PART - I

SAURASHTRA IN GENERAL

REGIONAL AND COASTAL SETTING

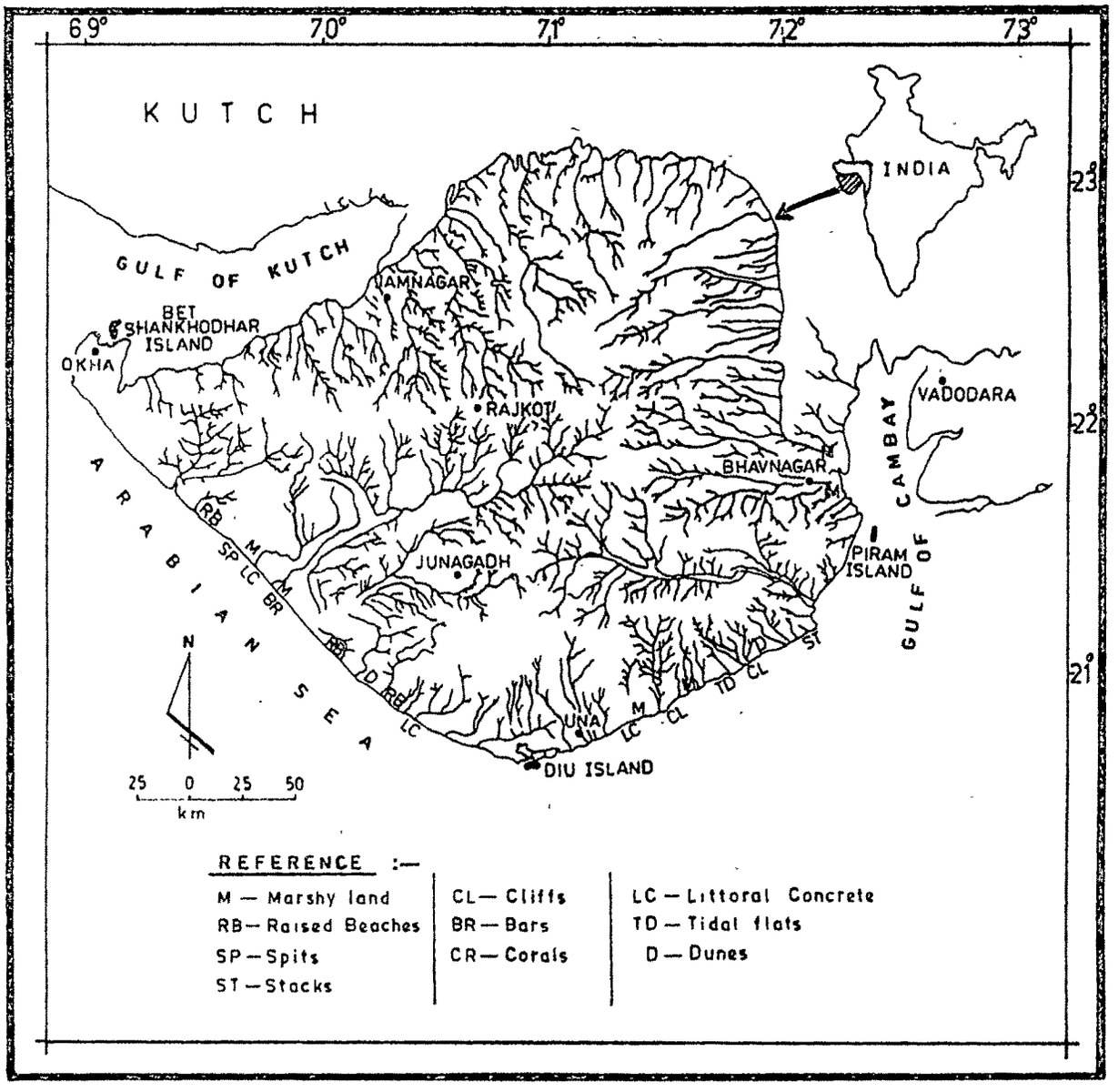
The purpose of this discussion is to provide background information on the geology, geomorphology, and tectonics of the Saurashtra region in general and the coastal track of Saurashtra in particular.

