Integrating 3-D Seismic Attributes and 3-D Petroleum System Modeling for Analyzing Exploration Uncertainties in Geleki and Adjoining Areas: A Case Study of Assam and Assam Arakan Basin, India*

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Abstract

In a present day scenario, exploration for hydrocarbons needs a paradigm shift in conventional approach and the time has come to realize that the success in the exploration for oil and gas can be achieved by incorporating best practice strategies in estimating the geological uncertainties from seismic data and geological models. An amalgamation of the seismic trace information and basin modeling may allow for a consistent handling of uncertainties related to generation migration and entrapment of hydrocarbons. Seismic uncertainties start from acquisition parameters design to velocity modeling and finally conversion to depth domain, the positioning of structural interpretations including correlation of seismic horizons to faults, and assigning flow properties from seismic attributes. Output from the seismic studies could be provided as necessary fields that may be used as input to hydrocarbon migration modeling.

Petroleum Systems Modeling integrates all basin-forming elements into a complete and consistent time and spatial framework. Major global oil companies have recognized the need for 3D-Petroleum Systems Models since they organize data, facilitate visualization of geologic processes and add value by converting static data into dynamic processes. Petroleum System Modeling can impact significantly on exploration decision making by presenting an alternative viewpoint arising from the integration of all available data for the petroliferous basin. A rigorous application of this technology during E&P campaign and the subsequent stages of upstream activities are likely to decrease the uncertainty in the exploration decision-making processes.

Introduction

Assam & Assam-Arakan basin in the NE part of India is an established petroleum province and one of the oldest producing basins of the world. The basin is a typical polyhistory basin having more than one phase of tectonics and sedimentation. The evolution of the basin is essentially influenced by the movement of the Indian plate in relation to the Eurasian and Burmese plates. The area of study falls in the upper shelf part of the basin and is referred to as the North Assam Shelf (Figure 1). In the recent past this part of the basin has acquired a large amount of 2-D and 3-D seismic data along with the latest depth domain processed data, petrophysical, and geochemical data. With this amount of G&G data and acquisition of state of art technologies in ONGC, a need was felt to analyze certain uncertainties related to GME in the Geleki and adjoining Naga-Schuppen belt area, which is considered near to source kitchen. The study area covers the frontal thrust corridor of Naga Schuppen belt and adjoining Nazira low up to Charali in the west. Geleki field, discovered in 1968 is one of the major fields discovered in Assam Shelf and has established presence of oil in multiple stratigraphic levels, Tipams (Miocene), Barails (Oligocene) and Kopili (Eocene). Presence of hydrocarbon is established in nearby areas, viz., Bihubar, Laxmijan, Mekeypore and Charaideo farther northeast of the study area. The area has been covered by 3D seismic data of about 200 km^2, which is being used for the present study. Kopili and Barails have all the elements of a petroleum system i.e., source, reservoir and seal and therefore achieves attention and appropriate GME model in the area, which will minimize the exploration risks and have impact on future exploration strategy in the basin. From the available data, this study aims to bring out the GME model and future thrust areas of exploration in the entire Geleki and Naga-Schuppen belt. A 3D model has been generated for Geleki and Schuppen Belt and has revealed hydrocarbon migration flow paths, drainage areas and hydrocarbon accumulations in Oligocene and Miocene reservoirs besides indicating the kerogen transformation ratios and other source rock properties of the Oligocene (Barail Coal Shale) and Eocene (Kopili). The findings shall help for delineating areas of higher prospectivity leading to significant risk reduction in exploration.

Approach Adopted

There is a need to develop a new workflow for populating and constraining basin models by seismic information for optimal utilization. Furthering the concern, a new workflow has been formulated which is given below:

- Defining structural framework. Seismic data correlation on 3-D seismic Geleki merged volume, Calibration of identified seismic markers within Basement, Sylhet, Koipili, BMS, BCS, LCM, Lakwa sandstone, Girujan and Namsang and preparation of time and depth relief and structure maps.
- 3-D seismic attributes, spectral decomposition and ESP slices were extracted to bring out spatial and temporal extent of the reservoir facies.
- Depth domain surfaces: Basement, Sylhet, Koipili, BMS, BCS, LCM, Lakwa sandstone, Girujan and Namsang were loaded on to the Petromod 3-D modeling workstation subsequently layer splitting was done to accommodate petroleum system elements in the model.
- Tracking of fault on relief surfaces were carried out to generate fault model for 3-D modeling.
- Well data were posted on the well editor to visualize well positions.
- Layers were further given depositional ages.
- Lithologies were assigned and source rock properties were finalized.
- Defining and assigning facies and boundary conditions were done.
- Finally, simulation was carried out.
- Integration of available G&G inputs.

