CHAPTER - 4

STRUCTURAL SET UP

The structural history of the Khari river basin of Central Kachchh Highland is very interesting. Apart from the regional structures of Mainland Kachchh, the basin exhibits other local structural features of significance like faults, folds, domes, anticlines, synclines and dykes indicating that the area has a complex structural setting (Fig.4.1). The continued seismic activity in the area suggests that the area has not yet attained tectonic stability. The morphology of the area is very well conformable with the structure and lithology. Domes and anticlines usually stand out as areas with positive relief while synclines form valleys. Highly resistant rock units for example, dykes

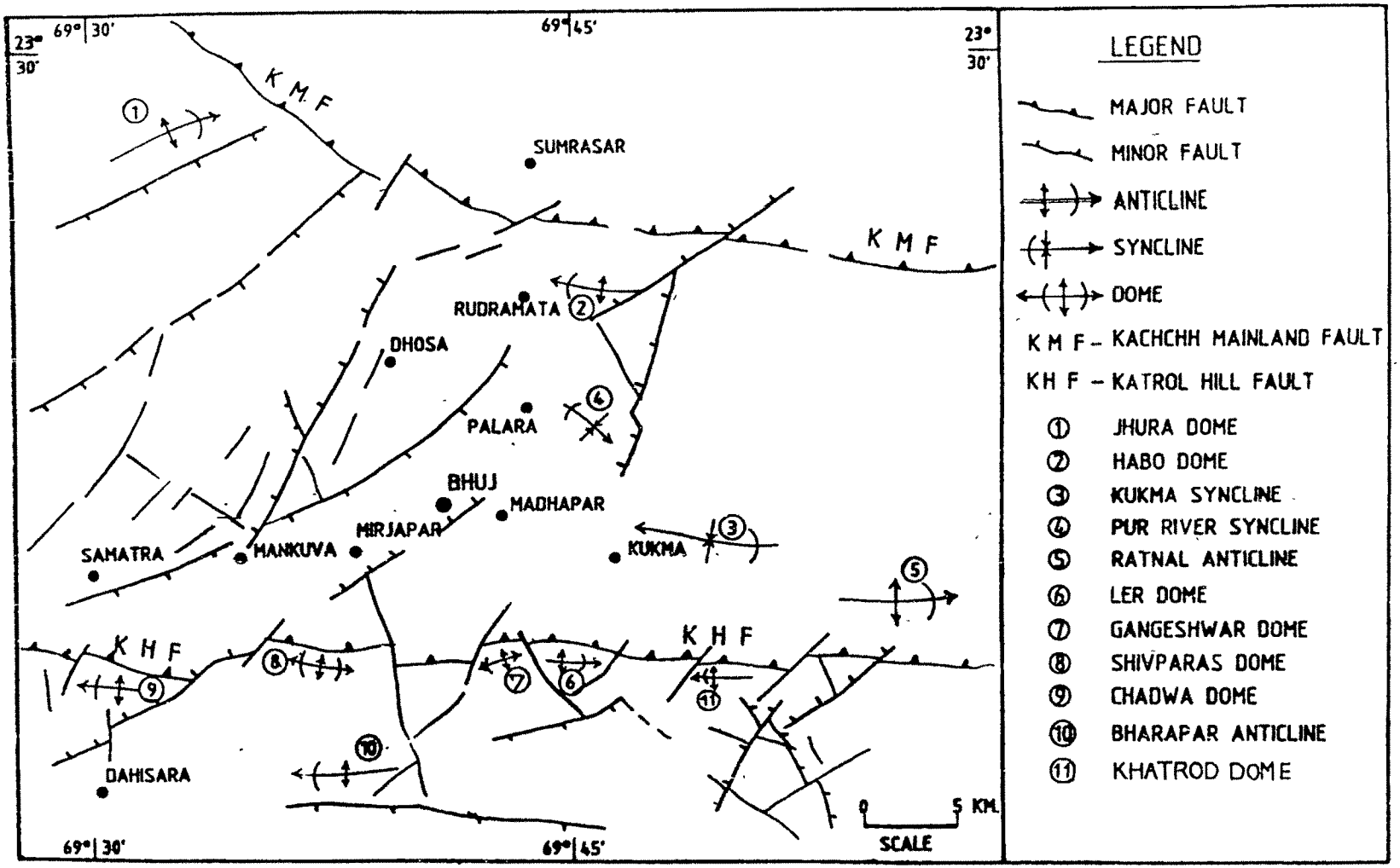

Fig. 4.1 Structural map of the study area.

also stand out amongst the surrounding area. Some of the scattered hills like Bhujiya hill and Kalitalawadi Hill are the results of basic intrusives in their core.

