Petroleum System Modelling of Assam Shelf (Northern part) and Naga-Schuppen belt in Assam and Assam Arakan Basin, India*

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Abstract

Preliminary analysis of the results of the simulation for the Geleki-Disang Thrust section suggests that at least four zones of oil generation (i.e. Early Oil, Main Oil, Wet Gas and Dry Gas) zones may be present in the sub-thrust part of the Schuppen. Besides, significant early oil generation is also indicated in the Nazira Low and the Gaurisagar Low southeast of Panidihing within the Paleogene section. The foredeep sediments younger than Barail Group (Oligocene) are dominantly immature in character both within the thrust belt and in the foreland. Overall transformation ratios are very high towards the east of the Disang Thrust. Several accumulations of wet gas and are indicated within the Tipams. Analysis of migration vectors for oil and gas suggests hydrocarbons have migrated from mainly the sub-thrust part of the Schuppen Belt and to a subordinate extent from the Nazira and Gaurisagar lows updip towards the foreland. Fault breakouts to surface are indicated in the Schuppen Belt, and this substantiates the observed oil seepages recorded by numerous authors within the Naga Imbricate Thrust Belt. 3D modeling corroborated the hydrocarbon generation and migration model as envisaged from 2D model in Geleki area (North Assam Shelf) The present work also substantiate the view-point that the main locale for the generation of hydrocarbons is within the subthrust part of the Schuppen Belt from where it has migrated updip towards the north-west to form the prolific oil fields of the Assam Shelf. Similar structures, if present below the sub-thrust, are likely to form significant accumulations.

Introduction

Petroleum System Modeling (PSM) is the quantitative numerical modeling of Petroleum Systems to evaluate the Generation-Migration-Entrapment (GME) cycle by integrating diverse datasets into a composite basin evolution model. The regional structural style evolved in Assam shelf using 2D/3D Move software (jointly with M/s Midland Valley) has formed an input for the Petroleum System Modeling project using PETROMOD. In-house efforts were made to carry out 2D and 3D modeling using this state of art software in order to understand the genetic linkage to generation, migration and accumulation of hydrocarbons. The present work aims to bring out the Petroleum System modeling of Assam Shelf including Schuppen belt.

A 65 km long NW-SE seismic section converted to depth was palinspastically reconstructed extending across the Geleki Structure up to the Disang Thrust. This section was modeled along with Midland Valley experts in order to investigate the possibility of generation of hydrocarbons from Kopili-Disang source rocks in the subthrust part of the Schuppen. Analysis suggests that at least four zones (i.e. Early Oil, Main Oil, Wet Gas and Dry Gas) may be present in the sub thrust. In addition, early oil generation is indicated in the Nazira and Gaurisagar Lows. Fault breakouts were indicated in the up thrust portion of the Schuppen Belt during simulation. Overall transformation ratios (TR) appear to be very high towards the east of the Disang Thrust. However, TR values drop progressively towards the foreland. Simulations carried out taking into consideration different scenarios suggest little hydrocarbon generation potential within the foreland due to insufficient maturity of source rocks, except some early oil generation in lows. The foredeep sediments above Oligocene are immature in character. Several accumulations of wet gas are indicated within the Tipams in Rudrasagar area.

Results of this simulation substantiate the view that the main locale for the generation of hydrocarbons is situated in the sub thrust part of the Schuppen Belt from where it has migrated up dip towards the north-west to form the prolific oil fields of the Assam Shelf with minor generation potential in Nazira and Gaurisagar Lows. Mainly two Petroleum Systems have been established in the Assam shelf: (i) Paleocene to Middle Eocene-Paleocene to Middle Eocene, and (ii) Late Eocene to Oligocene-Oligocene.

