Gondwana Sediments and Their Hydrocarbon Prospectivity in Dhansiri Valley, Assam and Assam Arakan Basin - India*

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Abstract

Dhansiri valley is a part of Assam and Assam-Arakan basin, which is an established petroleum province situated in the northeastern part of India. The major oil production of the basin is from Assam shelf, which falls between two orogenic belts i.e. Himalaya in the north and Schuppen belt in southeast. A major E-W lineament (Jorhat Fault) divides Assam shelf into two parts; northern part is know as Brahmputra valley (North Assam shelf) and southern part Dhansiri valley (South Assam Shelf). The Precambrian basement forms base for the sedimentary rock, basal sand stone derived from the granitic basement forms the first sedimentary sequence over which Gondwana sediments (early Permian to Early cretaceous) have been deposited. These are uncomfortably covered by the Mikir trap, which is also a interface between Tertiary and Pre-Tertiary sediments. The significant commercial oil and gas production in Dhansiri Valley are from Tertiary as well as Pre-Tertiary reservoirs. In Tertiary it is mostly from sandy layers within Bokobil (Miocene), Kopili and Sylhet Formations (Eocene) whereas in Pre-Tertiary the production is from Basal Sandstone and fractured Basement. Although there had been hydrocarbon shows from Gondwana drilled section in few of the wells but gas bearing sand encountered in Gondwana section from East Lakhiwari well no-1 has generated lot of hope and interest for Gondwana hydrocarbon exploration in Dhansiri valley. In the study area, the Gondwana sediments are restricted in pre-existing graven and chasing these in grabens can be rewarding to meet gas requirement of the area.

Introduction

Dhansiri valley (South Assam shelf), bounded to the east by Schuppen belt, west by Mikir Massif, north Jorhat fault and to the south by North Cachar hills. The Dhansiri valley is separated from Brahmputra valley by the E-W trending Jorhat fault (Figure 1).

The structural trends, the sediment characteristics and the thickness pattern are quite different in both side of Jorhat fault. In Dhansiri valley the basement surface slopes towards southeast is somewhat shallower and steeper in comparison to the North Assam Shelf.

The exploratory efforts in Dhansiri valley has established commercial oil from fractured basement, Tura, Sylhet, Kopili, Barail and Bokabil Formation and Gas from Tipam and Namsang Formations. The study is aimed to delineate the Gondwana sediments and to assess their hydrocarbon prospectivity in Dhansiri valley.

Tectonic and Stratigraphy

Dhansiri valley is a part of Assam - Arakan Basin that represents a classic example of a poly-tectonic basin having history of more than one phase of tectonics and sedimentation. The movement of the Indian plate in relation to the Eurasian and Burmese plates essentially influences the evolution of the basin. Tectonically Assam shelf lies between two orogenic belts one the Himalayan orogenic belt trending in ENE-WSW direction and another Schuppen belt trending NE-SW direction. The southeast-dipping Assam shelf lies between these two orogenic belts and extends southwestwards across Dhansiri valley up to near North Cachar hills (Figure 2). The sediments in Dhansiri valley, represents three tectonic regimes. The oldest sediments are of rift setting followed by passive margin setting and foreland settings. The rift setting is represented by the Gondwana sediments, whereas passive margin setting characterized by the Paleogene sediments and foreland settings by Neogene sediments.

Metamorphic Basement Complex

The sedimentary rocks rest on Precambrian crystalline rocks in Shillong Plateau was first reported by Oldham in the year 1858. Later, these crystalline rocks have been studied by the different workers and referred by various informal and formal names e.g., Shillong Granite, Shillong Series, Mikir Granite etc. All the crystalline rocks found at the base of the sedimentary sequence and formed prior to the oldest known sedimentary rock in the basin are termed as the Metamorphic Basement Complex (M.B.C.).These rocks are referred as basement in the present study.

Pre-Tertiary: Medlicott, (1872), Feistmantel (1876), Fox (1937) observed that the Gondwana rocks exposed in Singrimari area of Garo Hills (District Goalpara), South Shillong Plateau, is uncertain in other part of the basin. The exposed gritty sandstones with carbonaceous shale and presence of typical Lower Gondwana plant fossils viz. Vertebrartia indica and gymnospermous rhizomes etc. in Singrimari was assigned Carboniferous to Lower Triassic age. These sediments were deposited in continental environment and were termed as "Gondwana sediments". So far, besides Singrimari area of Goalpara district (Meghalaya), no outcrop occurrence of Gondwana sediments have been reported in Assam shelf.

In subsurface, wells drilled in Dhansiri valley on structures, Dergaon , Barpathar, Jamuguri, East-Lakhibari, Farkating, and Gamariguri have encountered Pre-Tertiary section equivalent to the Gondwana sediments. Maximum thickness of 350 m Pre-Tertiary section is encountered in East-Lakhibari .The palynological evidences for these sediments from these wells suggest Permian to Early Cretaceous age (Singh et al., 1986; and Sharma et al., 1986, Ramesh et al., 2003).The correlation of Pre-Tertiary sediments are shown in Figure 3 and Figure 6. High resistivity of 100- 200 ohm and fluctuating GR mark the sequence. The whole Gondwana sequence is characterized by alternations of argillaceous sediments (clay stone, silt stone and shale), sometimes shown very high Gamma ray count (> 150 API) and low SP. Gondwana sequence can be identified seismically but its sub-division is difficult to resolve seismically as the data quality is not very good Figure 6. However, division of Gondwana sequence in study area has been made, with the help of palynological data and electro log characters Figure 3, Figure 5a, and Figure 5b. The time thickness and isopach map (Figure 4b and Figure 4c) of Gondawana unit indicate a maximum thickness of 350 m in Barpather- Gamarguri area graben oriented northwest-southeast multiple sediment entry. Pre-Tertiary strata though recognized only in a few restricted areas of Assam basin, these represent an important phase of tectonic evolution and form a potentially, yet untested, petroleum system concept in Northeastern India (Naik et. al., 2004).

