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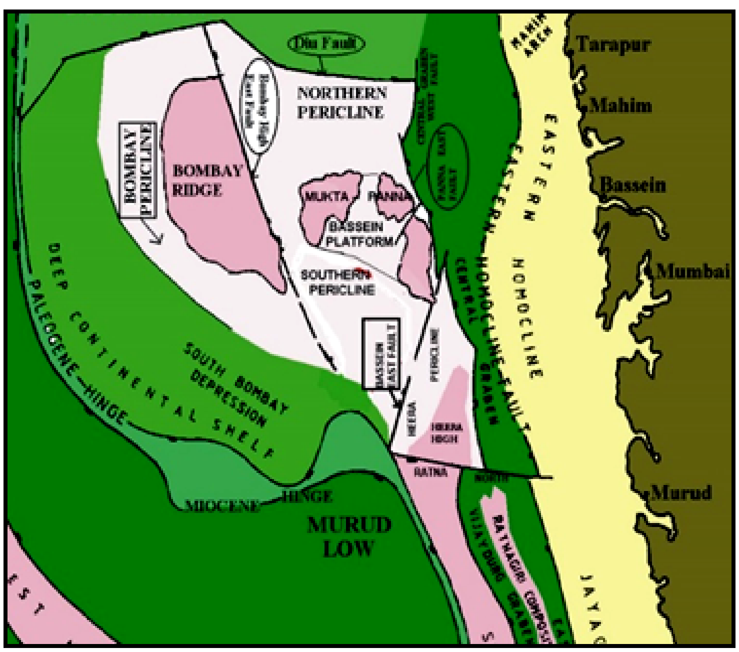
STRUCTURAL DISPOSITION OF THE MUMBAI OFFSHORE AT KEY GEOLOGICAL TIMES

Abstract:

The Mumbai Offshore Basin (Fig 1) evolved in a Passive Margin set up through three distinct phases of tectonic activity. The directional trends of the Precambrian structural grain over the Indian Shield controlled to a large extent, the later pattern of continental fragmentation and rifting which gave rise to the present tectonic configuration of India. The three phases are primarily, the separation of Madagascar from Seychelles-Mascarene- India at C33 (83Ma) along the NNW-SSE structural trends of Proterozoic mobile belt (Dharwarian trend), when the NNW-SSE striking Normal faults propagated into the area. The Second phase of modifying tectonic event was the Doming and eruption of volcanics related to the Reunion Hot Spot at C29 (65Ma) when the Deccan Trap was laid down. The third major tectonic event was the significant crustal shortening which occurred at the India-Eurasia collision boundary, (C21, 48Ma) resulting in deceleration of the northward movement of the Indian plate. A final tectonic event to profoundly influence the Western Offshore Basin was the Himalayan Orogenic Movement IV, caused excessive sedimentation in the western offshore basin, thereby creating the post Miocene westerly tilt and leading to final configuration of the structures. The tectonic upheavals thus recorded in the Mumbai Offshore Basin which controlled its sedimentation, structuration and the entrapment has been demonstrated in this paper, through a series of maps and paleotectonic reconstructions.

Introduction:

