CHAPTER-II

PREVIOUS WORK

In the present study area in and around Gir forest area, Junagadh district, very few geological investigations have been carried out in the past. Most of the past researches have been based mainly on the floral and faunal aspects. However, the Saurashtra peninsula, during the last 150 years, has attracted many geologists, who have investigated one or the other aspect of its geology.

Broadly speaking, the following aspects of Saurashtra geology have received attention :

1) the Deccan Trap and its interesting differentiates,
2) Jura-Cretaceous and Tertiary rocks,
3) the Quaternary carbonate sands (miliolites), both coastal as well as inland, and
4) the tectonic framework.

In the last decade or so many archaeologists have been involved in the Saurashtra peninsula.

In this chapter, the author has endeavoured to summarise only such information which is directly or indirectly relevant to the present study. A number of studies on other parts of Saurashtra have been omitted, while a few have been purposely referred to, with a view to provide the necessary background for numerous observations and inferences arrived at by the present author.

The geology of Saurashtra peninsula has been studied by a number of workers, but these studies have been generally restricted to one or the other above mentioned aspects, except Fedden (1884), who 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. A brief chronological account of the relevant previous work is described in the following pages.

Hughes (1836), Falconer (1845), Carter (1849), Theobald (1857) and Blanford (1869).

Some of the earliest workers like Hughes (1836), Falconer (1845), Theobald (1857) and Blanford (1869) made sporadic references to one or the other aspects of Saurashtra geology in their works. Carter (1849) made an exclusive study of the coastal carbonate deposits of Quaternary age and gave them the name "Miliolite" or "Miliolite Limestone". He described them as "granular deposits composed of oolitic particles of calcareous sand united together into a firm compact rock on the Arabian sea coast, having predominance of the form belonging to the genus Miliolina".

Fedden (1884)

The first ever detailed and systematic geological account of the Saurashtra peninsula was given by Fedden (1884), and his work forms the basis for almost all the later works carried out in the peninsula. He clearly recognised and described the major stratigraphic units (Table : 2) of Saurashtra and prepared a fairly detailed geological map showing the distribution of the various formations. He recorded numerous dyke rocks cutting across the basalts of the Deccan Trap and pointed out the existence of central foci of eruption in the Girnar and Barda Hills towards the later part of the Trappean period.

Regarding Deccan Trap basalt, Fedden (1884) opined that the Trap formations in Kathiawar were an extension of those in Kutch on one hand, and of those in Gujarat and Malwa on the other, stretching from the east coast at a point below Gogha, to the western shore, where they sink below the Gulf of Kutch.

Moreover, he has opined that the accumulative thickness of volcanic rock in the Girnar mountain cannot be less than 3500 feet, but one-half that amount would suffice for the thickness of the bedded Traps throughout the greater part of the field.

TABLE - 2

STRATIGRAPHIC SUCCESSION OF SAURASHTRA PENINSULA

(after Fedden, 1884).

Formation	Approximate geological position
Alluvium (sand dunes, tidal flats, freshwater alluvium, `rann´clays, raised beaches and miliolite)	Recent and Sub-Recent
Dwarka beds	? Higher Tertiary or Post-Pleistocene
Gaj beds	Upper Miocene -(lower Manchar in part, and Gaj of Sind)
Lateritic rocks	? Lower Eocene -[sub-nummulitic (Wynee) of Kutch, and ? high-level laterite of the Deccan]
Traps	Cretaceous-Eocene (Deccan Traps)
Trappean grits	? Cretaceous [Infra-trappean grits (Wynne) of Kutch]
Wadhwan sandstone	? Cretaceous (Infra-trappean of India)
Umia beds	Jurassic (Upper Gondwana)

He described that the Trap rocks of Kathiawar resemble in nearly every respect, those of the Deccan and Malwa in peninsular India. The several flows vary considerably in character. Some of the Trap-flows are thoroughly crystalline, often showing a porphyritic appearance on the weathered surface; others are more homogenous, compact and aphanitic; while others are more or less decomposed, many of these are highly amygdaloidal.

He has proposed Girnar to be a focus of eruption. According to him the great central mass now represents much of the core, or plug, of the vent, the outer portion having been more readily removed by denudation owing to the decomposition of the component minerals.