Regional Geology

Structural Evolution

Tectonically Assam-Arakan basin has been defined as a poly-history basin that evolved synchronous with the other East-Coast basins of India concomitant with the rifting and subsequent drifting of the Indian Plate from Eastern Gondwanaland (Figure 1). The basin was initiated in an extensional phase and modified by different episodes of compression phase of tectonic movement subsequently. Super-imposition of compression phase on extensional regime modified the earlier extensional structures indicate the Poly phase/Poly history nature of basin. The tectonic evolution of northeastern India was explained (by various workers) with an “oblique collision and tectonic wedging model.” According to some authors, the Assam Foredeep adjoining to the subduction margin represents the updip extension of an ancient passive margin. This basin is bounded to the north by the Eastern Himalayan fold belt, the Mishmi hill to the northeast, the Patkai-Arakan fold belt (Subduction complex) to the east and the Shillong plateau-Mikir hill massif in the west The basin is tectonically differentiated into northeasterly plunging linear ridges and depressions to the north of the Dauki-Naga faults and oriented in NE-SW directions. The depressions and ridges represent the extension of the tectonic elements. Some time the depressions are interrupted by few intra-depressions horsts in the area. Tectonic loading from the Naga-Burmese orogeny initially controlled the sedimentation as evidenced by the basinal slope towards southeast until Miocene time. The tectonic loading in the north due to the Himalayan Orogeny caused the tilting of the basin to the northwest with the regional slope remaining south east south of Jorhat fault. The “Proto Brahmaputras” from the south shifted gradually to the present day position as the tilting continued.

Stratigraphy

Regionally, Assam Shelf exhibits a “Wernerian layer cake” stratigraphy typical of epicontinental basins overlying the Precambrian granite basement. So far, in North Assam Shelf subsurface sedimentary records have been confirmed from Paleocene to Recent in age with a major break in sedimentation during Oligocene, Late Miocene and Pliocene time. The floor of the basin, represented by Precambrian basement rock consists of granite, granite gneisses and other metamorphic rocks. The oldest known unfossiliferous Pre-Mesozoic low to medium grade meta-sediments is exposed in the broad zone along Indo-Burma border. Cretaceous sediments are predominantly arenaceous with locally developed carbonaceous and argillaceous rocks, exposed in the Garo, Khasi and Jaintia Hills. Occurrence of Late Jurassic to Early Cretaceous basic to ultrabasic rocks (Sylhet and Rajamahal traps) are also reported in the south of Shillong plateau, in Abor, Naga, Manipur ranges and Rajamahal hills respectively. These rocks represent the rift related igneous suite formed during the continental rifting phase of Gondwanaland separation. Though sporadic in occurrence, all these Pre-Tertiary stratigraphic units provide valuable clues regarding basin formation and subsequent evolution in geological time. Further, relevance of these sediments to hydrocarbon generation and their contribution to the hydrocarbon resource potential of the region is still an enigma. The end of Paleogene is marked by the widespread well-recognized Oligocene unconformity. The generalized stratigraphic column for Assam Shelf is depicted in Figure 2.

Approach Adopted

Structurally restored paleo-sections were imported from Midland Valley 2D Move software into Petromod and the section was validated for compatibility with the Teclink module of Petromod 2D software. The various stages of palinspastic reconstruction were incorporated into TECLINK as paleo-sections and the correct geological ages as per Raju et. al were assigned to each paleo-section. Eight paleo-sections were constructed for the palinspastically-restored sections as depicted in Figure 3. These are paleo-sections for the Schuppen Restored, Namsang Restored, Girujan Clay, Tipam Sandstone, Lower Clay Marker, Barail, Kopili and Sylhet formations. Age and facies assignment was carried out for each layer. The TECLINK module differs fundamentally from the general Petromod 2D approach in that it addresses multiple Z-values in areas of complex tectonics by the cutting up of palinspastically reconstructed sections into blocks. A block is defined by a characteristic layer stack and by its boundaries, with no multiple z-values between its boundaries. Each block is bounded by faults or horizons and is in itself a separate 2D entity that is composed of a number of layers and can be gridded separately (Figure 4).

Analysis of Thrust Fold Belt Using 2D TECLINK

In spite of several decades of intensive exploration activity, the nature of sediments and their petroleum generating potential in the Naga imbricate Thrust Zone has remained enigmatic. According to current thinking, the petroleum system(s) existing in the Assam Shelf probably extending into the sub-thrust part of the Naga Thrust Belt and attain the maturity required for the generation of hydrocarbons. To this end, a balanced and retro deformable geological section was constructed across the Foreland part and extending approximately 65 km NW-SE across the Geleki field and up to the Disang Thrust. Combination thick- and thin- skinned tectonics with inversion and later thrusting along pre-existing down-to-basement normal faults was invoked in order to explain the salient features of the Naga Imbricate Thrust Belt. A shortening of 25% (14 Km) was inferred. At least two detachment levels viz. at the Kopili-Disang level and the Jenam-Baragolai level were inferred in order to explain the huge cumulative throw (over 4,000 m) in the Naga Thrust Belt. For the first time, a reasonable depth to basement of about 7,500 m MSL below the Disang Thrust SE of Geleki was inferred, with detachment surface at about 6,000 m. Further, a deeper sole thrust within basement was inferred in order to explain inversion tectonics in the foreland part. This sole thrust could also have acted as a conduit for the migration of hydrocarbons from the sub-thrust part of the Schuppen Belt to the foreland. Palinspastic reconstruction for this section was attempted at various levels from the Eocene to Recent. The results of this palinspastic reconstruction were incorporated into the TECLINK module of PETROMOD 2D software in order to estimate the source rock potential of sub-surface sediments.

