Geological Evolution of Surat Depression and Development of Hydrocarbon Pools in Contiguous Areas*

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Abstract

Surat depression is very significant geomorphologic feature, located south of Saurastra in western offshore region of India. The very presence of several hundred meter deep depression in the coastal region suggests continuing active subsidence. This ENE-WSW trending elongated feature is in the lateral continuity of Narmada-Tapti rift zone, which divides Indian peninsula into two distinct geological entities. Interpretation of seismic profiles, by processing the data by Pre-Stacking and Depth Migration (PSDM) techniques have given an insight to better understand the sedimentary sequences, below and above the Cretaceous volcanics, the thickness patterns and geological evolution. Rapid increase in thickness of both Mesozoic and Tertiary sequences within the Surat depression, indicates it's prolong geological history starting with the beginning of Mesozoic Era. The thickness of Cretaceous volcanics, however, remains unchanged. Seismic profiles also exhibit different patterns of distribution of coral reef complex across this depression. To the north across the Kutch- Saurastra offshore, Paleocene reefs are located on the western side, while successively younger Eocene and Miocene complexes are on the eastern side, while Paleocene reef complexes are overlain by younger Eocene reefs in the south.

Like all other half graben and rift structures of peninsular India, the Surat depression is also marked by the presence of discrete nearly vertical faults, with pronounced subsidence along northern margin, while on the southern side there are innumerable en echelon faults with incremental subsidence. Concentration of organically charged sediments in the floor portion of the Surat depression seems to have been due to various geological and oceanic processes. Rapid burial and thermal maturity seem to have generated hydrocarbons, which moved upward through innumerable nearly vertical faults to get preferentially accumulated in suitable reservoirs rocks, located on the submerged Bombay platform.

Introduction

The Surat depression is a very significant geomorphologic feature, located south of Saurastra in the western offshore region of India. The very presence of this several hundred meter deep depression in the coastal region suggests continuing rampant subsidence. (Figure 1)

This ENE-WSW trending elongated feature is in the lateral continuity of the Narmada-Tapti tectonic zone, which divides the Indian peninsula into two distinct geological entities. Like the Narmada–Tapti tectonic zone, there are several rifts and grabens transecting the peninsular India. (Figure 2)

These rift and grabens continue in offshore regions where they form sedimentary basins. The remnants of these basins are represented by large depressions. In land areas, thick seams of coal were deposited within these rifts and grabens during Gondwana times. The Gondwana sedimentation was terminated by Cretaceous volcanic activity which took place along these rift and grabens. (Misra, 2005, 2007) Several units of these volcanics are interlayered with sedimentary rocks, from the beginning to the end of the Cretaceous period (Misra, 2005, Misra 2008a). The outpouring of lavas was more pronounced in intersectional areas of these rifts and grabens and magma was generated by decompressional melting (Misra, 2009, Misra and Misra 2010a).

The rift and grabens continue in offshore regions where sedimentary basins have formed. Some of these basins such as Krishna-Godavari (K.G) host world class oil pools. Rampant subsidence in both land and offshore regions is observed all along the Narmada-Tapti tectonic zone. On the eastern side, in the Patalkoti area near Panchmadi in Madhya Pradesh, several hundred meters of subsidence is marked by the elongated valleys which are often filled by Quaternary alluvium. A huge dyke swarm related to Cretaceous volcanics has been mapped parallel to this tectonic zone (Misra, 2008b).

Various geological evidences suggest continued extensional tectonics along this zone, since the beginning of the Proterozoic Era. The integration of both land and offshore data during the present study has brought out very interesting results. The interpretation of seismic profiles generated by processing the data using Pre-Stacking and Depth Migration (PSDM) techniques have given an insight to better understand the sedimentary sequences, below and above the Cretaceous volcanics, the thickness patterns and geological evolution. (Figure 3)

Rapid increase in thickness of both Mesozoic and Tertiary sequences within the Surat depression indicates its prolong geological history starting with the beginning of the Mesozoic Era in the offshore region. The thickness of Cretaceous volcanics, however, remains unchanged. Seismic profiles also exhibit different patterns of distribution of coral reef complex across this depression. (Figure 4)

To the north across the Kutch-Saurastra offshore, Paleocene reefs are located on the western side. This distribution pattern suggests that during Tertiary period the gently subsiding grabens migrated from west to east. To the south of the Surat Depression in a profile, the Paleocene reefs are found overlain by the much wider Eocene reef complexes. Furthermore, these reef complexes have grown on the platform of Cretaceous volcanic rocks. This suggests that rampant basement tectonics continued only during the early Tertiary. Mapping and exploration of these reef complexes for hydrocarbons is thus suggested. Misra et. al. (1991) demonstrated an intricate relationship between basement tectonics and the formation of horst and grabens in Western Sedimentary Province of Canada. Gradually subsiding portions witnessed prolific growth of Devonian coral reefs and preferential accumulation of hydrocarbons in them. Like all other half graben and rift structures of peninsular India, the Surat depression is also marked by the presence of discrete nearly vertical faults, with pronounced subsidence along the northern margin, while on the southern side there are innumerable en echelon faults with incremental subsidence. (Figure 5)

Concentration of organically charged sediments in the floor portion of the Surat depression seems to have been due to various geological and oceanic processes. Rapid burial and thermal maturity seem to have generated hydrocarbons that moved upward through innumerable nearly vertical faults to get preferentially accumulated in suitable reservoirs rocks located on the submerged Bombay platform.