The structural features of the study area are broadly classified as under:

(1) Domes along the Mainland Fault,

(2) Domes along the Katrol Hill Fault,

(3) Flexures and folds,

(4) Transverse faults,

(5) Igneous Dykes.

DOMES ALONG THE MAINLAND FAULT

Significant features associated with the Kachchh Mainland Fault are half anticlines or domes (Fig.4.1). The fault marks the northern limit of Mainland Kachchh and trends in E-W to NW-SE direction. The Banni plains lie to the north of this fault. The major domes associated with this fault are 'Habo, Jhura, Keera, Nara, and Jumara . However only a part of the Jhura and Habo domes fall in the study area.

Jhura and Habo domes

Two of these domal uplifts Jhurio/Jhura (Plate 3.1) and Habo (Plate 1.2) are situated in the NE and NW of the study area respectively. Structurally the formation of the domes has influenced greatly on the geomorphology of the area. The streams traversing the Habo hills in N-S

direction are generally fracture controlled while a very few high order streams flowing in E-W direction are controlled by lithologic variations. Resembling the Habo dome, Jhura hills are also flanking at the Mainland fault; but here the fault trends NW-SE (Fig. 4.1).

DOMES ALONG THE KATROL HILL FAULT

The Katrol Hill Fault is comparatively smaller and runs for 64 km from Khatrod in the east to Roha in the west. The fault has greatly influenced the various river basins occurring to the north and south of the Katrol hill range. It becomes a drainage divide , the first order streams originating from the range flow onto the piedmont zone.

The Katrol Hill Fault is an almost E-W regional fault that has brought the older rocks in the south over the younger rocks to the north (Fig.4.1). The fault plane dips steeply (60-70°) towards south and shows hematitic nodules developed due to heat effect during the movements along the fault plane (Plate 4.1a). Near Hamadra lake reverse movement is seen along this fault (Plate 4.1b). The fault parallels the strike of the strata. Good sections of the fault zone are exposed in the area (Plate 4.2). The fault is somewhat sinuous rather than straight (Fig. 4.1).

Similar to the Kachchh Mainland Fault, Katrol Hill Fault also shows domes or half anticlines, but unlike those associated with Mainland Fault, here the extent of the domes are quite limited. The number of domes and flexures are more to the south than to the north of the Katrol Hill Fault (Plate 4.3). The northern limbs of the domes occurring to the south, are cut by the

Katrol Hill Fault. The southern limbs of the domes are gently inclined, as little as 10° towards south while the northern limb is steeply dipping towards the north or vertical (Plate 4.4). The northern limbs are overturned and showing steep dips due south at places (Plate 4.5). Some of these domes contain basic rocks in their central portions, N-S dykes and plugs with occasional sills. The eastern and western limits of the domes are marked by N-S transverse faults (Plate 4.6). In the central parts also the domes are extensively cut by these transverse faults.

In all five domes associated with the Katrol Hill Fault have been mapped. The domes are ideally seen in the areas around the Bhuj-Mundra and Bhuj-Mandvi roads. Some of the domal uplifts associated with the Katrol Hill Fault are as follows.

(1) Walakhawas / ShivParas dome,

(2) Chadwa dome,

(3) Ler dome,

(4) Gangeshwar dome,

(5) Khatrod Dome.