Integrated Interpretation of G&G Data

Correlation of seismic horizons was carried out after calibrating it from well picks of Geleki, Mekeypore, Sonari and Charali well data. The dominant frequency range was between 16 to 24 Hz for Girujan to Kopili and other levels. Eight horizons, pertaining to Basement, Sylhet, BMS, BCS, LCM, Lakwa sandstone, Girujan and Namsang were correlated for the structural and stratigraphic interpretation (Figure 2 and Figure 3). For faults correlation on vertical sections, time slices, ESP slices were used (Figure 4).

Structural Framework

In spite of the constraints of seismic imaging below Barail level of Oligocene age, we attempted to bring out composite maps for the correlated horizons. The time structure maps, fault traces observed on ESP and Coherency slices show dominant NE-SW trending faults and a NW-SE trending cross faults. The major faults in NE-SW direction with southerly hade shows variable throw along the faults. The NW-SE trending cross faults appear to be younger in age and appear to have strike slip component. These faults appear to have played a major role in forming structures besides facilitating hydrocarbon migration into structural closures from adjoining kitchen areas. The maps aptly depict the Nazira Low and Geleki high trending NE- SW direction and subdued highs and lows in the periphery of these structures (Figure 4 A-I).

Seismic Attributes

The discontinuous character of seismic reflections in the below Barails (BCS) sections, their low vertical resolution, and lithological heterogeneities in the study area reduce the utility of horizon amplitude extraction and the application of alternative techniques such as inversion etc. However, at the resolution of available seismic data, lateral and vertical continuity of reservoirs in the inter-well areas is not well resolvable but a composite trend from stacked reservoir section was observed. Average Absolute Amplitude attributes and Spectral decomposition slices were extracted from 100-120 m windows of the Barail and Kopili formations (Figure 5 A-F).

Barail Coal shale is a mix of shale, sand and coal alterations where as Kopili Formation is primarily an argillaceous section with some isolated scattered, discrete sands distributed in the entire North Assam Shelf. Sand thickness within Kopili is found to be of the order of 8-30 meters, but the depth of occurrence makes it difficult to resolve its heterogeneity and spatial geometry with confidence. Sands within Kopili can be recognized by moderate low to moderate amplitude anomalies in the attributes extracted (Figure 5 C, D, and F). We calculated sand thickness trends from logs and a reasonable horizon window was calculated to accommodate most of the sands from the Kopili pack to avoid tuning constraints. Accordingly, a window of 100 m below Kopili top was taken up for generating attribute maps. Discrete sand geometries have been observed as anomalous features on these attributes maps (Figure 5 C, D, and F). To identify the prospective areas, locales of sand maxima coupled with structural advantageous positions can be considered (Figure 5 E, F). To have a better-resolved picture of the BCS reservoirs, Spectral decomposition techniques have been attempted. The window is same as that of other attributes i.e.100-120 m below the BCS top. The consideration for this window lies in the fact that the prospective reservoir sands of the BCS mainly occur within this pack. Therefore, the window has been taken to accommodate maximum of this layer and to address tuning effect problem (Figure 5 A).

3-D Hydrocarbon Generation, Expulsion, Migration Modeling

Depth converted correlated surfaces for Tura, Sylhet, Kopili, BMS, BCS, LCM, Lakwa sandstone. Tops of the Girujan and Namsang formations were used. Facies characteristics have been taken similar to Geleki area with Kopili as source rock (TOC value and HI). Laboratory measured Kopili kinetics of key Geleki wells. Simulation was carried out using Hybrid method. 3D modeling in the Geleki area has revealed hydrocarbon migration flow paths, drainage areas and hydrocarbon accumulations in Oligocene and Miocene reservoirs besides indicating the kerogen transformation ratios and other source rock properties of the Oligocene (Barail Coal Shale) and Eocene (Kopili) Formation (Figure 6 A-F).

3D modeling in the Geleki area has reinforced the belief that while the foreland part has little or no oil generation potential due to immature nature source rocks, the Kopili-Disang shale source-rocks below the subthrust portion of the Schuppen Belt may have attained considerable maturity and may have been the main source of generation and expulsion of hydrocarbons towards the foreland.

Conclusion

Structural analysis of the area suggests the preeminent role of fault in the constitution of trap and the presence of two major fault systems (NE-SW and NW-SE) are believed to be playing important role in entrapment of hydrocarbons. The studies have also brought out accumulation patterns in the Lakwa sandstone (Tipam), which are falling in the areas of low to moderate amplitude anomalies as seen in Kopili and BCS attributes maps. Overlaying structural map upon the attributes extracts give a composite prospect map, which suggests the east of Geleki and northeast of Mekeypore are the prospective areas for Kopili, Barails and Tipam exploration. Seeing the available trend that came out from the studies, areas east of Geleki and northeast of Mekeypure, Charaideo-Bihubar-Laxmijan, Sonari-Nazira Low and adjoining areas are prospective locales that may open up huge exploration opportunities.

