Structural Styles and Its Implication on Petroleum Systems of North Assam Shelf, Upper Assam Basin, India*

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Abstract

The Upper Assam Basin is a composite foreland basin which is located between the eastern Himalayan foothills and the Assam-Arakan thrust belt. The basin is terminated to the northeast by the Mishimi Hills block and to the southwest it is partly disrupted by the Shillong plateau basement uplift (Figure 1). There are two petroleum systems present in North Assam Shelf of Upper Assam Basin and are described below (Sahoo and Gogoi, 2009):

(A) Paleocene to Middle Eocene-Paleocene to Middle Eocene (!)Petroleum System

The Paleocene to Middle Eocene-Paleocene to Middle Eocene (!) Petroleum System which is oldest and the source rocks of this system are of organic rich carbonaceous shales, coals and thin carbonate units of the Upper Paleocene-Lower Eocene Sylhet Formation and the Upper Paleocene Langpar Formation (Handique and Bharali, 1981). The carbonaceous shale and coal are often interbedded with clastic reservoir rocks which are thin to very thin and characterized by very high permeability and porosity.

(B) Late Eocene to Oligocene-Oligocene (!) Petroleum System

This petroleum system comprises the thick Kopili Shale as a major source rock and Sylhet limestone with marginal source rock potential (Figure 1). The lower Kopili is more argillaceous in nature than the upper with a shale content of more than 60%, whereas in the Sylhet Formation it decreases to 10-15%.

Structural Styles in North Assam Shelf

The regional structure of upper Assam foreland basin is known from geophysical surveys conducted for hydrocarbon exploration. The generalized structure inferred from seismic surveys, that the Assam plains form a broad arch at the basement level with its apex in the region of the present Brahmaputra River course and sloping towards the Himalayan foothills in the north and Naga Hills in the south (Figure 2). This arch is dissected by a number of faults with a general strike of NE-SW or ENE-WSW trending parallel to the fault pattern observed in the Mikir Hills metamorphic complex (Ray et.al., 1983) and also parallel to the Naga Thrust. The structural pattern in the sedimentary cover is controlled by the irregularities in the basement surfaces known from gravity surveys and differential movement along these faults.

Structural Styles in Geleki-Mekeypore Area

In the Mekeypur area the structural culminations are the upthrust anticlinal structures formed against the Geleki main reverse fault system which originate from late stage compressional tectonic events in the post-Girujan period (Figure 4). In Geleki area the effect of inversion is more pronounced and the dominant structural features are in the form of transversely dissected structural culminations, second order tip line folds, ramp structures and duplexes (Bastia et al., 1993). Earlier workers (Bhandari et al., 1973; Deshpande et al., 1993; Dasgupta and Biswas, 2000) indicated the possibility of growth fault tectonics and also invoke large-scale strike-slip movements in the basin (Figure 5). These longitudinal faults originated in the extensional regime in Paleogene time. These faults play a major role in entrapment of hydrocarbons in the area (Figure 3).

Structural Styles in Demulgaon Area

The main Demulgaon Field comprises a series of tilted fault blocks. The structural elements present in this field at the Barail level are dominantly controlled by ENE-WSW trending faults. In the Demulgaon area most of the NNE-SSW trending faults swing and continue in a ENE-WSW trend as shown in seismic section Figure 6. These structural features are bounded by two prominent depressions: Khelugaon low towards northwest, and Nazira low to the southeast. These lows are cut across by faults which are probably acting as conduits for migration of hydrocarbons.

Structural Styles in Lakwa-Tiphuk-Kuargaon Area

In the Lakwa-Lakhmani area, a number of normal faults are interpreted, most of which are related to movement of basement blocks. The fault patterns match with major lineament trends NE-SW and ENE-WSW in the area. Most of these longitudinal high angle normal faults are basement involved and extend up to the Girujan level (Figure 7). The Kuargaon and Mahakuti fields are intersected by mainly ENE-WSW trending faults having throw to the southeast. These faults divide the field into different fault blocks which are occasionally cut by secondary faults with NW-SE orientation. The orientation of antiformal structures, resulting from faulting, generally follow the trend of main faults. The structural features in Kuargaon and Mahakuti areas are bounded by the Khelugaon low to the northwest. The faults cutting across these structural lows are believed to have acted as conduits for hydrocarbon migration.

Structural Styles in Panidihing-Dhondarmukh-Disangmukh Area

In Panidihing and Dhondarmukh areas the structural trend in Paleogene time appears to be curvilinear fault geometries having linear ridges with horst and graben features along a NNE-SSW direction as shown in seismic section Figure 9. In Disangmukh area two prominent fault trends, NE-SW and E-W, have bearing on hydrocarbon accumulation in the area. These fault bounding ridges have yielded hydrocarbons in structural culminations. Several structural culminations with two distinctive sets of faults, ENE-WSW to E-W and NE-SW to NNE-SSW, are observed on seismic sections from Basement to LCM levels (Figure 8).