He has stated that the sedimentary deposits interstratified (Inter-trappean beds) with the Trap flows are seldom met within Kathiawar, and the few places where they have been observed are situated at no great distance within the northern margin of the Trap area; and, as usual in other parts of India, the Inter-trappean horizon is not far from the base of the formation.

Mentioning about the Trap dykes, Fedden (1884) has stated that the dykes are very numerous and large, often forming prominent features in the landscape, and many of the dykes are traceable for long distances. The general bearing is east and 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 and south, or north-by-west and south-by-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 the Girnar mountain and a few other hills, there is some evidence of the latter kind of discharge at the close of the Trappean outflow.

He stated that the character of the dyke-Trap generally differs from that of the adjacent flows or beds; this may probably arise from the difference of condition under which the matter solidified. The rock, in very many of the dykes, has a prismatic or columnar structure, transverse to the direction of the dyke. In very few instances was the dyke-Trap observed to be amygdaloidal or vesicular, and where such is the case, it may be presumed to occur near the surface, or overflow : at this latter point, a dyke would naturally become ill-defined and blended with the lateral flow.

He has mentioned that the agriculturists persistently sank their irrigation wells along the dykes, tracing out their course with great assiduity; they were almost invariably rewarded by the wells yielding water at a depth within 15 to 20 feet of the surface. In some instances it would appear that the joints and cracks in the dyke-rock communicated with some deep-seated water-bed; in other cases, the dykes seemed to wall up, keeping in on one side, the water of the adjoining strata.

Fedden (1884) defined `Miliolite´ as a finely oolitic freestone, almost free from sand or other foreign particles. The nuclei of the oolite grains being mostly organic. He gave details of the field characters of the rock from the coastal areas of Porbandar, Veraval, Jafarabad and Gopnath point. Amongst the inland miliolite deposits, he made a special mention of Chotila hill near Rajkot, where according to him, miliolite formed "a fringe around the truncated top at a height of 1173 ft above the sea-level".

He has described that the soils of the plains were very shallow; and varied from black cotton soil, where the floor was of Trap, to a light sandy one when resting upon sandstone.

He has briefly mentioned the occurrence of base-metal deposits in Gir area. He has stated that within the Gir hills, at Banej Nes, on the Machhundri river, some galena, associated with copper pyrites, occurs sparingly in a quartz vein in the Trap rocks. The vein, which bears about north 15^{o} -east, and south -15^{o} -west, is only a few inches (2"-6") in width where exposed, and it could not be traced for many yards, neither do the ores prevail throughout its course. It is therefore, not considered as a workable deposit. The uncommon occurrence (in India) of a metalliferous vein in the Trap rocks is worthy of note.

Foote (1898)

Foote (1898), a state geologist of the then pricely state of Baroda, reported a large number of acid and basic Trap-dykes intruded into the main Trap-flows. He described the geology and mineral resources of the Amreli area (which earlier formed a part of the Baroda state and at present forms a small portion of the study area). He more or less followed Fedden's work while giving his geological account.

Evans (1900)

Evans (1900) studied the miliolites of Junagadh and its neighbourhood, and he for the first time put forth an aeolian origin for these carbonate sand deposits. He wrote, "There seems every reason to believe that Junagadh limestone was formed by aeolian action.... but it is impossible to believe that this calcareous material could have been blown 30 miles over barren plains... We must assume that the city of Junagadh was close to the margin of the sea". He believed that the miliolites were formed in shallow waters between tidal limits as littoral accumulations. He considered the inland deposits to be "the products of transportation by wind action on the ancient coastal sediments".

Chapman (1900)

Chapman (1900), too restricted his studies to the miliolites, and he also invoked the aeolian origin for the deposits of Junagadh and Porbandar. He, however, suggested that the coastal miliolites were deposited under shallow marine conditions.

Adye (1914)

Adye (1914) classified the dykes of Saurashtra into two groups :

(i) older dykes of the lava period, forming low ridges, and studded with phenocrysts in a microlitic groundmass; and

(ii) post-flow dykes, forming massive high ridges, cutting the older dykes, and mostly holocrystalline and ophitic. He also mentioned the occurrence of a central type of volcanic activity.

Krishnan (1926)

Krishnan (1926), while studying the petrographic characteristics of rocks from Osham and Girnar, reported acid volcanic and hypabyssal rock types.

