CHAPTER 3

GEOMORPHOLOGY OF THE STUDY AREA

The study area as shown in figure 1.1 as inserted rectangular windows, lies in southern Kachchh between latitude 22°.50'-23°.15'N and longitude 69.10°-69.50°, occupying an average area of 1000 sq km. The four windows which were studied extensively due to its conspicuous occurrences of the miliolites are described further as Kotda-Roha Area (KA) Fakirwadi Area (FA), Gangeswar Area (GA) and Varli Area (VA) in this chapter for its geomorphology and local geological set up with a summary of the available understanding on the Quaternary sequences. Figure 3.1 shows the locations of the sites investigated in detail with reference to the overall physiography and major drainage network in Kachchh. Major structural lineaments i.e. faults are also shown in this map.

Geomorphology of Katrol Hill Range (KHR)

The scarp associated with Katrol Hill Range (KHR) is further divisible into two main geomorphic domains North Katrol Hill Fault (NKHF) scarp and South Katrol Hill Fault (SKHF) scarp (Fig.3.2). SKHF is a younger and relatively smaller scarp, located about 15–20 km south of the NKHF and is a splay of the main KHF (Patidar et al., 2007; Das et. al., 2016b). These physiographic highs characteristically show deeply incised areas manifesting a strong control of the tectonic elements in base level adjustments by the local seasonal rivers.

Based on the landform characteristics and altitudinal variability, geomorphic units of study area can be categorized into three broad major E-W structural lineaments trending zones (Fig. 3.3). These, from north to south, are (i) the structural origin highly dissected hills and valley of Katrol Hill Range (KHR) which rises to an elevation of 150-445m amsl includes North Katrol Hill Range (NKHR) and (ii) Moderately dissected hills and valley of central rocky plain (100-150m amsl) also known as Southern Katrol Hill Range (SKHR) (iii) Lower denudation origin piedmont plain (debris slope), pediment and pediplain complex to south (<100 m amsl). The Quaternary sedimentation is seen in the valleys and the stream channels draining through the lower pediment plains.

