Understanding depositional environment and sediment input for Tertiary & Mesozoic stratigraphy in Kutch basin, India

Anuj Kumar, Chandramohan Rautela, Ramakrishna Veni, Kasturi Das*

Cairn Oil and Gas, Vedanta Ltd.

Email id – ANUJ.KUMAR4@cairnindia.com

Keyword – Kutch-Saurashtra Basin, Gas frontier, Depositional environment, Mesozoic, Cenozoic

Abstract

The Kutch-Saurashtra basin has the potential to become a future gas hub through active exploration campaigns. Better understanding of Kutch-Saurashtra subsurface formations could open new area for exploration and production. The Kutch Basin is considered to be a relatively lightly explored and higher potential hydrocarbon basin.

The Kutch-Saurashtra basin is a pericratonic basin located on the western margin of India bounded by Nagar Parker Ridge In the north and North Kathiawar Ridge in the south which came into existence after Indian plate separated from African plate. Kutch basin is dominated by NNW-SSE trending fault. The rift evolution and syn-rift sedimentation of the basin continued from Jurassic to Cretaceous and later dominated mostly by passive margin setting from Paleocene to Recent times in a self-margin sedimentary environment. Recent exploration and gas discoveries in Mesozoic formations of Kutch basin (Naliya-Mundra, Lower Bhuj) and cluster discoveries within tertiary period mostly in Paleocene (Nakhtarana), Early Eocene (Jakhau) and Middle Miocene (Chhasra) formation having multilevel discoveries in GK 28 field having discoveries in GK-28-1, GK-28-3, GK-28-10, GK-28-12 and GK-28-14 wells and GK 42 field having discoveries in GK-42-1, GK-42-3 and GK-42-8 and GK-29A-1 well. Combining well completion reports, well logs, core study, seismic data analysis and gravity data has helped to decipher the reservoir units, depositional sequence and to come up with a robust depositional model present in Tertiary and Mesozoic period of Kutch-Saurashtra basin. Well log study combined with bio-stratigraphic data has helped to delineate different formations and their age, detailed analysis of well cutting and seismic data has helped to understand the structural and lithological aspect of the basin while gravity data gave a broader regional understanding. Further attribute analysis for tertiary has generated channel features in Chhasra and Paleocene formation which consolidate our understanding of depositional environment in Kutch basin.

Introduction

Kutch Offshore basin is located in the northern part of Western Offshore basin of India (Fig.1). The Kutch Offshore is bounded by Saurashtra arch to the south and Great Rann of Kutch in the north, the Arabian Sea to the west and Kutch onland to the east. It is typically a peri-cratonic embayed basin occupying a rifted graben (O. Catuneanu, 2017).

Fig 1. Location map of Study area (modified after Catuneanu 2017)

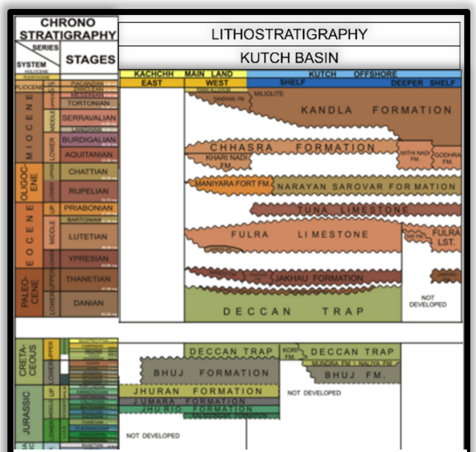


Fig 2. Generalized stratigraphy of Kutch Basin (modified after Zutshi et. Al, 1993