Discussion

The occurrence of hydrocarbon in North Assam Shelf block lies along the lineament patterns. The oil and gas prospects lie with the lineaments in NNE-SSW and NE-SW directions. Further, it has been observed that the deep-rooted basinal normal faults are associated with antithetic faults. These faults have controls on the building of anticlinal features, where oil and gas has accumulated. The paucity of suitable source rocks in the foreland along with the presence of large quantity of hydrocarbon reserves suggests the presence of mature source rock below the thrust belts. Hydrocarbon generation in the area occurred at a time when compression had modified the pre-existing structures. As a result, the structures formed have ideal locales for entrapment of migrating hydrocarbons (Saikia and Dutta, 1980).

The hydrocarbons started migrating from Sylhet and Kopili source rocks about 10-12 million years, when all the structures had already formed. The hydrocarbon expulsion is believed to be in the Schuppen Belt, where numerous fault conduits were developed to bring hydrocarbon charges to shallow reservoirs as shown in seismic section Figure 10. The migration was primarily up-dip to the northwest along the northeast-trending slope of the shelf as shown in NW-SE geological cross section Figure 11. Active thrust tectonics by the end of Pliocene resulted in reactivation of the structures in the foreland part of the basin. The subsidence during deposition of the youngest stratigraphic units of Plio-Pleistocene age is related to tectonic loading of an advancing thrust sheet from the southeast. This youngest phase of compressional tectonics determined the present configuration of structures which are suitable for the entrapment of hydrocarbons in the basin.

Conclusions

The type and orientation of structures mapped along the selected stratigraphic sequences indicate that the structural patterns developed are related to basement fault propagation folds sub-parallel to the northeast-trending Naga Thrust and suitable for accumulation of significant hydrocarbons on broad crests. Oil generated beneath the thrust sheet might have migrated to the leading edge of the thrust sheet in a primarily up-dip direction along the northeast-trending slope of the Assam Shelf. The source rocks in many structures are marginally mature, therefore it has been inferred that the oil might have migrated from deeper areas along the Naga Thrust.

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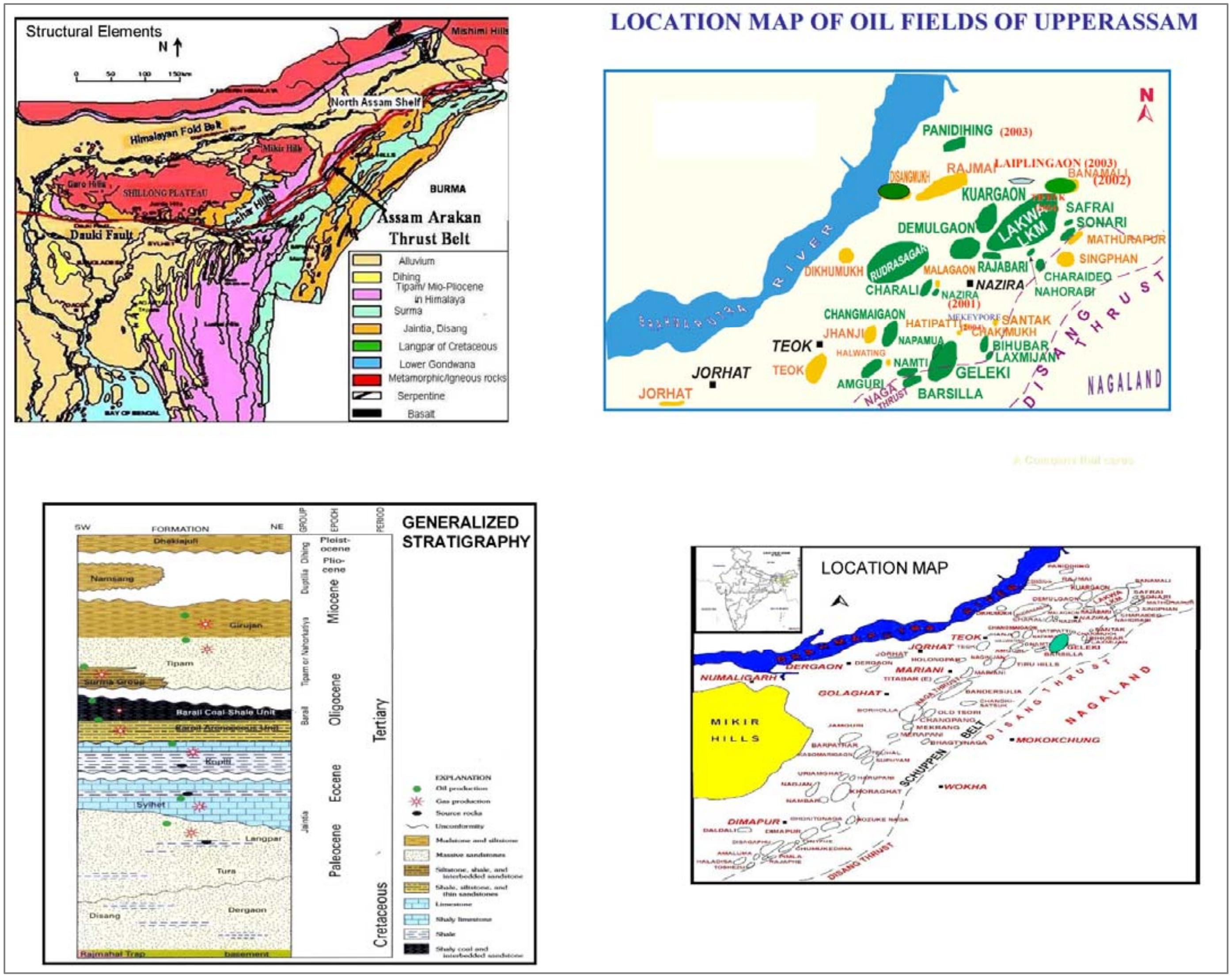


