a classical foreland basin flanked by Schuppen belt on the east and southeast and by Mikir massif in the west.

Dhansiri valley exhibits stable shelf with basement sloping towards southeast. The Pre-Tertiary sediments are directly resting over granitic basement. The Tertiary sediments are either resting over Pre-Tertiary or basement depending on the basin architecture. The Pre-Tertiary has been deposited in rift settings whereas Tertiary sediments initially in Passive margin setup (Paleogene) later in Foreland settings (Neogene and Quaternary) Fig.2.

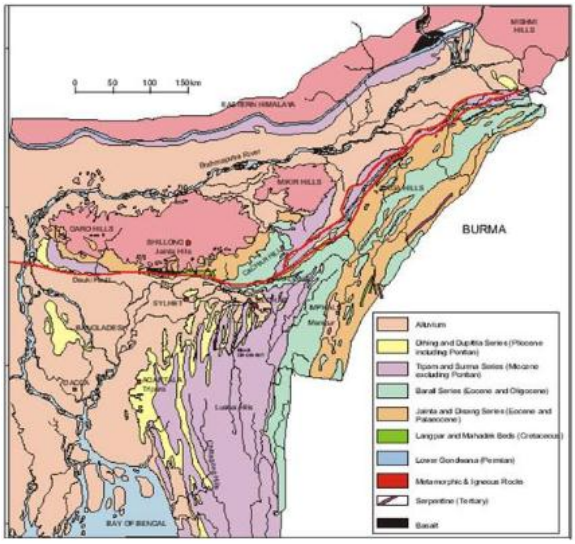

Fig.2. Geological Map of Assam & Assam Arakan Basin (A & A A Basin).

Generalized Stratigraphy

Pre-Tertiary

The Precambrian rock consists of granite and granitic gneisses rocks and forms floor of the basin over which Pre-Tertiary equivalent to the Gondwana have been deposited in Dhansiri valley. The Pre-Tertiary sediments are restricted in grabens. The study of palynological evidence collected from Pre-Tertiary sediments in Dhansiri valley suggests early Permian to Early cretaceous age (Singh et.al. 1986 and Sharma et.al. 1986). These sediments are equivalent to Lower and Upper Gondwana Formations (Fig 3.).

Tertiary:

The Tertiary sediments either resting directly over granitic basement or Pre-Tertiary sediments in Dhansiri valley. These rocks are divided into the Paleogene, Neogene and Quaternary sediments.

The Paleogene consists sediments of Tura, Sylhet, Kopili Formations of Jaintia Group (PaleoceneEocene) and are

overlain by the Barail Main Sand and Barail Coal Shale Formations of Barail Group (Oligocene). The Tura Formation is either resting over Pre-Tertiary or granitic basement. The Tura Formation is represented by calcareous sandstones with basal Conglomerate, are deposited in fluvial to shallow marine environment. Sylhet Formation (Middle Eocene) consists of fossiliferous limestone with shale and sandstone bands in between have been deposited in shallow marine shelf environment. The Kopili Formation (Late Eocene) consists the transgressive shale with intercalation of fine grained sandstone and marl streak have been deposited in shallow marine environment. The clastic intercalations within Kopili shale indicate the periodic regressive impulses during deposition. The Kopili Formation is overlain by the sediments of Barail Group (Oligocene). The Barail Main sand (BMS) Formation constitutes lower part of Barail Group and consists finegrained massive sandstone with cross bedding have been deposited in deltaic environment. The Barail coal shale (BCS) Formation constitutes upper part of Barail Group and consists of shale, coal and few channel sands have been deposited in swampy environment. The end of the Paleogene is marked by the widespread Oligocene unconformity (Fig.3.).

The Neogene sediments are directly resting over the sediments of Barail Group and consists Bokabil Formation (Surma Group), undifferentiated Tipam Formation (Tipam Group) and Namsang Formation (Moran Group) from bottom to top. The Bokabil Formation (Lower to Middle Miocene) consists predominantly of shale with subordinate sand at places have been deposited in a pro-delta environment. The Bokabil Formation is overlain by undifferentiated Tipam Formation (Upper Miocene). Tipam Formation consists predominantly of sand have been deposited in fluvial environment of deposition and are overlain by Namsang Formation (Pliocene - Pleistocene). Namsang Formation consists of unconsolidated fluvial sand, intercalated with clay and lignite. Namsang Formation has been deposited in intermontane depositional environment. The Neogene sediments are overlain by Quaternary sediments (Fig.3).