Study of other depressions along the west coast of India has also been very revealing. Further south, another depression in the offshore area is identified. This is located in the lateral extension of Kaladgi-Bhima graben. (Figure 6) This depression is in the lateral continuity of Kaladgi – Bhima graben. It has an altogether different tectonic history. Interpretation of the seismic profile is presented in Figure 7.

A thick succession of Mesozoic rocks can be seen below the Cretaceous volcanics. It suggests that this was subsiding mainly during Mesozoic times; Tertiary subsidence was minimal, shifted towards the southern margin. No prevailing depression in the ocean bottom is noticed in this case, suggesting that the subsidence has nearly stopped since the later part of Tertiary period. Many other depressions have been described in between the Surat and Kaladgi-Bhima depression both along and across the coast. The sedimentation history as well as thermal maturation of sediments has also being discussed (Chandra et. al. 2001). These depressions along the coast such as Mahim, Murud and Vijai Durg are located on the lateral extension of Cambay graben. Misra and Misra (2010b) brought out a distinct relationship between Paleocene, Eocene, Oligocene and Miocene hydrocarbon pools with different geological setting. (Figure 8)

Paleocene as well as Eocene pools are elongated in the N-S direction and seem to have developed in basins formed by subsidence. The basin-forming tectonics is believed by the present authors to be along the N-S trending Cambay structure. The effects of basin- modifying tectonics are more obvious in the northern part where Miocene pools, both on land as well as in offshore region show elongation in an ENE-WSW direction. The elongation of these pools is considered to be due to superimposed basin-modifying tectonics along the Narmada-Tapti tectonic zone. As mentioned earlier the Surat depression is also located in the lateral continuation of this tectonic zone. The relationship of other Miocene pools such as Bombay high and a couple of them in its vicinity appear to be related to lower Miocene marine transgression. The most unique are the Oligocene pools which are located on curvilinear submerged sand bars. These sand bars are emanating from the Gulf of Cambay and are submerged. However, their trend, shape and abrupt termination along certain straight lines can be mapped by interpretation of satellite data.

This profuse supply of clastic sediments has filled the eastern part of Surat depression. Normally the sediments analyzed in several depressions are quite rich with good quality organic matter; however, it is expected that due to rapid rate of subsidence the dilution might have occurred.

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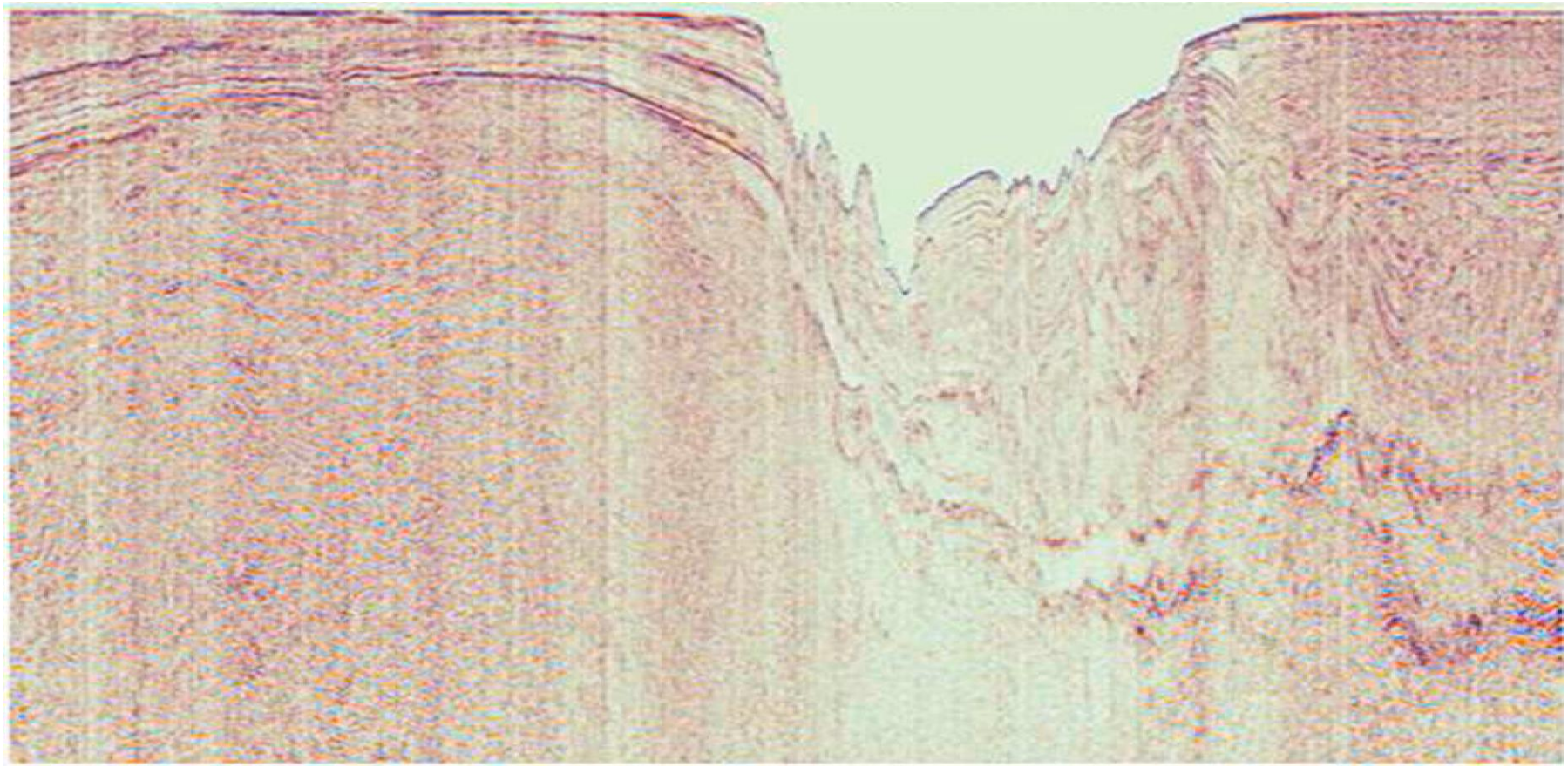