Figure 1. Four maps showing structural elements, location of oil fields, generalized stratigraphy and location of places in Upper Assam Basin.

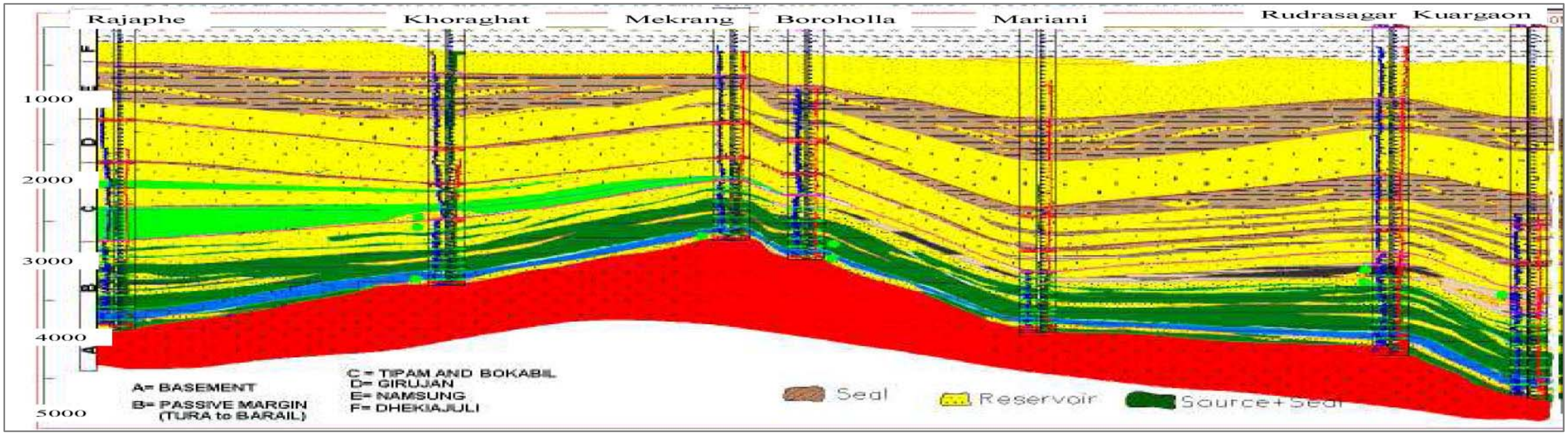


Figure 2. Diagrammatic cross section across upper Assam showing normal down-to-basin faults and later inversion during compression related to the development of thrust belt (Mathur and Evans, 1964).