3D modeling in the Geleki area has revealed hydrocarbon migration flow paths, drainage areas and hydrocarbon accumulations in Oligocene and Miocene reservoirs besides indicating the kerogen transformation ratios and other source rock properties of the Oligocene (Barail Coal Shale) and Eocene (Kopili) Formation.

Mainly two Petroleum Systems as brought out by 2-D modeling of Geleki-Disang section have been established in this 3-D model also which are (i) Paleocene to Middle Eocene- Paleocene to Middle Eocene (ii) Late Eocene to Oligocene-Oligocene.

Analysis of the results of the simulation for the 3-D modeling (Figure 7) suggests that at least four zones i.e. Early Oil, Main Oil, Wet Gas and Dry Gas generating zones may be present in the eastern part of the area particularly subthrust part of the Schuppen belt. Besides, significant early oil generation is indicated in the Nazira Low and nearby areas. Fault breakouts to younger formations cannot be ruled out in one or two places. Overall Transformation ratios are high towards the east Geleki. However, TR values drop progressively towards the north- west of Geleki. TR values, however, increase in the Nazira low and nearby areas. The foredeep sediments above Oligocene are, however, immature in character. Several accumulations of wet gas and minor oil are also indicated within the Tipams.

The results of this simulation substantiate the viewpoint 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.

Last but not the least the nonlinearity of the hydrocarbon migration process, including flow-path selection and entrapment mechanism, frequently requires that local uncertainties be addressed in more detail. These uncertainties may require high-resolution seismic data analysis in order to resolve the critical issues. The structural interpretation is of particular importance to accumulation uncertainties, and fault juxtaposition and carrier dip direction uncertainty estimations can improve prediction estimates in exploration prospects. Attempts were made to address such uncertainties pertaining to seismic data and interpretation.

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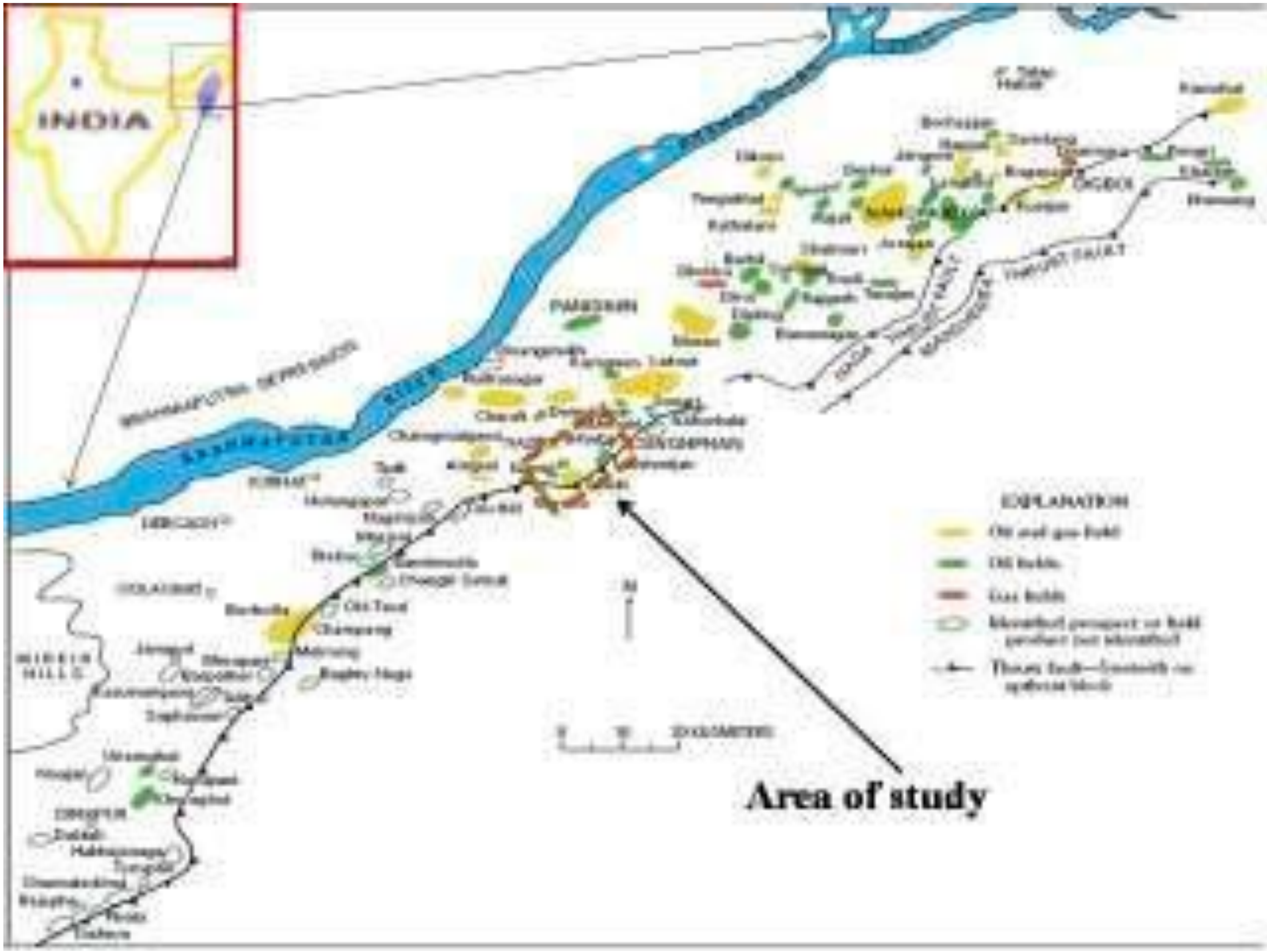