Rifting and consequent subsidence of the block between the Nagar Parker Hills in North and Saurashtra Peninsula in the south through Late Triassic, as evidenced by continental Rheatic sediments present in wells drilled within the basin affirms the initiation of sedimentation in Kutch Basin (Koshal, 1984). The first occurrence of marine sediments of Bathonian age indicates the basin was fully marine in Middle Jurassic. The basin formed the site for a westerly deepening epicontinental sea, in which a thick pile of sediments ranging in age from Middle Jurassic to Early Cretaceous, was deposited in shallow marine to deltaic environment. The sediments were deposited in two major stages – Middle Jurassic transgressive stage in which carbonate and shale was deposited and Late Jurassic- Early Cretaceous Regressive stage which is characterized by deltaic deposit (modified after Biswas,1983). Post Early Cretaceous basin went into regressive phase and sag phase characterized by the depositional of fluvial sediments. Mesozoic sediments were intruded and capped by Late Cretaceous – Paleocene time Deccan lava flow. During Cenozoic time the basin went into a passive margin setting with transgressive sea. The Kutch rift was initiated during Late Triassic break up of Gondwana land by reactivation of Precambrian Delhi Fold belts leading to faults in E-W trend, subsequent rifting during Late Jurassic, Early Cretaceous and Paleocene is characterized by dominantly NNW-SSE striking faults, corresponding to Dharwarian grain. Eurasian and Asian plate collision during Miocene led to strike slip movement in NNW-SSE faults creating wrench faults with divergent strike slip movements. The sense of movement was thus oblique slip along the reactivated faults (Fig 3). Since Kutch basin was collocated with Africa, Madagascar and Seychelles therefore possible source rock covers a wide spectrum. Dominant sediment supply was from Indian continent from NE directed influenced by the paleo-slope in NW direction (Fig 4). Kutch basin is a typical asymmetric rift basin tilted towards South (Fig 5), western part of the basin is open and merges with continental shelf and slope. Conjugate basin of Kutch basin is present in Africa (Somalia, Tanzania, Kenya, Seychelles Basin).

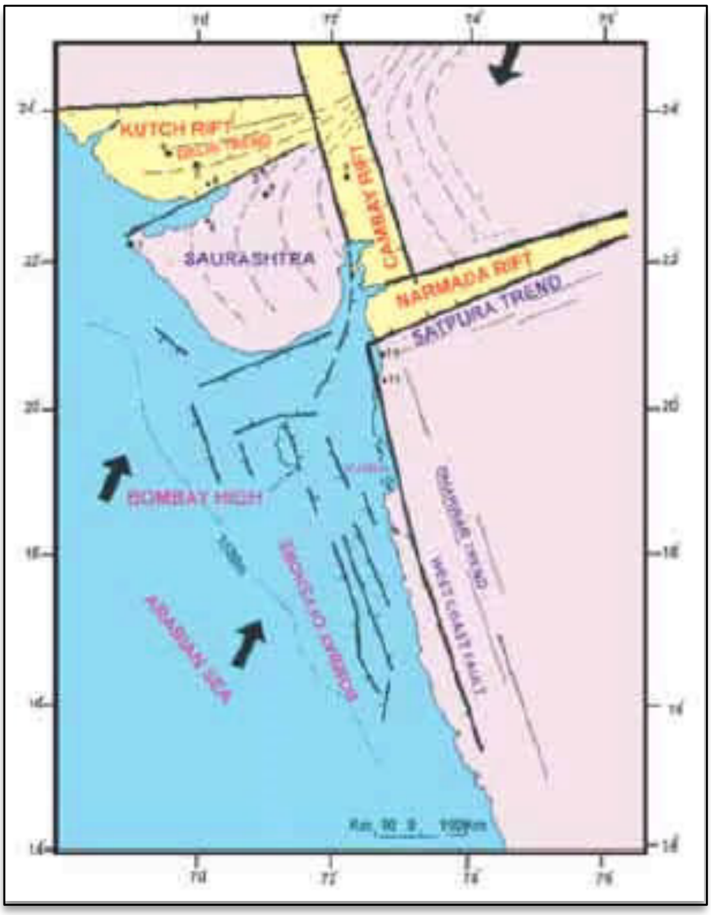


Fig 3. Rift system of Western India and major Precambrian trends (after Biswas, 2005). Black arrows indicate regional stress direction.