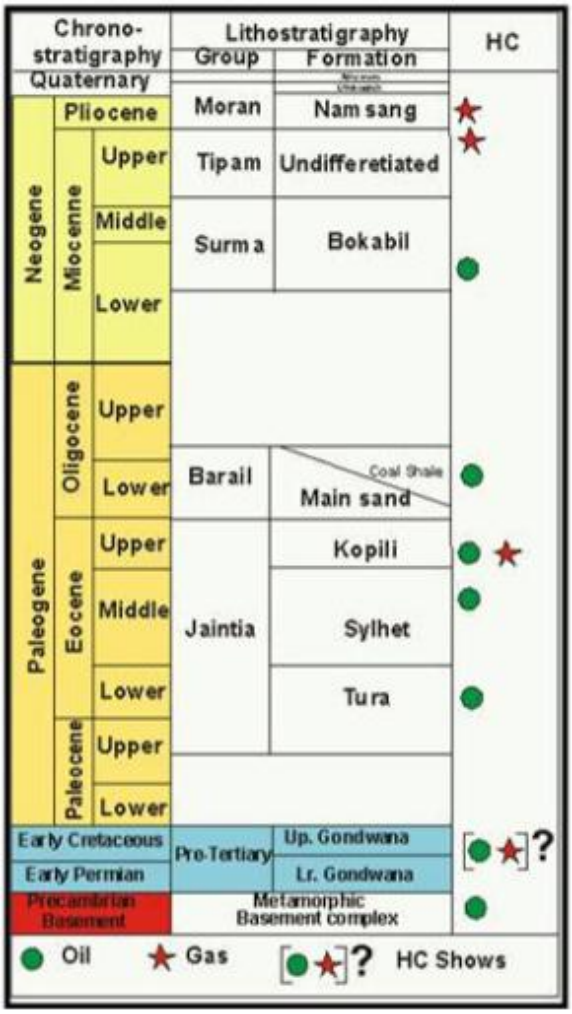

Fig.3. Stratigraphy of Dhansiri valley

Tectonics

Thick Skinned Tectonic and Entrapment of Hydrocarbon in Fractured Basement and Overlying Tertiary Reservoirs in Borholla-Changpang Field, Dhansiri valley, A&AA Basin. Dhansiri valley evolved through rift, drift and collision stages and exhibits a complex structural pattern of poly Tectonics history. The early extensional tectonic modified by later compressive tectonic has reactivated and rotated the pre existing faults. This has generated numerous crisscross faults of variable magnitude and transforms the basin in to present Foreland basin.

Tectonically, the region has been divided into **Eastern Himalaya** on the north and northwest side, **Mishmi Hills**

on extreme northeastern side forming an orographic bend ("Assam Syntaxis" or "Northeastern Syntaxis"). **Assam Shelf** (Assam Foreland), an intermontane basin covered by recent alluvium lying between Eastern Himalaya. **Mobile Fold Belt** area of **Schuppen and Arakan-Yoma** on the southeast side extends southward, Shillong and Mikir Massif on the west. **Bengal and Surma Valley**, lying south west of Dhansiri valley (Fig.4.0).