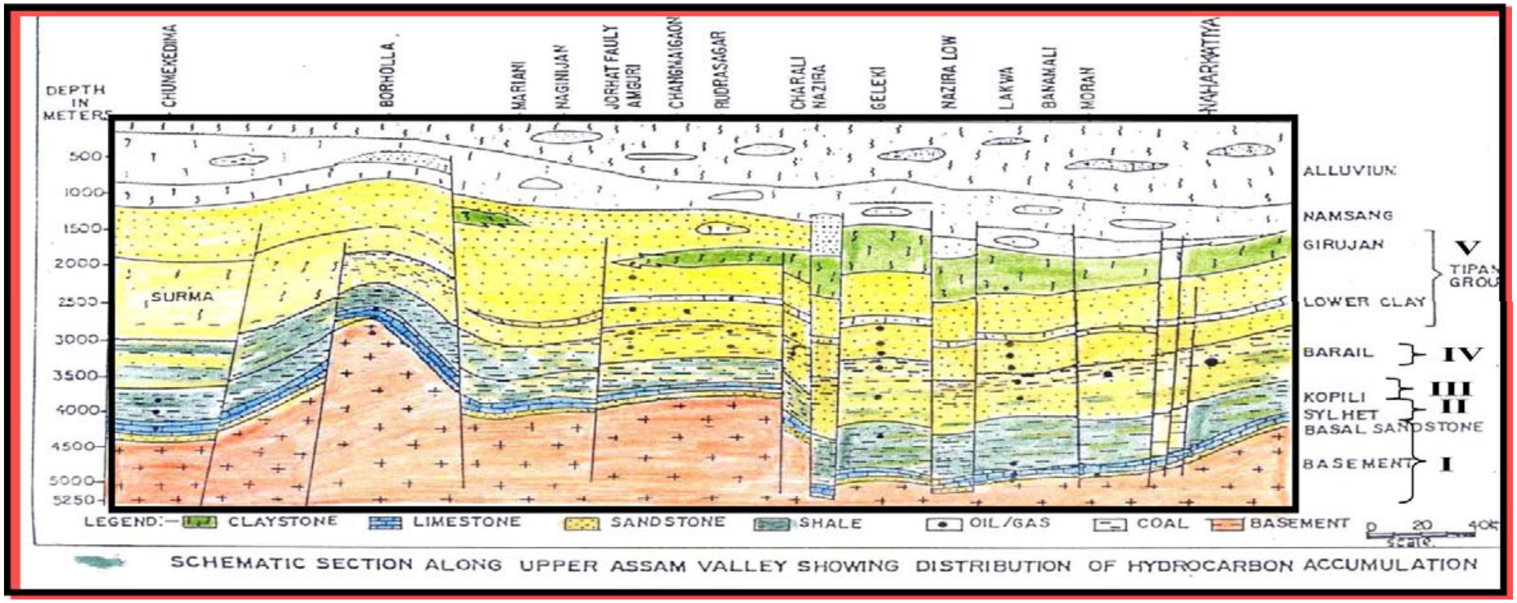


Figure 3. Schematic geological cross section along Upper Assam Shelf showing distribution of hydrocarbon accumulations.

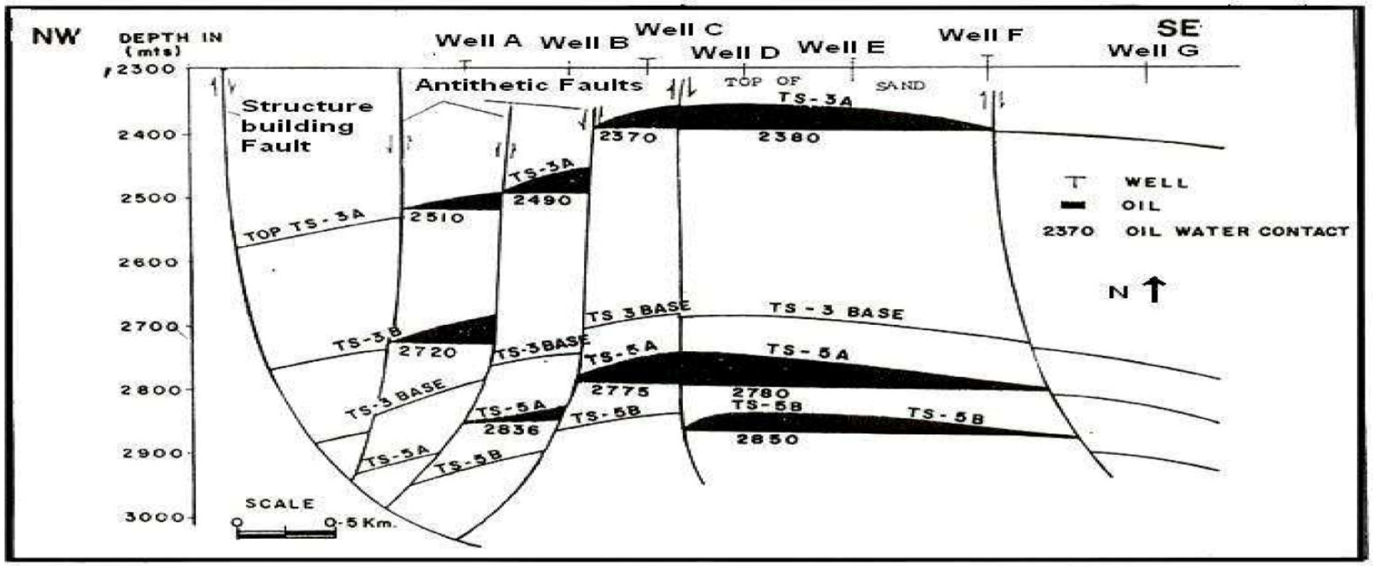


Figure 4. Cross section based on well data showing fault patterns controlling multiple pools in Geleki Field (Sahoo and Gogoi, 2009).