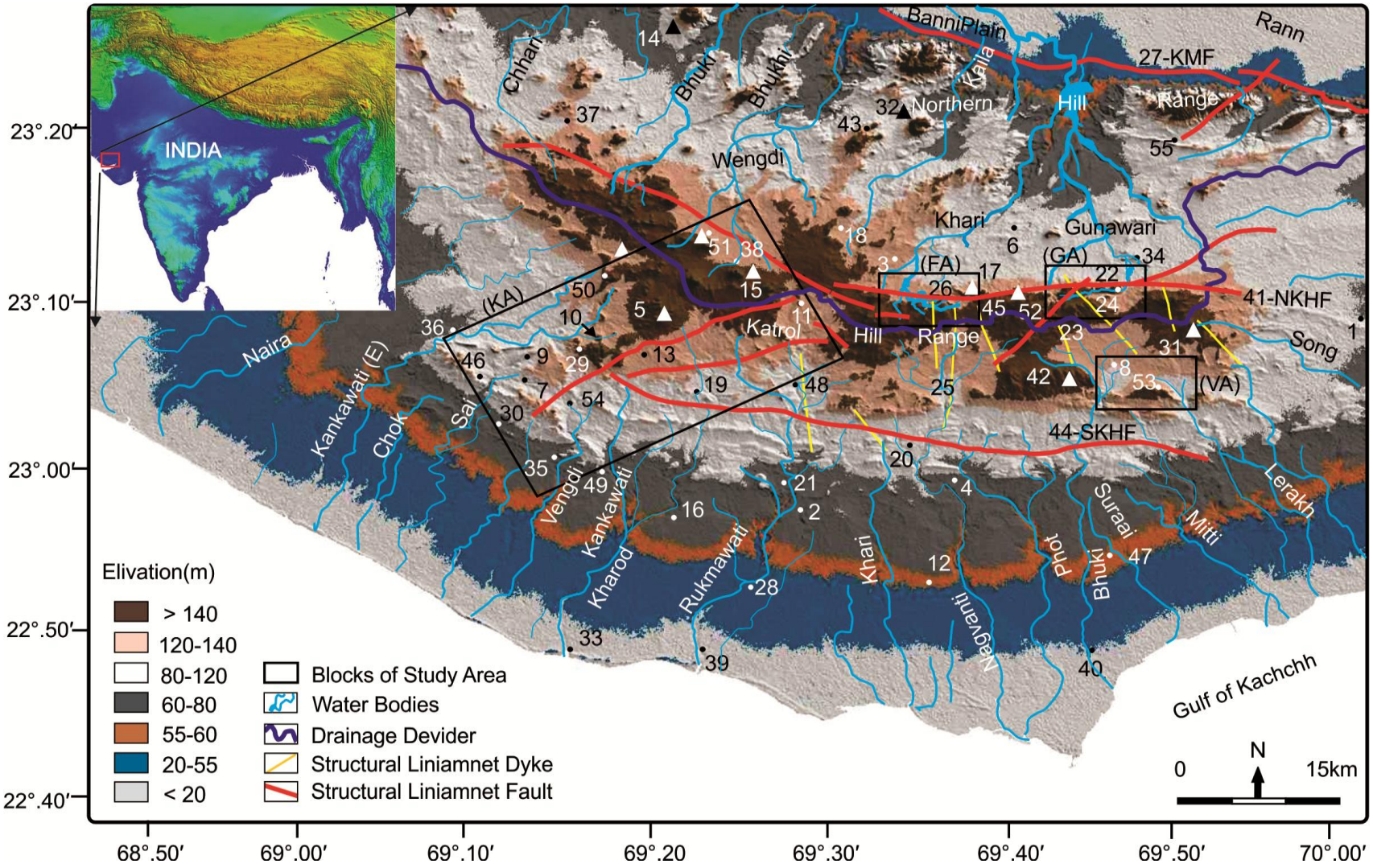

Fig. 3.1 Topographic-Structure Lineaments and Drainage Map, Kachchh. Rectangular area exposures were studied extensively namely Kotda area (KA) Fakirwadi area (FA), Gangeswar area (GA) and Varli area (VA).1. Anjar; 2. Asambia; 3. Bharasar; 4. Bharudia; 5. Bhopa Dunger 237m; 6. Bhuj; 7. Boha; 8. Chakar; 9. Chiyasar; 10. Conical Hill 281m 11. Desaplar (south); 12. Desaplar; 13. Devpur; 14. Dhinordhar Hill 358m; 15. Dhribiyo Dunger 348m; 16. Don; 17. Fakirwadi Hill 258m; 18. Fotdi; 19. Gadhsisa; 20 Gajod; 21. Gangaji; 22. Gangeswar Dome 225m; 23.Gunawari Tributary; 24.Gunawari Southern Plain; 25. Kera; 26. Khari Tributary; 27.KMF-Kachchh Mainland Fault; 28. Koday; 29. Kotda; 30. Kotdi; 31. Katrol Hill 349m; 32. Jhura Hill 344m; 33. Layza; 34. Ler Dam; 35. Nagrecha; 36. Naredi; 37 Nakhtrana; 38 Madhapar; 39. Mandvi; 40. Mudra; 41. NKHF-North Katrol Hill Fault; 42. Marutonk Dome 263m; 43. Sumarasara; 44. SKHF-South Katrol Hill Fault; 45. Satpura Dunger-250m; 46.Raydhanjar; 47. Ratadiya; 48.Ramapar Wakra; 49.Ratiya Nana; 50. Roha-Roha fort-Trappean Hill,266m; 51.Varamsida- Nana Dunger 433m-Trappean Hill; 52.Tapkeswari 255m; 53.Varli,160m; 54.Poladiya; 55. Zikdi.(Source-1LIS III Data, ISRO, GSI and National Geomorphological and lineament Mapping).

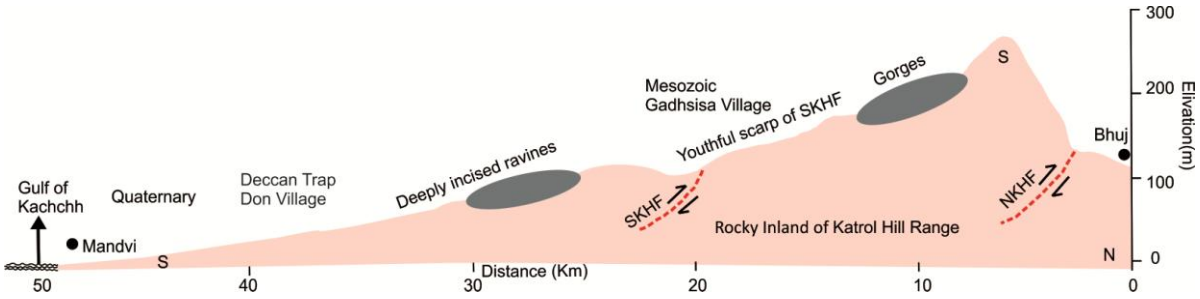

Fig 3.2 Schematic diagram showing tectonic configuration of tilt block structure of Southern Kachchh Mainland along with Tectonogeomorphic features. (After Das et al., 2016b)

