Chapter II

GEOLOGICAL INFORMATION

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GENERAL BACKGROUND

Study of geological environment encompassing lithological types, tectonism, structural style and their manifestations; in terms of landform characteristics are vital components for any areas land and water resources potential evaluation.

The study area broadly falls within the limits of Deccan Traps domain and is characterised by variety of formations, belonging to different geological ages. To working out the details on the geology of the study area, author has compiled the available information after going through the various literatures critically.

The geology of the area has received very little attention. The earliest account on the geological investigation of this area dates back to late nineteenth century by W.T.Blanford (1867) and later on the area has been studied by the various agencies particularly the Geological Survey of India; Directorate of Geology and Mining, Govt. of Gujarat; Oil and Natural Gas Corporation and The M. S. University of Baroda, Vadodara. The Oil and Natural Gas Corporation had carried out an in depth study on the litho-tectonic aspects of the area, while exploring the prospects of hydrocarbons. Infect it was the exploration works of ONGC who had supplied an

indepth information on the litho-stratigraphy of the area; which in turn has helped the author in working out the geological setup of his study area.

LITHO-STRATIGRAPHIC SETUP

The litho-stratigraphy of the study area represents a variety of rock types representing a variety of lithologies of different geological age. A geological map depicting the disposition of various surface outcrops is given in Fig. 2.1.