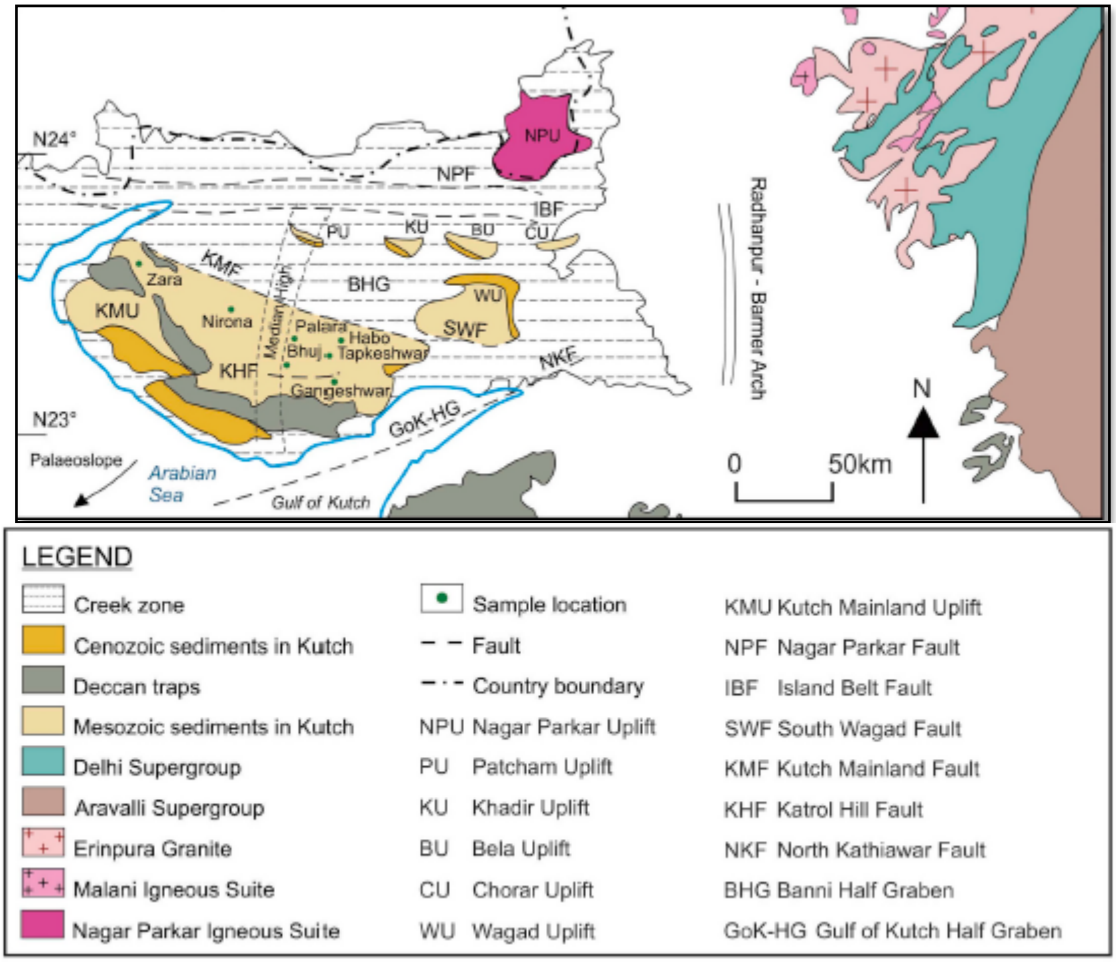


Fig 4. Tectonic elements and inferred paleoslope in Kutch Basin during Mesozoic along with nearby source areas (adapted from Biswas, 2005; Ramakrishnan Vaidyanadhan, 2008)