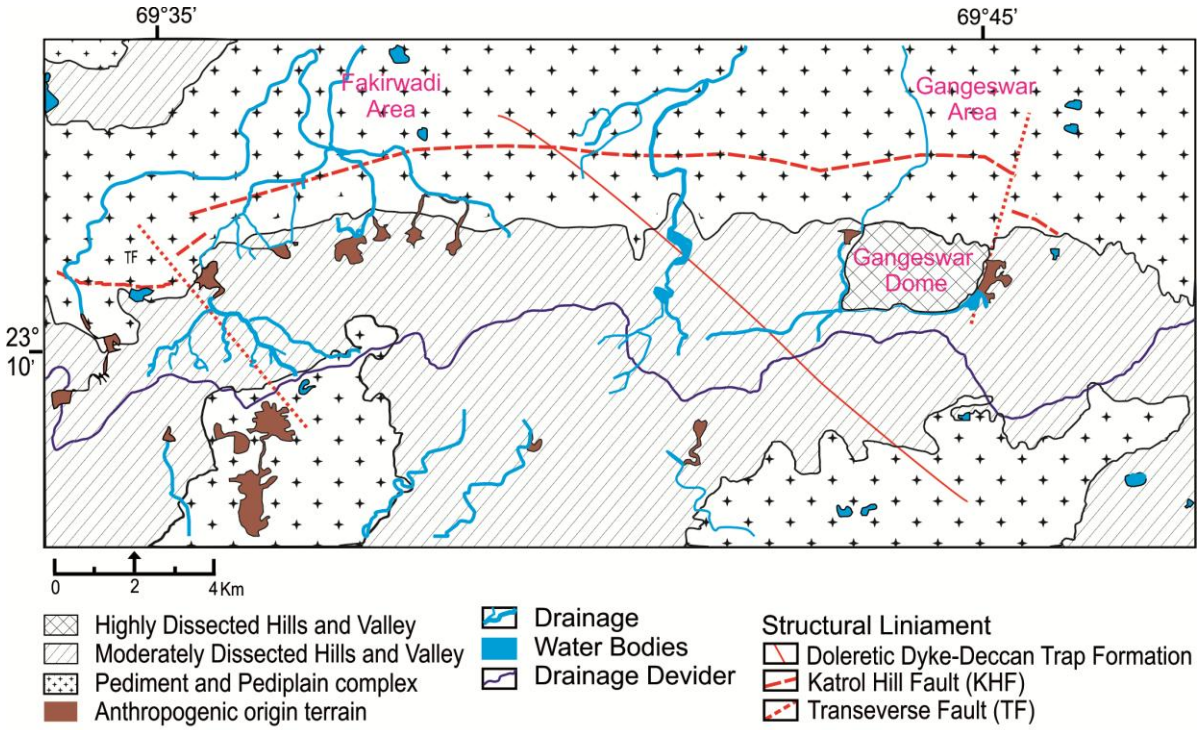

Fig 3.3 Geomorphology of study area Katrol Hill Range (KHR). Source-1LIS III Data, ISRO, GSI and National Geomorphological and lineament Mapping.

Digital Elevation Model (DEM) of Katrol Hill Range (KHR)

Digital Elevation Model (DEM) of the study area of KHR shows depression and domal structures of south dipping Mesozoic rocks, forming East-West trending valley structures (Fig. 3.4). DEM clearly shows contrast between northern side of the KHF and rugged topography to the south of the fault (KHF). There are several domes and structural lineament clearly marked on the DEM. The presence of a narrow zone of domal structures to the south of KHF is a significant feature of the KHR with Dhola and Satpura Dunger. Prominent domes are the Khatrod hill, Jogi Timba, Gangeswar dome, Fakir wadi dome and Marutonk dome (Thakkar et al., 1999).