The paleo-sections were then gridded block by block, and individual lithological facies for each layer in each block were assigned. Standard lithologies as defined in PETROMOD were used for post – Barail sequences. For Barail and older sediments, however, mixed lithologies were constructed using the lithology editor to closely replicate the actual lithologies observable in the field or as defined in various texts (e.g. Deshpande et. al., 1993). Porosities interpolated by the software were in close agreement with actually observed porosities of the various formations.

Petroleum System elements were assigned to each lithofacies. The Girujan Clay Formation was defined as the regional seal, while the Kopili Formation was defined as the regional source. Barail Group sediments were not considered as a source in the area as the detachment surface is likely to have risen through the Jenam Formation and decapitated most of the Barails below it. The formations in between Girujan Clay and the Kopili Formation were designated as likely reservoirs (i.e. the Lakwa Sandstone, the Geleki Sandstone and the Barail Group). Geochemical Data (TOC and HI) was input as per available data. Kinetic equations derived from field data were used. Simulation of the Geleki-Disang Thrust was run using the Hybrid (Darcy + Flow path) Model for migration. The relative difference observed on running the software falls within satisfactory limits.

Analysis of Geleki and Adjoining Area Using 3D

3D modeling of Geleki and adjoing area was attempted as shown in Figure 5 using various stratigraphic layers and faults to make known the drainage area of Lakwa sand stone reservoir, source maturities of BMS and Kopili, their kerogen transformation and accumulation locales. It reveals that BMS sources are in mainly early mature oil generation window with significant kerogen transformation whereas Kopili source are in early to main oil generation window with significant expulsion and expulsion time was ~ 1Ma (Figure 6).

Conclusion

Preliminary analysis of the results of the simulation for the Geleki-Disang Thrust section suggests that at least four zones of oil generation (i.e. Early Oil, Main Oil, Wet Gas and Dry Gas) may be present in the sub-thrust part of the Schuppen. Besides, significant early oil generation is also indicated in the Nazira Low and the Gaurisagar Low southeast of Panidihing within the Paleogene section. The foredeep sediments younger than Barail Group (Oligocene) are dominantly immature in character both within the thrust belt and in the foreland. Overall Transformation ratios are very high towards the east of the Disang Thrust. Several accumulations of wet gas and are indicated within the Tipams. Analysis of migration vectors for oil and gas suggests hydrocarbons have migrated from mainly the sub-thrust part of the Schuppen Belt and to a subordinate extent from the Nazira and Gaurisagar lows updip towards the foreland. Fault breakouts to surface are indicated in the Schuppen Belt, and this substantiates the observed oil seepages recorded by numerous authors within the Naga Imbricate Thrust Belt. 3D modeling corroborated the hydrocarbon generation and migration model as envisaged from 2D model in Geleki area (North Assam Shelf) The present work also substantiate the view-point that the main locale for the generation of hydrocarbons is within the subthrust part of the Schuppen Belt from where it has migrated up-dip towards the north-west to form the prolific oil fields of the Assam Shelf. Similar structures, if present below the sub-thrust, are likely to form significant accumulations. The views expressed in this paper area those of the authors and not necessarily of the organization.