Figure 1. Seismic profile a cross Surat Depression. This profile is generated using Pre-Stacking Depth Migration PSDM processing technique by GX Technologies.

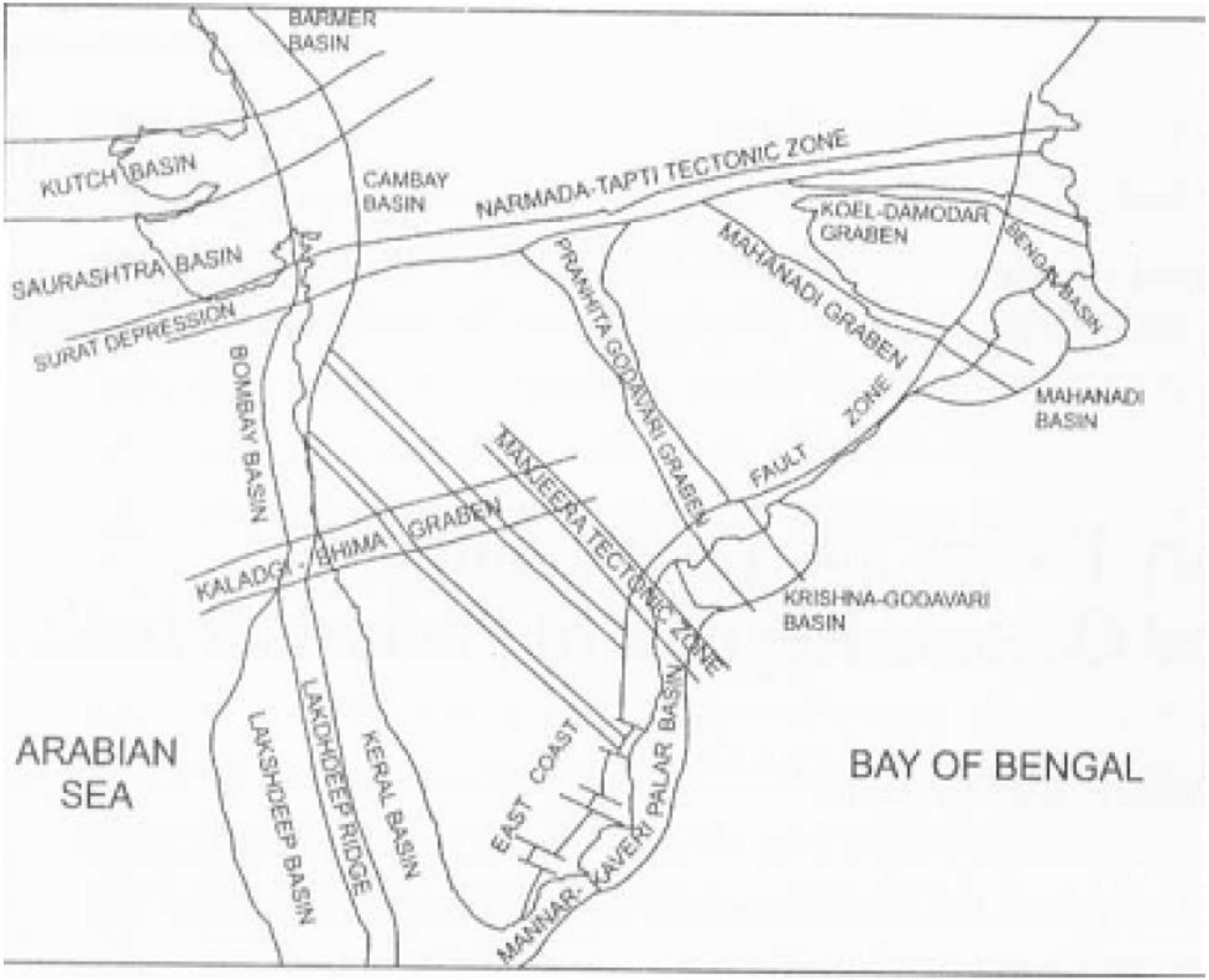

Figure 2. Outline map of India depicting distribution of rift and grabens.

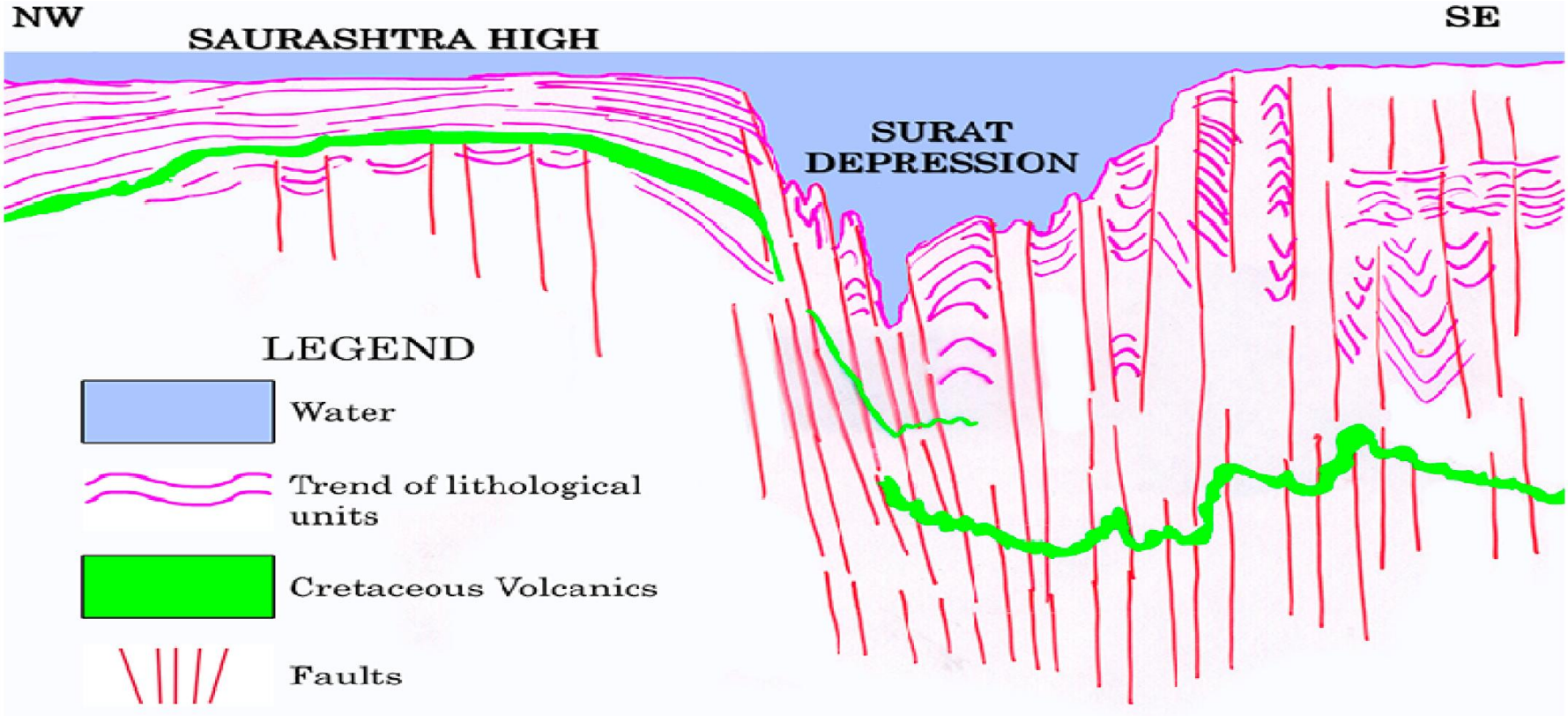

Figure 3. Interpretation of seismic profile across Surat depression. The depression is remnant of major rift and depicts rampant subsidence.