Chatterjee (1932)

Chatterjee (1932) studied the igneous rocks of west Gir forest and on the basis of chemical analysis he classified the dolerites of west Gir forest into two broad types :

(i) "saturated" - resembling the dolerite and basaltic flows of Deccan Traps and characterized by enstatite-augite (pigeonite), and

(ii) "unsaturated" - which may be called olivine-dolerites. These have purplish or brownish pyroxene characteristic of alkali olivine-basalt.

He also described an oligoclase-basalt from west Gir forest area.

Dubey & Bajpai (1937)

Dubey & Bajpai (1937) carried out radioactive element determinations of Deccan basalts from western India. For Kathiawar basalts, they showed that there was not much variation in the radium and thorium contents in successive lava flows and in the younger dykes of the same period. They mentioned that the greater part of the province of Kathiawar was covered by the lava flows of the Deccan Trap age, traversed by several long dykes of basic and ultrabasic rocks, particularly in central Kathiawar and in the Gir ranges.

Auden (1949)

Auden (1949) described numerous types of dykes in the Kathiawar peninsula viz. radial dykes, dyke clusters, dyke networks and arcuate dykes. He studied the age and distribution pattern of the Deccan Trap dykes. For the dykes of Saurashtra, Gujarat and Konkan, he was of the view that some of them may have belonged to a post-lava hypabyssal phase. He was also of the opinion that calderas existed in Kathiawar.

West (1959)

West (1959) studied the Deccan Trap flows around Sagar, Madhya Pradesh, and concluded that the lavas were erupted through fissures now seen as dykes, and that the major foci were off the west coast, in Saurashtra, and up the Tapti and Narmada valleys to the eastern Satpuras and beyond. He also stated that the flows travelled great distances to reach the northern, eastern and southern margins of the Trap outcrop, and that they were extremely fluid.

Chatterjee (1961)

Chatterjee (1961) while working on the magmatic differentiation of Deccan Traps has concluded that the fluidity of the Deccan Traps was due to the high content of iron, the chemical changes in the magma and accompanying gases. He suggested that the localization of the alkali-olivine basalt type in Western India was due to special tectonic conditions associated with deep fissures and faulting.

Saxena (1962)

Saxena (1962) has divided the Deccan Traps into two viz. upper and lower, based mainly on the geochemistry.

Wadia (1966)

Wadia (1966) is of the opinion that the Deccan Trap eruptions were subaerial and subaqueous and that the discharge was through linear fissures.

He has given the following stratigraphic relations of the Deccan Traps :

Nummulitics of Surat and Broach ; Eocene of Kutch ; Laterite

----------------------- UNCONFORMITY -----------------------

Upper Traps Of Bombay and Kathiawar. Lava flows with
1500 ft. numerous ash-beds, sedimentary inter-trappean

	beds of Bombay with large number of fossil vertebrata and mollusca shells.
Middle Traps 4000 ft.	Of Malwa and Madhya Bharat. Lavas and ash beds forming the thickest part of the series. No fossiliferous inter-trappean beds.
Lower Traps 500 ft.	Of Madhya Pradesh, Narbada, Berar etc. Lava with few ash-beds. Fossiliferous inter-trappeans numerous.

---------------------slight unconformity---------------------

Lameta or Infra-trappean series; Bagh beds; Jabalpur beds and older rocks.

He has also mentioned that numerous dykes of varying dimensions have intruded into the Trap area of Kathiawar. These dykes follow different directions and are composed either of an acidic trachytic rock or of a coarse-grained dark dolerite or dioritic mass.

Subbarao (1965a,1965b,1967)

Subbarao (1965a) has concluded on the basis of petrography that the parental magma of the Deccan Trap region is tholeiitic in composition.

According to Subbarao (1965b), the Deccan Trap igneous activity indicates only three phases, the volcanic, the major, and the minor intrusions, which can be further divided into different episodes. He has concluded that the minor intrusions had brought about a complete cessation of igneous activity in the Deccan Trap region.

Subbarao (1967) states that there was no renewed eruption of lava after the plutonic intrusions of the Deccan Traps.