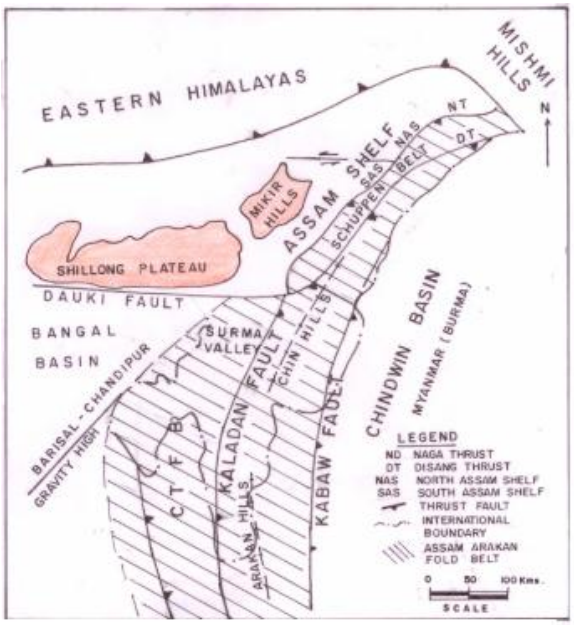

Fig. 4. Tectonic Map of A & A A Basin.

Source Rock, Reservoir Rock and Cap Rock in Dhansiri valley

(a) Source Rock

The source rock studies indicate that shallow marine thick carbonaceous shale of Kopili Formation (Upper Eocene) having average TOC values ranging between 2-8 % and HI value varies from100-300, suggesting Type III kerogen (Fig.5b.). The Tmax values ranging from 410-450 ºC indicate that the Kopili sediments are well within oil window and confirm the presence of mature source rock (Fig.5a.). The organic richness and their maturity increases towards Schuppen belt (Singh, et al., 2008). The gross thickness of Kopili sediments varies from 50-300m with a gradual thickening towards southeast. (Fig.5)

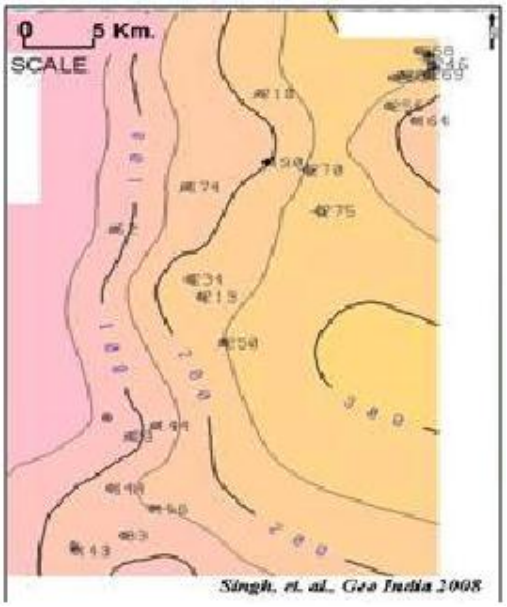

Fig. 5 Kopili Source Rock Map Dhansiri valley

Fig. 5a. T Max & HI Map of Assam Shelf , A & A A Basin

Fig. 5b. TOC & S2 Map of Assam Shelf, A & A A Basin

(b) Reservoir Rock

The sandstone within Bokabil (Lower Miocene), Tura (Upper Paleocene – Lower Eocene), Sylhet (Middle Eocene) and Kopili Formation (Upper Eocene) are having good reservoir characteristics, besides Fractured basement of Precambrian age. The thickness of multilayered sandstone reservoirs within Sylhet and Kopili Formation varies from 2 to 17 m with porosity variations from 11-29 %. The thickness of lenticular sand within Bokabil Formation varies from 3 to 12 m with porosity variation from 15-21 %.

The sandstone layers within the Tura, Sylhet and Kopili Formations are proven hydrocarbon reservoirs (Fig.6). The transgressive shale with intercalation of fine grained sandstone and marly streaks of Kopili Formation were deposited in shallow marine environment (Ranga Rao, 1983).

The sandstones intercalations within these formations represent regressive impulses and are proven reservoirs in study area beside the fractured basement (Fig.6).

(c) Cap Rock/Seal

The shale of Kopili Formation acts as lateral seal in host-graben settings for fractured basement reservoirs. The shale at the top of each reservoir sand within Tura, Sylhet, Kopili, Bokabil Formations are acting as seals for different reservoirs in the area (Fig.6).

Structural Modelling

Forward modelling and sequential block restoration has been carried out in east- west direction across Dhansiri valley along Dergaon-New Tsori (Borholla) section (Fig.12a&12b). The study indicates thick skinned tectonic scenario at deeper stratigraphic level towards Schuppen belt (Borholla-Changpang area) and thin skinned tectonic deformed scenario at younger stratigraphic level. The study brings combination of thick and thin skinned scenario for the deformed present day situation in Dhansiri valley and adjoining Schuppen belt.