Figure 1. Index map showing area of study.

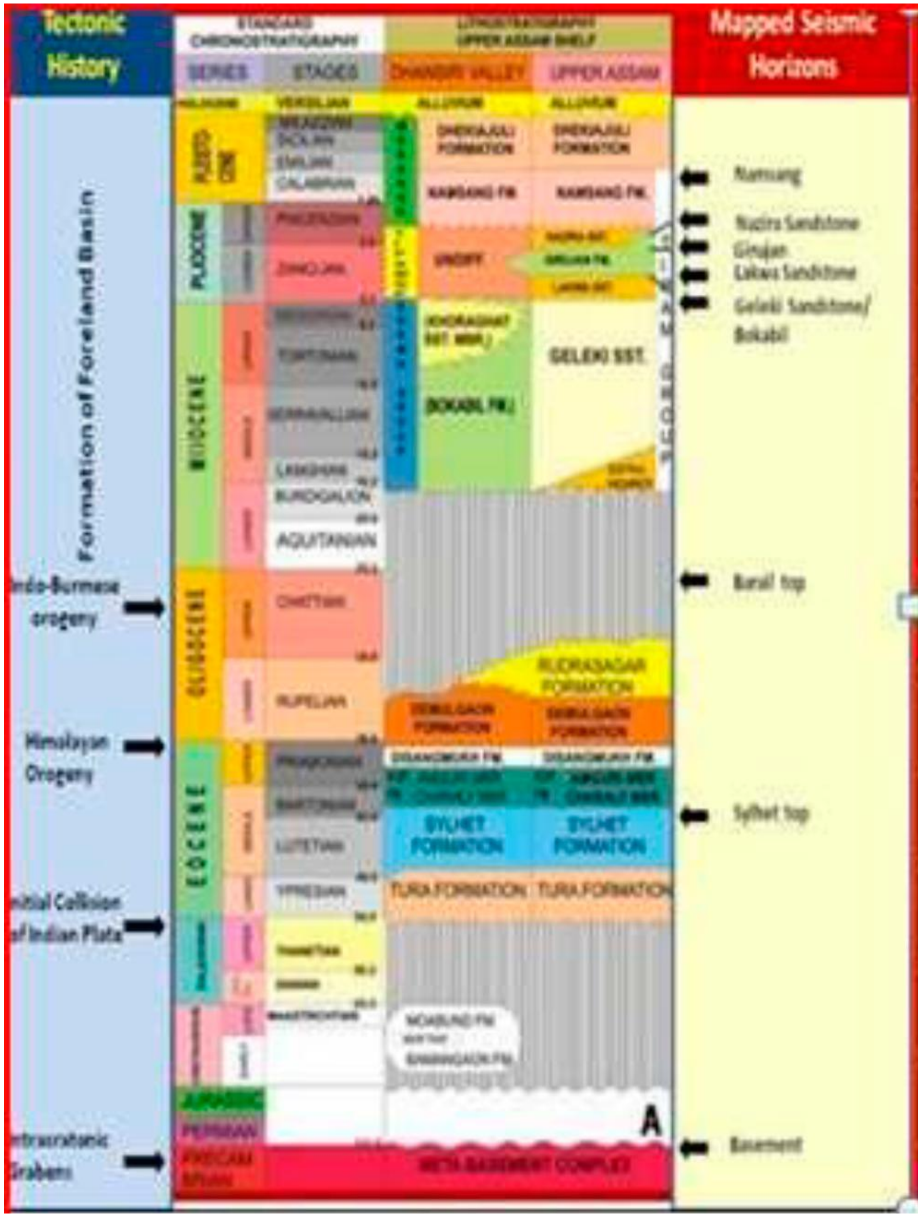

Figure 2. Lithostratigraphy of Assam shelf.

