CHAPTER - III

CHAPTER 3

GEOLOGICAL SETTING

General

The geology of the Saurashtra peninsula has been studied by a number of workers, who restricted themselves to studies on the Deccan Traps, the Quaternary carbonate sands (miliolite), the Juro-Cretaceous and Tertiary rocks and the Tectonic framework. Before describing the general geology of the study area, the author has tried to present some of the early works on the geology and some important contributions of various workers on the geology of the Saurashtra peninsula as a whole. A brief chronological compilation of the work done on the geology is described in the following pages.

FEDDEN (1884)

Fedden(1884), gave an exhaustive account of the geology of Saurashtra as a whole. His monumental work even today provides an excellent source of information on almost all aspects of the Saurashtra geology. He clearly recognised and described the major stratigraphic units of Saurashtra (table 1). He prepared a fairly detailed geological map showing the distribution of the various formation. He also recorded the numerous dyke rocks cutting the basalt of the Deccan Trap.

According to Fedden (1884 pp 34 & 35), the lateritic rocks were in "all respects identical with the high level laterites and its associates of peninsular India". Regarding the origin of these rocks he remarked "the material of the rocks of this formation have undergone so many changes by decomposition and lateritization that its original aspects or primary condition has ever been a subject of conjecture and speculation, but there appears good evidence in the character of some of the Kathiawar rocks, that the original material were mostly volcanic ejectaments and that the group represents an eruption subsequent to and differing in many respects from the trap outflows". He also said that ùGaj beds' included all the Tertiary rocks of the SE part of Saurashtra, Upper Miocene in age and equivalent to Manchar (in parts) and Gaj beds of Sind. Fedden (1884) did not distinguish Tertiary rocks from Quaternary, and included his agatiferous conglomerate with the Gaj beds.

Mentioning about the Trap dykes, Fedden (1884) has stated that the dykes are very numerous and large, often forming prominent

TABLE 1

STRATIGRAPHIC SUCCESSION OF SAURASHTRA PENINSULA

(after Fedden 1884)

FORMATION	APPROXIMATE GEOLOGICAL POSITION
Alluvium (sand dunes, tidal flats fresh water alluvium, ùrann´ clays, raised beaches and miliolite)	Recent and Sub-recent
Dwaraka beds	? Higher Tertiary or post-Pliocene
Gaj beds	Upper Miocene-(lower Manchar in part, and Gaj or Sind)
Lateritic rocks	? Lower Eocene-(Sub-nummulitic (Wynne) of Kutch, and ? high - level laterite of Deccan)
Deccan Traps	Cretaceous-Eocene
Trappean grits	? Cretaceous (infra-trappean grits)
Wadhwan Sandstone	? Cretaceous (infra-trappean of India)
Umia beds	Jurassic (Upper-Gondwana)

features in the landscape and many of the dykes are traceable for long distances. The general bearing is east - west, this being the prevalent direction of the dykes in that part of the country; though they may be irregular for some portion of their course, and even interrupted or not visibly persistent throughout, or they may bifurcate. Several cross-dykes bear north-south, or north-west and south-east, and are generally of a later date than the east and west set.

Regarding the source of these dykes, Fedden (1884) has opined that the Deccan Trap period was a period of fissure eruption. Considering the enormous volume of discharge that these numerous and extensive fissures afforded, there was no need to look for volcanic vents, or foci, although, in Girnar mountain and a few other hills, there is some evidence of the latter kind of discharge at the close of the Trappean outflow.