1.1 LOCATION AND BOUNDARIES

The Saurashtra promontory on the west coast of India is a prominent rectangular land mass, bounded on the western and southern sides by the Arabian Sea; on the northern side by the Gulf and little Rann of Kutch; on the eastern side by the alluvial tracks of Gujarat, and partly by the Gulf of Cambay (20° 00' 00' to 23° 00' 00" north latitudes; and 69° 00' 00' to 72° 00' 00" east longitudes), Fig. 2.

The major part of the peninsula is under the cover of the Deccan Trap basaltic flows, while the coastal plains fringing the volcanic plateau comprise the younger sedimentary formations.

FIG. 2 MAP SHOWING LOCATION, DRAINAGE AND GEOMORPHIC FEATURES OF SAURASHTRA (MODIFIED AFTER SOOD et.al. 1982).



The monotonously flat coastal plain is often dotted by low lying hillocks and mounds of limestone and marls.

A characteristic feature of the Saurashtra coast is the narrow belt of low coast aligned ridges and cliffs made of Sub-Recent to Recent carbonate sands and other near shore deposits. Such coastal sand deposits in the form of sand ridges and dunes often are found to vary from 3 to 8 mts in height. Along the southern coast, these stabilized carbonate sand dunes form high cliffs against the sea, rising 16 to 33 mts. In contrast the northern shore of the peninsula is only slightly raised above the level of the shallow Gulf of Kutch.

1.2. PREVIOUS WORK

Geological investigations have been carried out in Saurashtra (Kathiawar, as it was formerly called) by a large number of workers over a period of more than hundred years. Some of these were Hugel (1836), Falconer (1845), Theobald (1857), and Blanford (1863) who made sporadic observations on the geology of the peninsula. Carter (1849), published an account of the foraminifera from the coastal sediments of Saurashtra. The first official geological mapping of the region was carried out by Fedden (1884), whose work was published as a memoir by the Geological Survey of India. He clearly recognised and described the major stratigraphic units in the Saurashtra peninsula and, his work forms the basis for almost all the subsequent investigations. An extensive account of the Miliolite beds in

the former Junagadh state was published by Evans (1900). Microfossils from these beds were described by Chapman (1900), Sinor (1927) described the petrology of the igneous and sedimentary rocks around Bhavnagar. Geology of the area around Ghogha assumed importance with the discovery of natural gas in a borehole drilled for drinking water (Vinayak Rao, 1930). This led to various geological expiditions by Ghosh (1936), Crookshank (1940) and Dunn (1942) in the Ghogha region.

During the last three decades, the officers of the ONGC and Geological Survey of India have carried out intensive geological investigation on the offshore and inland regions of Saurashtra coast. These workers include, Shrivastava, 1968; Rao, 1962; Raju, 1968; Biswas and Deshpande, 1983; Mathur, 1978 and Verma 1979. Simultaneously, the Scientists of the Physical Research Laboratory, Ahmedabad, studied radiometric ages of the coastal sediments. Important contribution were made by Agrawal (1977) and Bhaskaran (1985). Recently, Hardas and Shringarpure (1982); Oza and Shringarpure (1982); Desai and Shringarpure (1982); Thorat and Shringarpure (1982); Jadia and Shringarpure (1982); Sakhawala and Shringarpure (1988) and many other members of the department of Geology, M.S. University of Baroda have carried out important studies on the different coastal segments of Saurashtra and brought to light important new information. In spite of all these effort in depth geological surveys towards the Island zones are missing surprisingly.

1.3 GEOMORPHOLOGY

The geomorphology of the Saurashtra coast has been studied by a number of present and past investigators (1.2). Amongst those an important contribution based on landsat imageries, aerial photographs, topographic maps and field traverses, is reported by Sood, Subramanyan and Baldev Sahai (1982). The following brief account is drawn from their studies.