Bamangaon Formation (Gondwana): The lower part of the Pre-Tertiary section encountered in the well Dergaon-1, comprises sandstone-dominated strata designated as the "Bamangaon Formation" by Khanna and Srinivasachari (1973). Based on the drilled well data from Dhansiri valley,

Das et al., (2004) divided the Bamangaon Formation in to Lower Gondwana (Early Permian) and Upper Gondwana (Early Cretaceous). Das et al., (op. cit.), divided entire Gondwana drilled section in to two litho-units, the lower unit dominated by sandstones and upper sandstone-shale alternation. The lower unit belongs to Early Permian (Asselian-Sakamarian) age equivalent to Talchir stage whereas the upper units and trap (basalt/dolerite) with thin intertrappeans belong to Early Cretaceous (Aptian) age equivalent to Rajmahal stage (after Basavaraju et al., 2002). Hence, variations in Lower Gondwana (Early Permian) and Upper Gondwana (Early Cretaceous) and major unconformity separating these Two units are distinct on Electro-log characters (Figure 5a

and Figure 5b).The maximum thickness of Gondwana sediments, mostly Early Permian age are encountered in Dergaon area in the north where the associated trap has not been encountered (Figure 4c). Whereas in the southern part, towards Yampa area the thickness of Gondwana sediments encountered are minimum.

Mikir Trap

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Gondwana Upper (Bamangaon Formation)

Gondwana (Early Cretaceous)

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Lower Gondwana (Early Permian)

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Basement

Lower Gondwana (Early Permian)

Das et al., (op. cit.) 2004, described "Lower Gondwana" to the lower most unit of Bamangaon Formation, overlying basement composed of dominantly sandstone with shale intercalations. A correlatable litho-facies of pebbly shale having pebbles and cobbles embedded in clay matrix (tillite?) has been observed in the cores of well drilled in Dergaon and Barpather. Palynofossil assemblages and sedimentological characters indicate Early Permian age (Lower Gondwana) possibly equivalent to Talchir Formation. The unit shows overall low gamma count on the Gamma Ray log (GR). Dominantly coarser clastics with fresh feldspars, rock fragments and high angular grains indicate immature nature as well as limited transportation of the sediments. Depositionally, these sediments belong to non-marine to marginal marine conditions (syn-rift phase with marine influence). The marine influence was from north (Tethys Sea) as described by Biswas (2003). Well and seismic data indicating thicker Early Permian sequence towards western margin of the basin. The Early Permian (Lower Gondwana) sediments were deposited in the grabens formed along pre-existing weak planes / lineaments mostly representing the boundaries of Archaean protoplates (Mitra, 1994). Naik et al., (op. cit.) 2004 Palynological studies of sidewall cores of Degaon well have yielded a rich assemblage of monosaccate genera. Early Permian (Lower Gondwana) sediments consists of Brevitriletes unicus, Horriditrilets sp, Cyclogranisporites sp, Thymaspora sp, Indotriradires sp, Parasaccites obscurus, Plicatipollenitesindicus, Virkkipollenites Mehta, Divarisaccus sp, Illinites sp, Faunipollenites sp. and Leiosphaeridia sp. etc and assemblage envisage marine environment.

Upper Gondwana (Early Cretaceous)

Das et al., (op. cit.) 2004, the unit-II is represented by alternations of sandstone and shale which depicts high gamma on electrologs and found mostly in Furkating, East Lakhibari, Jamuguri, Barpather area (the central part) Figure 5a. Similar facies having relatively lower gamma counts might be correlatable in Dergaon area. Lithological characters of sandstones are medium- to coarse-grained, poorly sorted, angular and feldspathic. Shales are black to greenish grey in color, carbonaceous and contain occasional coal laminations. This unit has reworked Permian palynofossils in Dergaon area as compared to Jamuguri-Barpathar area. These characters point to a fluvial depositional conditions where streams cutting through Lower Gondwana from up dip were deposited along with Early Cretaceous sediments in Dergaon area. In Barpathar- Jamuguri area, it represents relatively quiet water sedimentation with less circulation and anoxic environment possibly in a lacustrine set-up. The Upper Gondwana sediments represent narrow rifted grabens associated with crustal thinning and trap (basalt) flow prior to breakup and movement of Indian plate from Antarctica. Well and seismic data indicating development of thicker Early Cretaceous sequence in Barpathar-Jamuguri- East Lakhibari area and further thickening towards east suggest two independent paleodepositional trends. The Early Cretaceous sediments deposited in the NE-SW trending grabens generated by crustal thinning and development of fault systems prior to breakup of Indian plate from Antarctica and Australia (Das, et al., 2004).