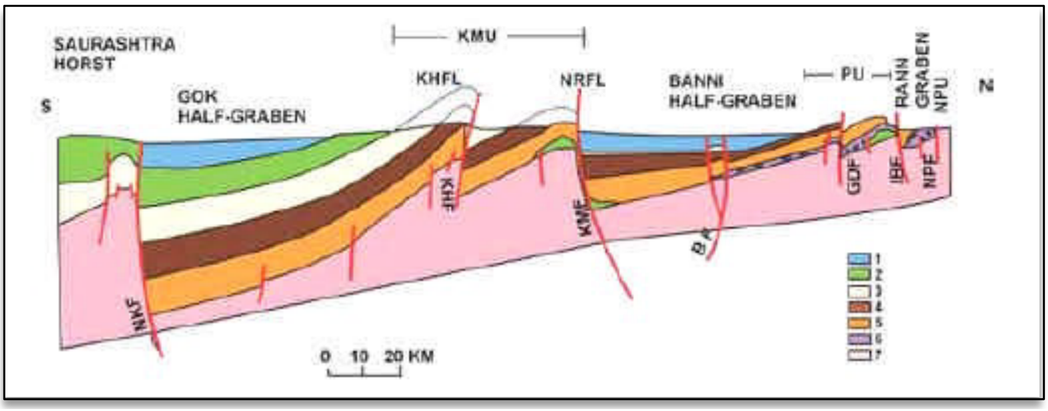


Fig 5. Geological cross section Kutch basin along Median High in Fig 4: KHFL, Katrol Hill Flexure, NRFL, Northern Range Flexure Box Index: 1, Quaternary and tertiary, 2, Deccan trap/intrusive; 3, Lower Cretaceous; 4, Upper Jurassic; Mid, Jurassic; 6, Lower Jurassic-Upper Triassic; 7, Pre-Cambrian

Data used in this study

Well Data:

35 wells are considered for the present study mainly focusing upon Tertiary formations in the Basin. Conventional logs (GR, RT, NPHI, RHOB and DT) were available in most of the wells and log were conditioned before using for interpretation. Understanding from well log correlation was used to formulate depositional trend and environment.

Seismic Data:

Multiple vintages of 3D and 2D data are available, seismic interpretation along with well to seismic tie was gave a broader understanding of basin geometry and preliminary seismic attribute analysis on 3D PSTM and PSDM seismic data were used to understand provenance direction and depositional setting.

Present Study

Study carried out in this paper is done by bringing different domain of hydrocarbon exploration under single umbrella. Well data such as Well log, cutting and core data were used to formulate lithofacies of Tertiary and Mesozoic formations, to understand stacking pattern throughout the basin history. Well log correlated with seismic data provided major stratigraphic markers (Unconformities, MFS) (Fig 6). Biostratigraphy data provided extra impetus to the understanding of depositional environment. Integrated study and interpretation of 2D and 3D seismic data provided the detailed study of stratal pattern and basin geometry, attribute analysis on 3D PSTM data provided channel like feature in tertiary formation and gave a better understanding of provenance.