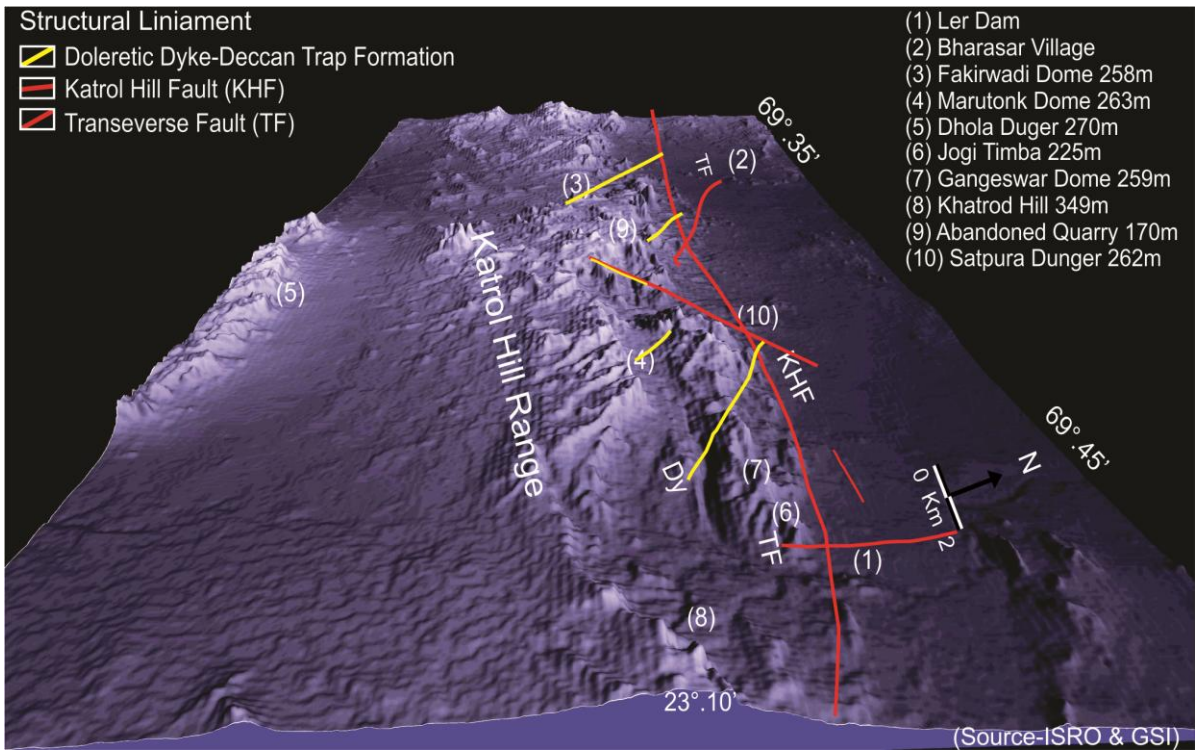

Fig 3.4 Digital Elevations Model of study area showing depression and domal structures of south dipping Mesozoics, forming East-West trending gorge and valley structures. Also contrast between North of the KHF and rugged topography to the South of the KHF can be seen.

The northern limbs of the domes occurring to the south are truncated by the KHF. The southern limbs of the domes are gently inclined, as little as 5-10° towards south while the northern limb is steeply dipping towards the north or is vertical. Some of these domes contain several N-S trending dykes and plugs with occasional sills in their central part. The sandstones of Bhuj Formation to the north of the KHF show broad open E-W trending anticlinal and synclinal folds. To the south, the various Mesozoic Formations dip southwards and are overlain by the late Cretaceous Deccan Trap basaltic flows, Tertiary rocks and Quaternary sediments extending up to the coastline of Gulf of Kachchh. The Quaternary deposits fill the structural valleys within the KHR and cover rocky pediments in the foot hills (Patidar et al., 2007, 2008).

Drainage characteristics of Katrol Hill Range (KHR)

Geographically, Kachchh peninsula is situated in the western most part of India, fringed by the Arabian Sea to its west and Gulf of Kachchh to its south. The east-west running Katrol Hill Range (KHR) acts as a major drainage divider for north and south flowing streams (Fig. 3.5; Maurya et al., 2003a, 2003b; Das and et al., 2017).