Naik et al., (op. cit.) 2004, predominantly arenaceous with locally developed carbonaceous and argillaceous rocks of Cretaceous age are exposed in the Garo, Khasi and Jaintia Hills. The base of the sequence is generally irregular, resting either on granite gneiss or on conglomerate of metamorphic and igneous pebbles. In this area the Cretaceous sediments are known by Mahadek and Langpar formations. In Manipur, impure limestones that occupy large areas near Ukhrul, Lambui and Hundung are of Cretaceous age (Basu and Rangaraju, 1964; Prithiraj et al., 1992). The lower Disang shales are also of Cretaceous age. The presence of Hayesites albiansis and Pemme dasquensis indicate an Early Cretaceous (Aptian-Albian) age. The assemblage also belongs to Early Cretaceous. Presence of Micrantholithus indicates a shallow marine (near shore) environment. In Dergaon about 550 m of thick quartzose sandstone and argillites sequence having typical Maestrichtian fauna (Heterohelix planta, Globotruncana cf. contuse, Hedbergellaplanispira, Globogerina sp., Pararotalia sp., Rotalia sp., etc.) as been encountered (Mohan, 1970). This sequence of Late Cretaceous age is known as the Moabund Formation of Dergaon Group (Deshpande et al., 1993). Overlying section, Upper Gondwana (Early Cretaceous) yielded Contignisporites sp., Cicatricosisporites sp., Cyclinospora reduncus,Microcachryidi sp., Classppollis sp, Callialosporites segmentatus, Callialosporites trilobatus and the sediments deposited under shallow non- marine condition. The present day sporadic occurrence of Cretaceous sediments in the foreland part is visualized as the remnants along the transverse grabens developed during rifting phase.

Depositional History of Gondwana Sediments: The palynological studies of the Gondwana sediments encountered in the different wells in Dhansiri valley, suggests Permian (Lower Gondwana) to Early Cretaceous (Upper Gondwana).The Permian section drilled in different wells and are interpreted to be deposited in marine conditions, while Early Cretaceous sequence were considered as shallow marine to fluvial deposits (Basavaraju et. al., 2002). In Assam and Assam Arakan Basin, similar marine Permian sediments also reported from Arunachal Himalayas. It appears that such deposits in this part on the Indian Sub-continent are confined to the fault block resulted due to rifting of Gondwana Super Continent during Permo-Carboniferous period. The marine sedimentation during this period may be due to incursion of sea.

The Upper Gondwana sediments are dominated by more arenaceouse sequence and deposited mostly in fluvial environment. Deposition of these sediments is a result of another phase of rift related tectonic activity during Late-Jurassic - Early Cretaceous period. The phase also associated with igneous activity (Mikir Trap).

Hydrocarbon prospectivity

The prospectivity of Gondwana sediments in Dhansiri valley is focused on source rock characteristics, reservoir quality and entrapment conditions. The geochemical studies of Barpathar-1, Jamuguri-1, Dergaon-1, suggests that Upper Gondwana sediments have fair hydrocarbon generation potential. The average TOC in Dergaon (Upper Gondwana) ranges from 0.58-0.73 and HI ranges from 8-95(V. Prabhakar et.al.2002 and P. Ramesh, 2003), The organic matter shows dominance of Sapropeli c- Humid type. The Upper Gondwana section encountered in the drilled wells E. Lakhibari-1, Furkating-1, Barpather-1, Dergaon shows development of good reservoir facies. The well Barpather -1 indicates the source rock layers with fair hydrocarbon generation potential in Upper Gondwana (S2.2) and migratory bitumen in Lower Gondwana with S1-0.63 and PI -0.41. In Jamuguri-1, the interval 1655-1685 has shown good hydrocarbon generation potential (TAI-2.5, SI-0.2,-2.83 and SI-0.51 to 29.88). The study indicates two regional pods, in the area SW of Jamuguri and Around Dergaon. Superimposing time structure map on thickness map in these areas indicates prospective area lying against the NE-SW trending fault. Another entrapment condition can be visualized as Upper Gondwana reservoirs juxtaposing against Kopili source facies with fault as a conduit and entrapment in the up thrown block. Such play may occur SW of E lakhiwari and appears to be rewarding (Figure 4a, Figure 4b and Figure 4c).

Conclusions

1. The Permian section drilled in different wells and are interpreted to be deposited in marine conditions, while Early Cretaceous sequence were considered as shallow marine to fluvial deposits (Basavaraju et. al. 2002).
2. The study also indicates that Upper Gondwana sediments are good reservoirs and have good hydrocarbon generation potential.
3. Lower Gondwana sediments were deposited in marine conditions and appear to be good source rocks for hydrocarbon generation.
4. Gondwana sediments are restricted in the inverted graben and can form ideal condition for hydrocarbon entrapment.