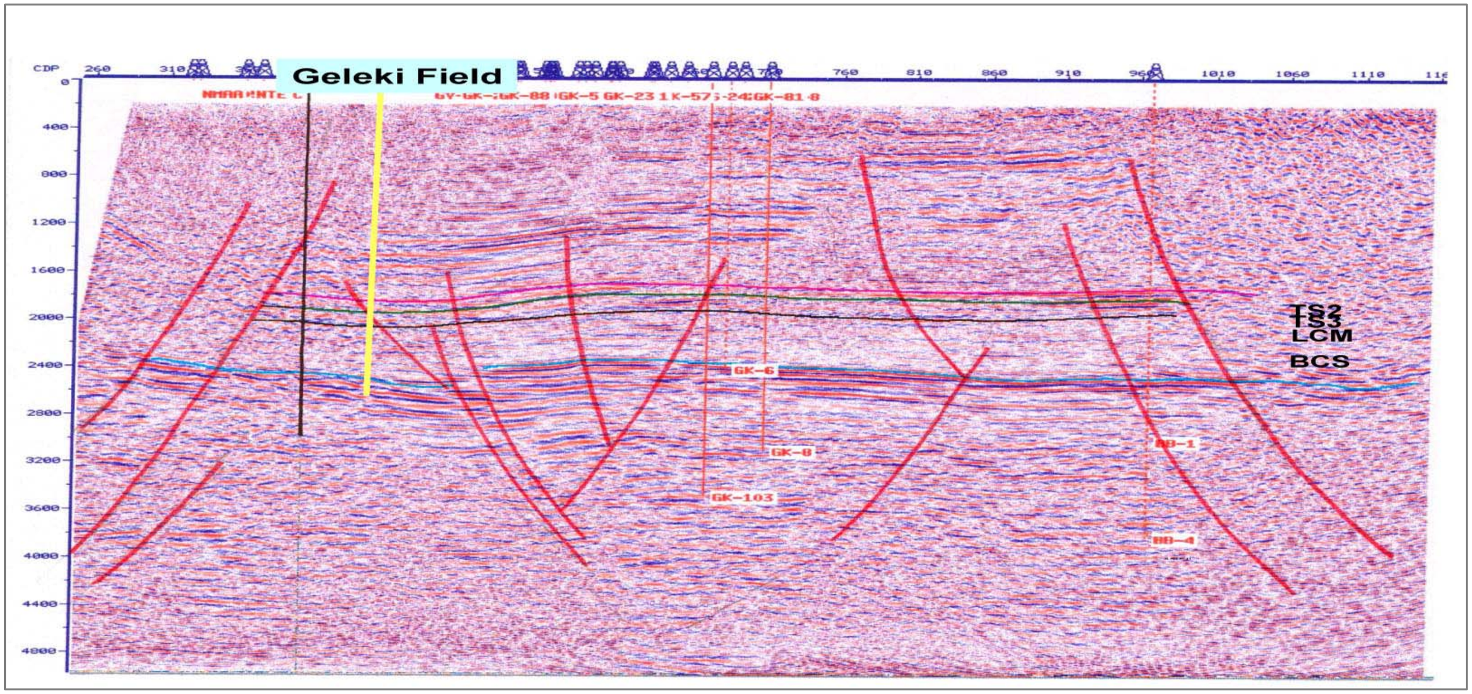
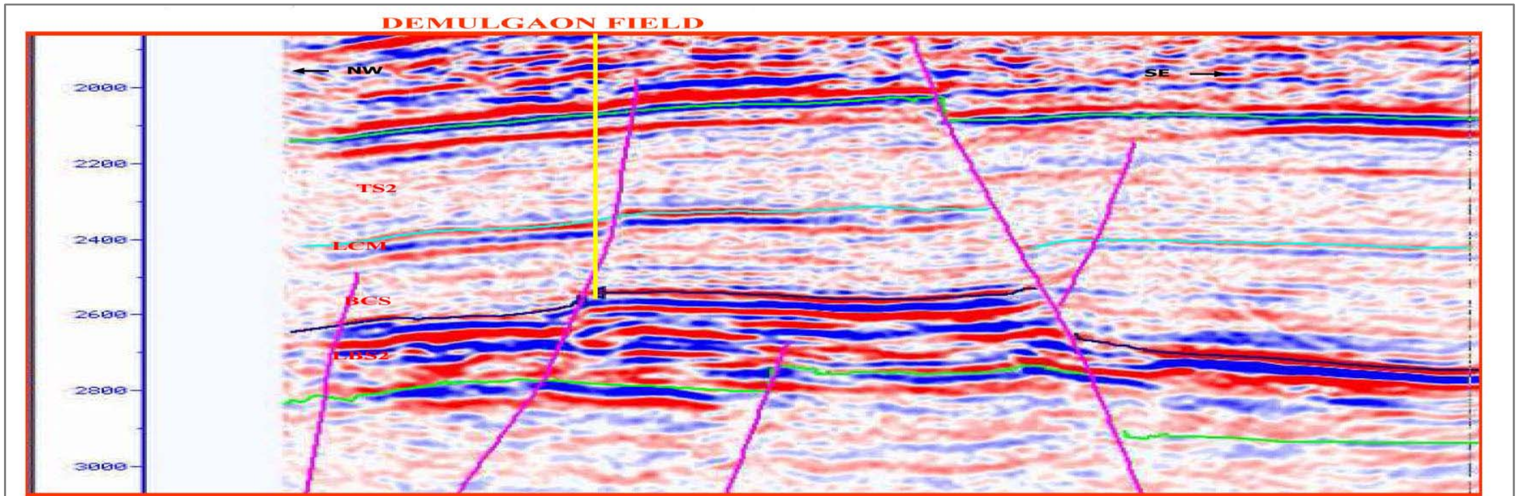


Figure 5. Interpreted in-line seismic section passing through northern part of Geleki Field.