NEGI (1955); BABU (1958); RAO & JAIN (1959)

The various officers of the Oil & Natural Gas Company conducted geological and geographical studies along the Bhavnagar-Gogha coast in connection with their Oil exploration programme. Seismic and gravity magnetic surveys of the region were carried out by Negi(1955). Babu (1958) and Rao & Jain (1959), mapped Tertiary rocks

DATTA (1959)

The credit of a detailed geological mapping of the Bhavnagar-Gogha region goes to Datta (1959). As a part of the oil exploration programme of the O.N.G.C. he reinvestigated the area

and considerably updated and revised the geology of the area. He gave formation status to the Piram beds and agate conglomerates and sandstone and called them Piram formation and Rampur formation respectively, and suggested a stratigraphy as shown in table 2. Datta (1962), in his doctoral thesis revised some of his earlier views. He considered the Kuda sandstone to be equivalent to the Ratanpur clays and correlated Bhumbli Conglomerates with the Piram beds, the latter resting over the Kuda sandstone with an uncomfirmity.

SHRIVASTAVA (1963, 1968 a&b)

Shrivastava (1963) of the O.N.G.C. made a significant contribution to the geological studies of Saurashtra in general and Bhavnagar-Mahuva area in particular. In his report based on compilation of all the data available with the O.N.G.C. including his own investigation he has provided a modified geological picture. Though he more or less followed Datta's (1959) stratigraphy, he furnished a detailed and systematic petrographic account of the various rock types.

Shrivastava (1968 a & b) has considered most of the miliolite occurrence (including the inland ones) to be of marine origin. He observed that the so called oolites were in fact pellets and according to him the miliolite limestone comprised mostly biopelsparites, pelsparites, biosparites and micrites on the basis of various field and petrographic evidences. Shrivastava (1968 a), concluded that the formation represented mostly beach

TABLE 2

STRATIGRAPHIC SUCCESSION EXPOSED IN AND AROUND GOGHA

(after Datta,1959)

GEOLOGICAL AGE	NAME OF FORMATION	LITHOLOGY	THICKNESS (in mts.)
Recent & Sub-Recent	Alluvium	dune sands,clays gravels etc.	
Pleistocene(?)	Rampur formation	agate conglomerate, maroon and brown clays	3-6
Paritian (Upper most Miocene)	Piram formation	grey arenaceous shaly clays with thin clay bands & mammalian bones, pieces & Pelecypodes	3.6 4.6
----------Disconfirmity----------			
Lower Miocene (Bardigalian)	Kuda Sandstone	fine grey argillaceous sandstone with occassional clay	75.75
	Bhumbli Conglomerate	fossiliferous conglomerate & grits with interbedded fine argillaceous sandstone and grey clays	209
----------Discomfirmity----------			
Lower Miocene (Aquitanian?)	Ratanpur Clays	grey and gypsiferous clays with thin bands of limestone and coarse gritty, current bedded sandstone	248.48
----------Unconfirmity----------			
Lower Eocene to Oligocene		variegated lateritic clays and, residual bentonite clay ?	
Upper Cretaceous to Eocene		Deccan Traps	

sediments that were formed in agitated warm and shallow water only a few feet deep and that during Pleistocene the sea-level stood much higher than the present level. The sea has since receded to its present stand and a succession of progressively younger beach and allied deposits were formed following the regressive shoreline. He further suggested that the aeolian sands interstratified with the limestone were probably deposits formed on the old shoreline which were submerged under the advancing pleistocene sea. These were now elevated above high water line, consolidated during submergence and overlain by younger beach deposits. Shrivastava (1988 b) attributed this sea-level rise to Quaternary tectonism postulating down faulting of the entire Saurashtra peninsula in Pleistocene that caused widespread marine transgression. He explained the miliolite in Bhavnagar-Gogha region by invoking this area to form uplifted block during the Pleistocene period and sub-recent time and according to him (1988 b) the agate conglomerate and sandstone were deposited during that period in this area.

MATHUR et al (1988); RAJU (1988)

Reference to the study area are found in the works of various officers of O.N.G.C. on the Cambay basin.

Some structural aspects of the study area were discussed by Mathur et al (1968) in their paper on the tectonic framework of the Cambay basin. According to these authors, the basin comprised a graben divisible into several fault blocks. The Bhavnagar-Mahuva coastline falling within the Jambusar-Broach block marks

the site of the two major faults, a N-S fault (Sanand-Gogha) and an ENE-WSW fault (extension of Narmada fault).