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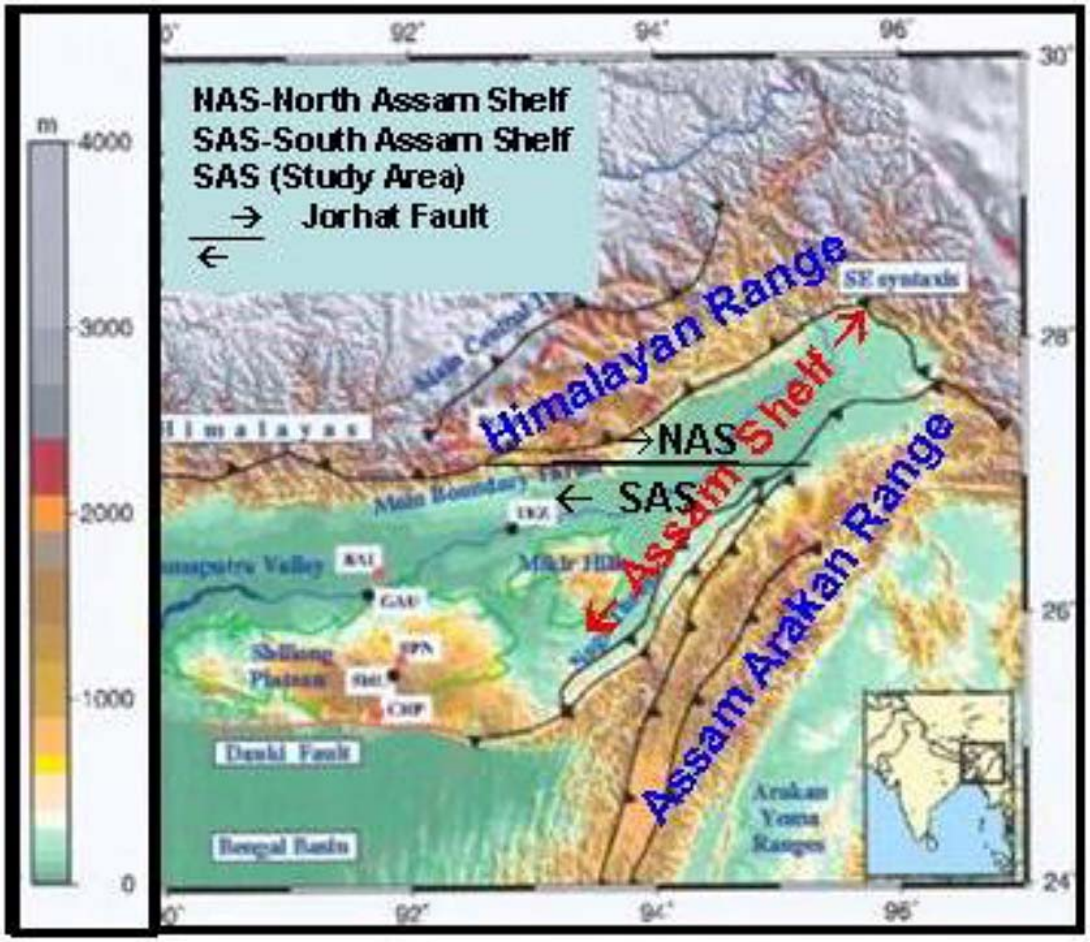

Figure 1. Location map.