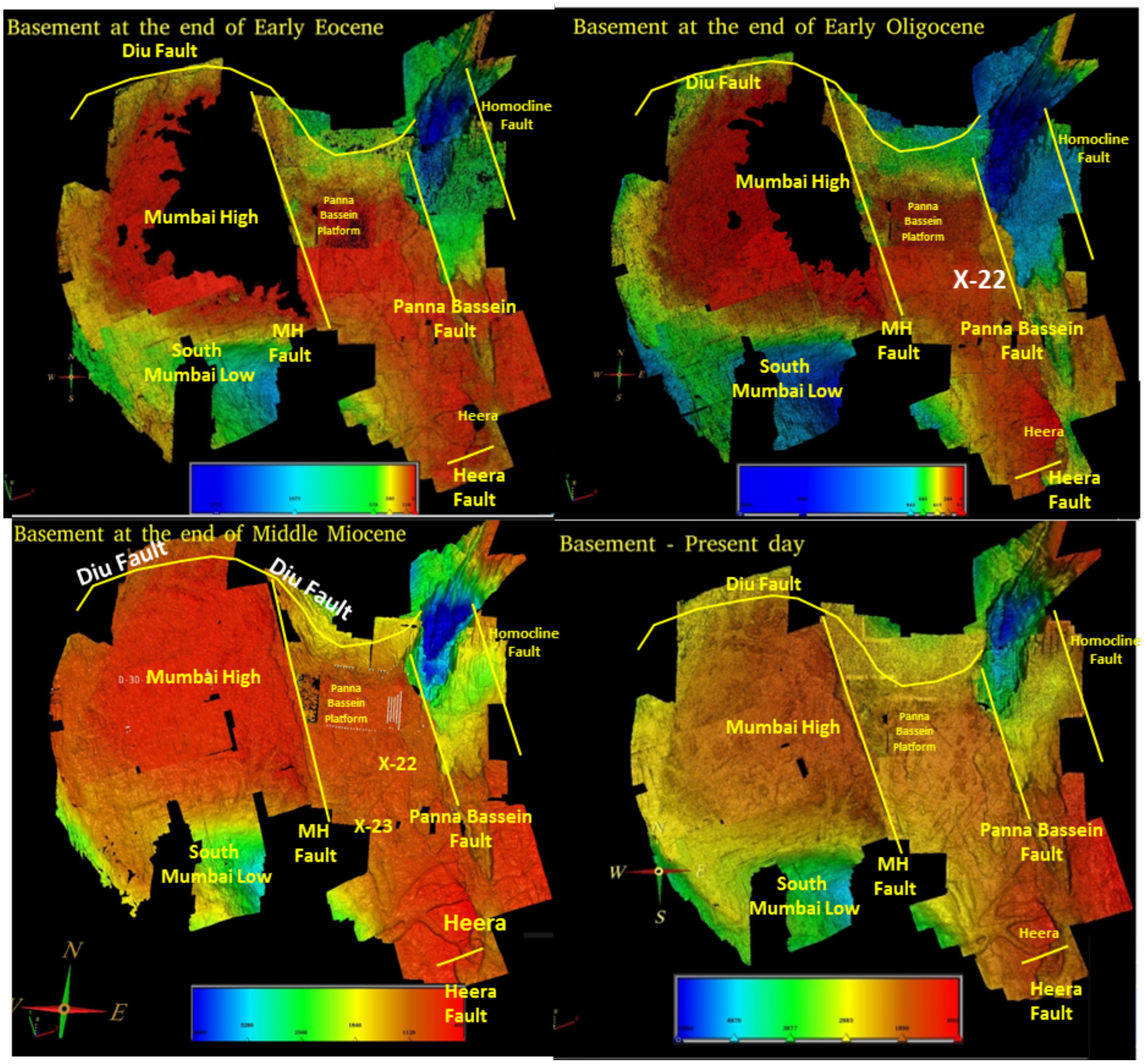
The Sequence Stratigraphic framework of the Basin places nearly the entire sedimentary column in a 1st Order Passive Margin Sequence, beginning Early Eocene to Recent. Within the Passive margin Sequence, three 2nd Order sequences, CII30 (Early Eocene) and CII40 (Middle-Late Eocene) and CII 100 (Oligocene to Miocene) have been defined. A prominent 3rd Order Sequence Boundary CIII 30 (Early/Late Oligocene unconformity) assumes significance since it forms a conspicuous seismic marker to help reconstruct the structural history. The different Sequence Boundaries, Formations, ages and corresponding seismic markers which hold the key to this discussion are as follows. H5 or the Economic Basement, H4/ Panna Formation or End of Early Eocene, CII30, H3B/ Bassein Formation or End Eocene, CII40, H3A/ Mukta Formation, Early Oligocene and H1A/ end Middle Miocene. The various times at which these key surfaces have been analysed are that of Early Eocene, Early Oligocene, Middle Miocene and of course Present day.



The disposition of each surface at crucial geological times has been interpreted through stacking of the younger sequences which brought out areas of active faulting and accommodation. Time thickness and Isopach maps as well as paleo-structural reconstruction through flattened geological sections have been made to build the narrative of structuration.