As suggested by Sood, Subramanyam and Baldev Sahai (1982) the maximum elevation of 1117 meter of the Saurashtra peninsula gradually falls off on all sides and facilitates development of a radial drainage pattern (Fig. 2). This inturn results into six watersheds, draining into the Gulf of Cambay, the Arabian sea, the Gulf of Kutch, and the little Rann. The sediment load carried through these patterns invariably contributes to the present day coastal development in the Saurashtra region. Sood et.al. (1982) have further divided the entire Saurashtra coast into the following four coastal segments.

(i) The eastern coast : This coast borders the Gulf of Cambay. The coast as a whole has resulted into irregularities by the parallel patterns of dendritic streams draining westward into the Gulf of Cambay. In the sheltered regions of such irregular near shore zones development of marshes is seen extending 6 to 8 km inland. This coastal tract as such is grouped with category of submergent coast.

(ii) The southeastern coast : This is essentially a submergent coast though some offshore bars and other depositional features do indicate emergence. Along the coast from Gopnath point westward numerous cliffs (rising 10 to 25 mts), many Islands, tidal flats, deposits of littoral concrete, rocky beaches, estuaries, embayments and stacks are located. Behind the cliffs near Mahuva, a row of dunes trending NE-SW can prominently be marked. Here again, the streams are mutually parallel and dendritic, most of them have wide mouths with many distributaries that end abruptly against the sea.

(iii) The southwestern coast : This is essentially an emergent type with considerable marginal addition in the form of spits and bars all of which have possibly helped to straighten the coast.

The coastal tract from Diu onwards presents, a series of interesting geomorphological features including sandy beaches, spits, bars and hooks, marshes, estuaries and raised beaches with littoral concrete (between Veraval and Porbandar), and corals, dead and living (near Mithapur). The streams are parallel, running southwest, though individually dendritic. Around Porbandar the marshy tract curves inland and is traceable for many kilometers. Spits and bars can also be observed near Porbandar and Navabandar.

(iv) The northwestern coast : This is highly indented coast. It has a number of cliffed, rocky Islands, fringed by coral reefs.

Marshes and littoral concrete deposits also characterize this coastal tract. The overall evidences favour the northwestern coast to be a submerging coast.

As concluded by Sood et.al (1982) the submergence and emergence in Saurashtra took place during the Quaternary period, partly due to the (Pleistocene) changes in the sea level, and partly for the neotectonic activity.

1.4 GEOLOGY AND STRATIGRAPHY

An earlier attempt to investigate the geology of Saurashtra was made by Fedden (1884). He was the first who clearly recognised and described the major stratigraphic units. He described a large number of fossils and fixed the position of Gaj and Dwarka Formations. He, however, stated that some of the rocks incorporated under Dwarka beds might be as young as Pleistocene and must be separated on closer examinations. One of these rock types he described is the "coastal fringing rock, which is seldom met at any great distance from the coast and forms Dwarka cliff in the type area of Dwarka beds". The following table describes the rock formations and their approximate geological ages as suggested by Fedden, (1884).

Table : 1 Classification of Quaternary and Tertiary sequence of Saurashtra (after Fedden, 1884)

Formation	Approximate Geological Age
Alluvium, tidal flats, sand dunes, Rann clays, raised beaches and Miliolites	Holocene, Recent and Sub-Recent
Dwarka Beds	Higher Tertiary or Post Pliocene
Gaj Beds	Upper Pliocene (Lower Manchar in part of Gaj of Sind)
Lateritic Rocks	Lower Eocene (Sub nummulitic of Kutch and high level laterite of Deccan)
Traps	Cretaceous, Eocene (Deccan Trap)

After a gap of nearly 75 years, of real insight towards the geology of Saurashtra came from Sastri and Pant (1959), who mapped the Quaternary carbonates covering Veraval and Mangrol coasts. They gave entirely a new classification in which chronostratigraphic units of Pleistocene, Sub-Recent and Recent ages were distinguished (Table.2). Under this scheme, Miliolite limestone forms the oldest unit, followed by consolidated fossiliferous rocks, while the unconsolidated sediments and coral reefs constitute the younger units.