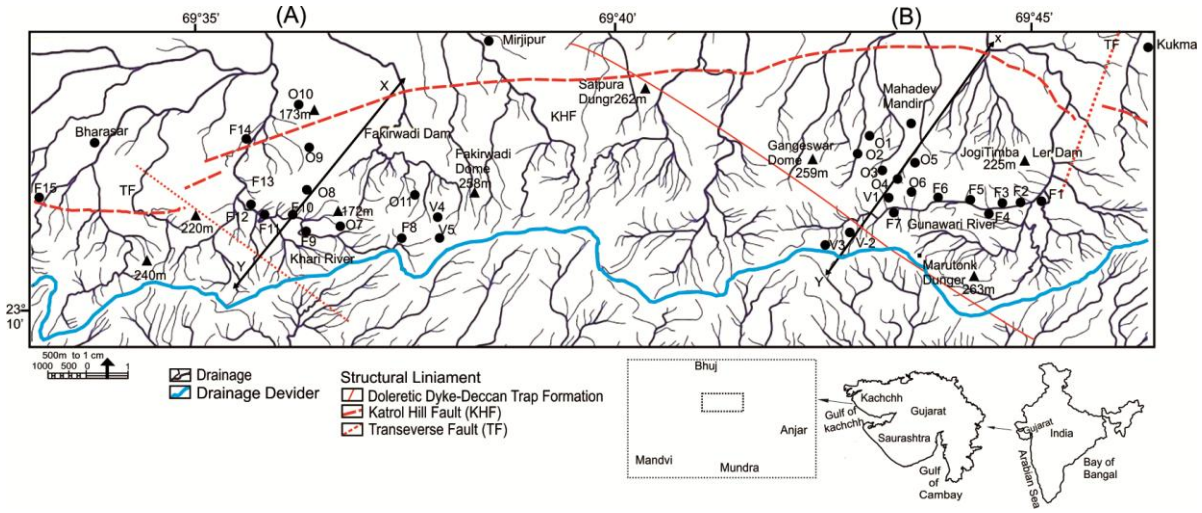

Fig 3.5 Katrol Hill drainage map. (A) Fakirwadi area-Khari river, (B) Gangeswar area-Gunawari river.

The geomorphic configuration and the drainage network of the Kachchh mainland are controlled by the E–W trending KHF along KHR is dividing uplift in to two south tilting blocks namely NHR and KHR in KMU by main faults viz, KMF & KHF. The surface expression of the KHF is manifested in the form of the north facing steep escarpment (Thakkar et al., 1999). According to Biswas (1974), tectonic activity along the KHF was responsible for the development of the cyclic plantation surfaces in the southern Kachchh and the present day rivers flow on the early Quaternary surface.

In the mainland the KHR forms the main drainage divide between the north and south-flowing drainages shows a dense network of streams that is in contrast to the hyper-arid climate of the region (Fig 3.1). The present ephemeral rivers appear to be in an erosional phase, as evidenced by their deeply incised courses that expose Mesozoic rocks with very thin and scattered recent channel deposits (Patidar et al., 2007, 2008).Vertically incised sections and deflection in the lower-order drainages within the vicinity of fault suggests neotectonic activity along the KHF (Maurya et. al., 2017). These rivers in the vicinity of the KHF have incised deep gorges along with the development of knick points indicating continued tectonic activity during the Holocene (Thakkar et al.,1999; Bhattacharya et al., 2013).

Drainage characteristics of North Katrol Hill Fault (NKHF) and South Katrol Hill Fault (SKHF)

KHF is the major tectonic structure in the study area, which is geomorphologically expressed as a linear scarp and acts as a drainage divide for the fluvial systems of Kachchh mainland, as several north flowing rivers originate from it to eventually cut through NHR and debouch in the Banni Plains and Great Rann of Kachchh forming alluvial fans and the south flowing rivers originate from it and cut through the SKHF and debouch in the Gulf of Kachchh (Fig 3.1) Further, the area is traversed by lineaments, anticlines, and domes (Thakkar et al., 1999, Maurya et al., 2003b, Patidar et al., 2007, Bhattacharya et al., 2014, Das et al., 2016a).

North Katrol Hill Fault (NKHF) is drainage divider for rivers which flows either south to north or north to south direction, while South Katrol Hill Fault (SKHF) provide natural drainage barrier. At this point tributaries of rivers making a junction point and gives opportunity to built a dams on rivers Sai, Vengdi, Khandkawali, Rukmavati, Des, Bhuki and Mitti (Fig.3.1). All tributaries abruptly change their river course due to the SKHF and pass through lower altitude of SKHF range and debouched in Gulf of Kachchh.

North-flowing Rivers

The Pur, Pat and Khari are the major North-flowing rivers that originates within the mountainous terrain of the KHR and subsequently flows across the KHF, the rocky plain, the Northern Hill Range and the KMF before dying out in the Banni-Rann plains through three major breaches that have been formed by the northward flowing Khari River, Pat River and Gunawari River. In general, the KHR shows a dense network of streams that is in contrast to the hyper-arid climate of the region due to early tectonic upliftment alters the topography and geomorphology of an area and hence if a dense net work of stream happens to flow (Patidar et al. 2007). Further neotectonic upliftment along KHF during the Holocene has incised deep gorges and development of knick points (Thakkar et al., 1999; Bhattacharya et al., 2013).

South-flowing Rivers

The south-flowing rivers drain a major part of the KHR and flow along the tectonic slopes incise through a narrow coastal alluvial plain comprising of late Quaternary deposits before draining

into the sea to meet the Gulf of Kachchh. The Rukmavati, the Kharod, the Nagwanti, the Phot and the Bhukhi are the major consequent rivers flowing towards the south (Fig. 3.1; Patidar et. al., 2007; Maurya et al., 2003; Das et.al. 2016b).