Shrivastava (1968a & 1968b)

Shrivastava (1968a) considered most of the miliolite occurrences (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 he concluded that the formation represented mostly beach sediments that were formed in agitated, warm and shallow waters, only a few feet deep, and that during the Pleistocene, the sea-level stood much higher than at present. The sea has since receded to its present stand, and a succession of progressive younger beach and allied deposits were formed following the regressive shoreline. He further suggested that the aeolian sands inter-stratified with the limestone were probably deposits formed on the old shorelines, which were submerged under the advancing Pleistocene sea. These were now elevated above high-water beach deposits.

Shrivastava (1968b) attributed this sea-level rise to Quaternary tectonism, postulating downfaulting of the entire Saurashtra peninsula in the Pleistocene that caused wide spread marine transgression.

Agrawal (1969,1971)

An attempt at radiometric dating of miliolites and some coastal rocks of Kutch and Saurashtra was made for the first time by Agrawal (1969,1971) of Physical Research Laboratory (P.R.L.). He dated some of the aeolianites of Saurashtra and Kutch by C^{14} method and found them to show a Late Pleistocene age.

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, and winds transporting the exposed calcareous sands 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) in respect of the origin of inland miliolites. 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.

Gupta (1972,1977)

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 m above the present level. He dated these high strandlines as 1,20,000 , 30,000 and 6,000 B.P. Of course, he presumed that during Quaternary period, the Saurashtra peninsula was free from tectonic instability.

Rajaguru and his co-workers (Govindan et al.,1975,1977; Marathe et al., 1977; Rajaguru & Marathe,1977,1982).

Rajaguru and his co-workers investigated the miliolites of Hiran River valley of southern Saurashtra, and on the basis of geomorphological evidences, they invoked a marine origin for the miliolite deposits upto a height of 40 m, while those occurring above (upto 104 m), were considered to be aeolian. Marathe & Rajaguru (1982) correlated the Stone Age sites in Hiran valley with two major trangressive phases of the sea during the Late Pleistocene.

Sharma (1978)

While carrying out radiometric survey near Tulsishyam hot spring, Sharma (1978) has reported two acidic dykes on the eastern and western sides of the hotspring fracture zone.

Verma & Mathur (1975 to 1979)

A substantial contribution to the Quaternary geology of Saurashtra came from Verma & Mathur of G.S.I. (Mathur & Mehra,1975; Mathur,1978; Verma & Mathur,1978; Verma,1979), who made an exclusive study of the miliolites. In their doctoral theses submitted to the M.S.University of Baroda (Mathur,1978; Verma,1979), these two workers have provided a wealth of geomorphic, sedimentological, and palaeontological information on the miliolites. The salient features of their contribution include (i) a revised classification of these carbonate deposits, (ii) establishment of field criteria for distinguishing the marine and aeolian miliolites, (iii) evidences in favour of the stability of Saurashtra during Quaternary, (iv) studies on the cross-bedding in miliolite rocks for establishing the palaeo-wind direction, and (v) studies on the textural characteristics of the carbonate beach and dune sands, to establish criteria for separating the two environments.

Ganapathi & Patel (1979)

Ganapathi & Patel (1979) have reported and described a number of erosional and depositional geomorphic features related to a past higher strandline of 4 to 5 m above the present level of the sea. The erosional features include dead cliffs and abandoned wave-cut platforms, while the depositional features comprise fossilized coastal dunes and elevated tidal flats.

Pandya (1979)

Pandya (1979), an archaeologist, who explored the lower course of the Shetrunji River and found human settlements of Harappan (i.e. about 4,000 years ago) age, has suggested that during the Harappan times the sea-level was slightly higher than the past.

Merh & his co-workers (Merh, 1980; Merh, 1982; Patel et al., 1982; Ganapathi et al., 1982; Ganapathi & Merh, 1982; Merh & Ganapathi, 1985; Patel, 1988; Merh, 1989).

Merh (1980) reviewed the entire miliolite problem in his presidential address to the Geology and Geography Section of the 67th Indian Science Congress. He has concluded that, "the miliolite occurrences comprise both marine and aeolian.... the so called \`ooliths´ of the miliolite rocks are mostly \`peloids´ and these have originated by a process quite different from that which would give rise to ooliths." He (1980, p.38) has stated, "The deposition of miliolite rocks took place during more than one transgression and regression. Successive transgressions and regressions along the coastline would give rise to a mixed sequence of marine and aeolian beds; also the fossil aeolianites of inland areas would belong to more than one generation."