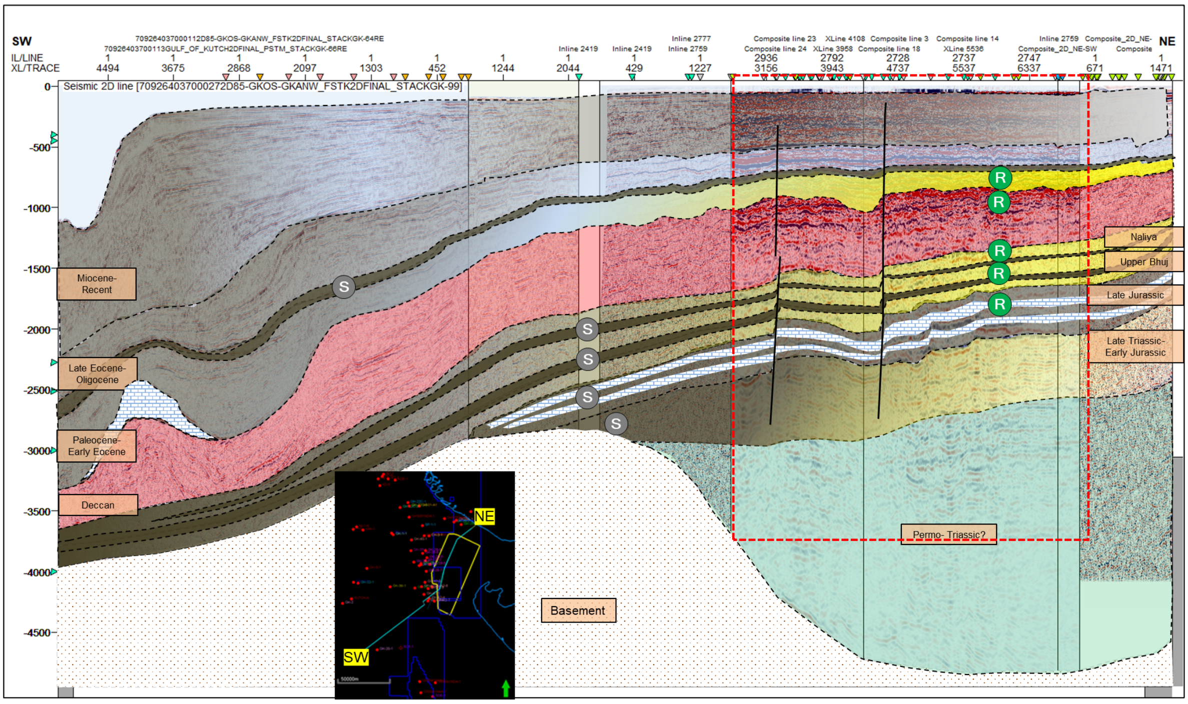
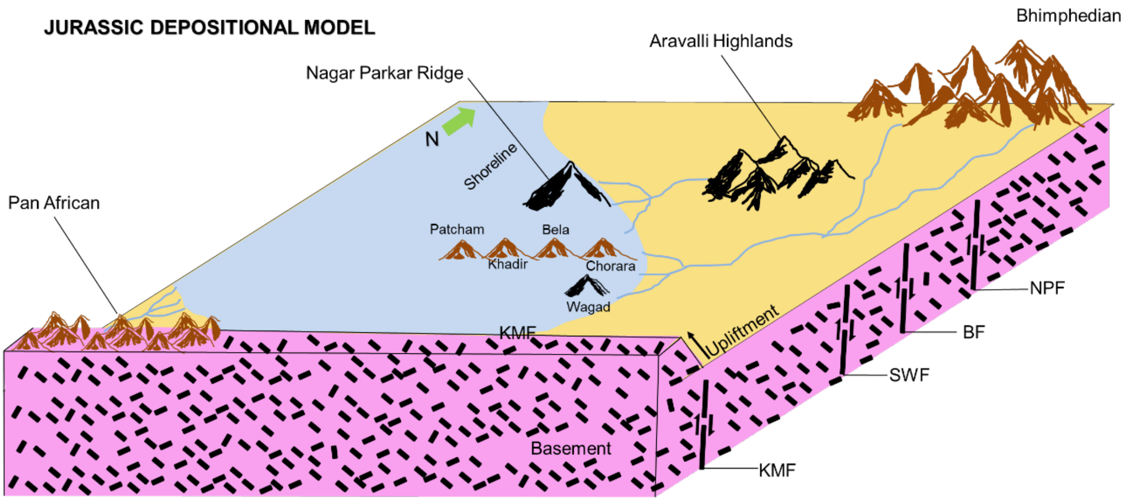


Fig 6. Composite Seismic cross section from NE-SW marking major horizons from Jurassic to Miocene delineating expected source and reservoir rock facies variation.

Conclusion

This present study is aimed at better understanding of reservoir unit, area having better reservoir prospectivity, depositional environment corresponding to each major stratigraphy in hope to expedite the process of hydrocarbon exploration in Tertiary and Mesozoic formation of Kutch basin.

1. Kutch Basin has evidence of multiple sources in initial stages of rifting probably from African Provenance and Bhimphedian Orogeny (Fig 7).



2. Multiple reservoir facies developed during Late Jurassic and Early Cretaceous syn-rift and Late Cretaceous syn-rift facies in Mesozoics (Fig 8).
3. Shallow marine shoreface sediment have proved to be excellent reservoirs in Tertiary sequence.
4. Ukra Member shale, Upper Bhuj and Naliya-Mundra shale are believed to be in mature stage.