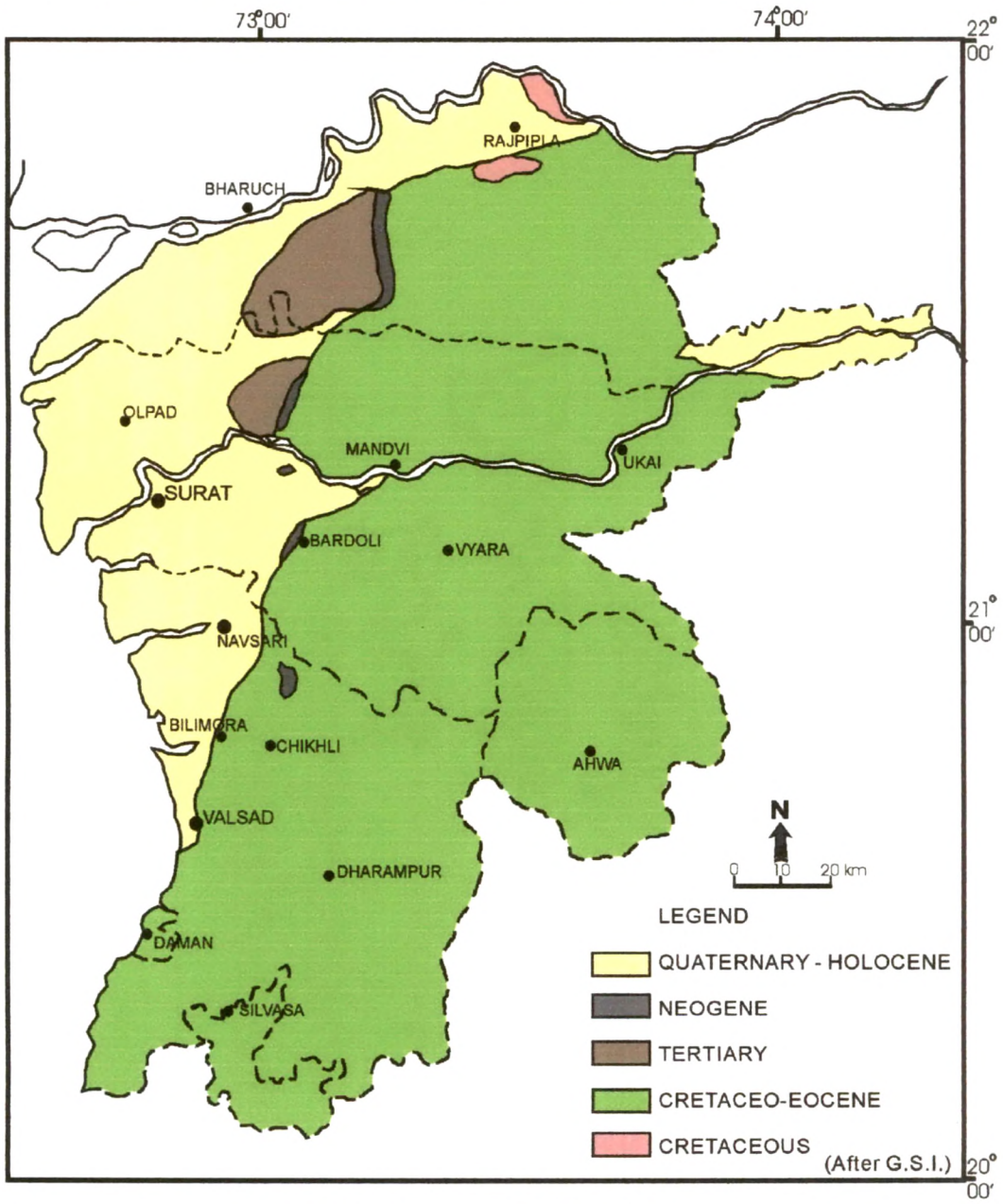

Fig. 2.1 Geological Map of South Gujarat.

Taking into account the works carried out by Rao, 1969; Chandra and Chaudhary, 1969; Gadekar, 1977; Kaila et al, 1981; Agrawal, 1984; Pandey et al, 1993 etc. The author has attempted to present the latest available information. A detailed litho-stratigraphic succession of the study area and its surroundings is given in Table 2.1.

Table 2.1 Litho-stratigraphic Setup of South Gujarat and its Environs

(After Pandey et. al., 1993)

Age	Formation	Lithology
Quaternary	Alluvium	Alluvium, dull reddish and grayish sandy clays, kankar.
Upper Miocene	Jhagadia Formation	Calcareous, micaceous, sandstones with occasional conglomerates (< 300m).
Middle Miocene	Kand Formation	Grey clays, fossiliferous marls and limestones, sandstones, agate conglomerates (150 - 400 m)
Lower Miocene	Babaguru Formation	Ferruginous sandstones, conglomerates, white sandstones and clays (200-575 m)
	Tarkeshwar Formation	Grey bentonitic clays with thin lateritised bands (125 - 345 m).
Upper Eocene	Nummulitic (Tarapur) Formation	Foraminiferal, impure, argillaceous limestones, clays, marl (50 - 400 m)
Paleocene	Olpad Formation	Grey clays, tuffaceous sandstones and conglomerates (345 - 2700 m)
Cretaceo-Eocene	Deccan Traps	Basalts, trachytes, andesites, dykes of dolerite (300 - 3000 m).
Cretaceous	Bagh Beds /	Sandstones, shales and limestone.
Precambrian	Granitic basements	

Pre-Cambrian Granites

Granitic rocks, which form the basement for the above lying younger rocks are nowhere reported as surface outcrops. The existence of these magmatic bodies has been reported through the deep seismic soundings (DSS), carried out by Kaila et al. (1981). These rocks have been encountered at variable depths ranging between 6.5 and 1.2 km and attain shallow depth south of Navsari, which is the manifestation of deep crustal faulting (Kaila et al, 1981).

Bagh Beds

Exposures of these rocks representing the sedimentary sequence of sandstones, shales and limestones are predominantly confined on the southern banks of Narmada

River. Further south towards Kim and Tapi rivers these Mesozoic have been invaded by the Deccan Trap lava flows, thereby constituting a part of the basement. The evidences of their existence further south have come through the DSS profile carried out by Kaila et al (1981). Where in almost about 1.2 km thick Mesozoic sediments have been reported to exist below the Deccan Traps. The important localities are Kim-Kosamba, north of Tapi and the Billimora, south of Tapi River.

Deccan Trap

The close of the Mesozoic era (Cretaceo-Eocene) was marked by the outpouring of enormous lava flows (Deccan basalts), which spread over vast areas of western, central and southern India. The Deccan basalts represents horizontally bedded lava flows; at places showing gentle westerly dips. DSS studies carried out by Kaila et. al (1981) indicate their thickness tend to decrease from 1.8 km in north i.e. the Tapi valley region to 1.4 km in south near Navsari. Similarly these trappean rocks, which are seen lying below the vast thickness of Tertiary sediments in northern parts of Tapi valley, show considerable rise in its subsurface elevation. The trappean surface shows considerable rise from 1.7 km in north to almost 0.5 km in south and finally cropping out on the surface south of Billimora.

