CHAPTER IV

G E O L O G Y O F G U J A R A T S T A T E

GEOGRAPHY

The Gujarat State spreads over an area of about 1,87,000 sq.km and is bounded by the Arabian sea in the west. In the north it is flanked by the Rann of Kutch and the Rajasthan desert, while to the NE, its limits are marked by the granitic massif of Mt.Abu and part of the Aravalli ranges. On the eastern frontiers, lie the forests and hills of Vindhyas and Satpuras. To the south, it extends upto Umbergaon and Dadra-Nagar Haveli.

Physiographically, the Gujarat State can be divided into following three distinct geographical units:

(1) Mainland Gujarat,

(2) Peninsular Gujarat, and

(3) Kutch.

MAINLAND GUJARAT:

The mainland Gujarat extends from Umbergaon (Maharashtra Border) in the south to Mt.Abu (Rajasthan) in the north, and hills and forests of Vindhyas, Satpuras and Aravallis in the east to the Arabian sea, Gulf of Cambay, Saurashtra and the Little Rann in the west.

Physiographically, it comprises a vast alluvial plain flanked by hilly terrain in the east. This alluvial plain is mainly formed by the rivers Sabarmati, Mahi, Tapi and Narmada. It very gradually rises above the sea level. The soils in the southern part of this plain consist of loam, while the central part is a vast tract of blank cotton soil. The northern plains are almost uniformly covered by 'Bhal' soil.

The hills in the north & north-east constitute the Aravalli ranges merging into Vindhyas in the north of the Narmada river, while the eastern fringes of the plains are marked by Satpuras and Sahyadris. The

most conspicuous hill in this area is that of 'Pavagadh', a pile of Deccan trap flows over 825 m thick.

The rivers of the mainland originate in eastern highlands and after flowing southeasterly and westerly empty either in the Arabian sea, Gulf of Cambay or disappear in the Rann of Kutch. In the north, the river Banas, which rises in the Sirohi hills flows south-west and is lost eventually in the Rann of Kutch. Sabarmati rising in the Mewar hills flows southwards draining into the Gulf of Cambay. Mahi rises in the Malwa plateau in the Madhya Pradesh, forms the eastern border of the Kaira district, and discharges itself into the Gulf of Cambay. Narmada & Tapi rising in the hilly region of the Madhya Pradesh flow due west, draining into the Gulf of Cambay. The rivers Orsang, Karjan,etc., are the tributories of the Narmada river.

The rainfall varies from 500 to 1800 mm increasing southwards.

PENINSULAR GUJARAT:

This is known as Saurashtra, and is bounded on three sides by waters of sea, viz. in the north by the

Gulf of Kutch and the Little Rann, in the west and south by the Arabian sea, in the southeast by the Gulf of Cambay, while the opening gates by land are in the east connecting to the mainland Gujarat.

Saurashtra has a characteristic physiography. On the whole the central part is slightly elevated, but the entire region is dotted with hilly tracts and plain ground. The hills are more elevated in the south and west, while in the north and east, they are low. The central highland, the Girnar hill, is very prominent. From the central table-land, most of the rivers in Saurashtra rise. The terrain very gently slopes outwards, i.e. towards the coastal plains. Thus the drainage in this region is typically radial, with Shetrunji, Bhadar, Machhu, Bhogawo, Shingoda, etc., as major rivers.

The central part of Saurashtra has black cotton soils, those near the southern coast are of coastal alluvial type, and in the north those are shallow sandy soils.

The average annual rainfall varies from 500 to 750 mm, while in the central part it is as high as 1300 mm.

KUTCH:

The region of Kutch in the northwestern part of Gujarat State forms an independent geographical and geological unit. It has an international border in the north with Pakistan, making it strategically important. The Kutch area falls in the seismic zone and is often visited by earthquakes. The Kutch region itself comprises two physiographical units..

(1) the mainland Kutch, and

(2) the Rann.