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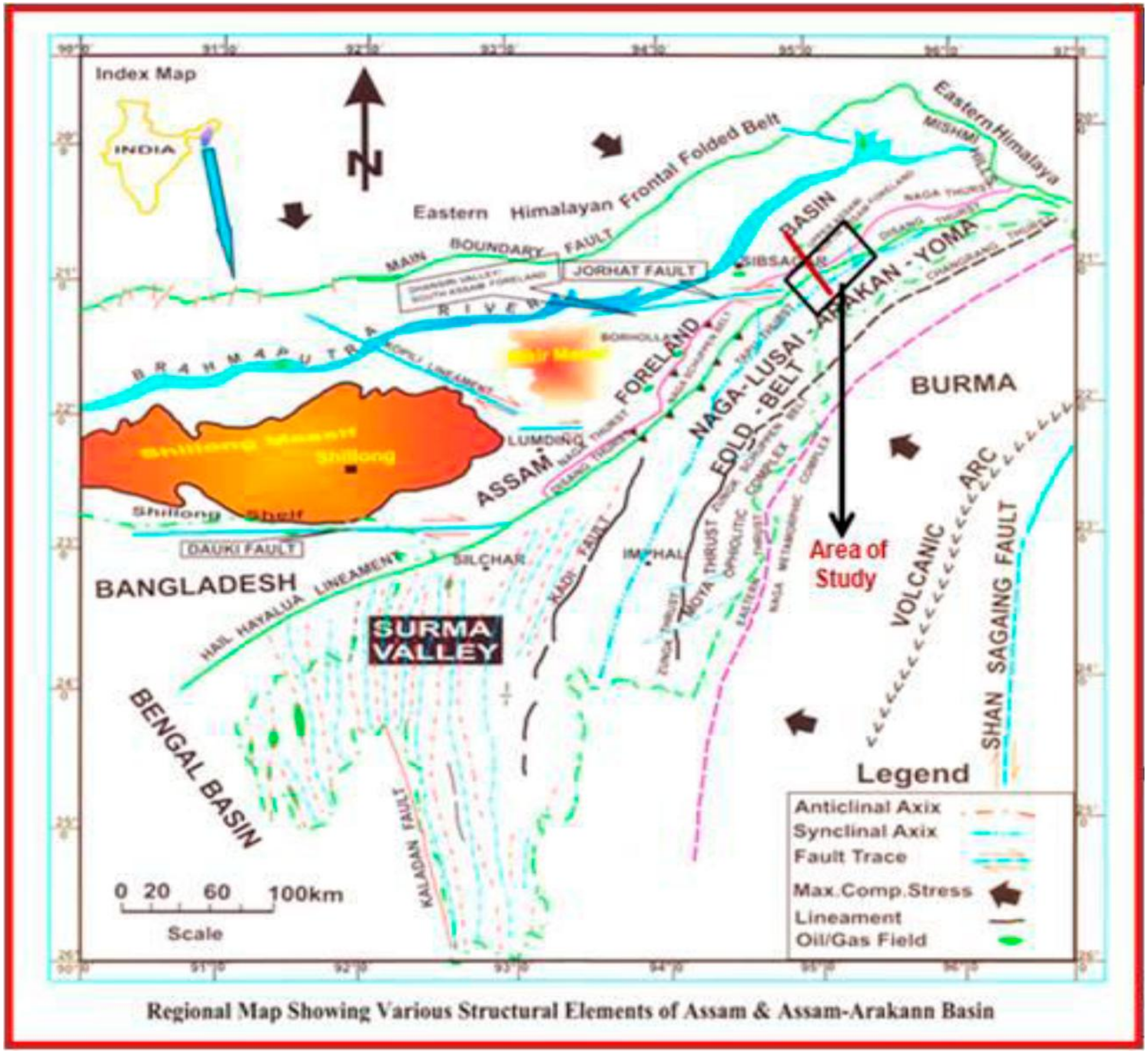

Figure 1. Regional map showing the study area.