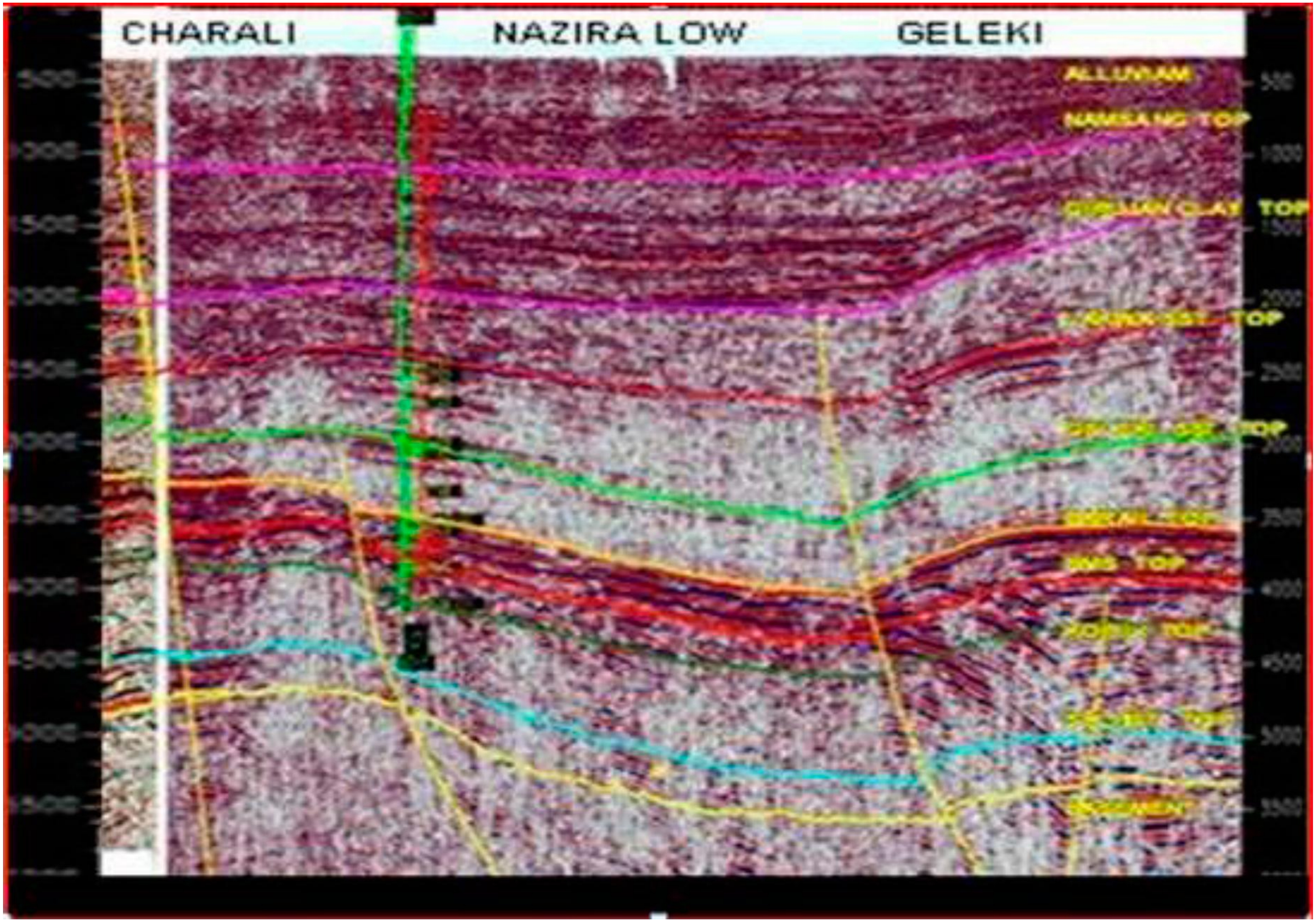

Figure 3. NW-SE seismic section showing correlated horizons.