PART OF CROSSLINE ALONG NW-SE DIRECTION IN DEMULGAON FIELD

Figure 6. Part of interpreted cross-line seismic section along NW-SE direction in Demulgaon Field.

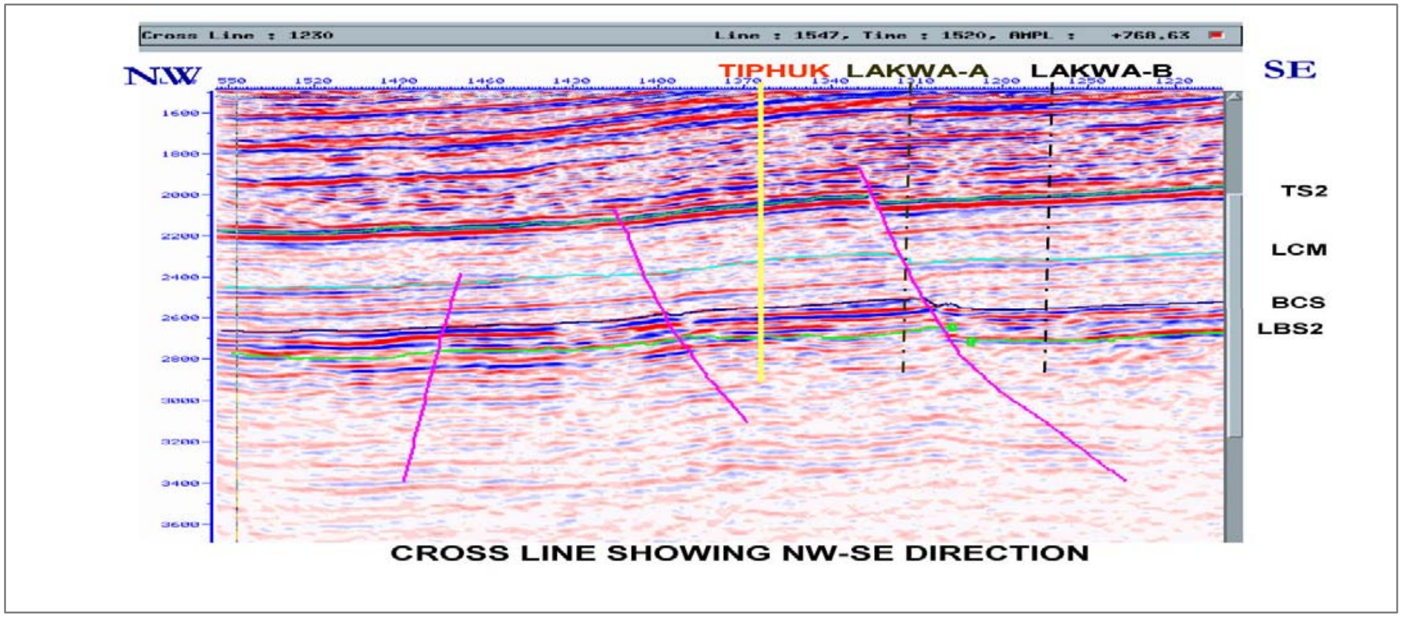


Figure 7. Interpreted cross-line seismic section along NW-SE direction in Tiphuk-Lakwa area.