Thick Skinned Tectonic and Entrapment of Hydrocarbon in Borholla-Changpang Field in Dhansiri valley

Dhansiri valley constitutes southern part of Assam shelf and lying between two orogenic belts i.e. Eastern Himalayas in the north and Schuppen belt in the east and south east (Fig.4.). It has evolved through different stages of tectonic phases, initially rift phase followed by drift phase and presently it is in the collision phase (Fig 7a & 7b).

During rift phase the area has been in extension regime and the horst and graben structures were resulted due to normal faulting. The Pre tertiary sediments were deposited in these grabens. Such grabens where Pre tertiary are preserved have been mapped in the areas around Dergaon, Barpathar, Jamuguri, East-Lakhibari, Farkating, Gamariguri of Dhansiri valley (Fig.8a). During drifting phase Paleogene sediments i.e. Tura, Sylhet, Kopili and Barail were deposited in passive margin setup relatively in calm depositional environment. The thickness of Paleogene sediments increases towards east and varies from 268 to 1178 m in Dhansiri valley (Fig.8b).

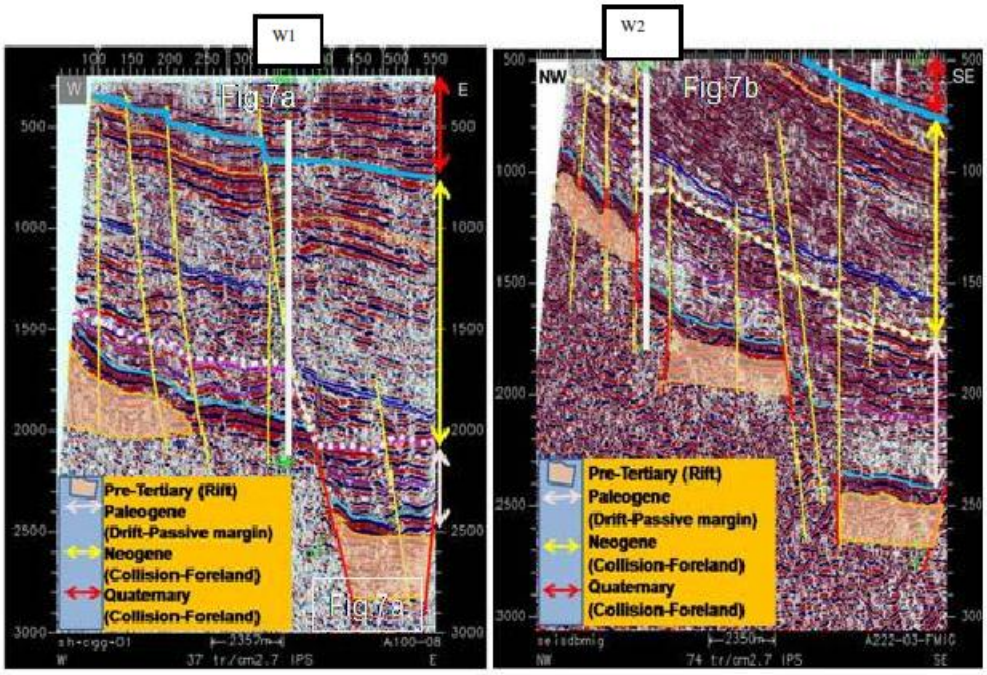

Fig.7a & 7b. Seismic Sections Showing Rift, Drift and Collision phases of Sedimentation in Dhansiri valley.