The mainland Kutch is an isolated and detached landmass, flanked by the Great Rann in the north, and to the east and southeast by the Little Rann. On its south lies the Gulf of Kutch, and to the southwest and west is the Arabian sea.

The central part of Kutch forms a table-land sloping on all sides. The Kutch landmass has a crescent shape, and is broadly made up of three east-west hill ranges with plains in the south.

The Rann is a dry bed of the remnant of a sea.

It is now a saline desert for the greater part of the year, and marshy during the monsoon, when a vast sheet of water inundates it. When dry, the surface is covered by a layer of salt and shingle. The Rann consists of fine silt and clays. It does not support any vegetation except in a few small raised areas where some fresh water is available.

There are numerous small rivers in the Kutch region. Those flowing north, disappear in the Rann, while those flowing in other directions, join the sea.

The monsoon is very irregular in this region, with annual average of 400 mm, varying from few mm to 90 mm.

GEOLOGY

GENERAL:

Though the geologic record of the Gujarat State is fragmentary, yet the formations belong to a number of important systems, and contain a varied and interesting assemblage of different rock types - igneous, metamorphic and sedimentary. The stratigraphy of the area is given in the table No.7. Geologically

TABLE NO.7

SUCCESSION OF GEOLOGICAL FORMATIONS IN GUJARAT STATE

Era	System	Series	Rock Units	Location	Facies and Enoironments of Deposition	Age (in million years)
1	2	3	4	5	6	7
CAINOZOIC (CAENOZOIC)	Quaternary	Recent and sub-recent.	Alluvium, Blown sands silts of Rann and Banni, tidal flats and raised beaches.	Alluvial plains of Gujarat, Rann, Banni and Coastal deposits.	Fluviatile, eolian	0.01
		Pleistocene	Miliolites.	(i) Saurashtra coast from Gopnath northwards extending beyond Porbandar. (ii) Kutch area	Epineritic to littoral(Marine)	1
	Tertiary	[illegible]ocene	rka beds [illegible]har be[illegible]	[illegible]ferous clays and [illegible]y foraminiferal limestones.	Dwarka, Piram Island,Kutch.	Neritic (Marine)	12
		Miocene		Highly fossiliferous clays and limestones. Agate bearing conglomerates. Kand formations.	Saurashtra coast and Kutch. Jhagadia, Kand near Ankleshwar.	Neritic (Marine)	25
		Oligocene	-	Tarkeshwar clays and argillaceous limestones.	Tarkeshwar area (District Surat). Kutch.	Neritic (Marine)	40
		Eocene	-	Nummulitic limestones and clays.	Tarkeshwar area, and Kutch.	Neritic (Marine)	60
		Palaeocene	Madh series	Supra Trappean, red, yellow variegated clays.	Kutch	Terrestrial to Transitional.	(?)

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Era	System	Series	Rock Units	Location	Facies and Environments of Deposition.	Age (in million years)
1	2	3	4	5	6	7
MESOZOIC (	Cretaceo-Eocene.	-	Basaltic lavas (Deccan traps) with intertrappeans.	Parts of districts of Sabarkantha, Panchmahals, Baroda, Broach, Surat. Major parts of Bulsar and Dangs districts. Saurashtra. Small parts of Kutch.	Continental fissure erruptions and Fluvio-Lacustrine (Intertrappeans)	
	Cretaceous		[illegible] nes	Balasinor, Parabia, Jhalod, Dohad, Devgadh Baria, Gabat (Districts Kaira, Panchmahals, Sabarkantha).	Fluviatile or Estuarine.	110
		Bagh Beds	Sandstones, shales, Limestones. (Includes Nimar, Songir, Himatnagar, Wadhwan and Bhuj Sandstones).	Narmada valley, Gora Surpan, Vanji, Amba Dungar, Near Pavagadh, Songir, Himatnagar, Wadhwan, Dhrangadhra (Saurashtra) & Bhuj(Kutch)	Epineritic (Marine).	
		Umia	Sandstones, Limestones and shales.	Saurashtra, and Kutch	Fluvio-lacustrine to deltaic (Plant fossils) Paralic sedimentation.	
	Jurassic	Katrol	Sandstones, shales and siltstones.	Kutch Mainland, and Islands (Patcham, Khadir, Bela, etc.)	Paralic sedimentation. Lamellibranchs, Ammonites, Branchiopods.	150
		Chari	Sandstones, shales, and siltstones.		Neritic to Littoral environment (marine to transitional) in constantly agitated waters.	
		Patcham.	Sandstones, shales, limestones, Oolitic limestones (Golden Oolite).			