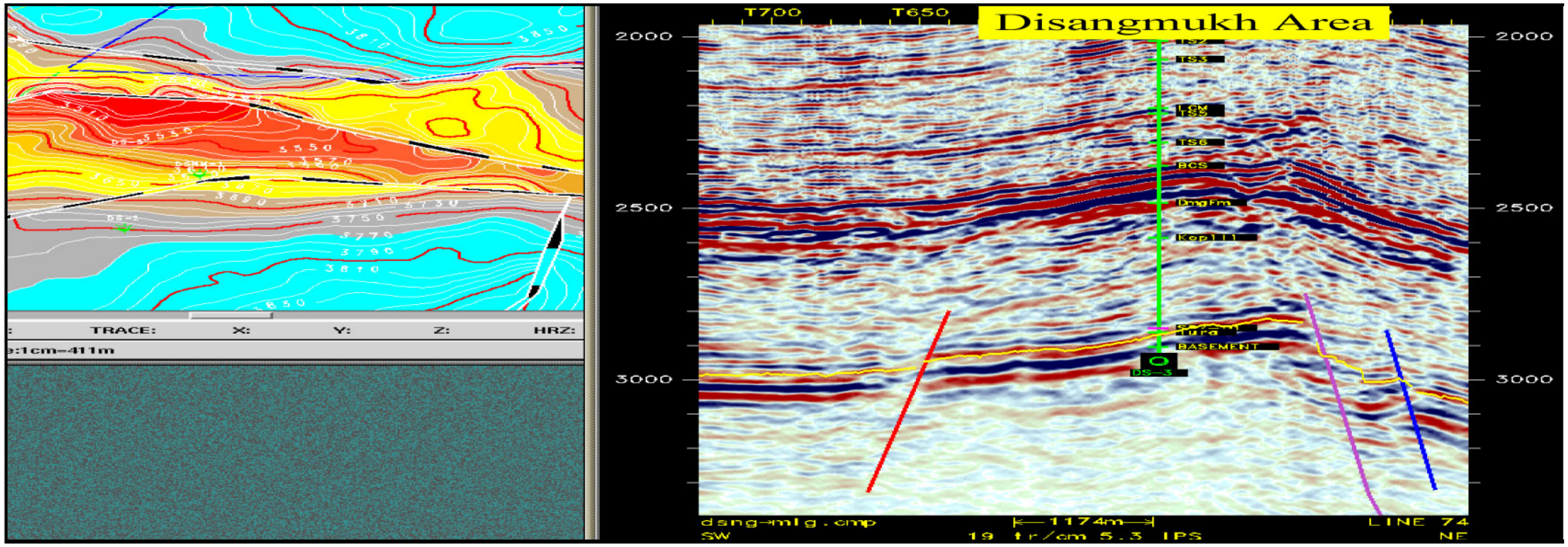


Figure 8. Interpreted in-line seismic section along SW-NE direction in Disangmukh Field.

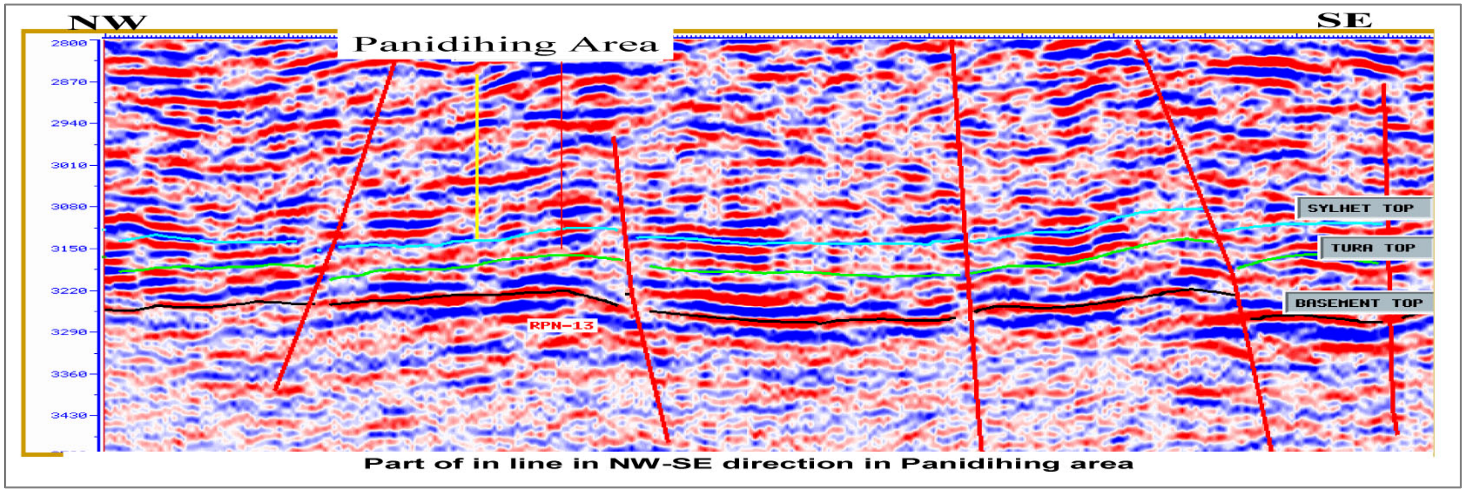


Figure 9. Interpreted in-line seismic section along NW-SE direction in Panidihing area.