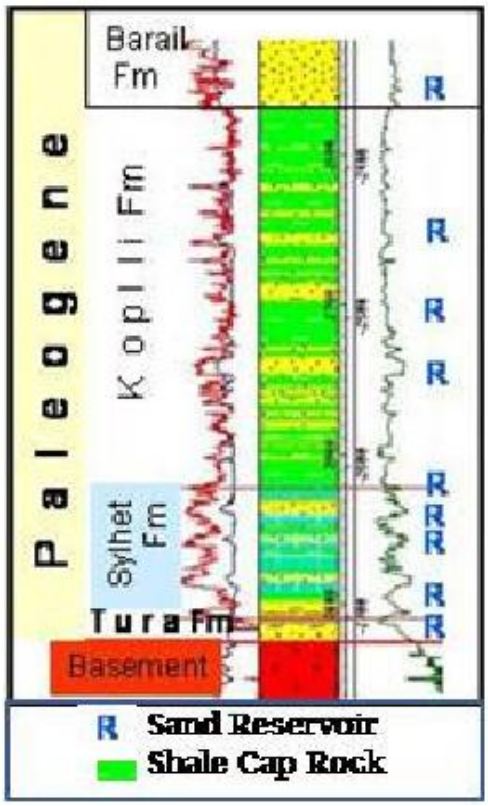

Fig.6. Reservoir and Cap Rock within Paleogene in Dhansiri valley

The collision has transformed Passive margin basin in to Foreland basin and depositional environment from marine to fluvial. It has started receiving sediments from higher altitude Himalayas and Burmese side. Presently the basin is in collision phase and being compress between Eastern Himalayas and Schuppen belt. During compression the pre existing faults have been reactivated and uplifted the basement and brought juxtapose to the Paleogene sediments.

The tectonic of Borholla-Changpang field exhibits thick skinned tectonic (deformation that involves basement rocks) where hydrocarbon are entrapped in fractured basement and overlying Paleogene reservoirs (Fig.8.). The fractured basement and directly overlying basal sand in the horst part of Borholla-Changpang field forms the reservoir and juxtaposing Kopili shale acting as lateral seal to entrap the hydrocarbon in fractured basement and directly overlying Basal sand.

The hydrocarbon entrapped in fractured basement and basal sands are hydro dynamically connected and shale over Basal sands forms top seal to entrap hydrocarbon in fractured basement and directly overlying Basal sand. The inverted overlying Paleogene section and lenticular sand within Tura, Sylhet and Kopili Formations are Paleogene

reservoirs. The shale above these sand reservoirs forms the seal for different Paleogene reservoirs (Fig.9).

The analysis of geo-scientific and production testing data of Borholla-Changpang field indicates that the hydrocarbon have been trapped in the basement involved "Faulted Horst and Graben" type structure (Fig.9.). Thick shale of Kopili Formation and at places shale and limestone of Sylhet Formation juxtaposing the fractured basement (Fig.9, 10 & 11) and forming ideal trap for hydrocarbon entrapment in fractured Basement. The folding in successive overlying Tura, Sylhet and Kopili Formations over tilted fractured basement forms favorable structural entrapment conditions for hydrocarbon entrapments in these formations (Fig.9, 10 &11).

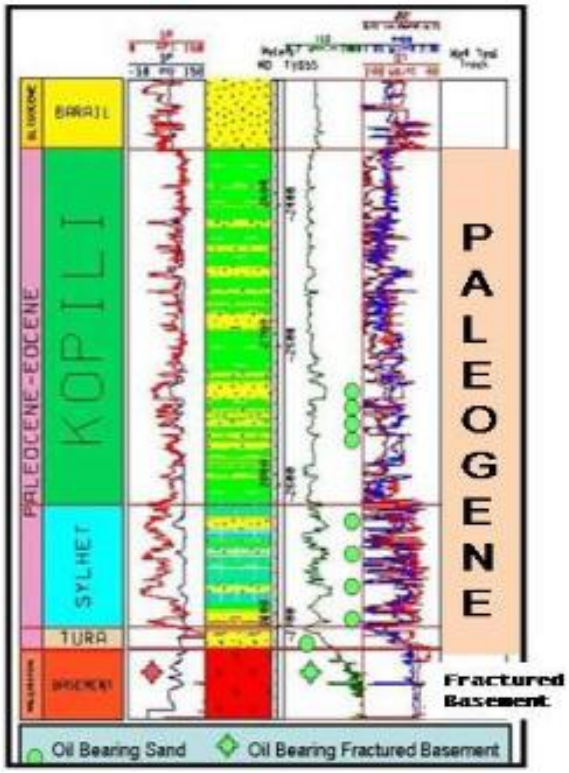

Fig.8. Log Motif of Fractured Basement and Reservoir within Tura, Sylhet and Kopili Formations, Borholla-Changpang Fields