Brief mention of the study area has been made by Raju (1968) in his paper on the geological evolution of the Assam and Cambay Tertiatry Basins. He has correlated the lithology with structural features.

GLENIE (1970)

It was Glenie (1970) who, for the first time invoked Quaternary polar glaciation to cause a lowering of sea-level in Saurashtra, thus exposing broad areas of the present continental shelf of Saurashtra to the interior parts of the mainland.

BISWAS (1971)

Biswas (1971) of the O.N.G.C., more or less supported the concept of Glenie (1970) regarding the origin of inland miliolite. He studied the miliolite rocks of both Saurashtra and Kutch and considered the coastal miliolites to be marine beds, while those of interior Saurashtra and Kutch to represent aeolian accumulations. According to Biswas (1971 p-162-163), the coastal rocks of Kathiawar might have been formed earlier than the rocks in the interior of Kathiawar and Kutch and the sediments for the latter were derived from the disintegration of the coastal limestone. The miliolitic rocks of the Kathiawar coast were deposited earlier perhaps in early Pleistocene time than the inland rocks of Kathiawar and Kutch which are late Pleistocene to early Holocene deposits.

GUPTA (1972,1977), LELE (1973)

Gupta (1972,1977) of P.R.L. investigated the Holocene raised beaches of Saurashtra and found them to indicate higher sea-level strands of 2 to 6 metres above present level.

Lele (1973) studied miliolite rocks of Bhadar valley and Chotila and concluded that they were shallow marine deposits. For the occurrences at Chotila he postulated a very high sea-level (300 m) and explained this by invoking teotonism.

VERMA AND MATHUR (1975 TO 1979)

A substantial contribution to the Quaternary geology of Saurashtra came from Verma and Mathur of G.S.I..

In their doctoral thesis submitted to the M.S.University of Baroda, Mathur (1978) and Verma (1979) have provided a wealth of geographic, sedimentologic and paleontologic information on the miliolite. The salient features of their contribution included

i) a revised classification of these carbonate deposits,
ii) establishments of field criteria for distinguishing the marine and aeolian miliolite,
iii) evidences in the favour of the stability of Saurashtra during the Quaternary period,
iv) establishment of sea-level comparable with the positions of higher strand lines during Quaternary period in other parts of the world,
v) studies on the cross-bedding in miliolite rocks for establishing the Paleo-wind direction and

vi) studies on the textural characteristics of the carbonate beach and dune sands to establish criteria for separating the two environments.

MERH (1980)

Merh (1980), reviewed the entire miliolite problem in his presidential address to the geology and geography section of the 67th Indian Science Congress. He concluded that the miliolite occurrence comprise both marine and aeolian rocks. The so called oolite of the miliolite rocks are mostly peloids and these have originated by a process quite different from that which would give rise to ooliths. The peloids have been derived from the formation of shells by a process of abrasion, rounding and recrystallization and this has got considerable environmental significance. Relatively low oolitic content and dominance of peloids derived from shells point to a shallow marine environment which was not conducive to the oolitisation of the carbonate precipitates. Merh (1980) has also expressed his reservation with respect to the stratigraphic division of the carbonate sediments into miliolite formation as suggested by Mathur (1978). Merh (1980,p30), has stated that the deposition of miliolite took place in more than one transgression giving rise to a mixed sequence of marine and aeolian beds. Also, the fossil aeolinites of inland areas would belong to more than one generation. It is therefore, rather too risky to reconstruct a dependable stratigraphy of miliolites in the absence of detailed studies of number of vertical sections and their proper correlations.

IQBALLUDIN & BANERJEE (1978); GANAPATHI & PATEL (1979); PANDYA (1979); MARATHE & RAJGURU (1979) AND PATEL et al (1979)

Sporadic but vital information on the different aspects of the study area are available in the recent works of the above authors.

Iqballudin and Banerjee (1979), on the basis of airphoto studies have described the dynamic geomorphic processes operating along the Bhavnagar coast.