Structural evolution of the Basement or H5:

The structuration history of the Basement (H5) has been traced through maps from Early Eocene onwards(Fig 2). During the Early Eocene period, there were mainly two areas of accommodation. The Northern "Central Graben" controlled by the active NNW-SSE Panna-Bassein fault trend. And the South Mumbai Low, which appears to have undergone subsidence through sinking and was not controlled by a linear fault system. The NE-SW trending South Heera fault was another major discontinuity to have been active in accommodation of sediments. Each Transgressive stage during this time, added to the sediment load in the active depocentres.



The NNW-SSE Dharwar trend controlled the formation of most tectonic elements like the major structure bounding faults which continued through geological time. These faults dominated the sedimentation and shaped the structural fabric as well. Locally, some movement along the NE-SW (Aravalli trend) is seen to be incipient, especially between the Panna and Bassein fields.

At the end of Early Oligocene (Fig 2), the Panna Bassein fault trend became firmly entrenched and extended to Heera, and beyond that, a connection with the Vijaydurg graben was established. The Eastern Homocline fault became better defined and the southern limit of the Central graben got demarcated. A fault system parallel to the Panna-Bassein trend is seen to establish itself stronger during this time. It runs east of B-22-5 and appears to be a raised block compared to the Panna- Bassein area.

By the end of Middle Miocene (Fig 2), the structural fabric shows overwhelming impact of the Dharwar (NNW-SSE), Aravalli (NNE-SSW) and Narmada (ENE-WSW) trends. Reactivation along NE-SW and NNE-SSW faults gave rise to translational/rotational movement of adjacent structural blocks with respect to one another. ENE-WSW trending Diu fault is observed to be dominantly active from north of Mumbai High in the west to B-170 area to the east, pronouncing the isolation of Saurashtra and the Mumbai Offshore basins from each other. The shelf-slope break took its shape along the western margin of the shelf.

Comparing the Basement configuration at Mid-Miocene with present day (Fig 2), one observes that the Mumbai High and a large surrounding tract and the Heera highs which were at a similar elevation at Mid-Miocene changed to a scenario where the Heera field is considerably shallower today. The Mumbai High fault appears to have remained active from Middle-Miocene since magnitude of the throw across the fault increased significantly during the period. The Panna-Bassein platform changed its slope to the west and gained altitude over the B-22-5 area. Later Structures like B-23 which formed due to transpressional movements along NE-SW trending strike slip faults also appeared at the last phase. The South Mumbai Low which remained shallower than the Central Graben till Middle Miocene, attained similar depths only during recent times.

Structural evolution of the Sequence Boundary CII 30 or Panna Formation (H4):

Post depositional changes for this event, has been mapped from the Early Oligocene (H3A) time onwards. The Panna formation at Early Oligocene time shows a median high trend in the platform area (B-22 to Heera) which slopes away in either direction. The major faults to have affected the Basement also included Panna in their movement which is seen replicated in the maps. The structural difference of the H4 layer between the DCS platform and the B-192 areas is considerable at this time. But by the end of Middle Miocene the difference appears to smoothen out and the western periphery of Mumbai High shows an overall gentle slope. From Miocene to present day, the disposition of the Panna Formation did not undergo significant changes other than the deepening of the DCS area. (Fig.3)

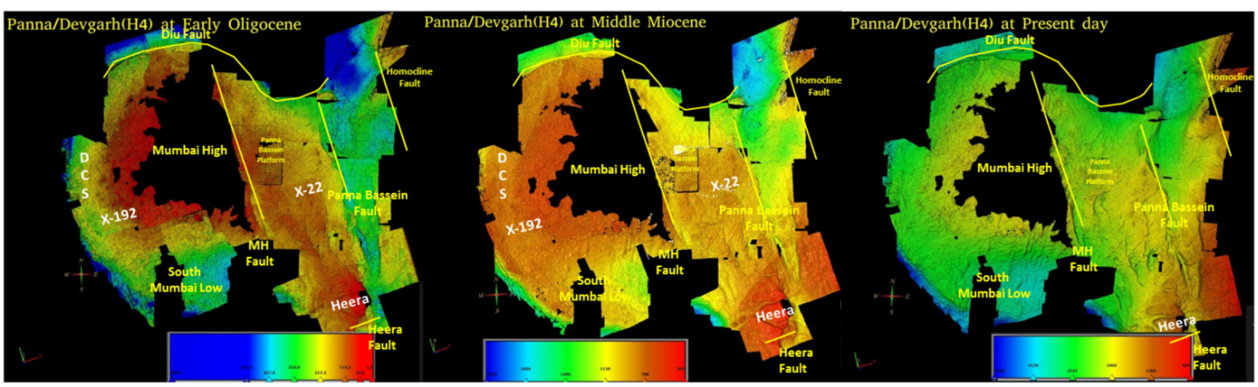


Figure 3: Panna Structural Configuration through time

The Bassein (CII 40/ H3B) and Mukta (CIII 30/ H3A) Formation:

The Middle-Late Eocene and Oligocene witnessed changes of a different nature in the Mumbai Offshore Basin. The fault controlled blocks of the Vasai East and the Neelam lows which were sites of major accommodation during Middle Eocene, reversed their movement during Late Eocene and created inverted structures along these faults resulting in uplifted blocks with complete absence of Late Eocene strata. The positive topography generated due to the structural inversion along these faults slopes gently to the west and has a steep rise to the east.

The time period from the deposition of Mukta and Bassein formations to that of Middle Miocene saw deposition of the Late Oligocene shale and Early Miocene Bombay Limestone. By the end of Middle

Miocene one of the most noticeable features to stand out in the Mukta-Bassein formation is that the D-1 area & the edge of the shelf was shallower than the rest of the Basin, disregarding Heera. This was primarily due to a series of reefal growths along this Mid-Miocene shelf edge. The Shelf margin and Diu fault were very well defined, and the control exerted by the earlier active faults appear to be diminished. Inversion structures in the Central Graben and further north-eastwards are seen to have formed during this time too.

From Mid Miocene to recent (Fig 4), the changes brought over the Mukta-Bassein layers were numerous. The Neelam, Vasai East and parts of the Central graben invert and transform to become much shallower. The South Mumbai Low and DCS area which accumulated the maximum Chinchini (Post Middle Miocene) thickness, achieved deeper levels than the Central graben for the Mukta Fm. The western part of the HPB platform deepened and correspondingly the eastern fault bound Panna-Bassein fields rose to their present height.

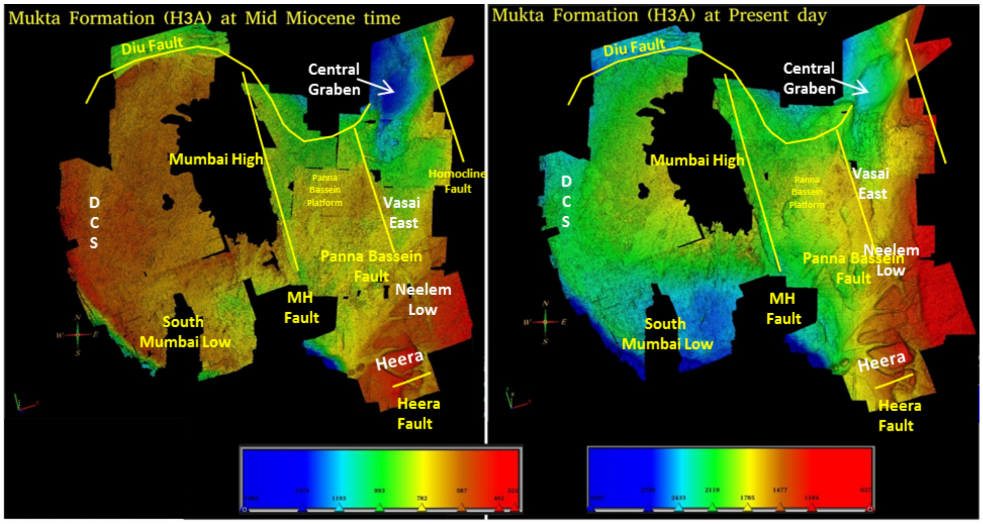


Figure 4: Mukta Structural Configuration through time

Structuration in the Period Post Middle Miocene (Chinchini Formation):

The final phase of sedimentation from 11.6Ma to recent times played a pivotal role in final shaping of the structures in Mumbai Offshore. The major tectonic events of HOM III (~3.6 - 2.58) and HOM IV (2.5 to Recent) induced very high rates of sedimentation. As a result of which, the Tapti Daman (to the North) area accumulated of huge thickness of clastics, the HPB sector and Ratnagiri underwent sea level rise and received increased clastic supply, and the Mumbai High-DCS also experienced high sedimentation rates.