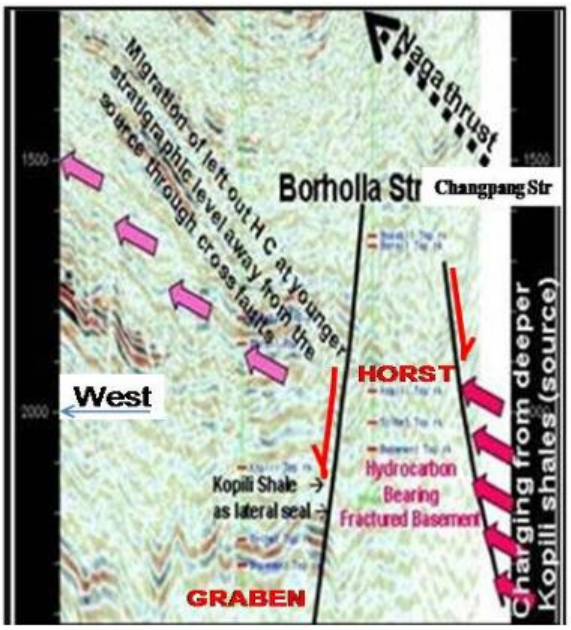

Fig.9. Borholla-Charging of Horst and Graben Structure and Migration of Left out Hydrocarbon to Younger Stratigraphic Level through Cross fault, Dhansiri valley.

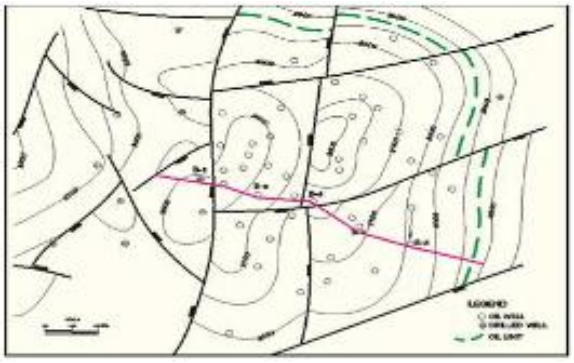

Fig.10 Structure Contour Map on Top of Basement, Borholla-Changpang Field

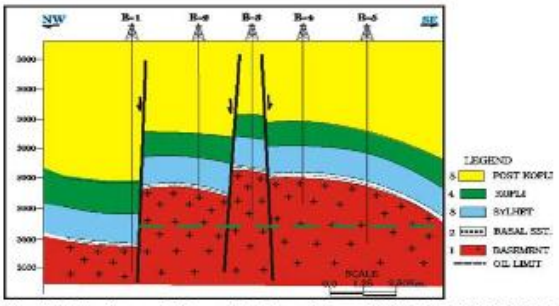

Fig.11. Geological Cross Section Along Wells B-1,B-2,B-3,B-4 & B-5 ,Across Borholla-Changpang Field, Dhansiri valley.

Basal sandstone of continental origin directly overlying fractured basement forms single hydrodynamically connected reservoir with fractured basement. Sylhet Formation composed of multilayered limestone, shale and sandstone alternation, where sandstone is charged with the oil (Fig.8&11). Kopili Formation consists of predominantly shale and thin lenticular sand in between at places. These lenticular sands at lower part of Kopili Formation become more arenaceous and oil bearing (Fig.8&11). Currently Borholla field is producing oil @ 175 M3/d from Paleogene reservoirs and 7 M3/d Oil from fractured basement.

The Neogene and Quaternary sediments have been deposited in foreland basin settings. The Neogene represents Bokabil, Undiffentiated Tipam and Namsang Formations. The Bokabil represents pro delta shales with intervening sands. These sands are devoid of hydrocarbon in Borholla-Changpang field and are producers in Khoraghat, Nambar, East lakhibari, Kasomarigaon, Uriumghat structures.. The undifferentiated Tipam Formation consists predominantly channel sands are gas bearing in Borholla-Changpang field. These sands are devoid of hydrocarbon in other producing structures in Dhansiri valley. The Namsang Formation consists of alternation of clay, shale and sand. The sands are only gas bearing in Borholla-Changpang field.