Walakhawas-ShivParas Dome

Walakhawas-ShivParas dome (Plate 4.7) is locally known as Lakki No Dungar. This dome has exposed rocks of older Jumara Formation in the form of elliptical inliers. Outcrops of this formation are seen on Bhuj-Mandvi road. The extension of this dome is not more than two kilometers. It is equally extended to the east and west of Bhuj-Mandvi road. The northern flank of the dome is exposed in NW of Bhuj-Mandvi road where the siltstones older than

Dhosa Oolite member of Jumara Formation is exposed near Walakhawas tank and is cut by a N-S transverse fault. The southern flank of the dome is characterised by Dhosa Oolite beds which are dipping 4-20° towards south. Doleritic type of intrusion overlying the Dhosa Oolite beds is reported from the core of this dome (Hardas, 1968).

Chadwa Dome

Chadwa dome is the largest of the domes associated with the Katrol Hill Fault (Plate 4.8).Occurring to the west of ShivParas dome between Samatra and Bharasar, it is an elliptical in shape elongated in E-W direction. Plug like masses of dolerite and four doleritic N-S trending dykes are noted within it. A large number of transverse faults cut the dome at places and displace the older rocks in the center (Hardas, 1968). Four such faults show major shifting of Dhosa oolite band. One big transverse fault cuts the dome into two halves. In the SW of Samatra this dome shows minor change in the dip as one traverses from north to south. The change continues for not more than two kilometers, which indicates minor flexuring in the manner of anticlines and synclines trending E-W occur near the Katrol Hill Fault. Further to the east of these low angle flexures they disappear suddenly and again appear a few meters south of these flexures that indicates shifting of these flexures due to the N-S transverse faults. To the west of this dome there occur two small domes exposing Jumara Formations in the center. Both collectively are extended for about 8 km.

Ler Dome

The Ler dome is situated in the eastern side of the Katrol Hill Fault about 14 km SE of Bhuj. It occurs as a quaquaversal unit of elliptical shape comprising rocks of Jumara Formation. The width of the ellipse is not uniform throughout, it gradually lessens to the east. Dip of the strata varies from 6° to 45° in the southern limb, while it is very high in the eastern part. The northern limb is somewhat separated by a fault running parallel to the Katrol Hill Fault.

In the vicinity of the Katrol Hill Fault hard, conglomeratic and nodular limestone of Jumara Formation is exposed. This limestone is shifted in N-S direction at a number of places, indicating the effect of transverse faults of later generation. Minor flexures in the older formation are observed 800 m SE of the Ler temple. At a number of places near the vicinity of the Katrol Hill Fault quartzites and hard, siliceous brecciated rocks are observed. Such beds are generally dipping with high angle due north. The dome is cut at places by later faults in the western and eastern parts. These faults are described as F2 and F3 faults by Agrawal and Pandya (1966). These faults have displaced the Katrol Hill Fault.

Gangeshwar dome

This dome occurs (Plate 4.3) a few kilometers west of Ler dome made up of similar quaquaversal outcrops of the oldest Jumara Formation. Northern limb of the dome is marked by 45°-60° northward dipping hard, nodular, conglomeratic limestone of Jumara Formation (Plate 4.9). In the vicinity of Katrol Hill Fault the oldest member of the Jumara Formation containing the

ammonites is exposed near Gangeshwar Mahadev. The southern limb however is marked by the valley exposing the shales of Jumara Formation.

A number of transverse faults of later generations offset the dome. One of the prominent later generation faults is Marutonk Dungar Fault, which displaces the Katrol Hill Fault and extends towards SE for about 10 kilometers (Plate 4.10). It trends NW-SE and makes a prominent fresh scarp at Marutonk Dungar. The steep triangular fans developed in the vicinity of the Marutonk Dungar Fault indicate neotectonic movements to have taken place in Recent times. Another distinctive fault near Satpura Dungar trending NE-SW displaces the Katrol Hill Fault. The effects of the NNE-SSW transverse faults are evidenced by the sudden ending of the conglomeratic hard limestone member of the Jumara Formation which abuts the younger shale member along the Gunawari river. The same conglomeratic limestone reappear to the SW of Marutonk Dungar Fault, that indicates the shifting on the dome by transverse faults. Apart from the N-S, NNE-SSW transverse faults the rocks are highly jointed in NE-SW and NW-SE direction (Plate 4.11).