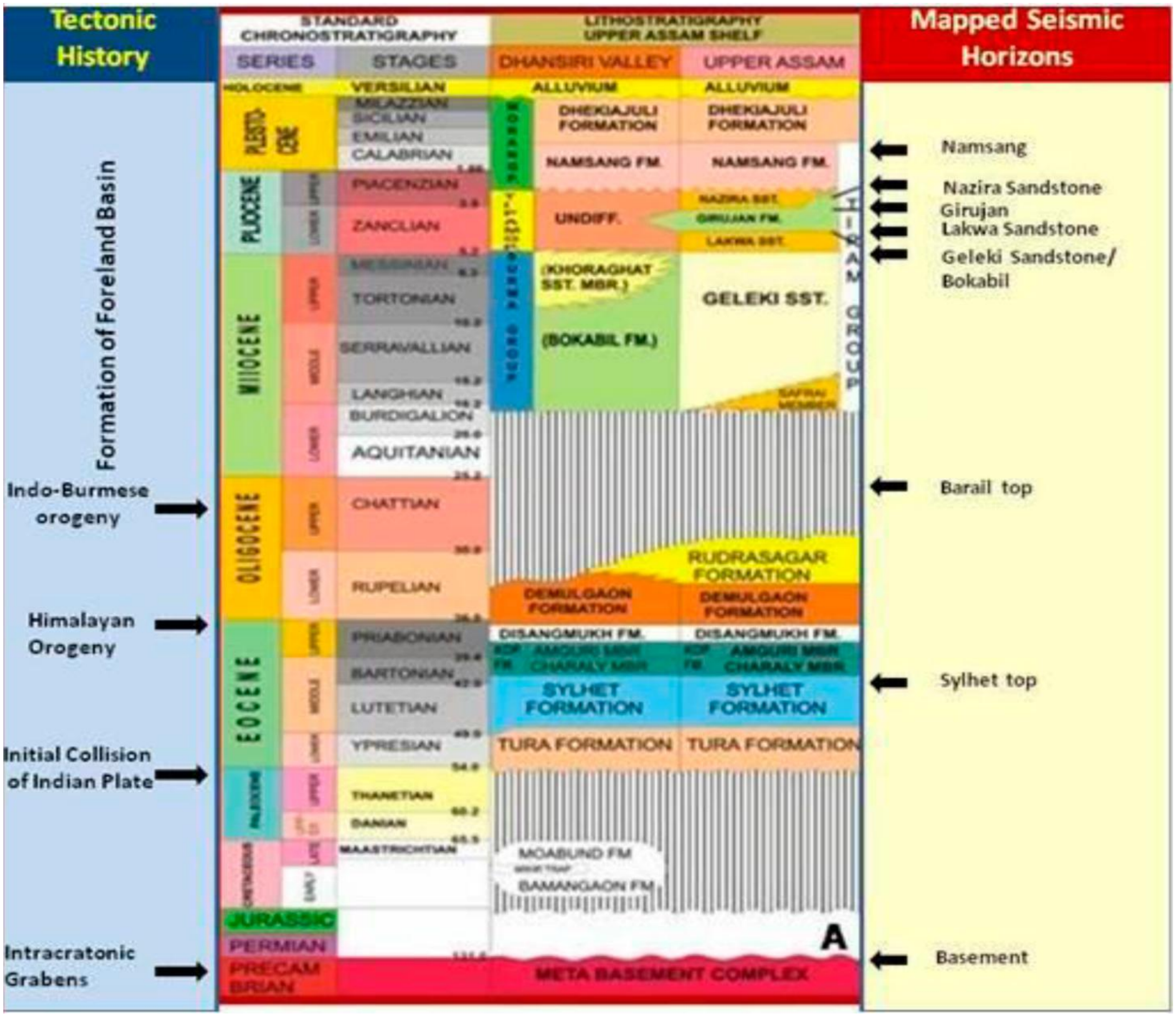

Figure 2. Lithostratigraphy of Assam shelf.