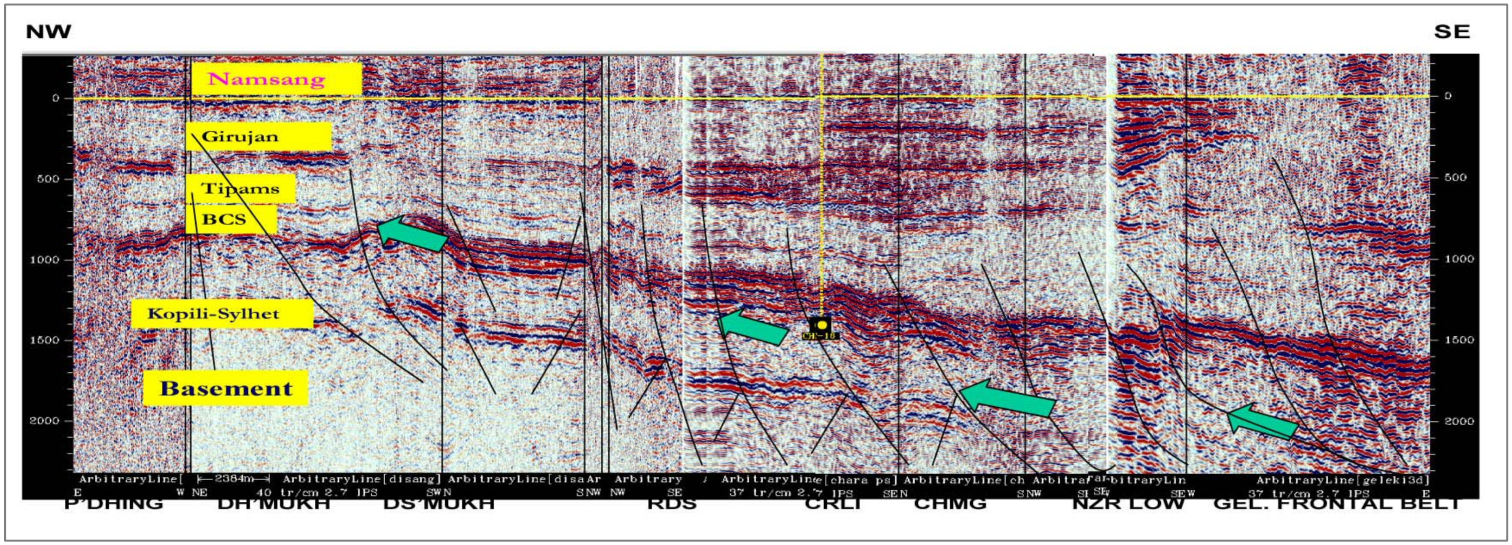


Figure 10. Interpreted seismic sections along NW-SE direction showing migratory pathways of hydrocarbon.

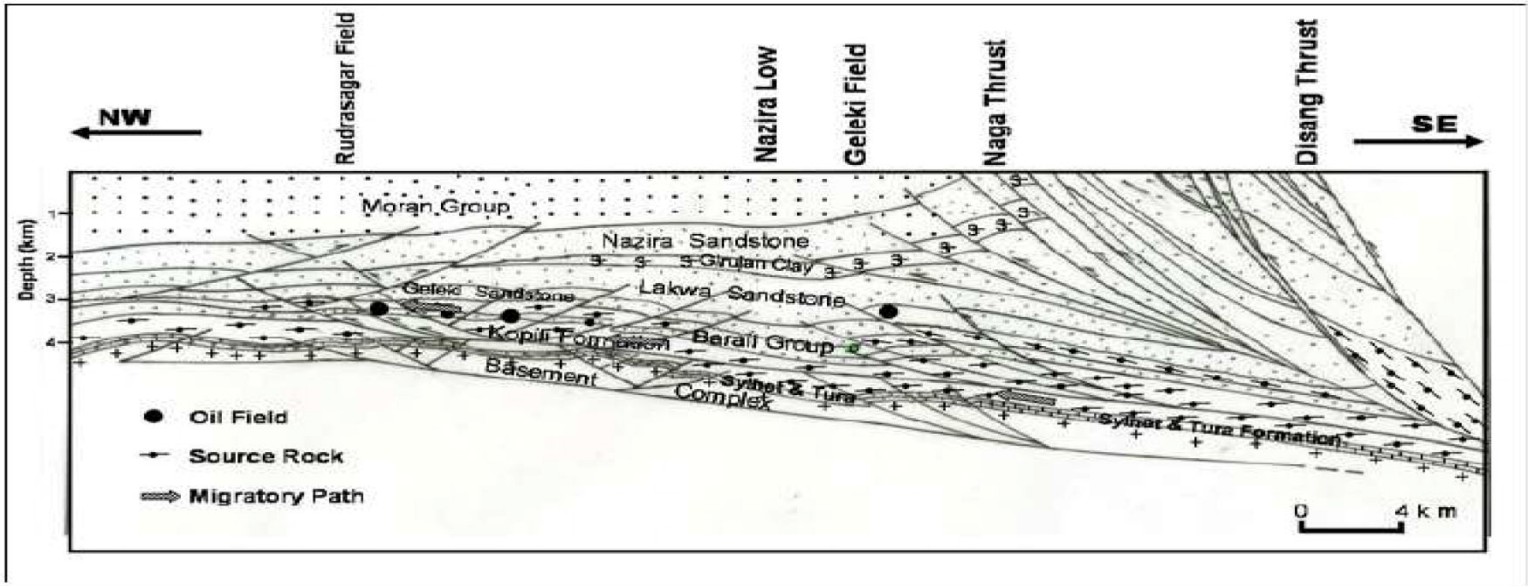


Figure 11. Schematic cross section along NW-SE direction showing migration pathways.