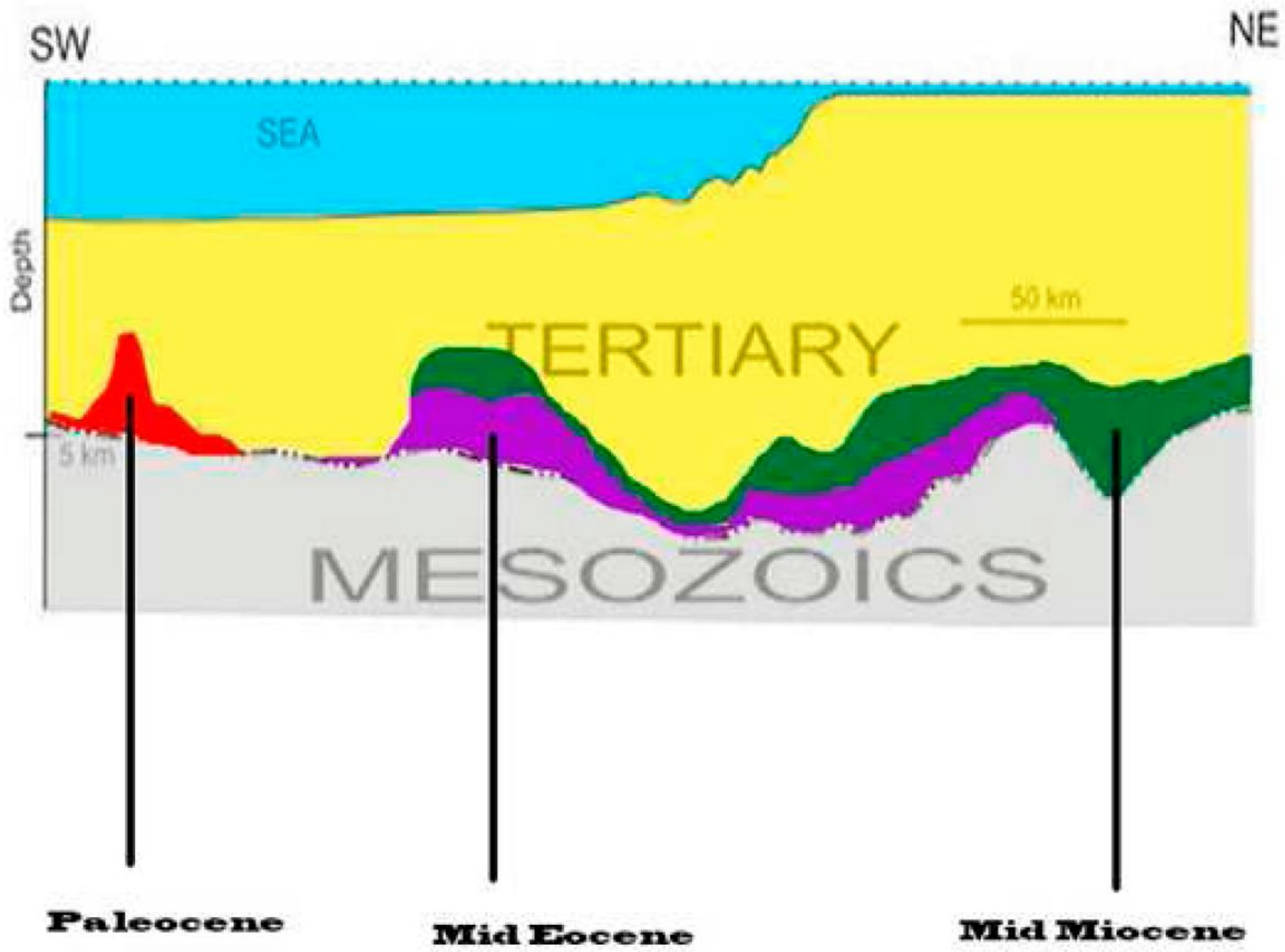

Figure 4. Interpretation of seismic profiles showing distribution of coral reef complexes on the northern side of Surat depression.