However, the vast area bordering the Tertiaries and Quaternary formation in east is represented by the surface out crops thickness of Deccan lava flows; attaining a maximum thickness of almost 1200 m (above MSL). This trappean highland has been considered as northern extension of the Sahyadri Range of Maharashtra State. Compositionally these effusive rocks comprises a variety of flows viz. olivine basalt, porphyritic basalt, andesite, tuffs and feldspar porphyry. The interflow surfaces are marked by redbole horizons. The thickness of these basaltic rocks tends to increase southward. These rocks mark a very deceptive pediment zone and the pediment plain. At lower reaches towards coast, the surficial continuity of these trappean rocks is delimited by the eastern marginal faults of Cambay Graben.

The trappean rocks have been dissected by a very large variety of discordant and concordant magmatic bodies, of post trappean activities. The dykes having azimuths of N-S, ENE-WSW and NW-SE:NE-SW are represented by olivine basalts, dolerites and epidiorite compositions and are of different generations (Auden, 1949).

Tertiary Rocks

Narmada-Tapi intersetream area represents an exemplary stratigraphic sequence of Tertiary period. Overlying the Deccan Traps, these sedimentary sequence are represented by the varied rock types viz. limestones, shales, sandstones, clays, conglomerates etc. These rocks based on facies variation and palaeontological evidences have been ascribed to Paleocene to Miocene age.

The Tertiary rocks of South Gujarat have been studied in great detail by the Gadekar (1977) and Agrawal (1984). Also, owing to high potential of hydrocarbons these rocks have been thoroughly investigated by the workers of Oil and Natural Gas Corporation. The most comprehensive account on Tertiary stratigraphy of the Cambay basin has been provided by Chandra and Chowdhary (1967) and latter on updated by Pandey et al (1993). These sedimentary sequences with an overall thickness of more than 4000-m have been divided into various formations (Pandey et al, 1993).

The Olpad formation (formerly Vagdkhol), which represents the oldest Tertiary, unconfomably, overlies the Deccan Traps. The lithological assemblages comprising sandstones, shales, and conglomerates, have been deposited under coastal environment (Agrawal, 1984).

The Vagdkhol formation is overlain by the Nummulitic formation of upper Eocene age and characterized by nummulites fauna. Its outcrops are very well exposed around Nandev, Dinod and Dungri villages. These formations compositionally comprise hard massive, yellow colour fossiliferous limestones. Fossils present within the rock indicate that the sediments have been deposited during regressive phase of late Eocene time. Near Tarkeshwar the limestone shows 10^0 dip towards southeast.

The nummulitic formation is further unconformably overlained by Tarkeshwar formation, generally composed of grey bentonitic clays. At places these Nummulitic rocks are seen directly overlained by Babaguru formation.

The outcrops of Babaguru formation are best exposed around Kosamba and Valia towns. Compositionally the rocks of these formations comprise conglomerate, sandstones and clays, formed under fluviatile environment (Agrawal, 1984).

Further the Babaguru formation is unconformably overlained by Kand formation. The lithological compositions comprise calcareous sandstones, clays, marls and thin fossiliferous limestones; deposited under shallow marine environment.

The Jhagadia formation, which represents the youngest formation of Tertiary sequence in the South Gujarat has been ascribed to Upper Miocene age. Compositionally this formation comprises sandstones, grit stones, conglomerates, breccia, clays and silt. The formation is poorly fossiliferous and it is deposited in continental fluviatile environment.

Supratrappean (Laterites)

The subaerial weathering of the basalts has given rise to lateritic rocks, which form a distinct horizon below the Tertiary sequence. The exposures of laterites are seen around the localities of Tarkeshwar, Valia, Mandvi and Gandevi. The lateritic outcrops are confined to below 100 m altitude and rarely exhibit complete profile. The lateritization of trappean rocks has been attributed to warm-humid climate and alkaline physico-chemical environment during Neogene period (Mehrban, 1990).

Quaternary Deposits

Quaternary sediments cover most of the alluvial and coastal plains of the area, and resting over Deccan Trap or Tertiary rocks with a marked unconformity. The Quaternaries are classified as under:

Holocene (sub-recent to recent)	Residual soils, flood plain deposits (newer Alluvium), coastal beach, dune sands and estuarine mud flats.
Late Pleistocene	Older alluvium.

----------unconformity----------

Deccan Trap / Tertiary rocks.

The older alluvium, which represents the ancient floodplain deposits of Narmada, Tapi and other westerly flowing rivers of south Gujarat, is highly weathered and contains plenty of lime-kankar, calcareous crust, clays etc. The younger alluvium is mostly confined to the proximity of streams as flood plain deposits. Blown sand is

found all along the coast whereas the tidal flats and estuaries contain fluvio-marine deposits.