Table : 2 Classification of Quaternary and Tertiary sequence of Saurashtra (after Sastri and Pant, 1959)

Formation	Lithology	Age
Recent Deposits	Alluvium, coastal sand dunes, fringing coral reefs.	Recent
Sub-Recent Deposits	Consolidated shell sands and beach deposits, dead reefs, emerged beaches, old sand dunes etc.	Sub-Recent
Miliolite Limestone	Fine to Medium grained oolitic limestone.	Pleistocene
Dwarka Beds	Variegated, flaggy limestones of varying texture and composition and with intervening yellow marls and clays.	Upper Miocene to Pliocene
Gaj Beds	Hard, compact, finegrained buff, yellow or red coloured limestones.	Lower Miocene
	Deccan Traps and other Volcanics	

Following Sastri and Pant (1959), work Shrivastava (1968) of the O.N.G.C. described the geology, stratigraphy and geological history of the peninsula of Saurashtra in his unpublished report (ONGC 1968). The stratigraphic units suggested by him are as under :

Table : 3 Stratigraphic sequence of Saurashtra (after Shrivastava, 1968)

Name of Rock Unit	Lithology	Thickness in m	Facies	Geological Age
Alluvium	Alluvium, black cotton soil, coastal sand dunes Rann salt waste, coral reef, laterite etc.	7-76	-	Recent and Sub-Recent
Porbandar Formation	Dirty white, oolitic, sandy limestone and calcareous sandstone; occasional grits, conglomerates and thin clay bands	30	Littoral	Pleistocene to Sub-Recent
Dwarka Formation	Silty clay occasionally gypseous; yellow calcareous clays and marl, Top portion arenaceous limestones with broken shell fragments.	32	Littoral to Epineritic	Upper most Miocene to Pliocene
	Unconformity			
Gaj Formation	Hard fossiliferous grit, conglomerates with clay marl layers.	40	Epineritic	Lower Miocene
	Unconformity			
Lateritic Rocks	Red and brown hard laterite with white patches, some times bauxite with volcanic ash and tuffaceous material.	10-15	Residual deposits	Lower Eocene
Deccan Trap Formation	Basaltic flows associated with some acidic lavas, plutonic masses and dykes intrusive in the trap flows and Mesozoic formation.	600 +	-	Upper Cretaceous to Lower Eocene

Another serious attempt to the geology of Saurashtra came from Mathur and Mehra (1975). These workers proposed a classification on the basis of their work on the Quaternary rocks

of Porbandar area and the reconnaissance of the rest of the Saurshtra peninsula. They gave Formation status to two of the three stratigraphic units suggested by Sastri and Pant (1959). The 'Miliolite limestone' was renamed as Miliolite Formation, while "Sub-Recent Deposits" were referred as Chaya Formation (nomen novem), the two being assigned Early Pleistocene and Late Pleistocene age respectively. The "Coastal fringing rock" of Fedden were taken out from "Dwarka Beds" and grouped with the newly proposed Chaya Formation.

Table : 4. Classification of Quaternary and Tertiary rock sequence of Saurshtra (after Mathur and Mehra, 1975).

Stratigraphic Unit	Lithology	Age
Alluvium and Coastal Deposits	Fresh water alluvium (sands, clays), coastal deposits (Lime mud; Bann clays with carbonaceous material marine shells; unconsolidated calcareous sands).	Holocene
Chaya Formation	Semiconsolidated to consolidated limestones (calcirudites); shell limestones, coral reefs and oyster beds.	Late Pleistocene to Holocene
Adatiana Member	Pelletoid limestones (calcarenites)	Early Pleistocene
Dhobaliya Talav Member	Alternating seqence of pelletoid limestones and finegrained limestone (micrites).	
Dwarka Formation	Flaggy,arenaceous limestones with recrystallised shells; clays.	Middle Miocene to Lower Miocene
Gaj Formation	Hard, compact, finegrained limestone with abundant foraminifera; variegated clays.	Lower Miocene
_____	Laterite and Deccan Trap	_____