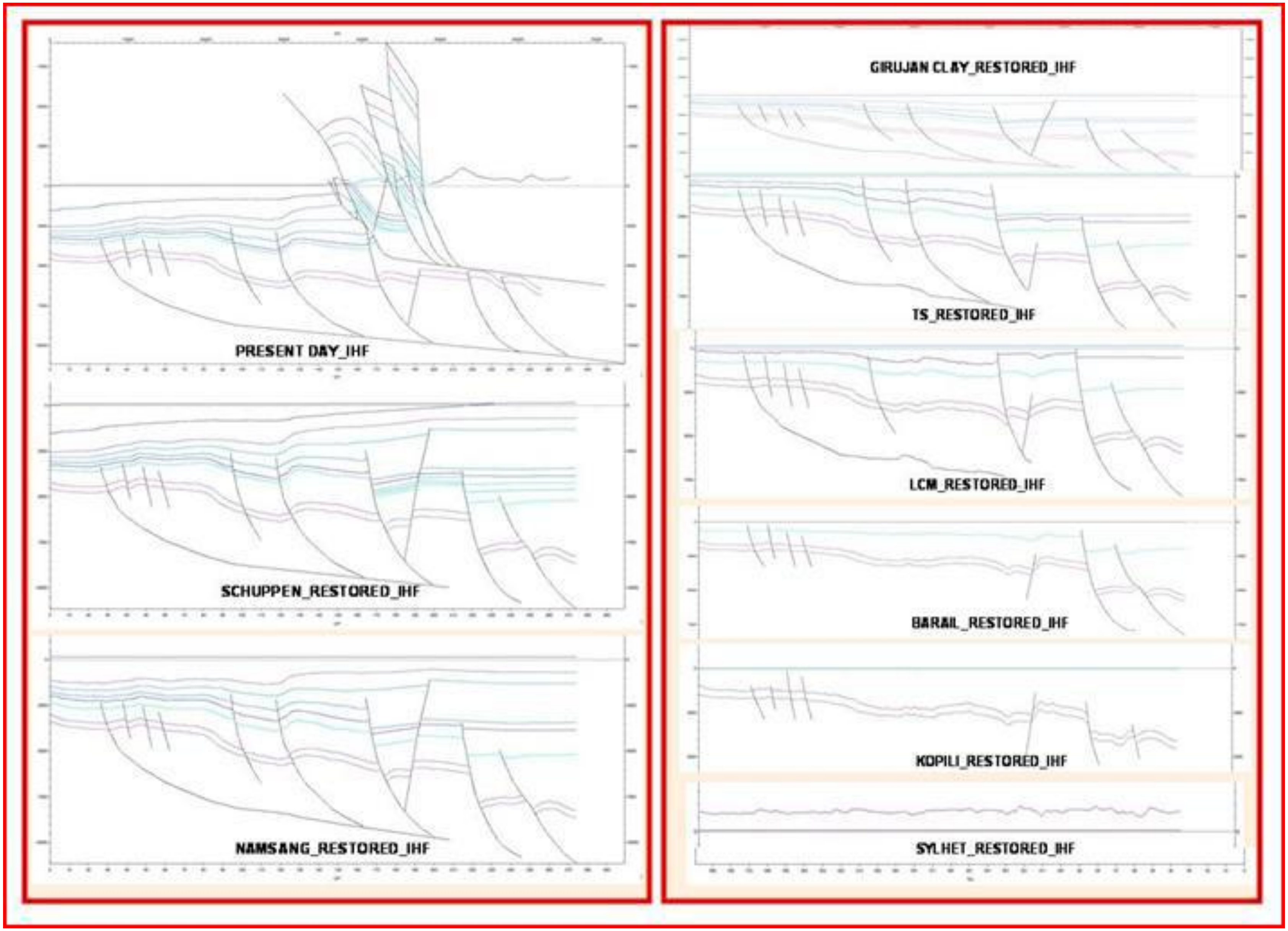

Figure 3. Structurally restored paleo-sections from 2-D Move.