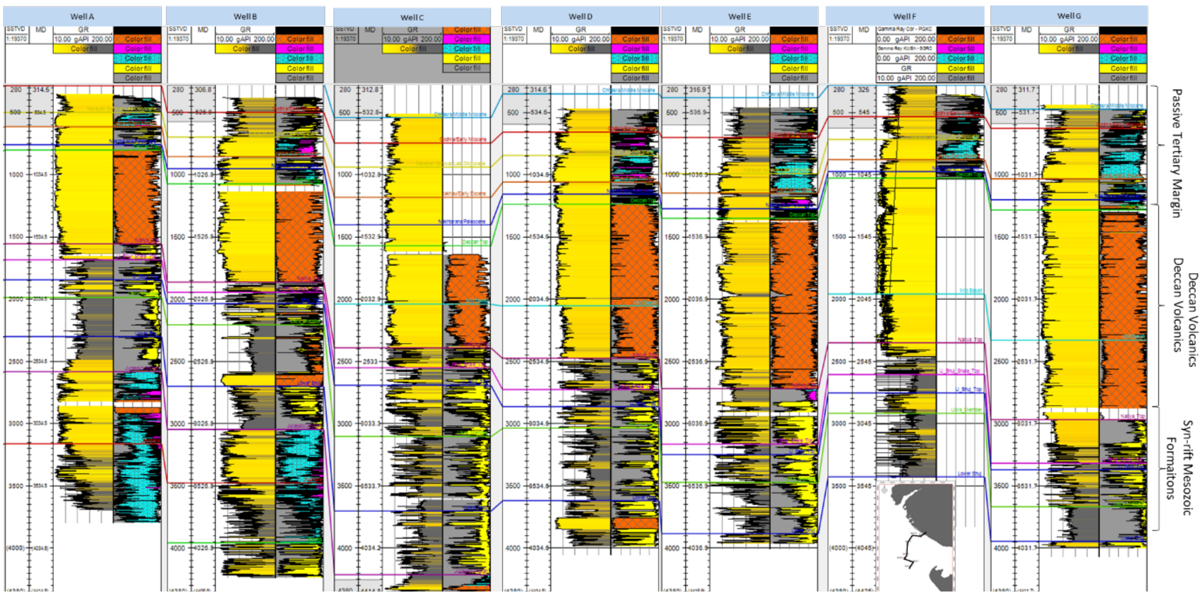


Fig 8. Well Correlation from well A in NE to Well B in SW

5. Sediments of Mesozoic and Tertiary are punctuated by unconformity in Naliya-Mundra and Paleocene which was exposed during continental upliftment and Deccan volcanism leading to lesser thickness.
6. Weathered basalt which has porosity in range of 25-30% can also act as reservoir rock.
7. Intraformational shale and Deccan basalt can act as potential seal within the basin.
8. Attribute analysis has generated channel features which are evident in Paleocene and Miocene formations.