Ganapathi and Patel (1979) have reported and described a number of erosional and depositional geomorphic features related to a past higher strand line 4 to 5 m above the present level of the sea.

Pandya (1979), an archeologist who explored the lower course of Shetrunji river found human settlement of Harappan (i.e. about 4000 yrs ago) age and suggested that during the Harrapan times the sealevel was slightly higher than the present.

Marathe and Rajguru (1979), have found several Paleolithic site in Quaternary agate conglomerate beds, south of Bhavnagar. They suggested that these agate conglomerate beds were deposited under continental environments. From the nature of weathering of pebble conglomerates they envisaged that the climatic conditions during the early Quaternary was more humid than that of today.

GENERAL GEOLOGICAL SETTING

The general geological setting of the study area is as shown in table 3.(fig 2a)

TABLE 3

GENERAL GEOLOGY OF THE STUDY AREA

FORMATION	LITHOLOGY	AGE
Gaj	conglomerate, sandstone, clay shales	Miocene to Pliocene
---	laterite, lithomarge, bentonite	Eocene
Deccan Trap	Basalt	Upper-Cretaceous to Lower Eocene

A brief description of the individual formations is as follows.

Deccan Trap

This formation covers almost the whole of the district except the eastern and southern coastal tracts which are covered by Tertiary and Post-Tertiary sediments. The Trappean rocks comprise dominantly of basaltic lava flows and dolerite dykes, forming the basement for the Cenozoic sediments. They commonly appear to be horizontally bedded though a gentle tilt towards south has been

