CHAPTER 9
CONCLUSIONS

The focus of the present study was on understanding the morphology and development of fault scarps along the Kachchh Mainland Fault in the Kachchh basin. The key objectives of the present study were achieved through critical analysis on available literature, extensive field mapping, quantitative terrain analysis with available SRTM digital elevation data, cosmogenic surface exposure dating using ^{10}Be isotope and detailed analysis of major north flowing drainages in the fault zone, with special emphasis on rivers originating from scarps.

The major findings of the present study are as follows.

1. The fault scarps along the KMF ranges in height between 6 to 190 m. Height of the scarp is considered as direct evidence for throw of the fault. However, in the case of KMF there exist no direct linkage between the throw and the scarp height. The present landform is a product of different episodes of tectonic uplift and denudation. However, a notable variation in scarp height along the different segments of the KMF indicates along strike variation in the tectonic uplift in the segments of the KMF.
2. The morphology of the present fault scarps along the KMF do not address the geometry of the fault. The scarps along KMF are highly eroded such that it lost the original fault characteristics. The present scarp angle is an indication of the severity of denudation and erosion to which the landform has undergone. However, the fault scarp in the eastern side of the Jhuran anticline have preserved fault plane and is near vertical with a scarp slope angle of 85 degree. Therefore, scarp outcropping at the eastern flank of the Jhuran anticline could be considered as an analogue of the initial scarp morphology along KMF.
3. The scarps along the KMF have variably retreated along the segments of the KMF. Scarps along KMF have suffered higher amount of retreat at the center of the domes than at the tips. The available evidences from the scarps suggest that the amount of retreat is not fully controlled by tectonic influence. Lithology has a secondary role in the retreat of scarp along the KMF other than tectonics.
4. In-depth field investigations and morphological studies carried out in the scarps along the KMF reveal that they can be included in two different types based on their morphological

characteristics- 1) Residual range front normal scarp, 2) Simple range front normal scarp. Most of the scarps along the KMF do not coincide with the present active fault trace. Furthermore, no trace of the original scarp or faulting remains persevered other than the ragged morphology. Considering all these characteristics of the scarps, it could be included in the category of residual range front normal scarp. The second category of the scarp is characterized by preserved or exposed fault plane and is coincident with the fault line. Therefore, the scarp could be included in the category of simple range front normal scarp. The scarp outcropping in the vicinity of Jhuran anticline is an example of simple range front normal fault scarp.

5. Considering the known facts and events in the Late Quaternary it can be elucidated that the two major events of heightened tectonic activity along the KMF resulted in the gravitational collapse of the scarp and adjoining landscape. These phases are characterized by maximum scarp degradation along the KMF. During periods of the lower tectonic events following the heightened event, the fluvial erosion dominates in the landscape. The rivers eroded the landscape to cope up with the disturbances produced in the previous event. The dominant fluvial erosion of the landscape continues till the next phase of the heightened tectonic event.
6. The north flowing rivers of the Jara-Jumara sector of western Kachchh show variable responses due to the differential tectonic uplift in the Jara and Jumara domes. The higher net uplift occurred in the Jumara dome during the Cenozoic. The higher uplift and fluvial erosion led the rivers in overcoming the structural control in the landscape and carving the present landscape along the Jumara dome in the western KMF.
7. The drainage analysis on the Jara-Jumara sector also indicates that the major rivers flowing through the region have not attained equilibrium. While the river flowing through the inter-domal saddle zone between the Jara and Jumara dome have balanced the uplift and erosion reflected from the equilibrium Hack profile. The balance in uplift and erosion led to the lateral retreat of JMS and creation of more straight segment of scarp in the saddle zone. Additionally, the L-shaped nature of the river originating from the Jaramara Scarp face suggests that the zone of erosion is concentrated in the upper middle portion of the river or in the scarp face. This indicates that rivers originating from the scarp face of Jaramara have a major role in the present morphology and recession of the JMS.

8. Calculated morphometric indices suggest that the long term erosion of the present landscape is also controlled by lithology other than tectonics. The hard sandstone unit of upper Jhuran Formation exposed at the top of the Jaramara Scarp is resistant to erosion. The episodic tectonic activity led to the uplift of the landscape with growth of relief and promotes headward erosion of the streams. At the same time the lithological resistance led to more parallel retreat of the scarp face. The resistant sandstone unit coupled with higher uplift along the Jumara dome favored development and preservation Jaramara Scarp along the Jumara dome.
9. The morphometric indices calculated for the eastern KMF suggest that segments of eastern KMF are in different geomorphic stages of development. The segment I and II with higher tectonic uplift have gone through longer periods of erosion and uplift when compared with segment III, IV and V. On a long-term scale, the spatial and temporal changes in the tectonic activity coupled with the lithological resistance of upper Jhuran exposed at the top of the scarp led to preservation of the present Kas Hill Scarp along eastern KMF.
10. The cosmogenic exposure dating is a useful geomorphic tool for calculating the age of landforms. The lithology and landforms in Kachchh basin are suitable for cosmogenic exposure dating. The exposure ages estimated from the scarp face suggest that a major tectonic event occurred in the KMF during the Late Quaternary period, more precisely during the Mid Pleistocene period. The elevated tectonic uplift along the KMF during the Mid Pleistocene period led to the development scarp along the easternmost segments of the KMF. The event can be related to the youngest scarp forming event along the KMF.
11. The exposure age from the Mesozoic sandstone exposed in the Jara River gorge suggests that intense fluvial erosion and gorge formation occurred in the landscape in the later part of Pliocene. The exposure age also confirms the tectonic reactivation and uplift induced erosion during the Late Pliocene and Early Pleistocene periods along NHRFZ that resulted in the commencement of gorge formation along Jara River. The continued phases of reactivation of the KMF during the later part of Pleistocene and Holocene resulted in the tectonically induced erosion and deepening of the gorge in the region. Overall, it can be summarized in all possibility that the KMF was active during the Quaternary period.

12. With the data generated form the present work and data from available literature, a simplified model of scarp development along the KMF is proposed. As per the model, the major geomorphic events are as follows-
    a) Deccan volcanism and doming of the marginal fault zone resulted in enhanced vertical movements and formation of scarp with significant relief along KMF.
    b) Initiation of drainages over the scarp face in the steep northern limp of the anticline. The scarp faces become the new erosional axes of the topography.
    c) The multiple phases of uplift and erosion occurred during Paleocene to Miocene periods resulted in the enhanced fluvial erosion, gravitational collapse and retreat of the scarp along the KMF. The higher uplift and inversion of stress in the basin resulted the formation of new scarp close to the KMF.
    d) The Burdigalian high sea advanced to the inland areas and inundated the basin during the Early Miocene period. The presence of younger scarp close to KMF zone prevented the high sea from invading the inland areas.
    e) The elevated Post-Miocene uplift and erosion led to further recession of the scarps along the KMF by fluvial erosion and gravitational collapse.
    f) Lateral propagation of the KMF during Mid Pleistocene period led to the formation of the youngest scarp along the eastern side of the KMF. The Mid Pleistocene uplift along KMF also enhanced the gravity collapse and lateral retreat of scarps in the other segments of the KMF.
    g) The continued fluvial erosion, gravitation collapse and enhanced gullying activity till the recent time further retreated the scarps to the present position.