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	Era	System	Series	Rock Units	Location	Facies and Enoironments of Deposition	Age (in million years)
	1	2	3	4	5	6	7
PRE - CAMBRIAN	Purana	Post Delhi System.	-	Epidiorite, Hornblende-schist, Gabbro, Dolerite. Erinpura Granite	Amba Mata, Khapra, Kanpur, Chitrasani, Kapasia etc. Palanpur, Danta, Idar, Modasa, Taranga, Dharoi, Virpur, Wanakbori, Godhra. etc.	-	-
		Delhi System	Ajabgarh Series	Calc gneisses, Calc-Schists of Ajabgarh series.	Parts of districts of Banaskantha, Sabarkantha and Mehsana.	-	
			Alwar Series	Quartzites, and Schists.			
	Archaean or Azoic.	Aravalli system.	-	Mica schists, Phylites quartzites, granites, gneisses, etc.	Parts of districts of Banaskantha-Sabarkantha, Panchmahals, and Baroda.		4000

too, the three divisions of Gujarat State viz. (i) the mainland Gujarat (ii) the Saurashtra peninsula and (iii) the Kutch, are quite distinct from one another, and hence each of the above regions has been separately described. Fig.1.

MAINLAND GUJARAT:

The rock formations of the mainland Gujarat show the following sequence -

TABLE NO.8

Quaternary	Recent and sub-Recent	Aryan Group
Tertiary	Tertiary	
Mesozoic	Deccan Trap	
	Lametas, Bagh beds, Himatnagar sandstone, (Cretaceous)	
	Erinpura Granite (Post-Delhi) Delhi System	Purana Group
Pre-Cambrian	Granites and gneisses Aravalli System (including Champaner Series)	Archaean Group
	Basement Complex	

ARCHAEAN GROUP:

In this group are included the basement gneisses, the overlying Aravallis and Champaners, and the granite rocks intrusive into the metasediments. A large portion of the central and northern mainland is occupied by these ancient rocks, and in fact, are the most dominant formations in this part of Gujarat.

Basement Complex:

As is the case in most of the Archaean areas elsewhere, it is rather difficult to delineate and demarcate between the pre - and post-Aravalli granite - gneisses in Gujarat also. These basement rocks have been intimately mixed with the late granite intrusives and there are no well defined areas where these rocks can be located with certainty. In fact, in Gujarat, undoubted pre-Aravalli basement has not been recorded by any of the previous workers. Recently Jambusaria and Patel (1968) have reported from Chhota Udepur area, the occurrence of gneissic basement over which the Champaners were deposited with an intervening distinct basal conglomerate. Thus, it is possible that all the

gneisses of Baroda and Panchmahals are not Post-Aravalli but at least some portion of them may be of pre-Aravalli age. At whatever places this basement rock has been identified, it is found to be coarsely foliated and rather granitic.

Aravalli System:

The rocks of this system represent the earliest sediments deposited and metamorphosed during Aravalli orogeny. Rocks of this system occupy large areas in Sabarkantha, Panchmahals and Baroda. In the southern Panchmahals, at Shivrajpur, a folded squence of sediments with manganese, has been named as Champaner Series. The rocks of the Aravalli system are mainly quartzites and phyllites with some beds of dolomitic limestones. The rocks all throughout show intense folding. In Sabarkantha the strike of these formations (fold trends as well as the foliations) is roughly NNE-SSW. The foliation strike and the fold trend swings gradually when traced towards Panchmahals, Baroda & at Shivrajpur; the folds are east-west, the strike of the metamorphic foliation being the same.