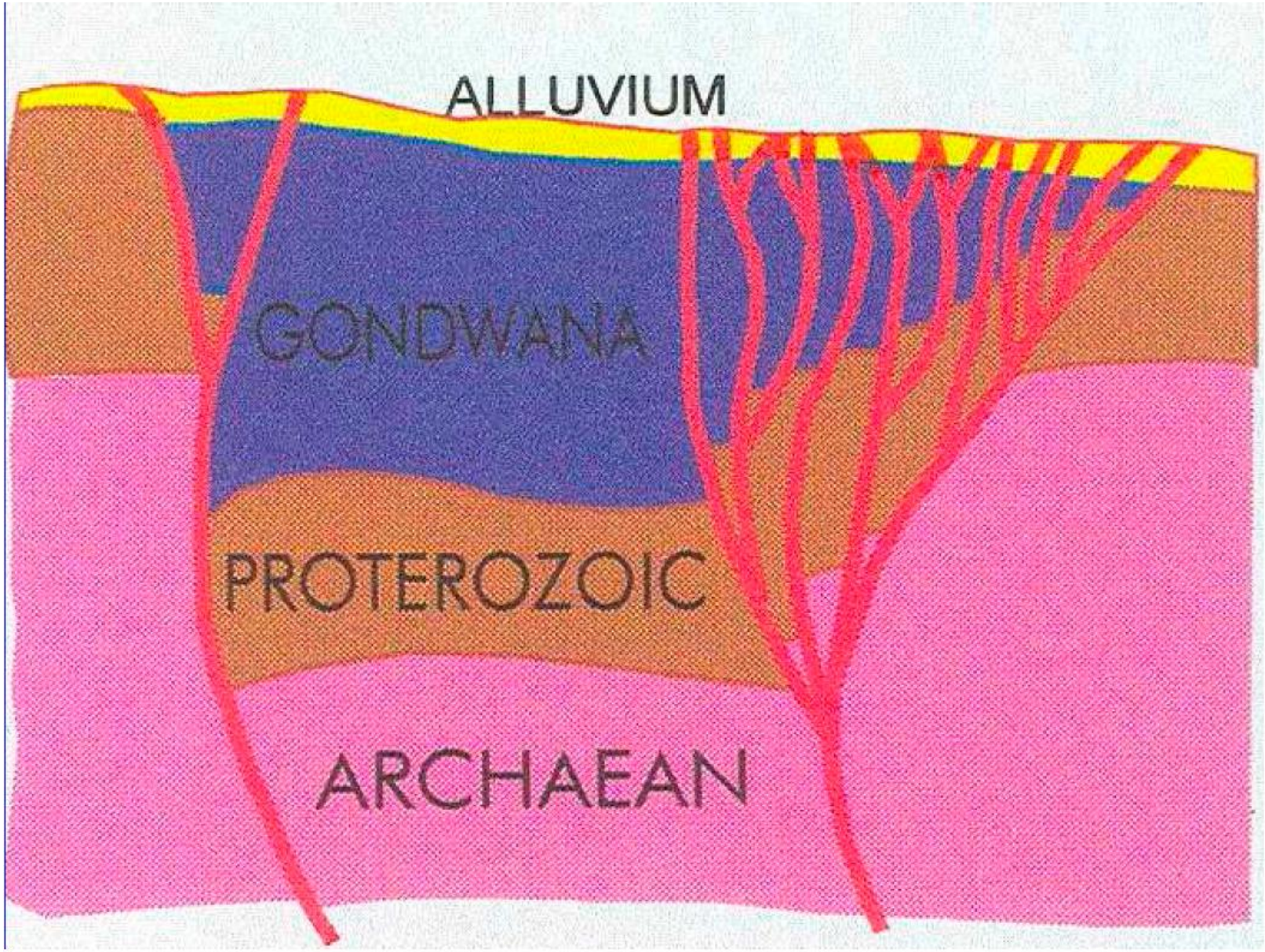

Figure 5. Generalized cross-section showing architecture of half grabens in peninsular India.