Fig.12a. Forward Modelling across Dhansiri valley along Dergaon -New Tsori (Borholla) Section .

West East

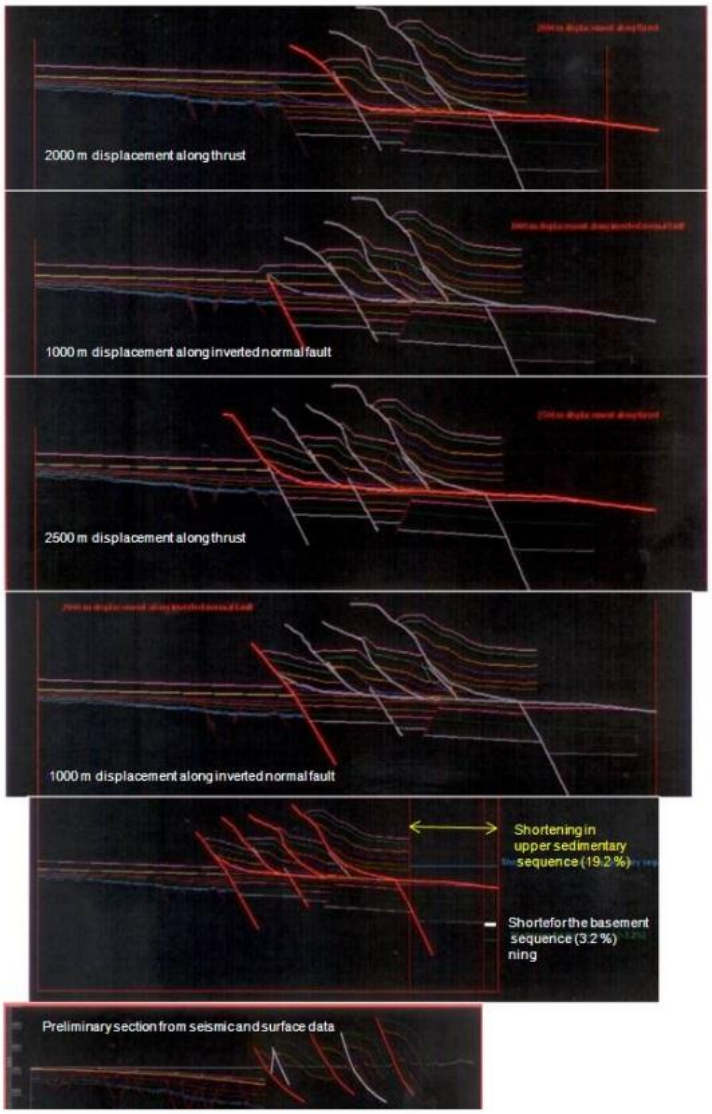

Fig.12b. Sequential Block Restoration across Dhansiri valley along Dergaon-New Tsori (Borholla) Section

Conclusion

The analysis of geo-scientific data of Borholla-Changpang field indicates thick skinned tectonic and hydrocarbon are entrapped in fractured basement and overlying Tertiary reservoirs in the horst part of Borholla-Changpang field.

The fractured Basement, Basal sand directly overlying fractured Basement and lenticular sand within Tura, Sylhet and Kopili Formation are producing reservoirs in Borholla-Changpang field.

Thick Kopili shale and at places shale and limestone / shale within Sylhet Formation juxtaposing the fractured basement and overlaying Basal sand forms ideal lateral seal for hydrocarbon entrapment in fractured Basement and overlying Basal sandstone. Shale over Basal sands forms top seal to entrap hydrocarbon in fractured basement and directly overlying Basal sand.

The shale above lenticular sand reservoir within Tura, Sylhet and Kopili Formations form cap for different inverted Paleogene reservoirs in Borholla-Changpang field.

The opinions expressed in the paper are of authors not the organization they belong.

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