Post-Aravalli Granites and Gneisses:

Large tracts of areas in Panchmahals and Baroda consist of these granitic rocks. These form a complex assemblage of gneisses derived by the granitisation of the Champaner metasediments and the intrusive bodies of massive granites, both intimately mixed together. A number of varieties of rock types are recognised, but mainly they belong to two broad categories, viz.

(1) coarse foliated biotite gneiss, and

(2) pink or grey non-foliated biotite granite.

PURANA GROUP:

Delhi System:

The rocks of Delhi system are confined to the northern part of the mainland, and are seen to outcrop only in Banaskantha and Sabarkantha districts in the region between Ambaji and Idar. The rock formations are mainly a thick succession of quartzite and metamorphosed calc-sediments (marbles, calc-genisses, etc.) with some phyllitic bands. The whole system is folded on NNE-SSW axial plane forming a north plunging synclinorium.

These Delhi rocks rest with a distinct unconformity over the Aravalli phyllites. On account of the strong imprint of Delhi orogeny on both Delhi & Aravalli rocks, the Delhis are seen going below the Aravalli. This fact intrigued Middlemiss (Merh and Patel, 1968). The marble rocks of Ambaji belong to the Delhi System.

Erinpura Granite:

The close of the Delhi period witnessed large scale intrusions of granitic rocks known as Erinpura granites. Striking exposures of these granites occur in Banaskantha and Sabarkantha. The Abu hill range is a mass of Erinpura granite. The hills of Ambaji and Idar are also made up of these granites. The Erinpura granite consists of a number of varieties - foliated, massive, fine grained or porphyry types and have different shades of colours. The gneissic variety represents granitoid and permeated schistose rocks, while the massive varieties perhaps represent late post-folding intrusive masses. The porphyries of Idar and Indrasi valley are perhaps the effusive equivalents of the granites.

In Panchmahals, granite rocks around Godhra, have been considered by Gupta and Mukherjee (1938) as equivalent to the Erinpura granites. Jambusaria and Patel (1968), however, believe that the Godhra granites are older (pre-Delhi, but post-Aravalli).

ARYAN GROUP:

Cretaceous System:

There exists a big hiatus in the stratigraphy of the mainland Gujarat after the Erinpura granite activity. The whole terrain appears to have remained an uplifted landmass almost throughout the Mesozoic era, and it was only during the close of this Era, during the Cretaceous period that marine transgression along the Narmada valley, resulted into the deposition of the next younger rock formation. Several isolated occurrences, overlying the Champaners and the gneisses are recorded in the sough-central part of the mainland, mainly to the east & south of Baroda. These have been considered as Bagh beds. Almost homotaxial to these, some marine Cretaceous rocks are present in Kaira and Sabarkantha known as Himatnagar sandstone. Fresh water deposits of Cretaceous period are also present at some

places in Kaira and Panchmahals districts. Following is a brief account of these Cretaceous rocks.

Himatnagar sandstone

Almost of the same age, Himatnagar sandstones are horizontally bedded with conglomerates, and shales, which form several outcrops near Himatnagar in Sabarkantha. These have now been confirmed to be of lower Cretaceous age on the basis of plant fossils. Perhaps, the identical exposures between Dakor & Kapadvanj in Kaira district, also belong to the same formation and age.

Bagh Beds

These represent a marine transgressional deposition along the Narmada valley. Good exposures are seen near Pavagadh in Panchmahals, Songir and Amba Dungar areas in Baroda, and Gora-Surpan in Broach districts. In Gujarat, these rocks are considered equivalent to the Bagh beds of Upper Cretaceous age, and show a thick succession of several hundred metres of sandstones and limestones with thin shale beds. This formation is seen resting over the quartzite, phyllites and gneisses with a distinct basal conglomerate bed. At most of the places, these

form inliers in Deccan traps. The limestones belonging to this formation have been investigated in detail.