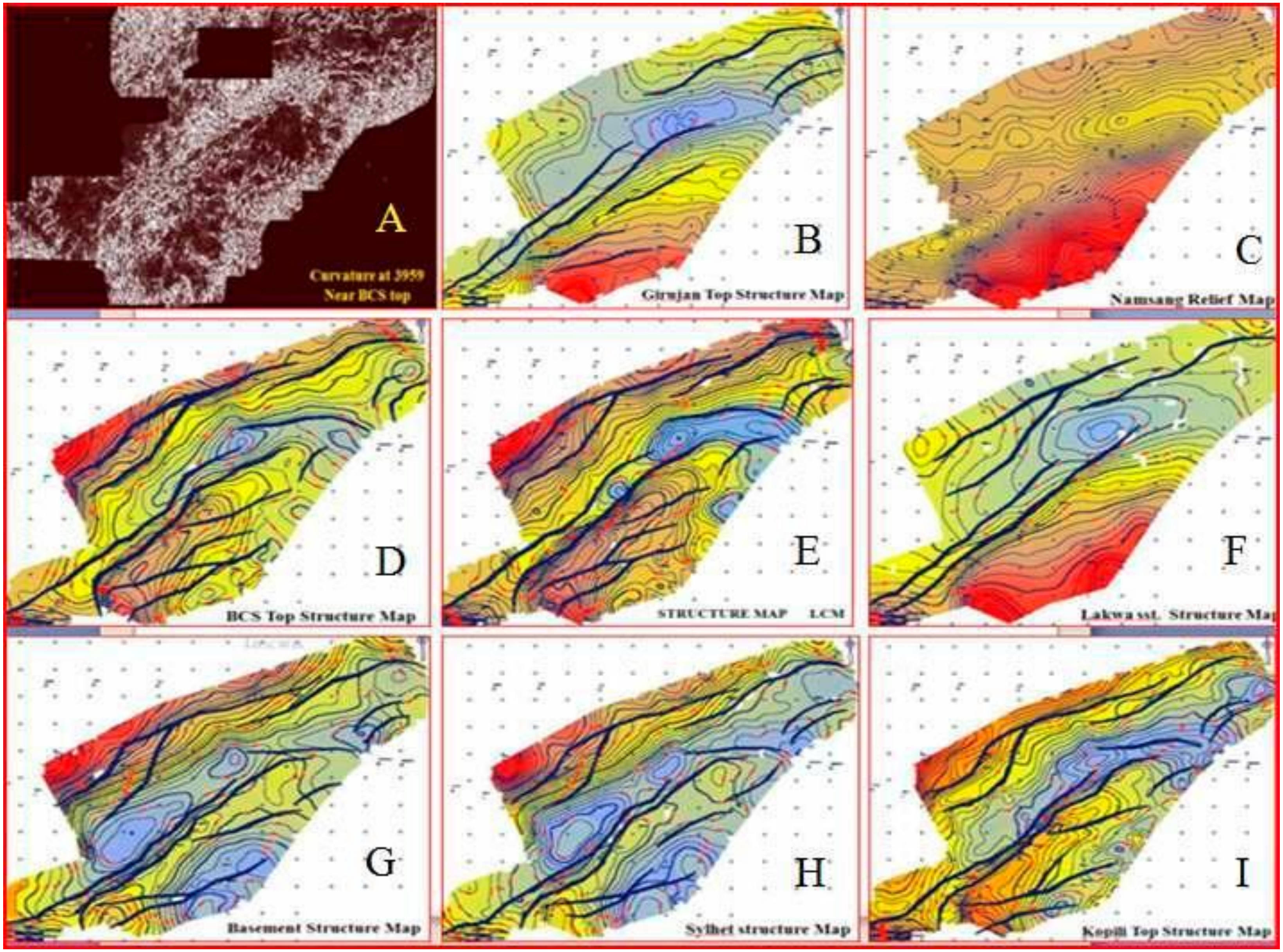

Figure 4. A-I showing coherency slice and structure maps at different stratigraphic levels.