Khatrod Dome

Khatrod dome occurs to the SE of village Kukma (Plate 4.4). It is made up of the rocks of Jumara and Jhuran Formations (mainly thinly bedded sandstones and shale).The southern limb of this dome dips gently (6 to 10°) towards south, while the northern limb is steeply dipping (45 to 70°) to north striking parallel to the Katrol Hill Fault.

FLEXURES AND FOLDS

In addition to domes, numerous anticlinal (Plate 4.12 a,b) and synclinal flexures are also present. The axis of the anticlinal and synclinal flexures trend in E-W direction (Fig.4.1). These flexures are a common feature in the vicinity of Katrol Hill Fault. Immediately to the south of the fault considerable drag effect is seen in the dips of the strata (Plate 4.13). The strata to the south show overfolding (Plate 4.14). Field evidences suggest that this folding and doming is related to the reverse movement along this fault plane. Fault breccias are rare but not absent.

About 6 km south of Bhuj there occur a cluster of hills around Tapkeshwari mandir in the vicinity of the Katrol Hill Fault. The rocks of Jhuran Formation are exposed near the fault and show low angle anticlines and synclines to the south of the fault. Two criss-crossing dykes to the NW of the Tapkadevi Mandir extend southward. Going further south, the rocks of Jhumara Formation show minor change in dip direction from south to north. Finally the northward dipping strata abut at Bharapar Fault running E-W for about 15 km. The structure therefore to the south of the Bharapar fault is a major syncline which is extended beyond the sanitarium on Bhuj-Mundra road.

A complex sheared zone is reported here in the vicinity of the Katrol Hill Fault and the later generation transverse faults. The yellow and buff coloured sandstones with grey shale in the sheared zone are inverted (Plate 4.15). To the NE of Ler dome and south of the Khatrod Hill and Kukma village there occur a gentle trough like structure known as Kukma syncline which is

Plate 4.1a Close-up view of hematite nodules developed along the fault pla ne of Katrol Hill fault due to the effect of heat during movement along the fault. (Loc. 2 km SE of Kukma village).

Plate 4.1b Photograph showing reverse movement in close vicinity of Katrol Hill fault. (Loc. Near Hamadra lake).

Plate 4.2 Photograph showing reverse movement in Jhuran shales in the vi cinity of the Katrol Hill Fault.

Plate 4.3 East facing view of the Katrol Hill Fault taken from Tapakadevi Mandir 6 km south of Bhuj. Note the lateral displacement of Katrol Hill Fault Scarp and the various domes to the south of the fault (K- Katrol Hill Fault, 1 Khatrod dome, 2 Ler dome, 3 Gangeshwar dome).

Plate 4.4 North facing view of Khatrod dome. Note the steeply dipping northern flank and the gently dipping southern flank. The northern face of the northern flank marks the Katrol Hill Fault.

Plate 4.5 Photograph of a minor flexure south of the Katrol Hill Fault. Note the steep southward dip of the overturned limb. (Loc. 8 km south of Bhuj on Bhuj-Mundra road).

Plate 4.6 Photograph of Khatrod dome truncating against a transverse fault in the east. The straight scarp in the background is the Katrol Hill Fault.

Plate 4.7 Distant view of Gangeshwar dome. The scarp in the foreground marks a N-S trending transverse fault.

Plate 4.8 Photograph of a part of Chadwa dome.

Plate 4.9 Photograph of the northward dipping northern flank of the Gangeshwar dome. The rocks belong to the Jumara Formation.