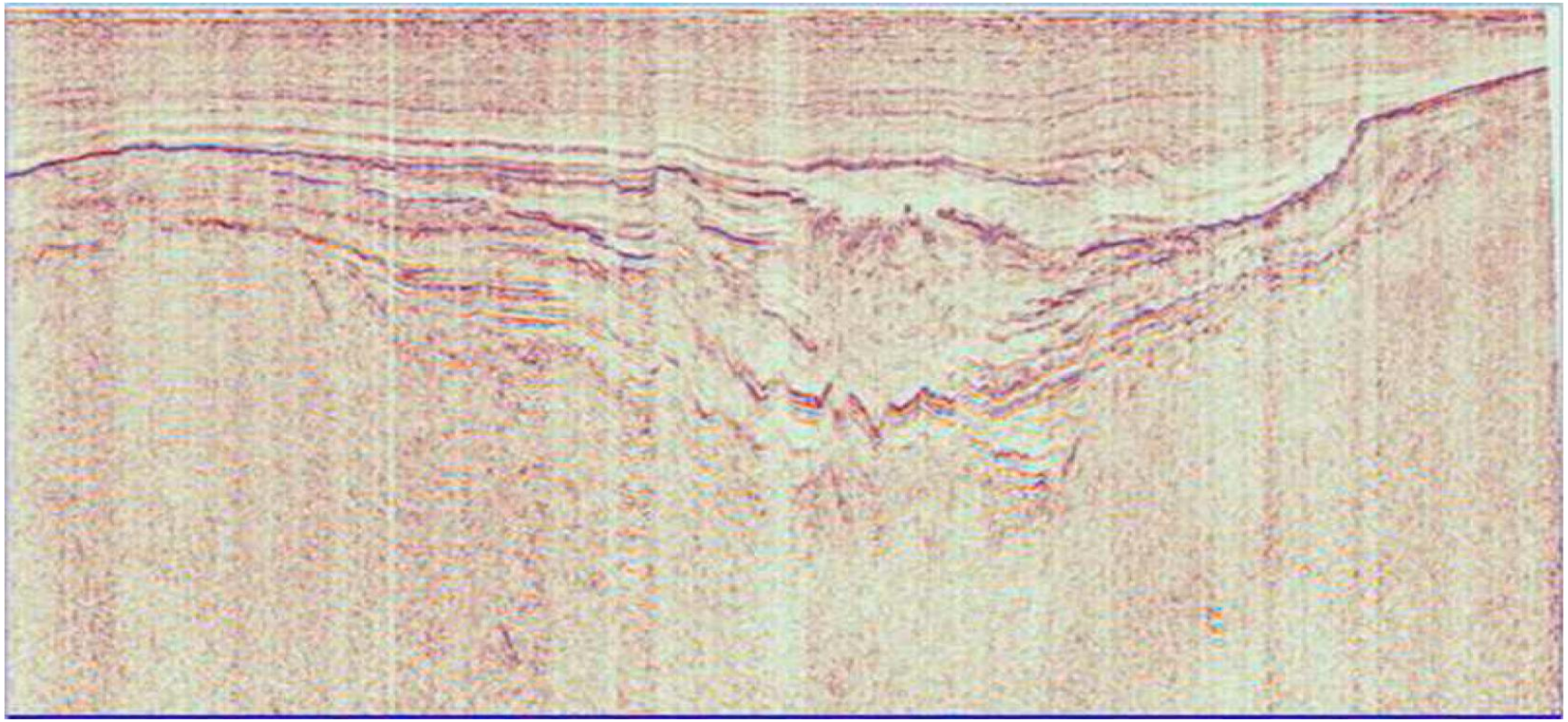

Figure 6. Seismic profile across Kaladgi – Bhima depression.