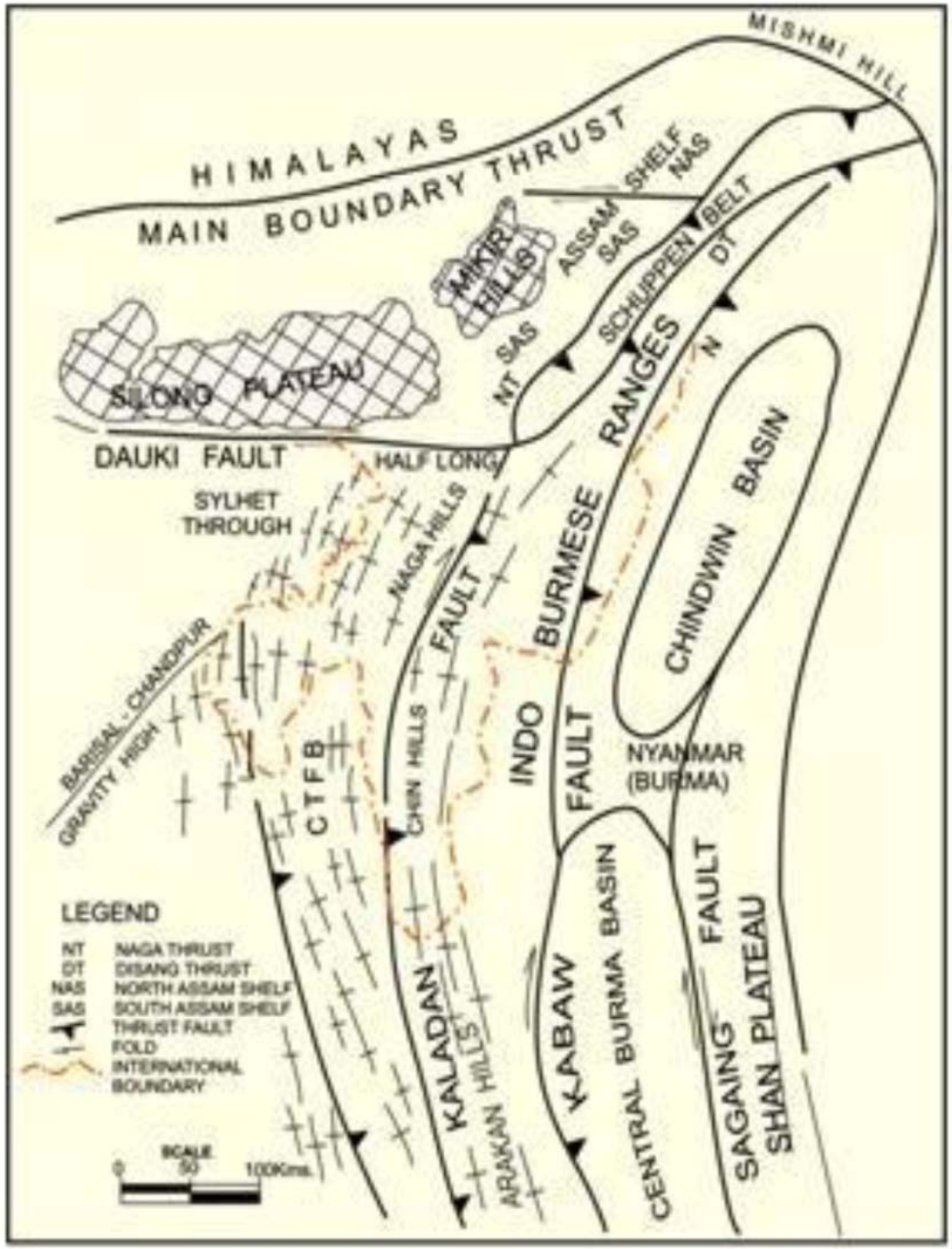

Figure 2. Tectonic map of Assam and Assam Arakan Basin.

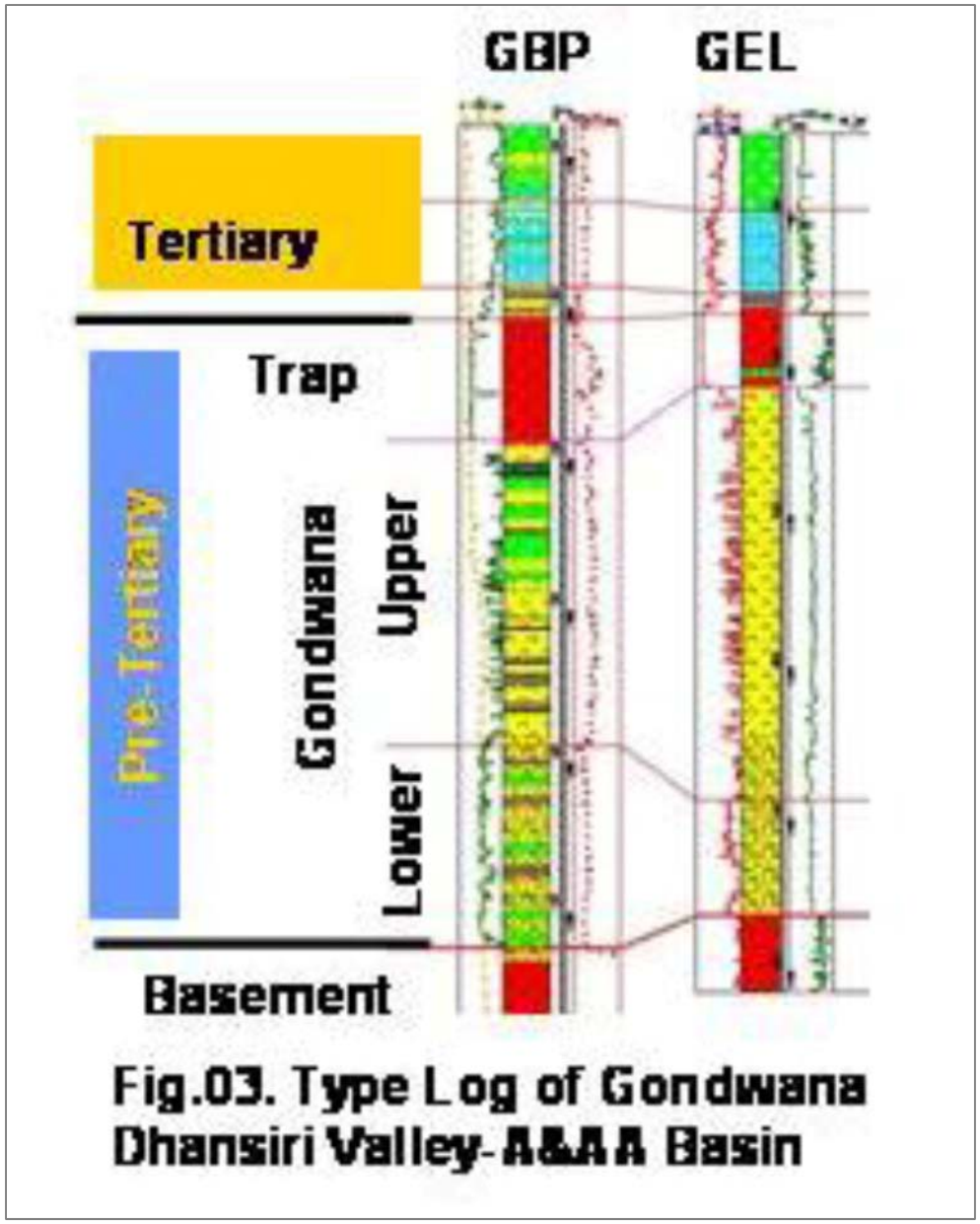

Figure 3. Type log of Gondwana Dhansiri Valley - Assam and Assam Arakan Basins.