Katrol dome exist in eastern side from where the prominent hill range starts and extend westward up to Naira River. Katrol Hill Range (KHR) hosts Late Quaternary sediments in the form of colluvium, fluvial gravels and carbonate sand (miliolite). The Katrol Hill Fault (KHF) is one of the most significant faults in Kachchh, which show several evidences of active tectonics during the Quaternary time (Sohoni and Karanth, 2003; Thakkar and Goyal, 2004; Patidar et al., 2008 and 2007; Chauhan et al., 2016).

Geomorphology and Drainage characteristics of Kotda Roha Area (KA)

The Kotda-Roha area located 43 km WSW of Bhuj city dominantly comprises of obstacle deposits and valley fill sheet miliolites, resting over Deccan Trap basalt. Physiographically, the trap hill ranges shows a WNW-ESE trend and varies from 1.5 to 4 km in width with altitude between 90m to more than 433m amsl. The southwestern area of Kachchh supports a number of rain gullies and rivers.

Based on the landform characteristics and altitudinal variability, geomorphic units of study area can be categorized into three broad major WNW-ESE structural lineaments trending zones. These are (i) the structural origin highly dissected hills and valley of rocky plain of western extent of KHR which rises to an elevation of 90-433m of Kotda area (ii) Moderately dissected hills and valley which rises to an elevation of 150-266 m includes (iii) Lower denudation origin piedmont plain (debris slope), pediment and pediplain complex to south (<90m) along with some anthropogenic activity and water bodies (Fig. 3.6). The southern slopes of the range support a number of rain gullies and Rivers like Kankawati Rivers 3rd order Ckock Nadi, Sai,Vengdi and Kharod Rivers.The Kotda area lies in between Naira and Kharod River both south flowing -existing from KHR passing through KHF, pediment and pediplain complex to south debouching in Gulf of Kachchh. One striking features in Kotda area is pediplain complex and well developed fluvial alluvial plain (Fig. 3.6).