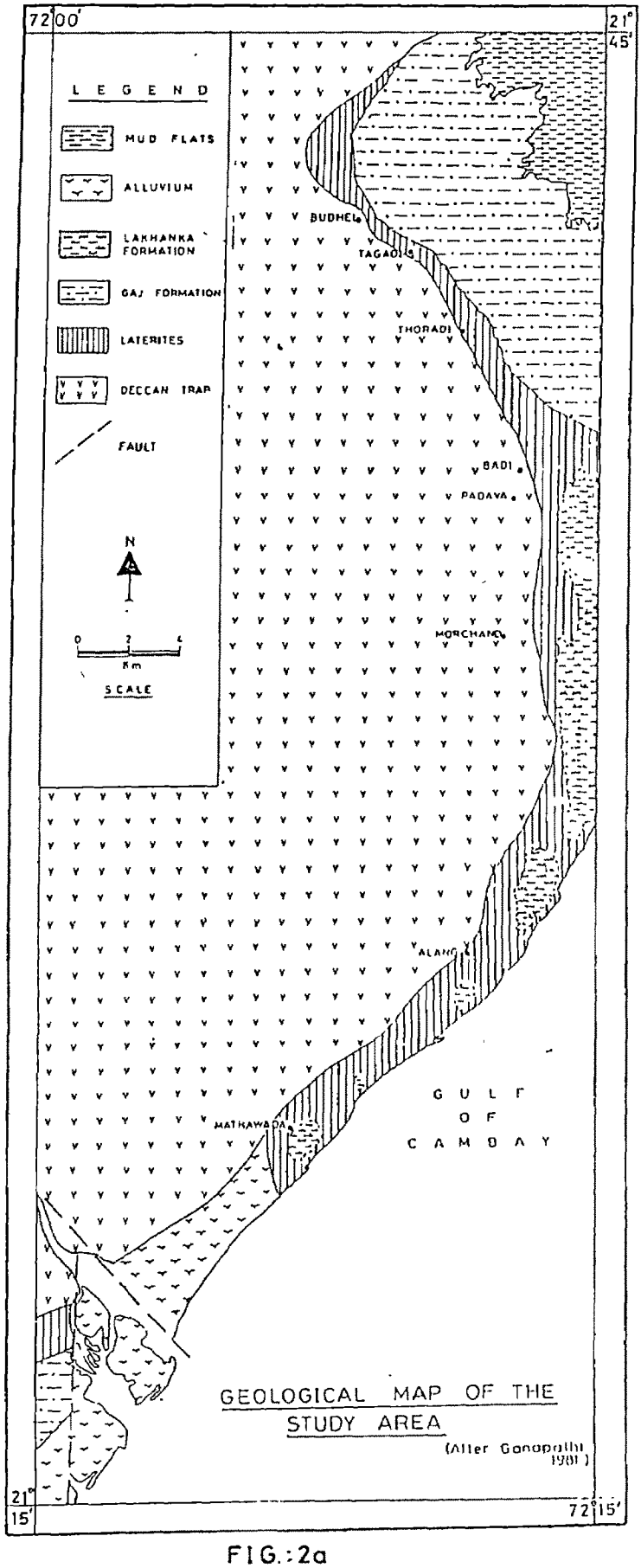

72°00'
21°45'
LEGEND
MUD FLATS
ALLUVIUM
LAKHANKA FORMATION
GAJ FORMATION
LATERITES
DECCAN TRAP
FAULT
N
0 2 4
Km
SCALE
BUDHEL
TAGADI
THORADI
BADI
PADAVA
MORCHAND
ALANG
MATHAWADA
GULF OF CAMBAY
GEOLOGICAL MAP OF THE STUDY AREA
(After Ganapathi 1981)
21°15'
72°15'

FIG.:2a

noticed in the Sihor hill range. The total thickness of the trap in the study area is considered to be around 600 m, while the average thickness of an individual flow may be somewhere near 13 m. (Rao et al, 1962 & Shrivastava 1963). The traps are invariably jointed. Besides sheet joints, more or less parallel to the surface, other vertical or inclined and columnar or prismatic joints, generally at right angles to the bedding planes of the flow, are also observed. The flows vary considerably in composition. The basaltic flows are generally amygdaloidal, containing geodes and amygdales filled with zeolites, chalcedony, agate and calcite. Scoracious breccia agglomerates, tuffs and ashes etc., are occasionally found interbedded with the flows. The Deccan Trap episode in the study area include various layers of the lava flows such as basalts, dolerites, felsites, granophyre, obsidian, pitchstone, rhyolite, trachyte, diorite, agglomerates, breccias, tuffs and ashes, etc.. Numerous dykes cut across the basalts and ideally follow the fracture pattern in the traps. The trap flows have been intruded by numerous dolerite dykes forming low knolls, elongated mounds or serrated ridges. There appear to be two sets of intrusions; the dominant one has an east-west trend, while the other exhibits a north-south or northwest-southeast trend. The dykes are more conspicuous in the south-eastern part of the study area around Talaja. The contacts of the dykes with the flows are generally distinct.

Lateritic rocks

Resting over the Traps along its fringes, lateritic rocks form an important unit overlain in turn by the younger Tertiary and Quaternary deposits. Essentially comprising a residual alteration product of the Deccan Trap, the laterites are quite important from the point of view of their economic value. Laterite forms a continuous band varying from 1 to 3 km in width and extending to a length of about 30 km, commencing from east of Adhewada and passing through Budhel, Thoradi, Badi towards Morchand. Isolated patches of laterite are also noticed near Mathwada, Talaja, Bhanvav and Gundarni in Mahuva taluka. Typically unstratified and mottled, the laterite shows a wide range of colours like red, brown, and yellowish brown.

Gaj Formation

In the coastal tracts of the peninsula, between Bhavnagar and east of the Okha Rann, marine Miocene rocks occur in a series of isolated outcrops. These were first mapped as Gaj beds by Fedden (1884), who regarded them to be Upper Miocene in age, equivalent to Manchar (in part) and Gaj beds of Sind. The type locality for this formation in Saurashtra is the Gogha area, south of Bhavnagar. A very detailed mapping of this formation was carried out by Babu (1958), Rao & Jain (1959) and Datta (1959). The out crops of this formation around Bhavnagar were studied by Shrivastava (1959), while some in the southern coast were mapped by Biswas (1959).