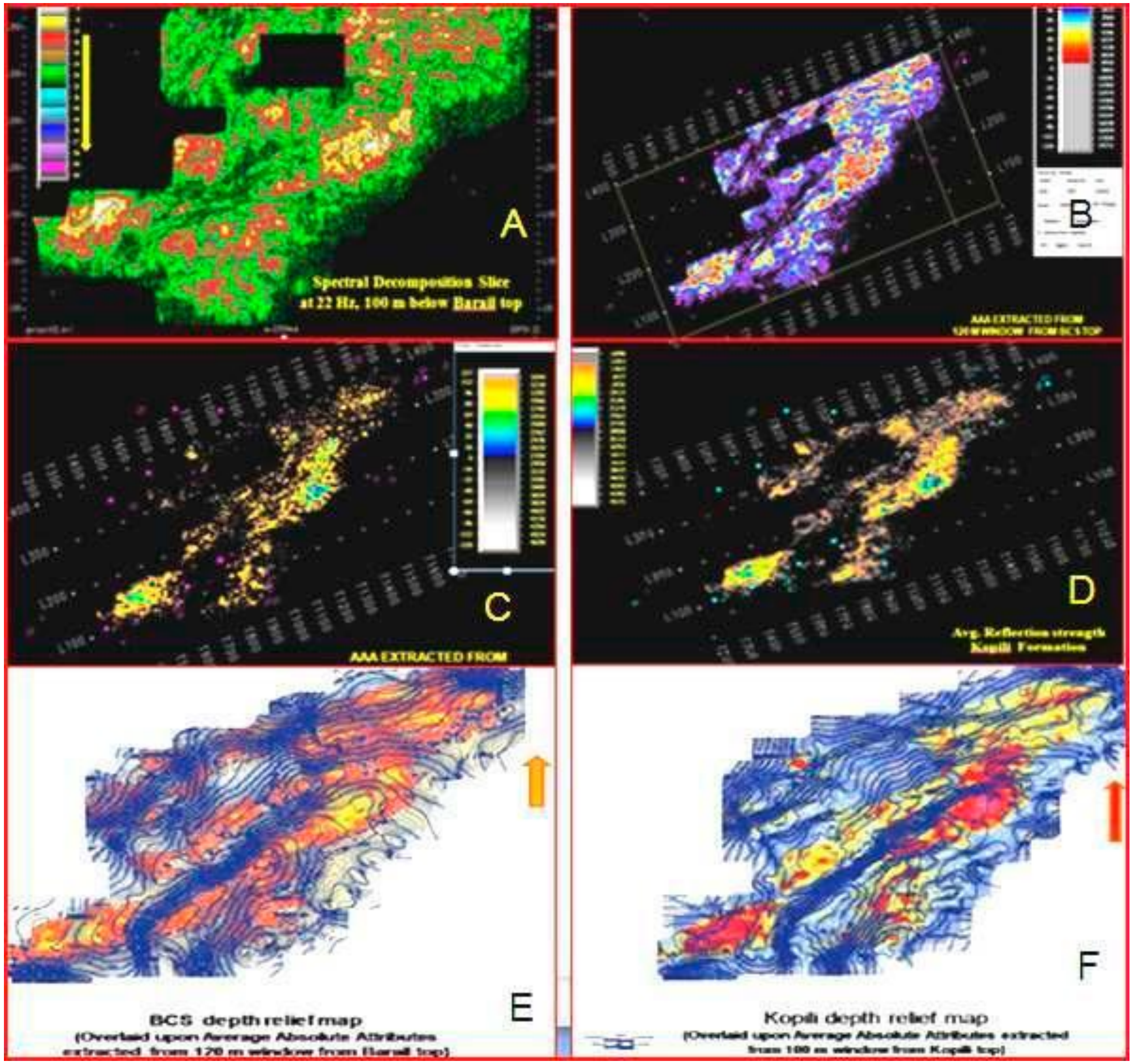

Figure 5. A-F Seismic attributes extracted from 100-120 m below BCS and Kopili tops.