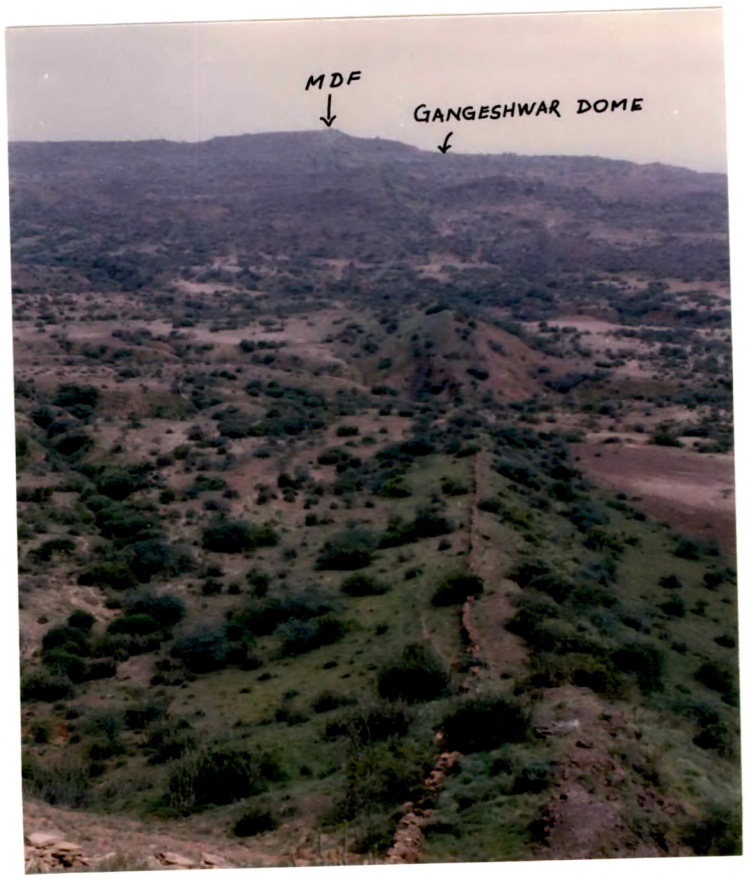

Plate 4.10 Northward view of Marutonk Dungar Fault truncating the Gangeshwar dome.

Plate 4.11 Complicated joint pattern produced by E-W and transverse faults (Loc. Near Chadwa dome).

Plate 4.12a Photograph of an anticlinal flexure south of Katrol Hill Fault (Loc.Near Hamadra lake).

Plate 4.12b E-W trending anticlinal flexure near Bharapar. Note the gently dipping southern limb and the almost vertical northern limb.

Plate 4.13 Photograph showing drag effect adjacent to Katrol Hill Fault (Loc. Near Hamadra lake).

Plate 4.14 Photograph of an anticlinal flexure near Bharapar. Note the overriding of the almost horizontal southern limb over the vertical northern limb along the fault pla nein the hinge portion.

Plate 4.15 Inverted yellow and buff coloured sandstones with grey shales in the sheared zone (Loc.Near Hamadra lake).

made up of rocks of Bhuj Formation. Northern and southern limbs of this syncline are dipping 2°-6° towards each other. In the middle part of this syncline occur rocks of Tertiary Vinjhan Formation.

The rocks of Jhuran Formation (chiefly gypseous shale and thinly bedded calcareous sandstone) exposed along the Pur river show minor open anticlinal and synclinal flexures.

South of Mankuva, the Bhuj sandstones form gentle E-W folds, a northern syncline and a southern anticline flatten out to the east and west. A major E-W flexure is recorded around Shedata village where it is flanked by several faults in the east, west and south. A small E-W flexure of about 500 m is seen south of Mankuva village immediately to the north of Katrol Fault.

Flexures are associated with the southern hills where younger formations are exposed. The beds here have sudden dip and become vertical or overturned and the other side is similar to the regional dip. It resembles the monoclinal structure or overturned folds. The flexure (Plate 4.14) near Bharapar is such an example, where southern, gently inclined or wavy limb is overriding the northern, vertical/ overturned limb along a small fault developed parallel to the axial plane and displaces the hinge of the flexure. The size of the flexure is very small but it represents the regional direction of the force that uplifted the Katrol hills. Such numerous flexures are seen parallel to the Katrol hill, especially where the first order streams are originated on the later land surfaces and running generally southward.