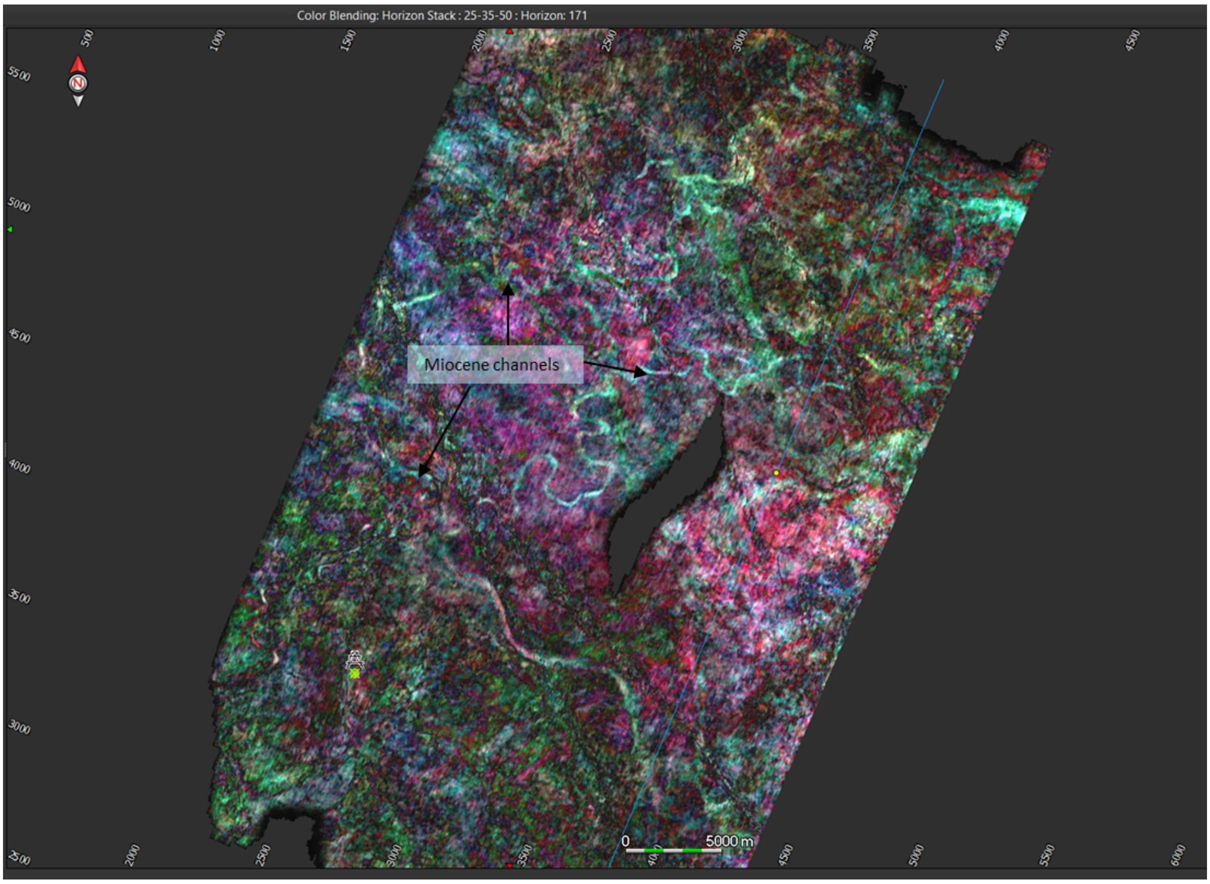


Fig 9. Channel features in Miocene generated by frequency blending of 25hz – 35hz and 50hz frequency

Acknowledgement

Authors are thankful to Cairn oil and Gas , Vedanta Limited for giving this opportunity to present the technical work. Authors also thank their co-workers at Cairn for support and technical input in completion of this paper.

References

Gombos Jr, Andrew M., William G. Powell, and Ian O. Norton. "The tectonic evolution of western India and its impact on hydrocarbon occurrences: an overview." Sedimentary Geology 96.1-2 (1995): 119-129.

Biswas, S. K. "A review of structure and tectonics of Kutch basin, western India, with special reference to earthquakes." Curr. Sci 88.10 (2005): 1592-1600.

Mouli, K. Chandra, et al. "Tectonic evolution of Kutch sedimentary basin, western India." Journal of Earth System Science 129 (2020): 1-15.

Dasgupta, Sanghita. "A review of stratigraphy, depositional setting and paleoclimate of the Mesozoic basins of India." Mesozoic Stratigraphy of India: A Multi-Proxy Approach (2021): 1-37.

Chaudhuri, Angana, et al. "Detrital zircon and monazite track the source of Mesozoic sediments in Kutch to rocks of Late Neoproterozoic and Early Palaeozoic orogenies in northern India." Gondwana Research 80 (2020): 188-201.

Catuneanu, Octavian, and Alok Dave. "Cenozoic sequence stratigraphy of the Kachchh Basin, India." Marine and Petroleum Geology 86 (2017): 1106-1132.

Directorate General Hydrocarbon (DGH) – Basin Information portal