The thickness of the Chinchini Formation increases exponentially westwards and the scale of increase is from 300m near the Eastern Homocline to more than 1800m in the DCS area. This immense accumulation of sediments along the western flank of the basin re-activated some of the faults and aided in the hydrocarbon entrapment process. The final phase of tectonics is best appreciated when the sections at Middle Miocene time and present day are seen in comparison.

As seen in Fig 5 & 6, for example, between the South Mumbai Low and the Central Graben, the latter was at a deeper level till the Mid Miocene times. Subsequent to the deposition of Chinchini Formation, the South Mumbai Low attains a deeper level. Similarly, the structural disposition of the Bassein Fm from Mid Miocene to present, changes from an average depth of 1000m over Bassein field to 1200m in the D-33 area to a difference of 1100m between them. (1700m over Bassein to 2800m in D-33).

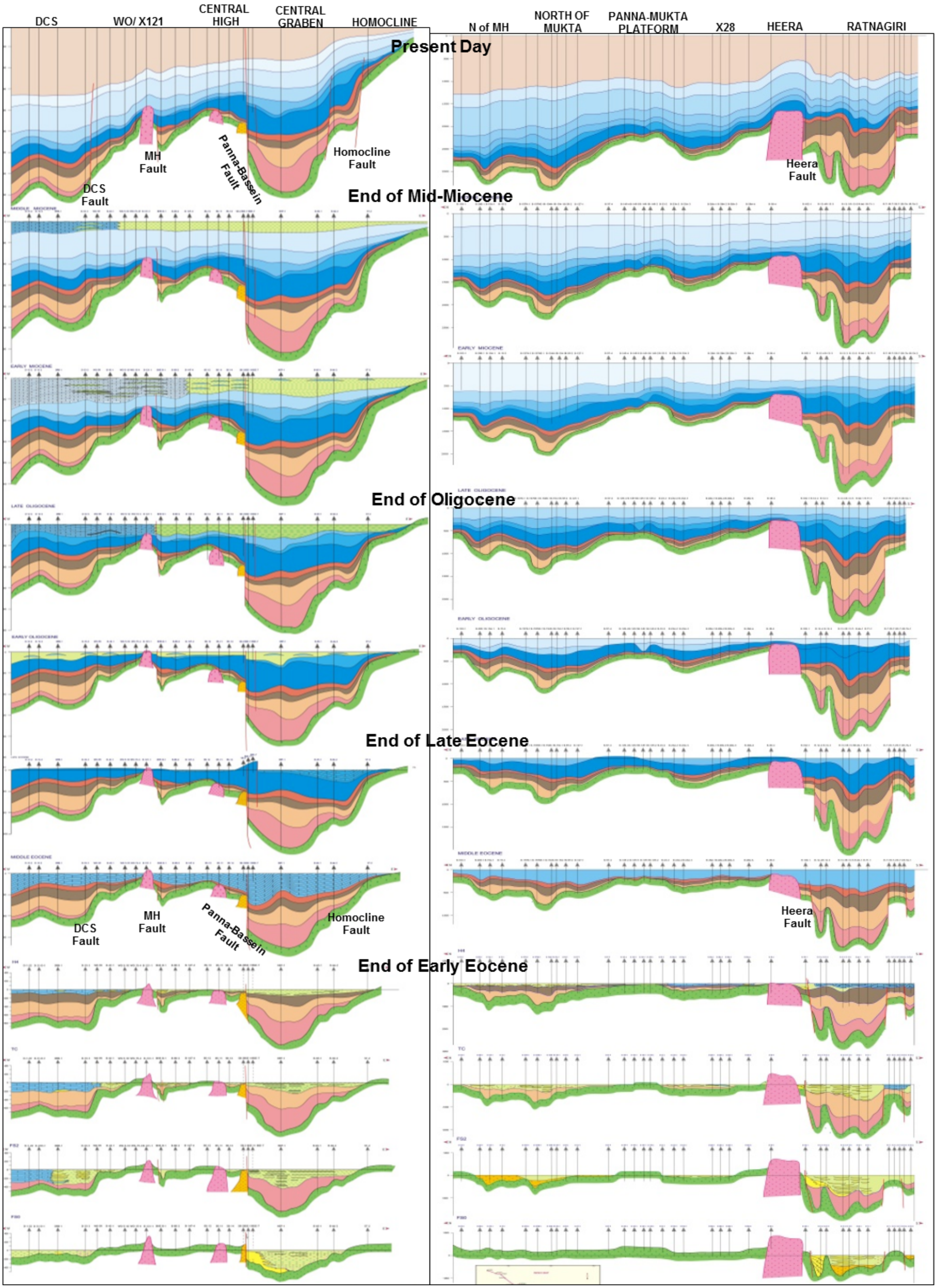
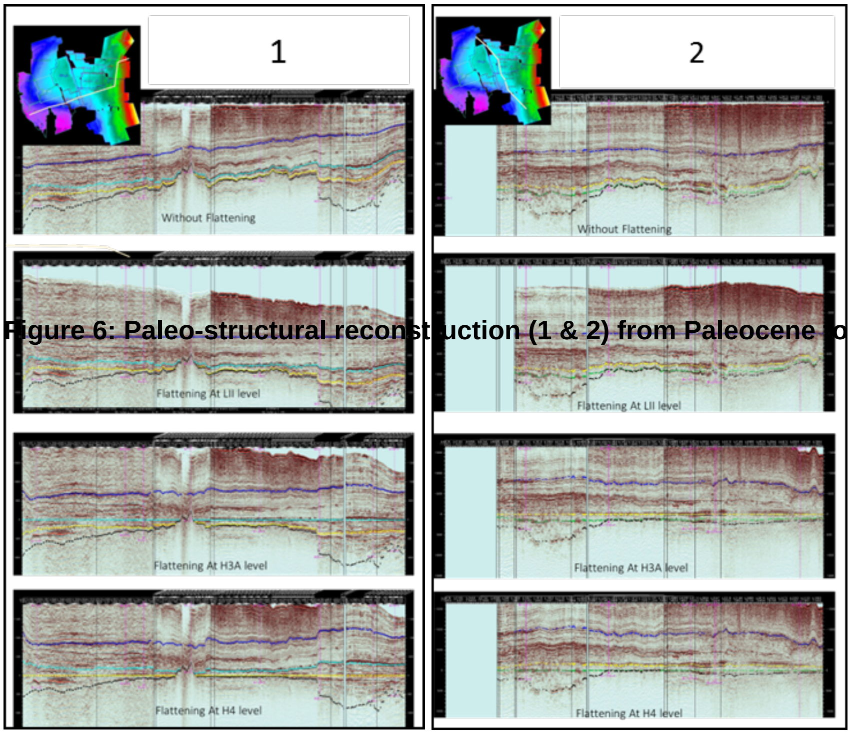