The rocks of this formation are well exposed in the Bhavnagar-Gogha region. Here it is divisible into three members, viz., the lowermost Ratanpur Clay , the Bhumbli Conglomerate, and the topmost Kuda Sandstone .

Ratanpur Clay

The Ratanpur clay derives its name from the Ratanpur village around which good exposures are found. At the base of this member there occurs a coarse and gritty to medium grained sandstone with argillaceous matrix. The clay for the most part consists of thick, grey to bluish grey, gypseous varieties, with yellow dense limestone bands which are a few inches to a few feet in thickness. The clays are well bedded and often show a shaly character.

Bhumbli Conglomerate

The Bhumbli conglomerate consists of conglomerates, grits, argillaceous sandstones and minor clays. The conglomerate with clayey matrix are soft, whereas, those with arenaceous matrix are compact and hard. This horizon appears to overlie the Ratanpur clay.

Kuda Sandstone

The Kuda sandstone consists of grey coloured, fine grained, argillaceous sandstones with minor sandy clay bands, overlying the Bhumbli Conglomerate.

Outcrops of Gaj formation stretch southward from Akwada upto Mathwada. Isolated patches are also noticed near Unadevi,

Sultanpur and Rohisa. In the Bhavnagar-Gogha region, the exposed thickness of the formation is around 1700 to 1780 feet. (Datta 1959).

Pascoe (1873) has reported the following invertebrates from these rocks.

Bryozoa	:	Eschadria balaensis, Discoflustralla vandenlcekai
Echinoidea	:	Cidaris sp.; Termmechinus sp.; Clypeaster sp.; Echinolampus sp.; Schizaster sp.
Pelecypoda	:	Arca sp.; Ostrea sp.; Cardium sp.; Venus sp.
Gasteropoda	:	Turitella angulata; Trochus lorvi; Cerithium sp.
Crabs	:	Soylla serrate
Foraminifera	:	Miogypsina; Lepidocyclina, Taberina

The rocks of Gaj formation are considered to have been deposited in a shallow marine environment, perhaps under epineritic conditions (Fedden, 1884; Shrivastava, 1963; Pascoe, 1973; Wadia,1975).

Quaternary deposits

The Quaternary rocks are unique in the sense that they comprise the most striking accumulations of carbonate sands over a dominant portion of the Saurashtra coast. Grouped under the Miliolite Formation, these include calcarenite and calcrudite

with intercalations of clays. The limestones, sometimes interbedded with sandstones are known as miliolite limestones. The name is derived from the foraminifer miliolite which forms the bulk of the rock. These pelletoid and oolitic calcarenites characterised by a warm and shallow marine microfauna dominantly foraminifers have remained highly controversial in respect to their mode of origin. According to Merh (1980, p 21) these Quaternary deposits are "partly marine partly aeolian consisting of more than one generation of carbonate sands deposited under shallow marine conditions and subsequently reworked by winds to form coastal dunes, all this having taken place during the successive periods of transgression and regression of the Quaternary sea".

Alluvium

Alluvium includes a variety of deposits e.g., sand dunes, tidal mudflats, raised beaches and fresh water alluvium. Sand dunes are common in the vicinity of coasts. Fresh water alluvium is observed along the river valleys and forms a thick blanket near Gogha, Bhavnagar, Vartej, Sihor, Talaja and also along the southern coastal tract. The soil cover, a product of in-situ sub-aerial weathering varies from black cotton soil to yellowish brown sandy soil. The former is derived from the Trap while the latter has originated from the Tertiary rocks.

STRUCTURE OF THE STUDY AREA

The sturctural setup of the study area as presented in the following pages is based on Ganapathi's (1987) work on the tectonic aspects of Bhavnagar-Gogha coastline.

The Saurashtra peninsula is bounded by a number of major faults on all sides. This peninsula as a whole might not be showing spectacular uplifts and subsidence as a single block, but there are ample evidences to suggest that its various parts did undergo differential movements especially during the Quaternary period.