Merh (1982) has stated that in addition to glacio-eustasy, neotectonism played a significant role in modifying the strandline positions in Saurashtra. Further, he stated that the inland miliolites of Saurashtra represent a combination of marine (horizontally bedded valley-fill) and aeolian (cross-bedded obstacle dune) accumulations having been deposited along the margins of an inland sea much higher than the present.

Patel *et al.* (1982) have reported for the first time miliolitic rocks from the southern coast of Kutch and northern coast of Saurashtra, marking the flanks of the Gulf of Kutch. They have invoked a combination of eustasy, isostasy and neotectonism to explain the occurrence of high level miliolites in Kutch and Saurashtra.

Considering the effects of tectonism, Ganapathi *et al.* (1982) have postulated the following sea-levels, correlatable with the major climatic stages of the Quaternary :

1. Tyrrhenian	Transgression	+40 m
2. Würm	Regression	-20 m
3. Flandrian	Transgression	+8 to 10 m
4. Present day sea level	---	---

In addition to Quaternary morphology and sedimentation, they have considered the role played by tectonism in the evolution of the coastline between Okhamadhi and Kodinar. They have considered that the coastline came into existence during Miocene when the west coast faulting occurred. They have stated that the neotectonic phenomenon is reflected in the marked altitude variation of the older high-level sheet miliolites, tongues of which extend inwards along most of the river valleys.

Ganapathi & Merh (1982) have indicated probable palaeoshorelines during Tertiary and Quaternary periods along the Saurashtra coastline. They have given an evolutionary model of a complex interplay of sea-level changes and tectonism during the Tertiary and the Quaternary periods.

Merh & Ganapathi (1985) have suggested that though the Saurashtra peninsula as a whole might not be showing spectacular uplifts and subsidences as a single block, there are ample evidences which indicate that its various parts did undergo differential movement during Neogene and Quaternary periods.

According to Patel (1988), the miliolites in Saurashtra occur as longitudinal dunes, parabolic dunes, and valley-fill sheet deposits. Their location at various altitudes point to their dumping at different heights on a pre-miliolite uneven topography.

Merh (1989) stated that all inland miliolite occurrences were aeolian accumulations of long distance transport of beach material and their present altitudes are mainly due to pre-depositional topography, some post-depositional topography and some post-depositional tectonism. It was during a period of aridity and regression that beaches were exposed to deflation and aeolian action. Most of the aeolian miliolite occurrences have been consolidated by freshwater diagenesis. The highest and perhaps the oldest, (Mid-Pleistocene) strandline, was around 40 meters above the present level. Occurrences of marine miliolite at levels higher than this could be due to subsequent neotectonism.

Verma (1982)

Verma (1982) of G.S.I. has for the first time fixed the field criteria to distinguish marine and aeolian miliolites based on the sedimentary structures and quantitative faunal characteristics. He stated that the Saurashtra peninsula was quite stable during the Quaternary period. He has tried to correlate the altitudes of marine terraces of Saurashtra with similar terraces in other parts of the world.

Patel (1982)

Patel (1982) has classified the miliolite rocks of Hiran valley as marine deposits, and those from the environs of

Sasan Gir, as aeolian deposits. He has estimated the major and minor oxides of various miliolite rocks from Kutch and Saurashtra.

Sukheswala (1981)

Sukheswala (1981) concluded that the eruptive source regions of the Deccan magmas may be the two major lineaments, one along E-W Satpura basin, and the other along the N-S Cambay basin with its extension in the south. He assumes that the first magma to erupt on a wider scale, forming the major part of the Deccan Traps, was the tholeiite, followed by rhyolite, in fairly large proportions; and the igneous activity closed with the final eruptive phase of minor quantities of the alkali olivine basalt magma and the carbonatite alkalic magma, occurring as small plugs within the tholeiite.

Mishra (1981)

Using remote sensing techniques, Mishra (1981) has worked out the tectonic setting of Deccan volcanics in southern Saurashtra and northern Gujarat. He states that field evidences like gradation from compound pahoehoe flows to simple \`aa´ flows, and the orientation pattern of amygdules indicate, that the Deccan Trap lavas of southern Saurashtra have flowed from north to south, while lavas of the major part of the Trap country have flowed towards the east.