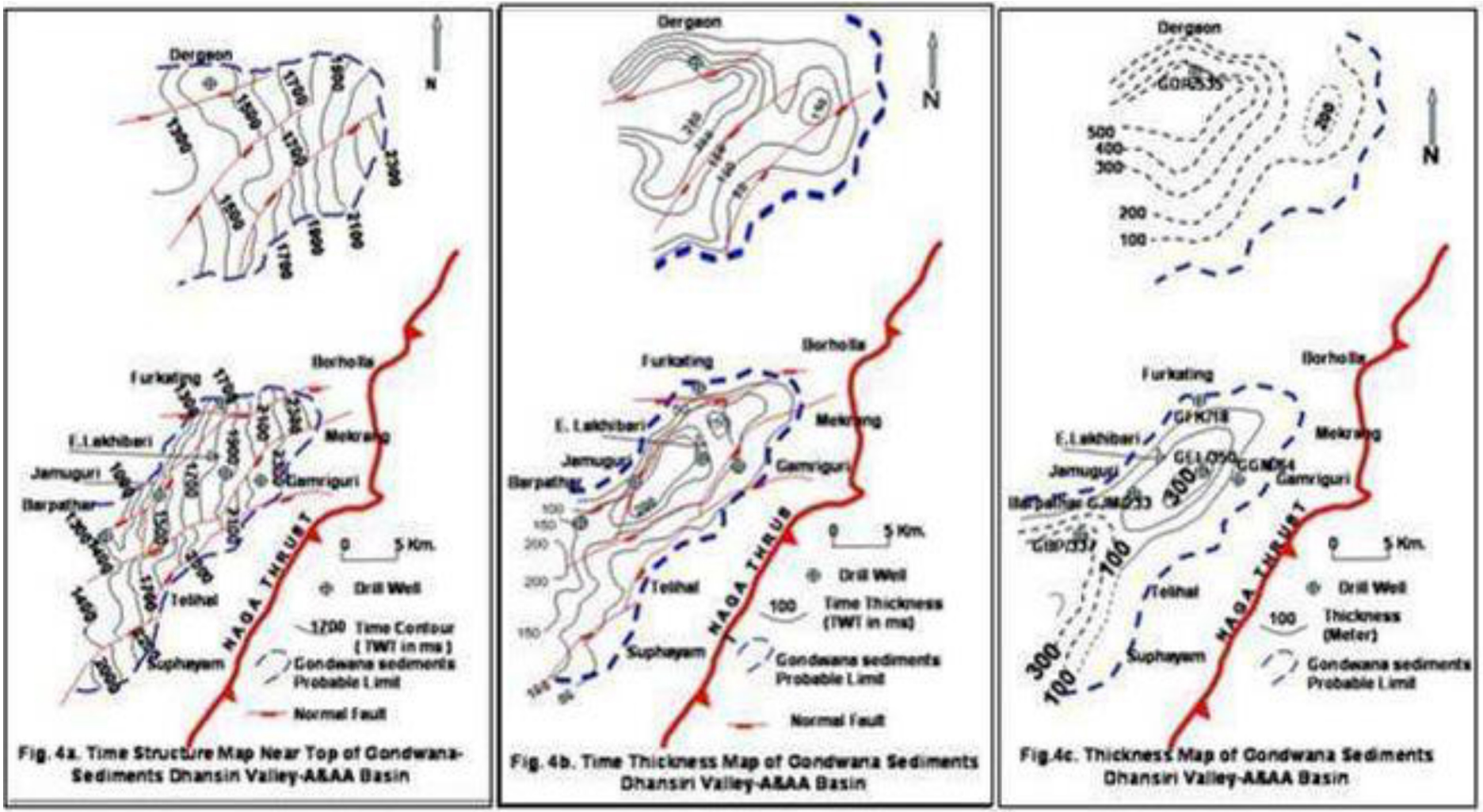

Figure 4. a) Time structure map near top of Gondwana sediments Dhansiri Valley - Assam and Assam Arakan Basins; b) Time thickness map near top of Gondwana sediments Dhansiri Valley - Assam and Assam Arakan Basins; c) Thickness map of Gondwana sediments Dhansiri Valley - Assam and Assam Arakan Basins.