Figure 5: Paleo-structural reconstruction (1 & 2) from Paleocene to Present



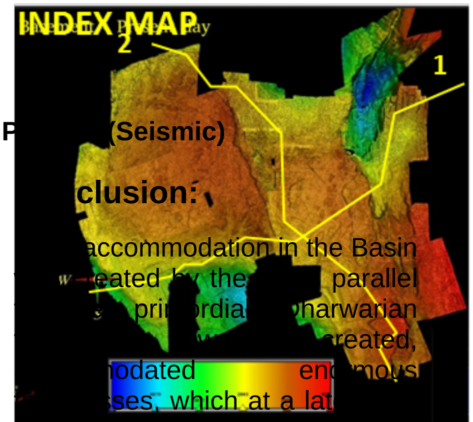


Figure 6: Paleo-structural reconst uction (1 & 2) from Paleocene o P (Seismic)

clusion:

accommodation in the Basin eated the parallel pri rdia harwarian reated, odated en mous ses, which at a lat formed inversion structures with a reversal of movement along the same faults. The structural and sedimentation history has been depicted with the help of paleotectonic sections along key profiles across the basin which demonstrates the changes which have overtaken the basin at each time plane. The Himalayan Orogenic movement during the Mio-Pliocene provided the final volume of clastics which brought the Basin to its present structural levels. The importance of this event cannot be overstated since it shaped the structural configuration of Mumbai Offshore as seen today and has a direct role in the final entrapment of hydrocarbons.

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