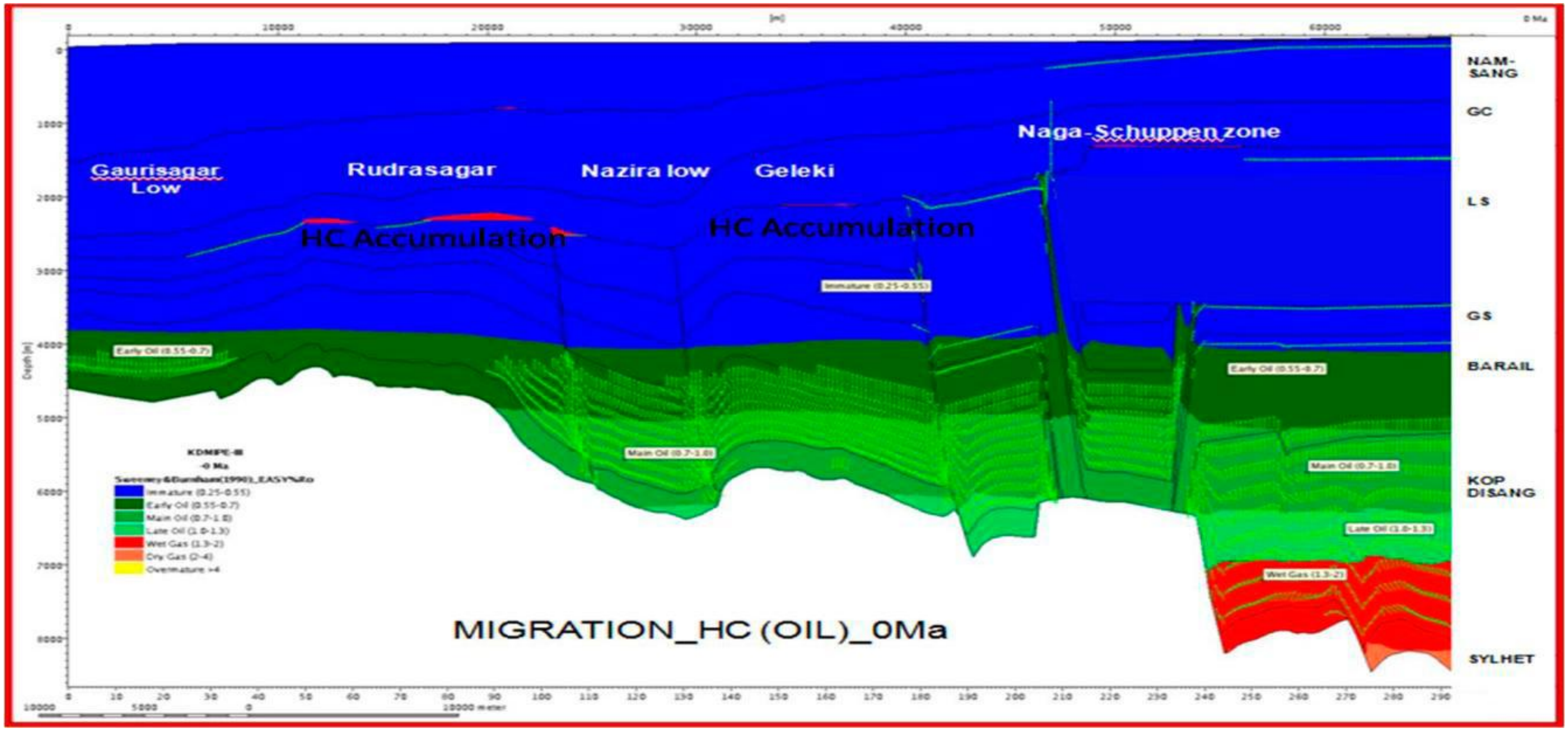

Figure 4. Showing generation of oil and gas in the subthrust part of the schuppen belt.