He has concluded that the eruption of basaltic differentiates in southern Saurashtra and northern Gujarat has taken place along deep fissures developed along the Narmada - Son lineament and Cambay graben.

Subramanyam (1981)

Using LANDSAT imagery, Subramanayam (1981) has worked out the geomorphology of the Deccan volcanic province.

Qureshy (1981)

On the basis of gravity analysis, Qureshy (1981) has tried to decipher the Deccan Trap volcanic episode and other related phenomena like isostasy, crust-mantle relationship, plausible channelways for lava movement, presence of fossil or present magma chambers, and possible rift zones in various stages of development.

For the Saurashtra region, he has given the following anomalies :

Anomaly	Description and correlation with geology
I 21° 36′N, 70°E	A high in the western parts of Saurashtra peninsula over the Girnar-Osham-Barda region with a positive relief of some 70 mgals.

II	21° N, $70^{\circ}30'$E	A high on the east coast of Saurashtra peninsula.It consists of three circlur anomalies with part of the northern most one falling over the Chogat-Chamardi hill region, which has a maximum relief of +80 mgals.

Kaila *et al.* (1981)

Deep Seismic Sounding (DSS) studies were carried by Kaila *et al.* (1981) of NGRI, along a 160 km long profile from Navibandar to Amreli in the Saurashtra peninsula. They have concluded that Trap thickness in general is larger (0.9 to 1.3 km) towards west of Junagadh. On the eastern side, near Bagasara it is thinning quite sharply, reaching a value of 0.35 km. A low velocity layer, probably Mesozoic, with longitudinal wave velocity of 4.0 km/sec is present underneath the Trap along the profile, with its largest thickness of 0.85 km around Amreli. A major basin during Mesozoic period probably existed from Bagasara in eastern Saurashtra, extending through Gulf of Cambay, Broach syncline, and ending near Rajpipla, where Mesozoics are exposed at present. The main feature of the crustal section is the Girnar horst flanked by Manekwara and Vanthali grabens. Another smaller horst exists near Mahiary. The Girnar uplift was formed due to upward movement of a plutonic mass from depth [Kaila *et al.* (1981, p. 231-232)].

Alexander (1981)

Based on K-Ar data, geological and palaeomagnetic findings, Alexander (1981) has tried to work out the age and duration of Deccan volcanism.

He has proposed a time scale for the evolution of Deccan Trap basalts as under :

110 Ma Seperation of Africa from India, Australia, New Zealand and Antarctica (Heirtzler, 1958).

100 Ma End of Lower Cretaceous : Extrusion of Rajmahal Traps (105-100 Ma) and the earliest Deccan Trap flows in Saurashtra (Dhanduka bore-hole sequence, 101 ± 3 Ma) together with intrusion of basic Gondwana dykes.

65-60 Ma Paleocene : Major episode of Deccan Trap activity which gave rise to a major part (two thirds ?) of the Deccan Traps, particularly of the western part.

50-42 Ma Eocene : Another significant episode of volcanism which gave rise to Deccan Traps of northeastern and other peripheral areas like Sagar, Jabalpur, Amarkantak and Malwa.

42-31 Ma Eocene to Oligocene : Low intensity volcanism giving rise to some younger flows (Koyna, Dohad) and post-Trap activity right down to Oligocene.

Balasubrahmanyan & Snelling (1981)

On the basis of conventional K-Ar age studies, Balasubrahmanyan & Snelling (1981) have concluded that the Deccan Traps are between 65 Ma and 70 Ma old.

West (1981)

West (1981) studied the Deccan Trap topography around Sagar and has concluded that the Deccan Trap eruptions took place in relatively rapid succession, giving little time for erosion to take place.

De (1981)

Based on geochemical studies of different lava flows from Kutch and Saurashtra, De (1981) has suggested the hot spot or mantle plume type origin for the olivine nephelinite and alkali olivine nodules (suggesting high speed magma supply and extension). The tholeiitic basalts were formed by quiet type of fissure eruption spread out over a very large area of peninsular India.

Krishnamurthy & Udas (1981)

Krishnamurthy & Udas (1981) have evaluated major, minor and trace element variations of the Deccan basalts from different areas.