Lameta Beds

Numerous lenticular outcrops of this fresh water group are noted at a number of places. The important localities are near Santrampur, Jhalod, Dohad, Devagadh Baria in Panchmahals, Balasinor and Parbia (near Virpur) in Kaira district and Gabat in the Sabarkantha district.

At most of the places, these rocks, have a conglomerate formation at the base, and an upper formation of earthy to massive limestones with cherty and chalcedonic stringers and veinlets. These are mottled with limonitic spots. Like Bagh beds, these too occur as lenticular bodies, and form narrow fringes along the base of Deccan Traps. The lithology and mode of occurrence of these sediments suggest deposition in shallow inland basins.

DECCAN TRAPS:

Basalts of the Deccan Trap cover large areas along the eastern margin of the State extending from

its southern tip to the Narmada river; further northwards there are scattered patches cropping out in alluvial tracts of Gujarat near Kalol & Timba in Panchmahals district, Kapadwanj in Kaira district and around Dhansura at Watrak in Sabarkantha district. Many varieties of basaltic rocks are known to occur, and apart from typical dark grey fine grained variety, layers of amygdaloidal and porphyritic basalts are also common. Ash beds and agglomerates are also frequently met with. Though mostly the basalts of Gujarat are calc-alkaline tholeiitic, differentiation and assimilation at many places have given rise to several modifications. The Pavagadh hill near Halol in Panchmahals affords an excellent example of the formation of rhyolites from the basalts. The hill at Mataphenai in Chhota Udepur area has of late been investigated in detail and its study has revealed an interesting suite of alkaline nepheline bearing rocks closely associated with the normal basalts (Sukheshwala & Sethna, 1964). A most striking feature of the trap country in Baroda and Broach districts, is the abundance of big ENE-WSW

dolerite dykes, some of them possibly being the feeders for the surface basalts (Auden 1949). In southern Gujarat, the major trend of dyke system is N-S.

TERTIARIES:

Tertiary rocks of Gujarat mainland, are exposed in the area between the mouths of rivers Tapi and Narmada forming a fringe along the edge of the Deccan Trap. Recent exploration for oil in various parts of Gujarat, has revealed a thick succession of Tertiaries, under the cover of the alluvium in the tract extending from Broach in the south to Mehsana in the north. Except at Broach these Tertiaries rarely outcrop anywhere on the surface. The exposed Tertiary succession of Broach consists mainly of basal beds of Nummulitic limestone and ferruginous clays of Eocene age; the overlying rocks - a group of yellow fossiliferous limestones (Kand formation), ferruginous sandstones and agate-bearing conglomerates are equivalent to the Upper Gaj of Miocene age.

The Tertiary and Quaternary succession in the

Cambay - Broach region in the Cambay trough as established in oil-wells by Oil & Natural Gas Commission is as follows:

TABLE NO.9

Alluvium, Kankar etc.	Recent & Sub-Recent
Sands and clays (100 m)	Pleistocene
Brown to greenish Sandy clays, sands and gravels (700 m)	Pliocene
Grey and greenish silts, Calcareous claystone bands, pyritic and carbonaceous clays (600-850 m).	Miocene
Grey and black shales with limestone bands (60-150 m)	Oligocene
Black shales, carbonaceous and pyritic shales with thin limestone layers (300 m)	Kirthar
Grey to black carbonaceous shales with sandstone layers (200 m)	Laki
Lateritic and carbonaceous variegated clays and trap-wash (40 m)	Palaeocene
Deccan Trap (over 1200 m) - bottom not reached	Cretaceo-Eocene

The basement for Tertiaries in the central and south Gujarat around Ahmedabad is Deccan Trap, which is at a depth of 1792 m at Kim, 2040 m at Cambay and 3040 m at Sanand, and in the Kalol area of Mehsana district, the basement is not touched upto 3029 m.