TRANSVERSE FAULTS

Apart from these structures a number of other transverse faults run NNW-SSE and NNE-SSW direction and cross the Katrol Hill Fault at places (Plate 4.16 a,b,c). The large transverse faults are a striking feature of the area. The various faults in the area trend in two major directions - the first along E-W to ENE-WSW and the second along NNE-SSW and NNW-SSE. The E-W trending faults are related to the regional E-W trending Katrol Hill Fault and the Kachchh Mainland Fault. The second transverse trend cuts across the regional E-W trend and thus seems to be younger. The various faults along this trend have displaced the Katrol Hill Fault and the Kachchh Mainland Fault. The fault planes (Plate 4. 16 a,b,c) are either vertical or steeply dipping (60 to 70°). In general, the fault planes dip towards the domes. The sense of movement is always dominantly lateral, both sinistral as well as dextral slips are noted. The lateral movement along these faults is very conspicuous in the field and is very significant. Effects of these faults are seen in the form of horizontal shifting of rocks and the E-W trending faults including the Katrol Hill Fault. In the vicinity of these faults the miliolites and the alluvial deposits are tilted and faulted (Plate 16,d,e). The Marutonk Dunger Fault is one of the major transverse faults running in NW-SE direction (Plate 4.17). Filled up with dolerite dyke (Plate 4.18) it extends from north of Roha Mota to south of Jamaywadi. A conspicous transverse fault striking 130-310° is seen to the north of Dharamsala cutting across the Bhuj rocks. To the west of Bharasar, a N-S transverse fault is recorded along the Bhuj rocks. This fault is truncated by another NE-SW fault in the

Plate 4.16a Photograph of N-S trending transverse fault to the west of Khatrod dome. Note the steeply dipping slickensided fault plane.

Plate 4.16b N-S trending transverse fault at the eastern fringe of Chadwa dome.

Plate 4.16c NW-SE trending transverse fault in Bhuj Formation (Loc. 8 km from Bhuj on Bhuj- Kodki road).

Plate 4.16d Tilted sheet miliolites in the vicinity of Marutonk Dungar Fault (Loc.Near Gangeshwar temple).

Plate 4.16e Quaternary deposits showing NW-SE trending faulted contact with the rocks of Jumara Formation in the vicinity of the Marutonk Dungar Fault (Loc. Gunawari river).

Plate 4.17 Photograph showing the youthful nature of NW-SE trending Marutonk Dungar Fault Scarp. A dyke runs parallel to the fault pla ne

Plate 4.18 Close view of the igneous dyke along the Marutonk Dungar Fault.

north while it abuts against the Katrol Hill Fault in the south..

The N-S fractures are occupied by igneous dykes. The fact that some of the transverse faults cut across the Katrol Hill Fault is significant. Some are truncated by the Katrol Hill Fault. The number of transverse faults is greater to the south of Katrol Hill Fault than in the north

A significant feature of the faults trending irrespective of the direction in which they trend, is the fresh nature of the fault scarps. The steep scarp marking Katrol Hill Fault is a prominent feature of the area. The fresh nature of the scarp, devoid of any gullies or projecting spurs, suggests that the fault has been neotectonically active. All along the base of the fault scarp several dissected colluvial fans are encountered. Across the fault, the geology, physiography and drainage pattern change abruptly. However, the NNE-SSW to NNW-SSE trending faults exhibit a decidedly still younger fault scarps. These faults are continuous and never found to cut across by other faults unlike the Katrol Hill Fault which is divisible into several segments by faults cutting across it. The Marutonk Dungar Fault scarp presents a spectacular example of a young undissected fault scarp.

IGNEOUS DYKES

The Mesozoic rocks in the area are intruded by a number of basic dykes trending mostly N-S or NW-SE (Plate 3.10,4.18). The dimension of the dykes vary at places but the common is 2-4 m wide and 2-10 km long. Most of the dykes are doleritic in composition. Some of the important dykes in the study area cutting either Jhuran or Bhuj Formations are as under:

1. 8 km from Bhuj on Bhuj-Kodki road,
2. 2 km from Kodki on Kodki-Mankuwa road,
3. 16 km from Bhuj at Rudramata dam,
4. Near Kukma village on Bhuj-Anjar road,
5. On the top of Bhujiya hill,
6. Near the bridge on Khari river on Bhuj-Kodki road,
7. 8 km north of Baukha village.

All dykes are located in the vicinity of transverse faults. The dykes and the associated faults trend in the same direction suggesting syntectonic nature of the intrusive rocks. Biswas and Deshpande (1973) described these dykes as conduits through which huge volumes of trappean lava was poured out during the Late Cretaceous volcanic phase. The dykes occurring to the south and north of Katrol Hill Fault abruptly terminate against the fault.