Sub-surfacely these Quaternary sediments, aggregating an average thickness of almost 200 m and are represented by an intercalated sequence of clay-silt-sand layers, deposited under varied environmental conditions.

The coastal plains are marked by patchy and at times concealed outcrops, as relict older alluviums. Similarly the fluvio-marine deposits occur as the present day mud flats and the raised (paleo) mud flats. The landward continuity of these paleomud flats has been marked as Holocene strandline (Patel, 1991). Further south Hasimi and Vashi, 1988 have reported the occurrence of 1-8 m thick beach rocks, representing high strandline during Holocene transgression.

The study area comprises considerable aeolian deposits, predominantly restricted along the coast tracks. These dunal materials have been occurring as older stabilized dunal ridges and the present day dunes. The older dunal ridges are again indicative of paleo-shoreline (Jottun, 1982). The pediment zones near the mountain front are characterized by a thick accumulation of colluvial deposits.

TECTONIC FRAMEWORK

The tectonic framework of the South Gujarat is the manifestation of the Cambay graben, Narmada rift system and the West Coast Fault (Fig. 2.2). The Cambay area lies in a trough fault running N-S in which the Deccan Traps have been dropped down to a depth of about 2000 m. (Kaila, 1981). The Deccan traps dip into the Arabian Sea at an angle of 7^0 to 10^0 as a monocline. This monocline feature, the Panvel Flexure, which runs northward through Panvel and Kalyan and ultimately follows the coastline from south of Surat.

The evolutionary history of the South Gujarat dates back to Post-Mesozoic break up of the eastern Gondwanaland, rifting of Western Continental Margin and the subsequent northeasterly drift of the Indian landmass, accompanied by Deccan volcanism were part and parcel of this tectonism (Murthy, 1981; Biswas, 1982, 1987; Powar, 1987). The existing configuration of Gujarat thus marks the culmination of the rifting phenomenon of the continental margin of India, and according to Biswas (1982), the Mesozoic of Kutch, the Tertiary of Cambay basin and the existing South Gujarat landscape, all comprise result of a genetically related tectonic sequence,

which was forming an integral part of the NNE drift during Mesozoic and Cenozoic times.

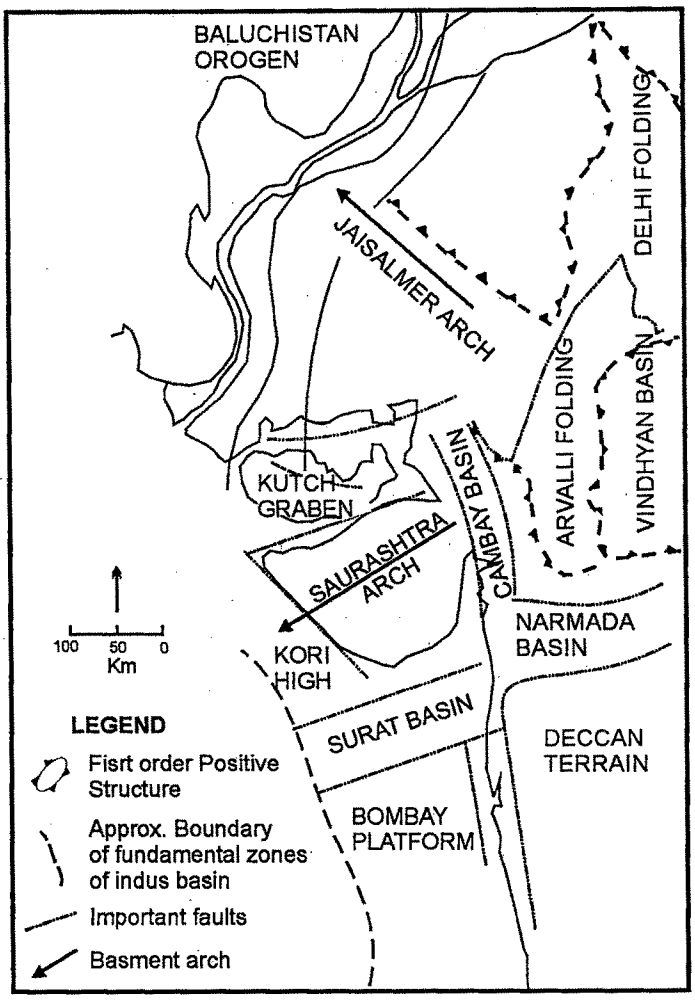

Fig. 2.2 Tectonic Framework of Western India (After Biswas, 1987).