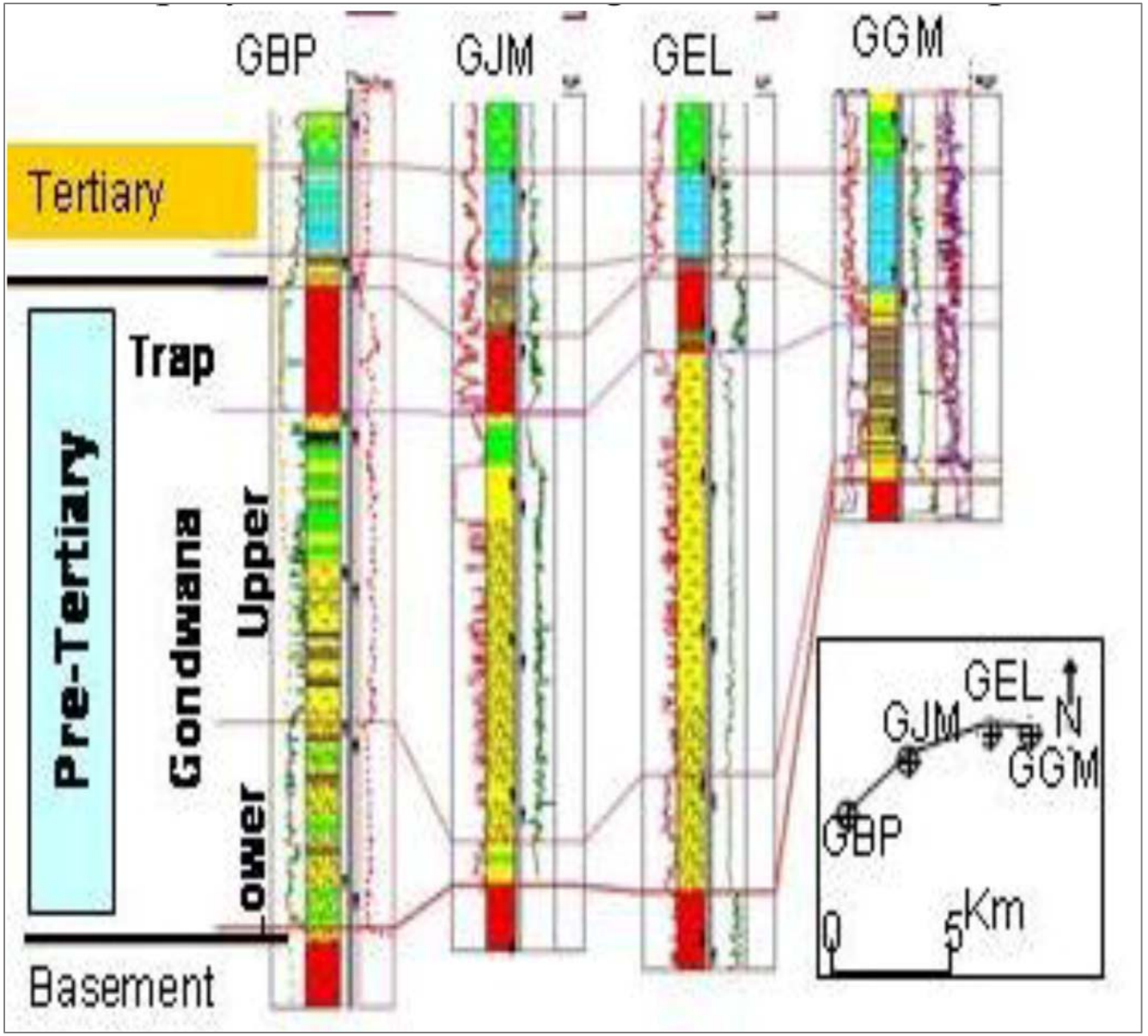

Figure 5a. Log correlation along wells GBP, GJM, GEL and GGM.