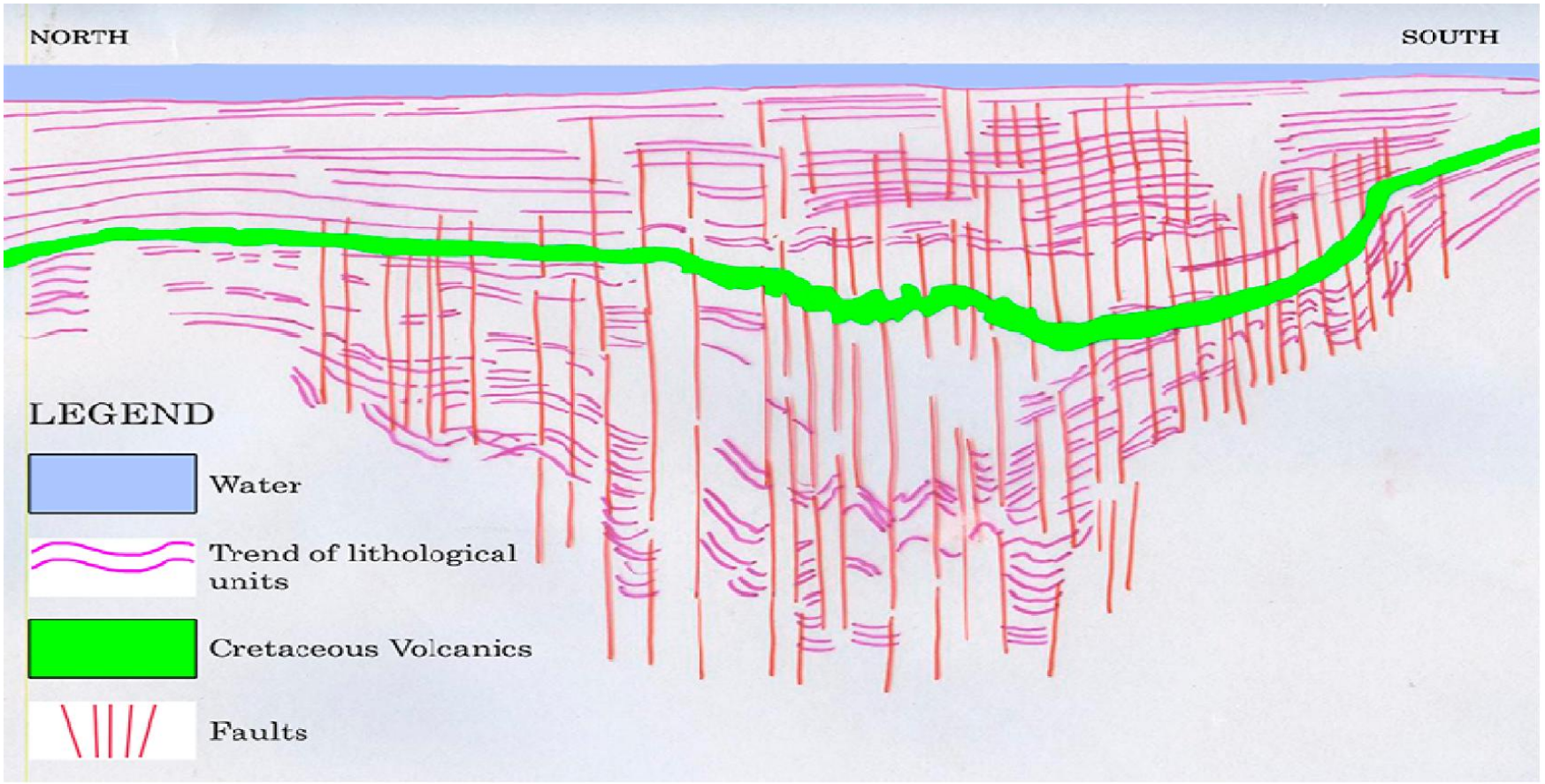

Figure 7. Interpretation of seismic profile across Kaladgi – Bhima depression.

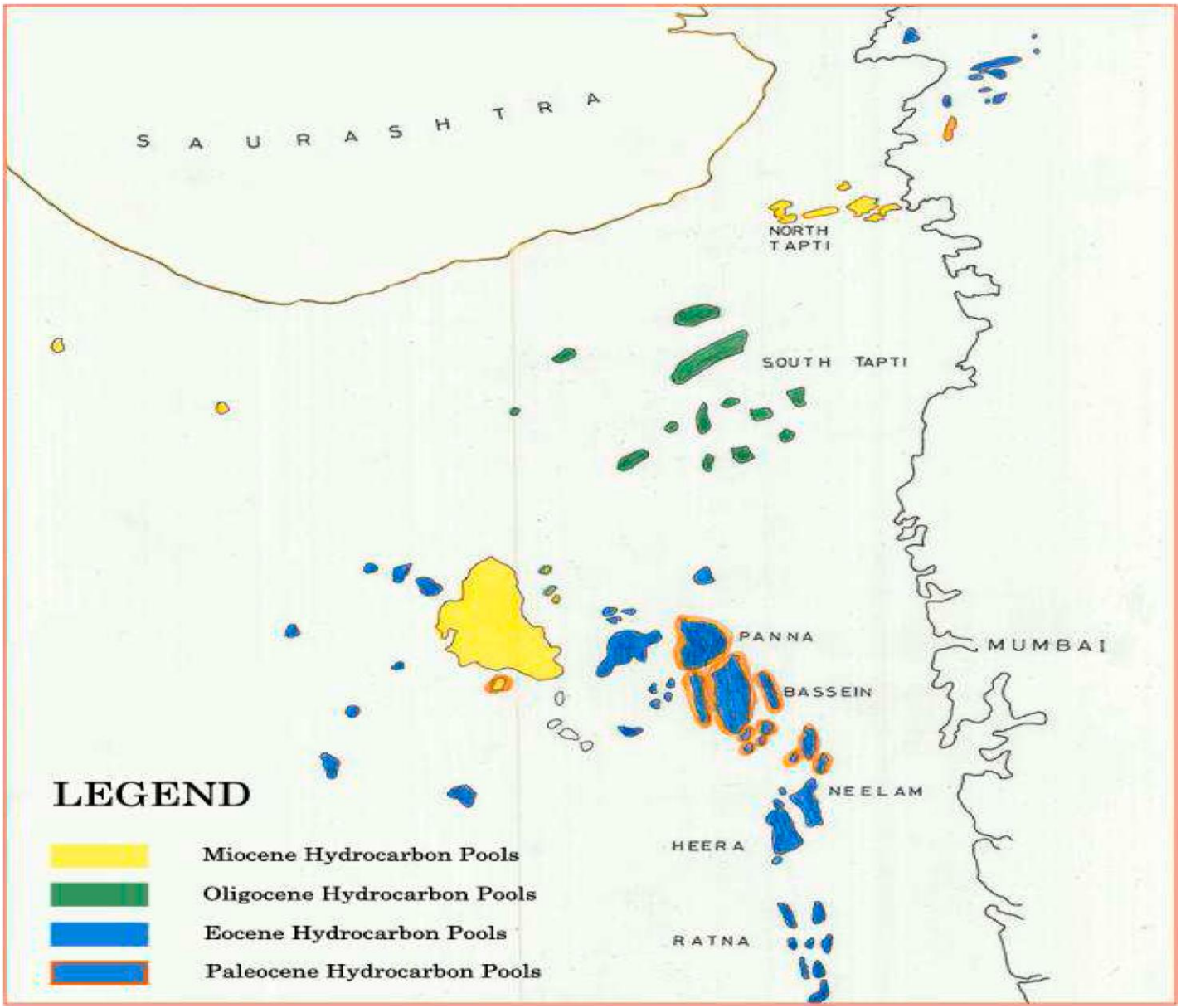

Figure 8. Outline map of western offshore of India showing disposition of hydrocarbon pools in different geological time and varied processes leading to preferential accumulation.