Tensional fractures generated during the earlier stage (rifting) were subsequently subjected to compressional stresses during later stages of the drift. During the rifting stage the tensional stress-field was so oriented that the two pre-existing major fractures opened up and resulted into Cambay and Narmada-Tapi graben systems. This was probably related to the transform or lateral displacement during Late Cretaceous, as visualized by McKenzie and Sclater (1971), and Biswas (1987). Sympathetic fractures, developed along the margin of these two basins are reflected in the structural features of South Gujarat.

The fracture pattern of the area, as revealed by the landscape in totality and the various faults and fractures points to a strong control exercised by these two basement tectonic lineament directions i.e. ENE-WSW (Narmada) and N-S to NNE-SSW (Cambay). Along the major ENE -WSW faults, various rivers are flowing. The studies carried out by Kaila et al (1981) through deep seismic profile in South Gujarat clearly shows the existence of these deep seated faults (Fig. 2.3).

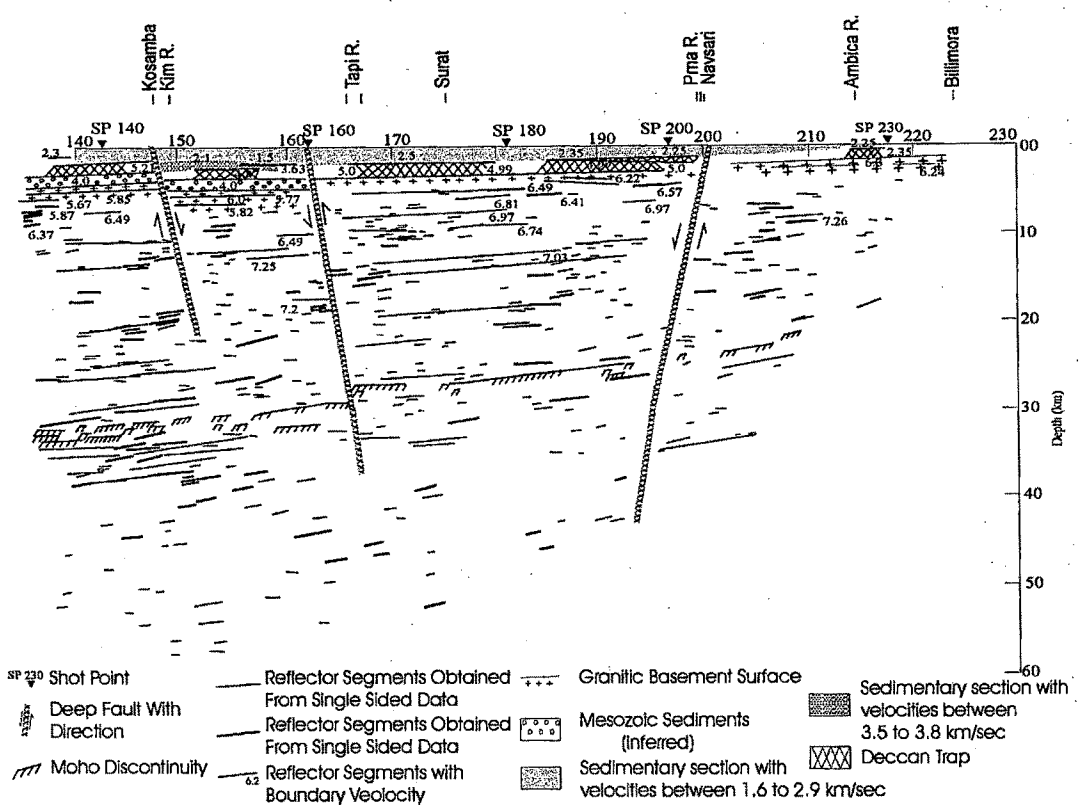

Fig. 2.3 Deep Seismic Profile Between Kosamba - Billimora (after Kaila et al, 1981).

The straight linear segments in rivers Tapi, Purna, Ambica indicates strong controls of these crustual faults, having ENE-WSW azimuths. The dykes system cutting the Deccan Traps in Gujarat trending ENE-WSW and N-S (Auden, 1949) also in conformation with these two major tectonic lineament trends.