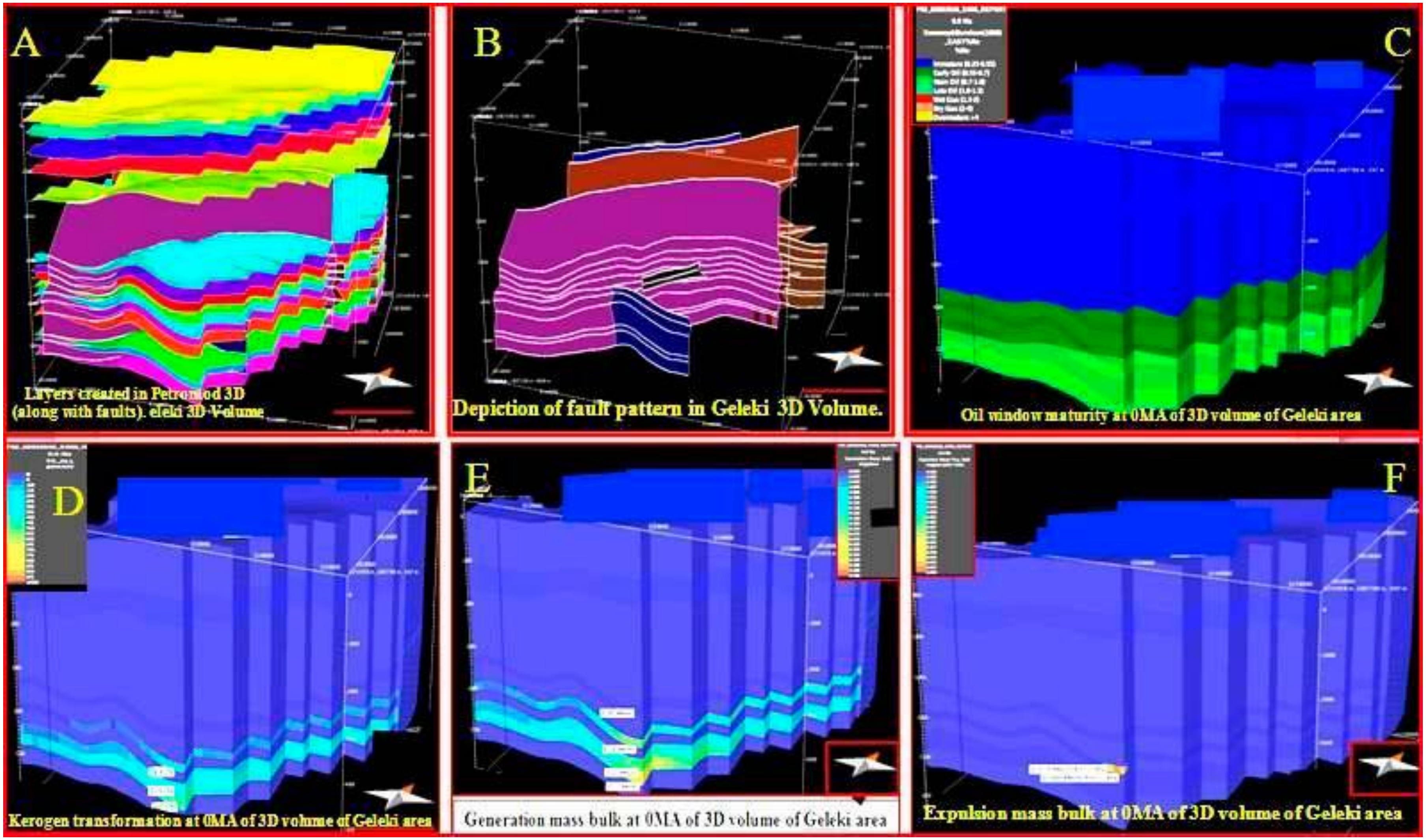

Figure 6. A-F presents different steps and outputs of 3-D Modeling.

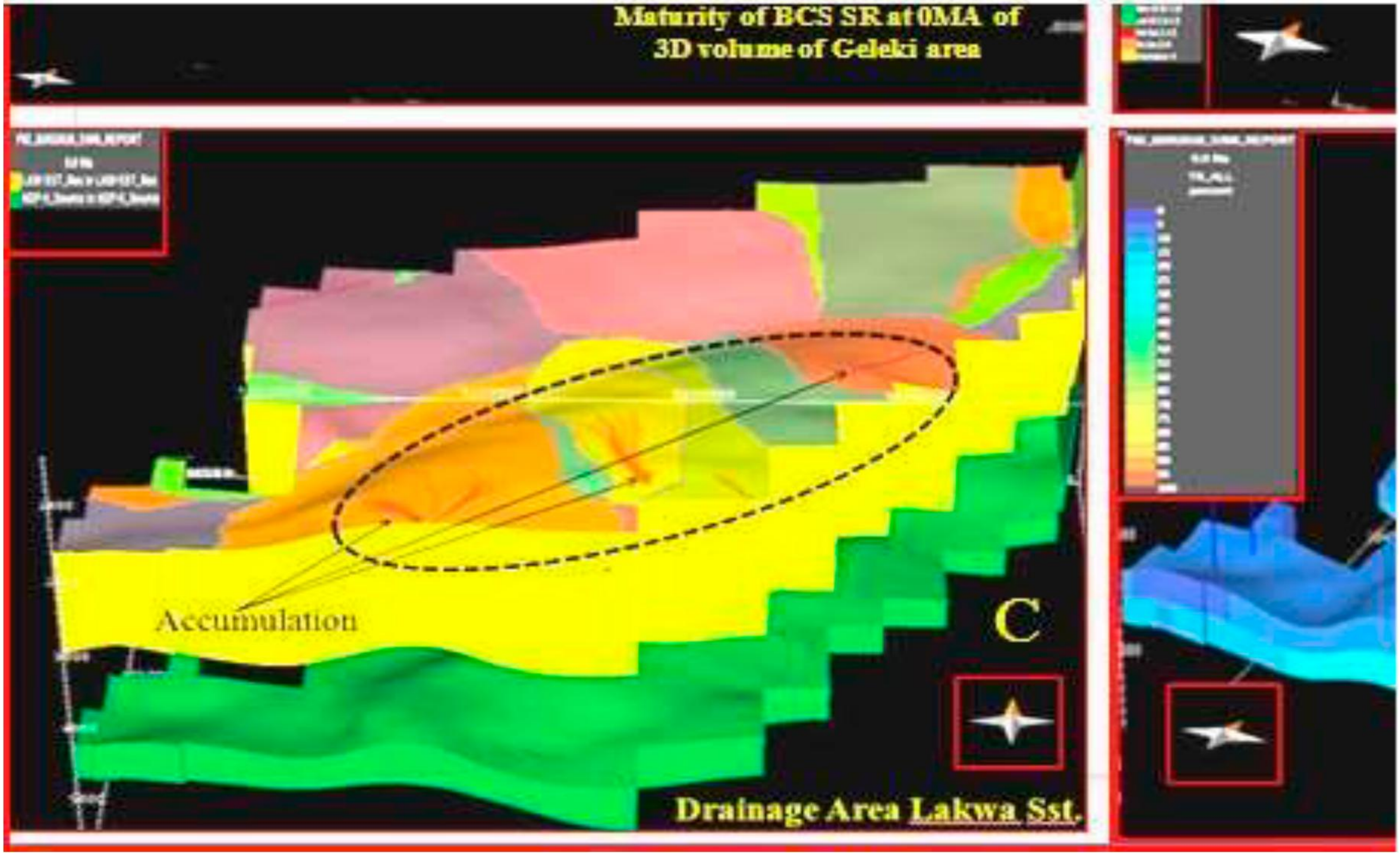

Figure 7. A-D showing simulation output from Petromod 3-D modeling.