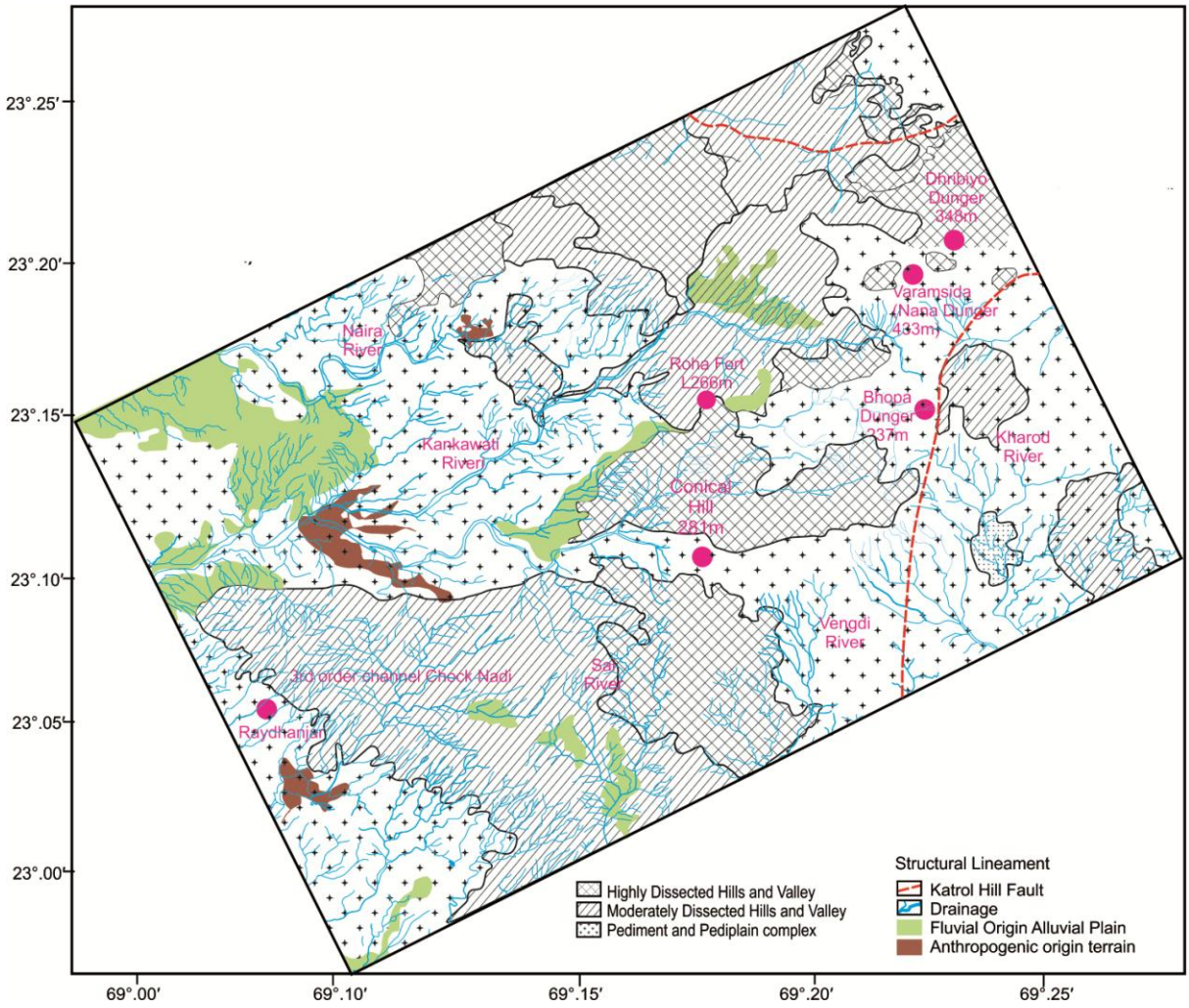

Fig. 3.6 Geomorphology of Kotda Area. Source-1LIS III Data, ISRO, GSI and National Geomorphological and Lineament Mapping.

Geomorphology and Drainage characteristics of Varli Area (VA)

The Varli area (VR) situated on the southern part of the KHR that lies between latitudes 23°.00' to 23°.10'N and longitudes 69°.30' to 69°.70'E, about ~15–20 km south of the Gangeswar area, occupying a 15 to 20 km E-W trend hill range about 160 to260m high picks associated with South Katrol Hill Fault (SKHF).

Based on the landform characteristics and altitudinal variability, geomorphic units of study area can be categorized into three broad major E-W structural lineaments trending zones. These are (i) the structural origin highly dissected hills and valley of rocky plain also known as Southern Katrol Hill Range (SKHR) of KHR which rises to an elevation of 160-266 m in Varli area covering with (ii) Moderately dissected hills and valley which rises to an elevation of 150-445 m

includes (iii) Lower denudation origin piedmont plain (debris slope), pediment and pediplain complex to south (Fig. 3.7). The Varli area lies in-between Bhuki and Larek River both south flowing -existing from Katrol Hill Range passing through SKHF, pediment and pediplain complex to south debouching in Gulf of Kachchh.