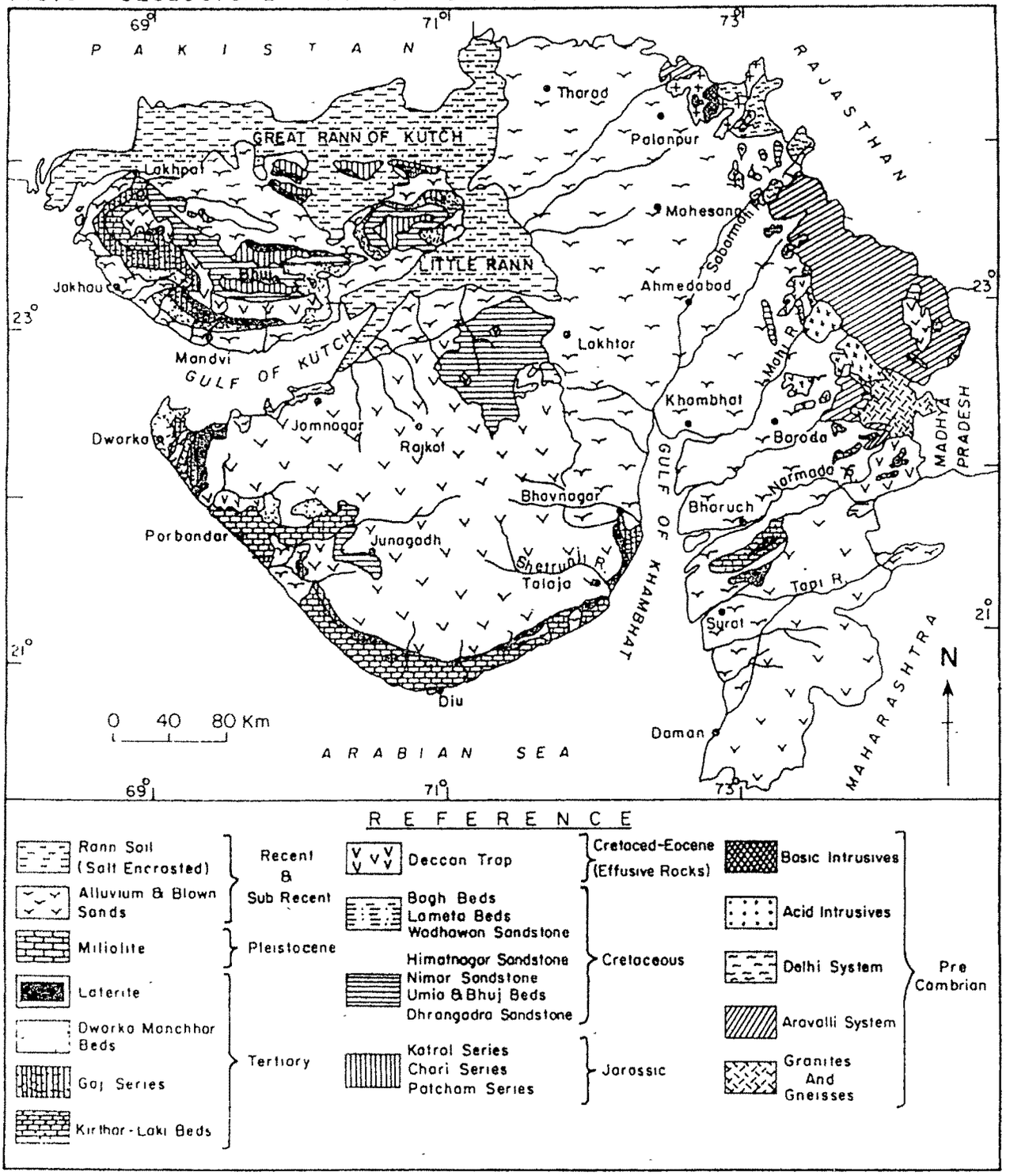
Recently, Marathe et. al. (1977), reconstructed a composite lithostratigraphic section (Table. 5) of the rock units encountered in the Hiran River valley of southern Saurashtra. The stratigraphic column shows two major rock units (Unit I and II), each one characterised by fluvial sediments grading into the miliolites. These authors suggested Middle Pleistocene (?) and Late Pleistocene ages to miliolite I and II of the above units respectively. Their field and laboratory (geological, petrological and archaeological) evidences are in favour of fluvio-marine origin of miliolite deposits that extend upto 20 km inland from the coast and upto 75 m above mean sea level. While those occurring above 75 m are according to them aeolian and fluvio-marine in origin.