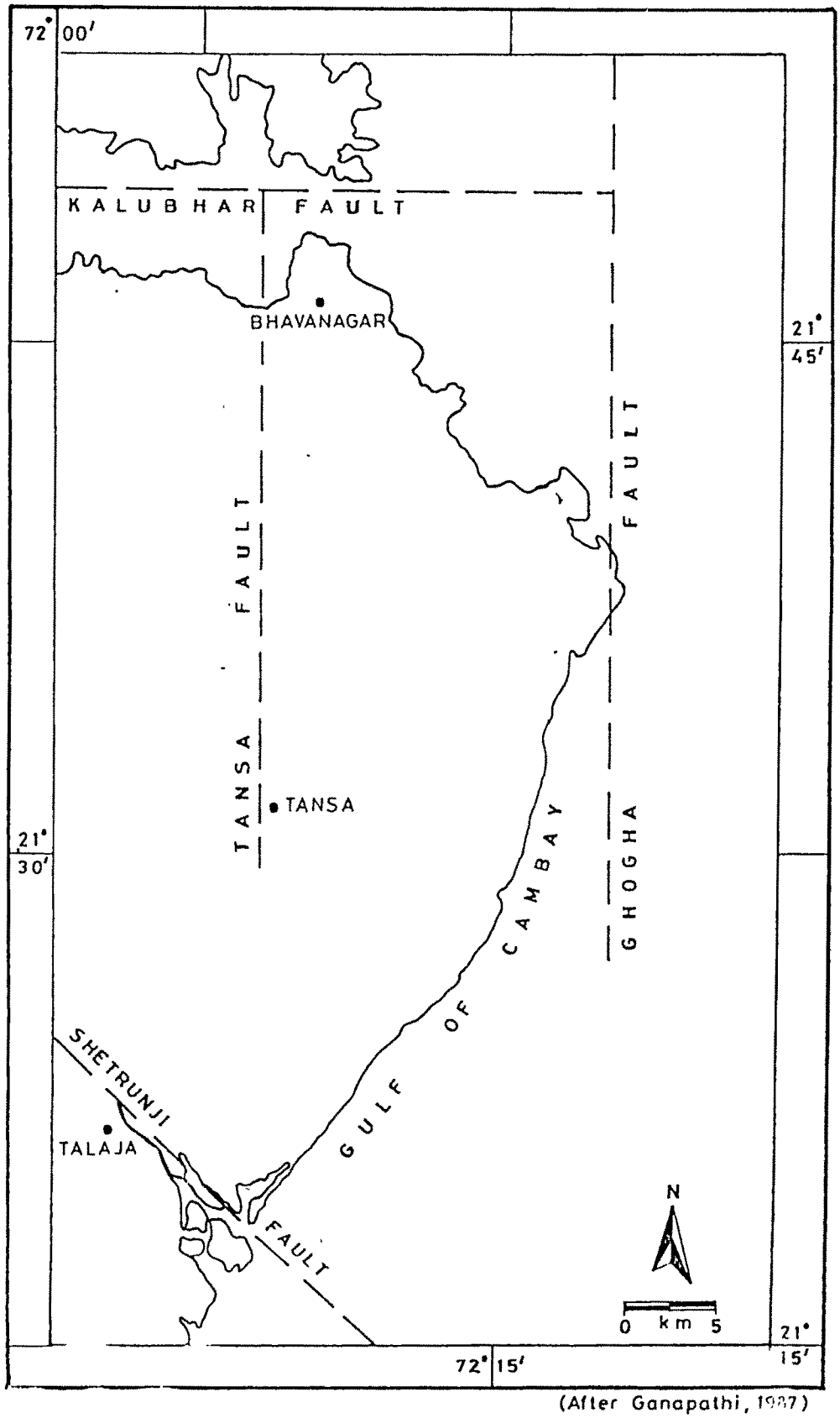
Following four major faults delimit the Saurashtra land mass.