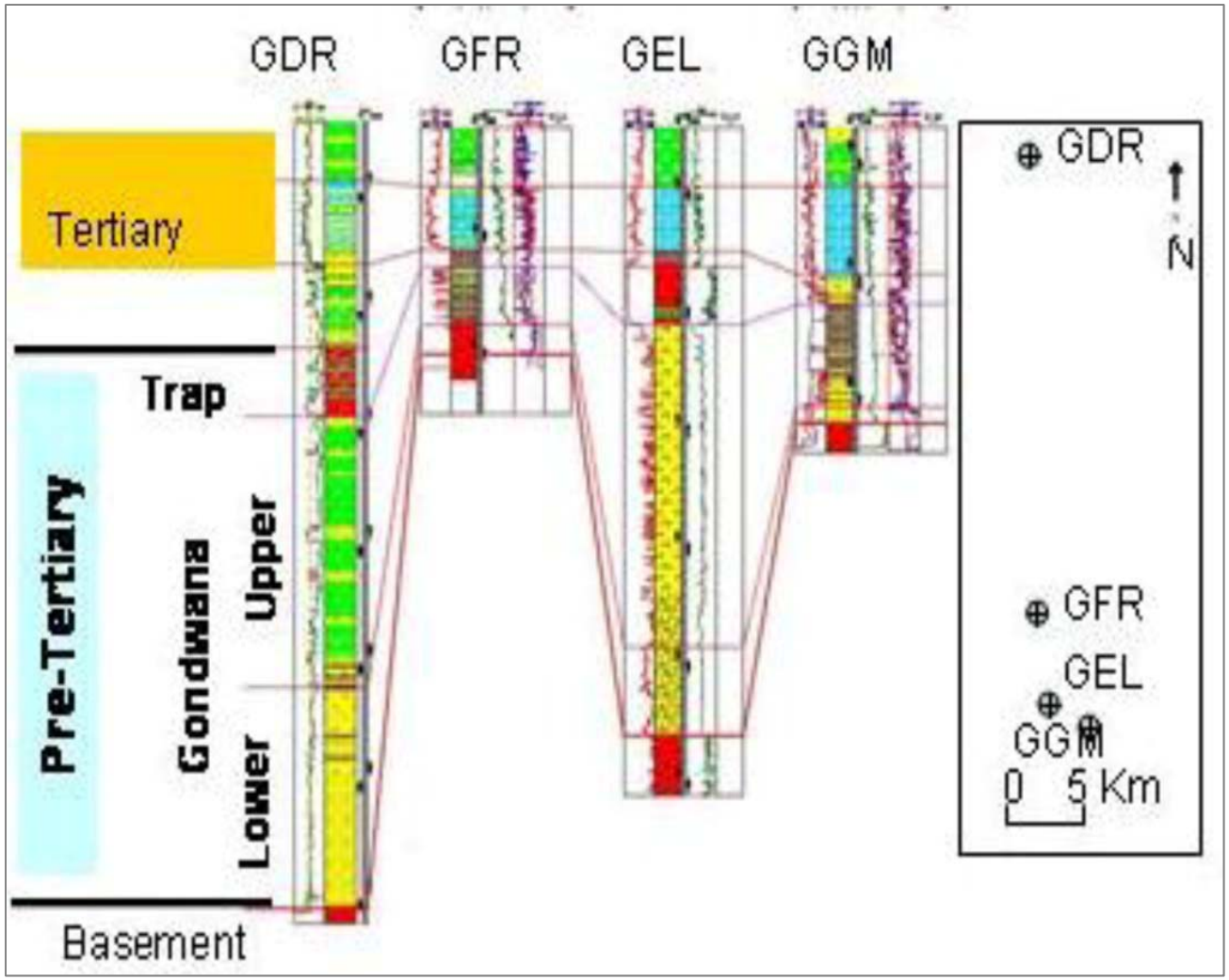

Figure 5b. Log correlation along wells GDR, GFR, GEL and GGM.

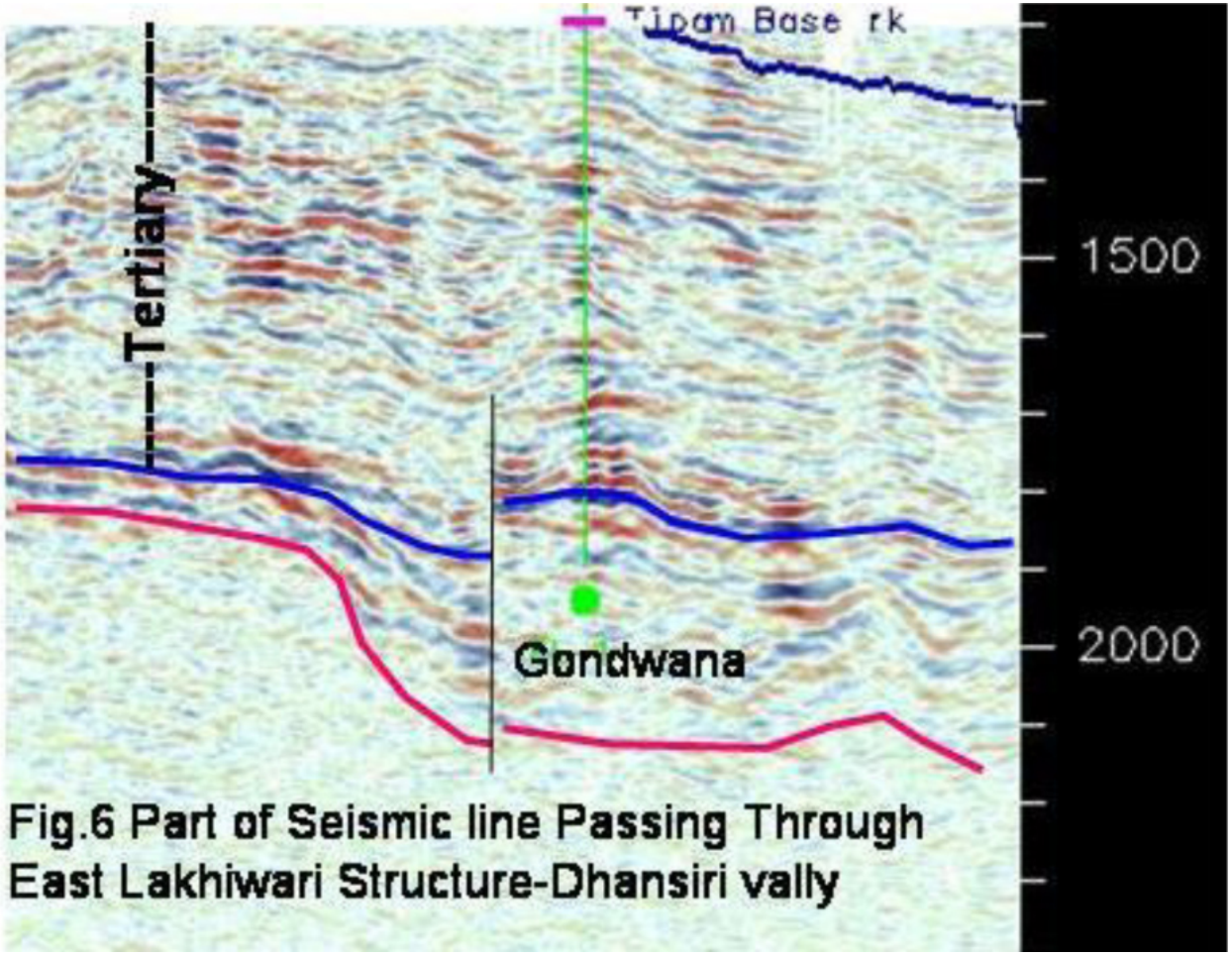

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Figure 6. Part of seismic line passing through east Lakhiwari structure - Dhansiri Valley.