Table. 5. Composite lithostratigraphic section of Quaternary rocks of Hiran River valley, southern Saurashtra (after Marathe et. al. 1977).

Average Thickness in mts.	Lithology	Probable Age
3.0	Soil, allviam, beaches and dunes sharp contact to (disconformity).	Late Holocene (4000 BP to modern)
----------	Sharp contact to (disconformity)	----------
1.0	Fossil soils, yellow-brown alluvial silts, gravels and aeolinite and beach rock.	Late Pleistocene to Mid Holocene (20.000-4.000 BP)
---------	Sharp Contact to (disconformity)	----------
1.5	Miliolite - II,oyster beds; shelly gravels, beach rock and aeolinite.	Late Pleistocene (30.000 BP)
---------	Sharp Contact to (disconformity)	----------
1.5	Fluvial gravels and brownish moderately calcareous silts and tidal clays.	Early Late Pleistocene (30.000 BP)
1.0	Calcareous fluvial gravels and clays.	Early Late Pleistocene
---------	Sharp Contact to (disconformity)	----------
	Miliolite - I, with intercalated tidal clays, aeolinites and terrigeneous sediments grading to fluvial gravels, silts and clays.	Mid-Pleistocene (1) Mid-Pleistocene (1)
---------	Unconformity	----------
	Beach rock, limestone etc. Deccan Traps	Gaj of Miocene Eocene-Cretaceous

The geology of Gujarat is represented in (Fig. 3)

FIG. 3 GEOLOGICAL MAP OF GUJARAT.



1.5 STRUCTURE AND TECTONICS

The structure and tectonics of Saurashtra has to be appreciated considering the various geological and geophysical evidences put forth by Rao et. al. (1962), Poddar (1964); Shrivastava (1968), Lele (1967, 1973), Sood et. al (1982), and Biswas (1987) (Fig. 4). Most of these authors have delt with their suggestions in context with Gujarat as a whole, or the western section of the Indian subcontinent in general. Main points of their arguments can be compiled as under.