1. Gogha-Sanand Fault (western Cambay Basin Border Fault)
2. Extension of the Narmada Fault
3. Gulf of Kutch Fault
4. West coast Fault.

In addition, a number of faults related to one or the other of these major lineaments are encountered all over the peninsula, and it is interesting to observe that ever since these faults were generated, periodic movements along them throughout the Tertiary and Quaternary periods, have taken place.

Within the limits of the study area and its immediate neighbourhood, a number of faults have been recorded, and these have played significant role in the post-Mesozoic geological history of the area. In all, four major faults have been observed (Ganapathi 1987) (fig. 2b).

Fig 2b: MAJOR FAULTS IN THE STUDY AREA.



(After Ganapathi, 1987)

i) Gogha-Sanand Fault (western Cambay Basin Bordrer fault)

ii) Kalubhar Fault

iii) Shetrunji Fault

vi) Tansa Fault

Gogha Sanand Fault

According to Mathur et al (1968), and Raju (1988), the Gogha-Sanand Fault seems to be a manifestation of the reactivation along an older fault trend, perhaps in the late Cretaceous times. This fault forms a part of the ùCambay Graben' and coincides with the Western Cambay Marginal Fault. Mathur et al (1968) and Raju (1968) are of the opinion that this fault is less severe and disturbed as compared to the fault that binds the basin to the east. Within the limits of the study area, this fault shows a negligible throw, forming a half graben only. Further north, however, this fault is demarcated easily on the basis of the present configuration. Mathur et al (1968) have envisaged a SSW swing in this fault. On the other hand, the joint pattern with dominant N-S fracturing (related to this fault), supports the possibility of the fault extending straight due south till it meets the Narmada Transverse Fault. The geophysical data by previous workers have further revealed that this basin margin fault of Cambay Basin in the traps is not a continuous fracture, but occurs as a series of en'echelon step faults (Mathur et al,1968 ; Raju, 1968 and Sengupta & Khatri, 1975). The reactivation along such en-echelon faults and resulting differential movements has been the main agency, for the development of the structues in the overlying sediments.

Kalubhar Fault

North of Bhavnagar a major E-W fault has been recorded. The fault has been named as the 'Kalubhar Fault' after the river Kalubhar, which flows along this fault (Ganapathi 1981). The abrupt termination of the eastward trending hills near Sihor, tilted gently to the south and forming scarps on their northern edges provides evidence for the existence of this fault. According to Krishnan (1968) the Pavagadh hill near Baroda and Chamardi-Goghat plutonic mass fall in a line, parallel to the Narmada rift and marking an important tectonic lineament. To the east, this fault meets the N-S Gogha-Sanand fault. The dislocation along the Kalubhar Fault has down thrown the northern block by nearly 50 m over which is now seen deposited a thick Quaternary alluvium (Shrivastava, 1969).

Shetrunji Fault

The Shetrunji Fault marks one of the important structural features dividing the study area into two equal halves. Though the river Shetrunji has almost attained the old stage, it is because of this fault that it continues to flow in a straight line across the Trappean country and meeting the sea at Sultanpur. According to Shrivastava (1963) the river Shetrunji flows along two fault zones almost at right angles to each other and he gave the name 'Shetrunja Fault' to the NE-SW fault which runs from south of Palitana and extends towards west. The other fault trending NW-SE which lies mainly within the study area has been named as the 'Shetrunji Fault' by Ganapathi (1981) after the river Shetrunji.

Tansa Fault

Near Tansa village, a fault trending N-S is marked along the eastern edge of the hill ranges. The steep scarps overlooking the low plains of the soil covered trap typically point to the existence of the fault. This fault has been named as 'Tansa Fault' after the village Tansa. This fault is clearly recorded from Tansa northward upto Trambak. Further north it might be extending upto and meeting the E-W Kalubhar fault near Bhavnagar. Southward, this fault terminates about 5 km south of Tansa village where it abuts against a NW-SE lineament.