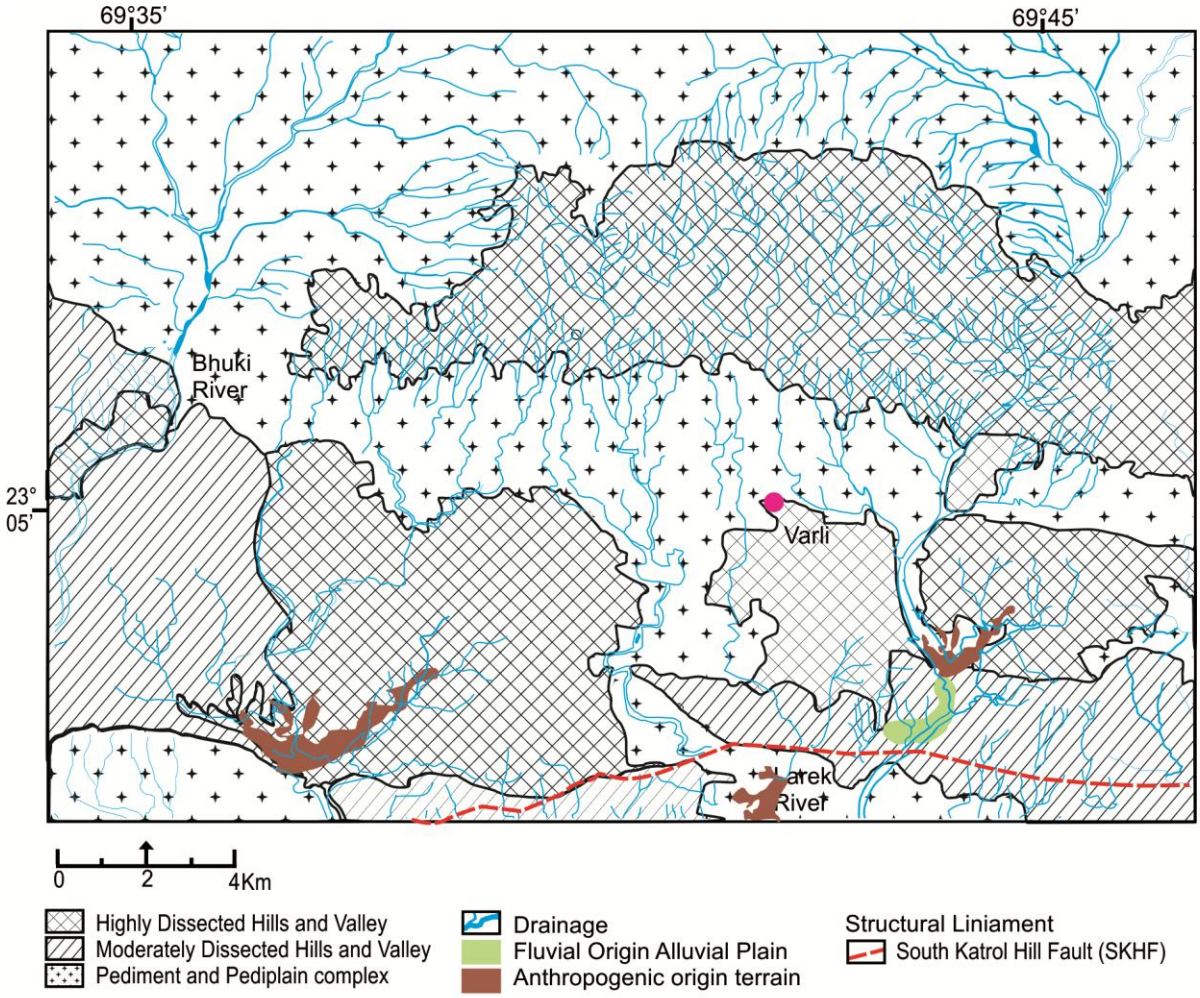

Fig. 3.7 Geomorphology of Varli Area (VA). Source-1LIS III Data, ISRO, GSI and National Geomorphological and Lineament Mapping.

Geological set up of the study area

The Katrol Hill Range (KHR) constitutes a conspicuous physiographic high which is formed due to the tectonic uplift along Katrol Hill Fault (KHF) situated south of the Bhuj. Major rock mass of this is composed of the shale and sandstones of Jhuran and Bhuj Formations of Jurro-Cretaceous age with thin patchy occurrences of the Miliolite limestone of Middle to Late Pleistocene age.

Katrol dome exist in eastern side from where the prominent hill range starts and extend westward up to Naira River. KHR hosts Late Quaternary sediments in the form of colluvium, fluvial gravels and carbonate sand (miliolite). The KHF is one of the most significant faults in Kachchh, which show several evidences of active tectonics during the Quaternary time (Sohoni and Karanth, 2003; Thakkar and Goyal, 2004; Patidar et al., 2008 & 2007; Chauhan et al., 2016). In the Gangeshwar dome along the northern side of the Katrol Hill scarp, patches of shale belonging to the Jumara Formation were encountered. This is the oldest unit in the study area that contains ammonite fossils. On its northern side the Bhuj Formation sandstone abuts against the KHF indicating the up thrown nature of the southern side which largely exposes shale and sandstone of the Jhuran Formation.

The KHF is 75 km long, on surface it is expressed as steep north facing scarp in the KHR, located in the central part of the mainland Kachchh Basin and exhibits a rugged mountainous landscape that exposes well-lithified rocks (sandstones, limestones and shales) of Mesozoic age.

Kachchh peninsula as a whole and the southern Kachchh, in particular, are seismically one of the most active regions in India after Himalaya (Biswas, 2005a and b, Patidar et al., 2007, Rastogi et al., 2012). The geomorphic setup of Kachchh indicates a strong structural control on the landscape evolution owing to the presence of several E-W trending faults (Chamyal et al. 2003, Das et al. 2016a). Within the KHR, the various peneplanation surfaces show southward tilting, which suggests episodic unidirectional movements along the KHF after the eruption of the Deccan Trap lava flows. The southward tilt of the planation surfaces and southward dips of the Mesozoic and Tertiary rocks indicate that the southern part of the mainland Kachchh Basin represents a tilt block, delimited by the KHF to the north and the North Kathiawar Fault (NKF) to the south (Fig. 1.2; Biswas, 1974; Biswas and Khattri, 2002; Maurya et. al. 2017). The present understanding on the Quaternary stratigraphy and major events associated with the sedimentary facies in the Katrol Hill Range (KHR) area which clearly signifies the bases and need of the present study.