Of the two major megafracture NNE-SSW faults, the western fault, marks the boundary between the Uplands and the Trappean Highlands, is the southerly extension of the Cambay Basin Eastern Boundary Fault (Biswas, 1987). The eastern fault that marks the sudden rise of the Deccan plateau forms the northern extremity of the regional fault that extends along the Western Ghat Escarpment (Kaila et al., 1981).

The fracture pattern of the study area is also revealed by the drainage pattern and landforms and is characterised by two distinct sets, viz. NNE-SSW and ENE-WSW, which is further confirmed through the lineament studies through satellite imagery (Fig. 2.4).

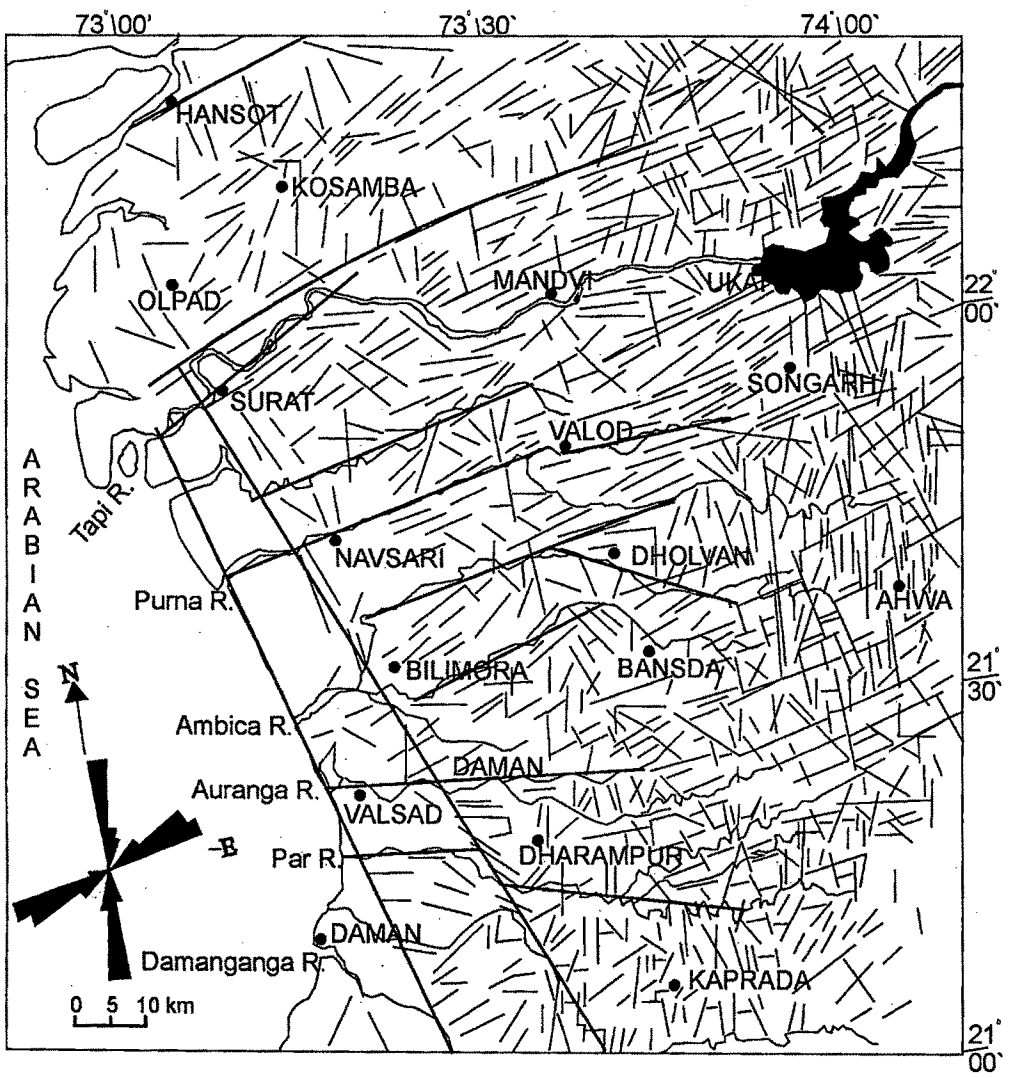

Fig. 2.4 Lineament Fabric of South Gujarat (based on IRS-IC Imagery).