Sood *et al.* (1982)

The first attempt to make a geomorphic approach to study the Kathiawar coast using remote sensing techniques was made by Sood *et al.* (1982). In addition to the southeastern and southwestern faults, they have suggested two more faults, one along the northern and the other along the eastern coasts. They have concluded that the oldest erosion surface in the peninsula has been upwarped cymatogenically to an altitude of 1117 m in the central part, and it falls peripherally to 600 m. They have shown that during the Quaternary era, the coast has been subjected to positive tectonic uplifts.

Singh & Merh (1982)

Singh & Merh (1982) of GWRDC, studied the problem of salinity ingress along the coastal areas of Saurashtra. They have found that overdraft of groundwater for various purposes has resulted into seawater intrusion. They have also suggested remedial measures.

Joshi (1982)

According to Joshi (1982), the semi-arid tract seemed to be the most favoured landform in all ages as, more or less continuous cultural development from Prehistoric to Early historic times could be traced in this zone of Saurashtra.

Pappu & Marathe (1982)

Pappu & Marathe (1982) have concluded that the inland plateau region lying between 40-80 m elevation was the major culture area, in Saurashtra, during Palaeolithic time. They have also traced Late Tertiary and Early Pleistocene erosional surfaces in Saurashtra.

Bapat (1982)

Bapat (1982) has inferred that the uplift of landmass in Saurashtra region cannot be attributed to the seismic activity. He states that the Saurashtra areas which are seismically active in present times had been active in the Tertiary and Quaternary periods also.

Sahai *et al.* (1985)

Sahai *et al.* (1985) have shown the application of remote sensing techniques for groundwater exploration in hard-rock formations like Deccan Trap basalt. They have mapped various hydrogeomorphological features and located potential groundwater areas in the Saurashtra peninsula. They have stated that remote sensing-geophysical-drilling approach has turned out to be a very effective procedure.

Biswas (1987)

Biswas (1987) has discussed the regional tectonic framework, the structure of the Kutch-Saurashtra, Cambay and Narmada basins which control the sedimentation and their geotectonic evolution. He has concluded that the Saurashtra horst is the uplifted part of a WSW-plunging basement area which divides the western continental margin into a northern Kutch-Saurashtra shelf and a south Bombay-Kerala shelf. The arch forms the southern limit of the Jurassic sedimentation of the Indus shelf basin.

Bhaskaran & Somayajulu (1990)

Dated miliolites of the late Quaternary period, from Saurashtra and Kutch regions were analysed for their detrital and clay minerals by Bhaskaran & Somayajulu (1990) of Physical Research Laboratory. They tried to trace the landward, seaward, aeolian and local sources which contributed the detrital and clay minerals in miliolite deposition.

ECOLOGICAL STUDIES

Joslin (1973)

Joslin (1973) was the first to study the ecology and behaviour of the Asiatic Lion in Gir Wildlife Sanctuary/study area. His work provided the initial guidelines to manage the sanctuary. He has studied the land-use pattern in and around the Gir Wildlife Sanctuary using oblique aerial photographs of selected areas.

Berwick (1974)

Berwick (1974) has worked out the basic ecological data needed for conservation and management of the natural community in Gir Forest. He has also classified habitat relevant to the ecological requirements of the wild ruminants.

Grubh (1974)

Grubh (1974) has studied the feeding habits of Griffon Vultures (Gyps. spp.) and the nature of their association with mammalian predators. He has concluded that competition for food between the lion and griffon vultures was rather insignificant in the Gir, just as in the African forests.

Rao (1983)

Rao (1983) has contributed in establishing forest communities of eastern Gir forest. He has evaluated the edaphic factors in relation to different forest communities, and has analysed mechanical and chemical properties of soils from six localities in eastern Gir forest.

Shaikh (1984)

Shaikh (1984) has evaluated edaphic factors of six localities in western Gir forest, and has tried to establish forest communities of western Gir forest.

Sinha (1987)

Sinha (1987) has reviewed the effects of past conservation measures, and suggested some new guidelines for the management of Gir Wildlife Sanctuary. He has focused on the status of Gir Wildlife Sanctuary with special reference to Asiatic Lion.

Khan (1990)

Khan (1990) has studied the herbivore density and habitat utilization in Gir Wildlife Sanctuary. He has also carried out vegetation and dietary analysis.