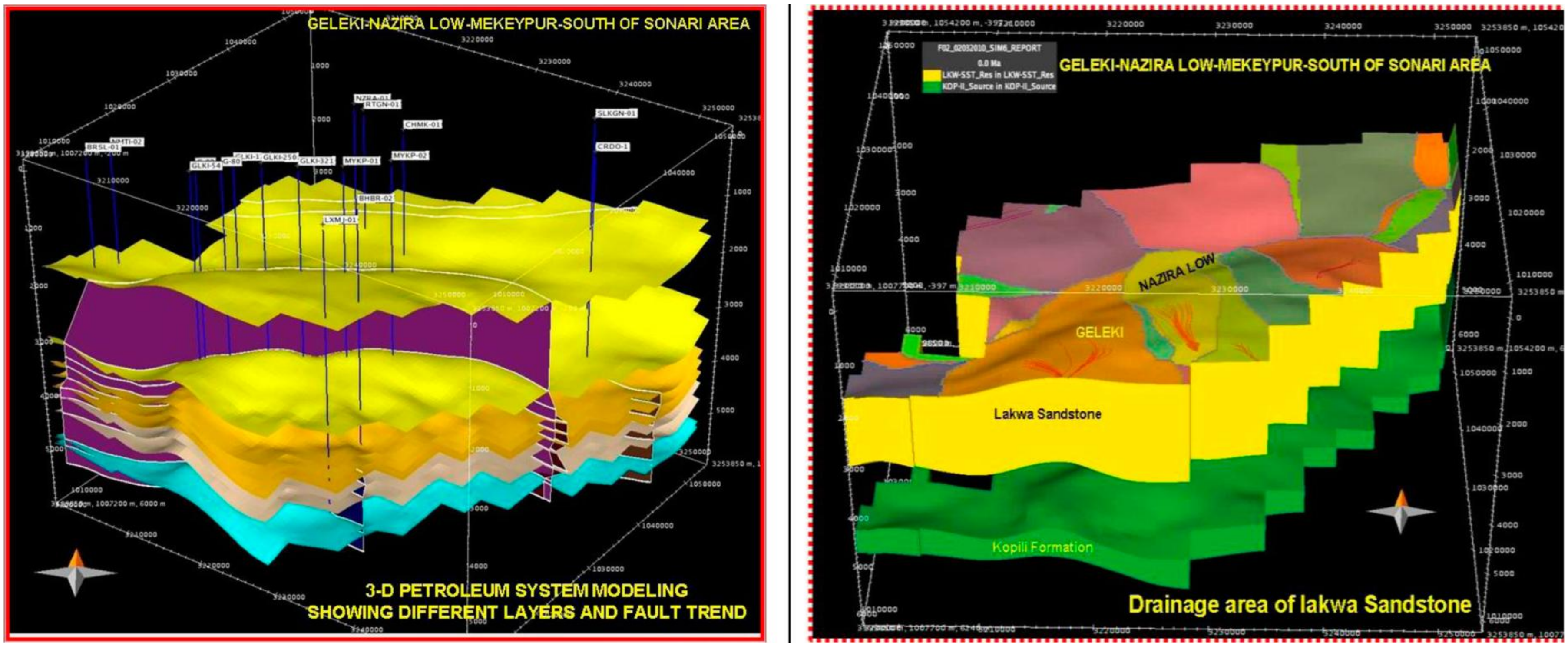

Figure 5. 3D volume showing different layers/fault and drainage area of Lakwa sandstone.

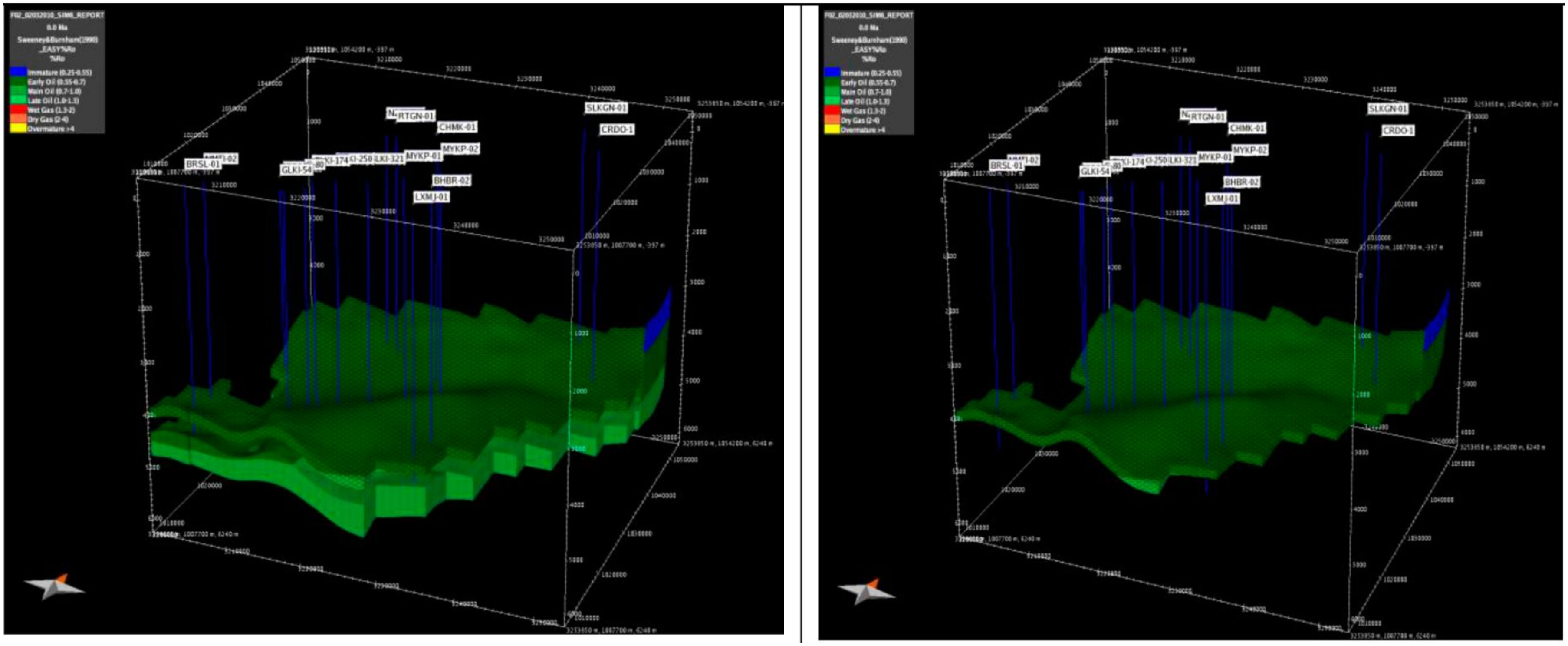

Figure 6. Maturities of BMS and Kopili source rocks.