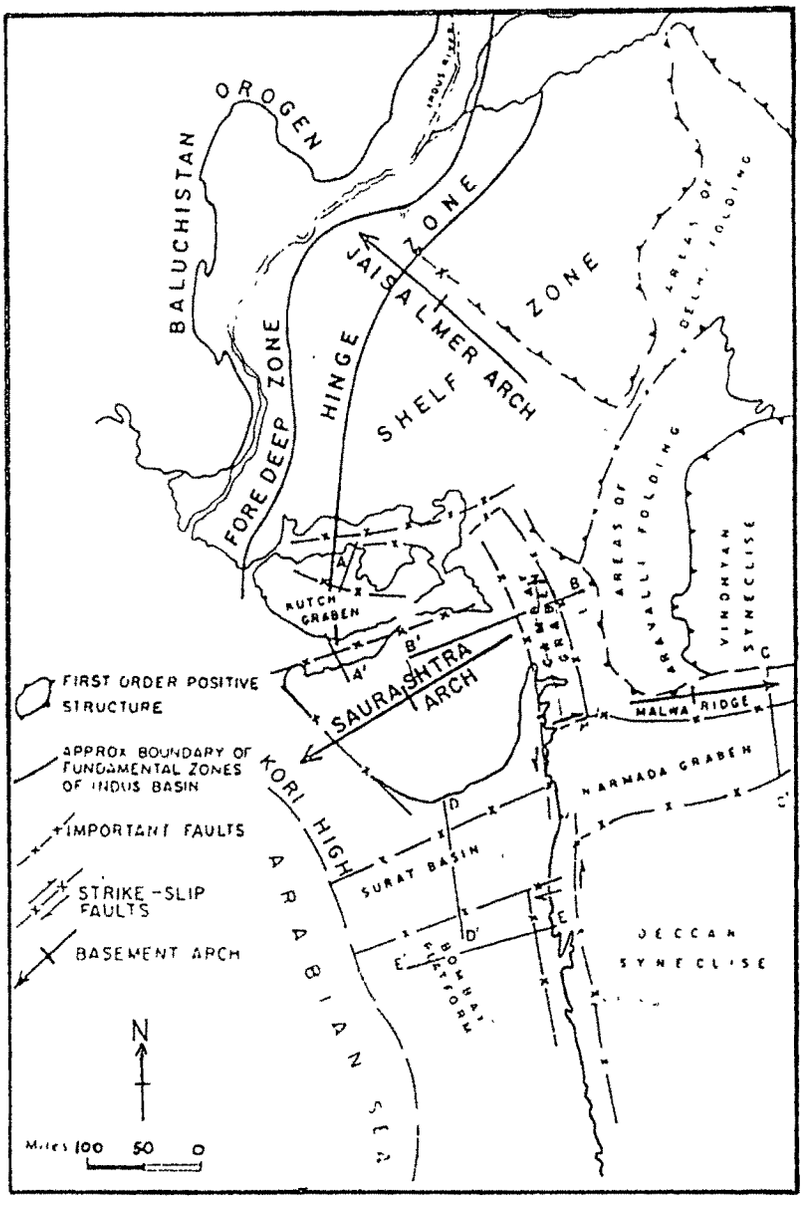
(i) Most of the authors believe that the faults along which the movement took place in Saurashtra existed in the basement and were reactivated during different geological periods.

(ii) The northern part of Saurashtra bounded by Little Rann and the Gulf of Kutch has a likely concealed fault running in a general east-northeast-west-southwest direction, and is probably the cause of a somewhat linear northern coast line of present day Saurashtra, and for the rather abrupt termination of the Tertiary rocks of the Okha-Mandal region and the Deccan Trap against this straight line coast. This fault belongs to the set of general east-west trending faults as in Kutch.

(iii) Some authors (Rao et. al. 1962), regard the Little Rann and the Gulf of Kutch as a zone of weakness, probably a graben or halfgraben.

(iv) Faulting is also claimed to have taken place along the western margin of Saurashtra, which again shows a striking

FIG. 4 TECTONIC FRAMEWORK OF WESTERN INDIA
(AFTER BISWAS, 1987)



straight coastline between Okha and Kodinar. This fault is probably the extension of the fault which is believed to have caused the almost straight western coast line of India.

(v) The southeastern coastline also shows similar characters with some steep scarp facies. This fault is thought to be the extensions of the zone of weakness along which the Narmada faulting in the east-northeast-west-southwest direction has taken place. The northern coastline fault would be almost parallel to this fault.

(vi) The eastern margin of the Saurashtra is bounded by the faults of the Cambay graben which are parallel to the west coast fault.

(vii) Thus, an almost rectangular Saurashtra peninsula is bounded on all sides by faults on the continental slopes.

(viii) All these faults were active during Tertiary times and till late Pleistocene and it is likely that they were existing even earlier and may be active even today.

(ix) It is further claimed by most of the workers that the Saurashtra peninsula was subjected to submergence and emergence during different geological periods of the Tertiary time due to eperogenic movements along the fault planes.

(x) The greatest marine transgression in the known geological history of the peninsula occurred during Pleistocene time during

which the miliolite carbonate sands were deposited. These are further claimed to have been uplifted in the inland areas to their present positions.

(xi) Such an upliftment which commenced in the late Pleistocene and Sub-Recent, is probably still under progress (Neotectonics). The mean sea level studies on the west coast of India according to Lele (1967,1973) are indicative of a rising trend of the coast which he claims is indicative of the instability of the region.