QUATERNARY:

Recent deposits belonging to this age occur practically all over the mainland. In the area drained by the lower reaches of the rivers Sabarmati, Mahi, Narmada and Tapi, the Recent formations are mostly alluvium. The coastal areas are built up of raised beaches and tidal flats. On the other hand, most of the deposits of this age in the north Gujarat, are to some extent of the type of wind-blown sands and at places loess.

The thickness of alluvium is maximum near Cambay; the oil-wells have established the thickness of alluvium, silts, gravels, sands and clays from Post-Miocene to Recent as 100 m around Ankleshwar, 700 m

around Cambay and 400 m around Kalol near Ahmedabad.

The alluvium basin is a good reservoir of ground water which is under artesian and sub-artesian conditions and is tapped by several tubewells.

SAURASHTRA:

The geological formations of the Saurashtra region (the Kathiawar Peninsula) show the following succession:

TABLE NO.10

Quaternary	Alluvium, Soils, tidal flats, sand dunes, raised beaches, coral reefs.	Recent & Sub-Recent
	Porbandar limestone-Oolitic Miliolite Limestone.	Pleistocene
Tertiary	Dwarka Beds - Clays, silts, cherty limestone.	(?) Pliocene
	Piram Beds - Conglomerates, grits and clays with mammalian fossils of Siwalik age; exposed on the east coast and Piram island.	Pliocene
	Gogha Beds - Thin bedded grits, and sandstones exposed on the east coast.	Mio-Pliocene
	Gaj Beds - Variegated clays, marls, impure limestones	L.Miocene

Mesozoic	Deccan Traps	Cretaceo-Eocene
	Light coloured and variegated sandstones.	Mid.Cretaceous
	Wadhwan Sandstones - Light sandstones with marine intercalations.	Cenomanian to Albian
	Dark Grey marls with some plant remains Ptilophyllum,Araucarites, Cladophlebis, etc.	Neocomian - Tithonian

(After Krishnan, 1968)

It will be seen that the entire succession of Saurashtra belongs to the Aryan group, the oldest exposed rocks being those of Cretaceous period.

CRETACEOUS SYSTEM:

Dhrangadhra and Wadhwan Sandstones

These formations occupy an area of about 2500 sq. km. in the north-eastern part around Dhrangadhra, Morvi and Surendranagar. The Dhrangadhra sandstones comprise in the lower parts, soft, yellow sandstones with white specks of kaolinised felspar, ferruginous concretions and intercalations of

carbonaceous shales. The upper beds consist of gritty, harsh sandstones of purple or dark colour with layers of conglomerate. Near Than, some intercalations of dark grey marls with plant remains are recorded. The occurrences of Ptilophyllum Cutchense, Cladophlebis Whitbyensis, and Araucarites Cutchensis, etc., are recorded. The fossil assemblage suggests that the Dhrangadhra sandstones are continental deposits of Lower Cretaceous equivalent to the Umia beds.

These Gondwana beds are overlain by the Wadhwan sandstones, which are probably equivalent to the Himatnagar sandstones and the Bagh bed of mainland Gujarat. It is interesting to note that the marine Jurassics, so prominently developed in the nearby Kutch region, are totally absent from Saurashtra area. Wells, which have been sunk in the neighbourhood of Dhrangadhra by the ground-water section of the Geological Survey of India, penetrated sandy formations lying nearly horizontal. Upto a depth of 420 m, they did not meet older Jurassic rocks. According to this

observations, the sandy series of Lower Cretaceous (plus Tithonian) should have a thickness of at least 600 m.

DECCAN TRAPS:

The basaltic rocks of the Deccan Trap igneous activity, constitute the most dominant rock formation of the Saurashtra Peninsula, and almost the whole of it except the coastal tracts and the northeastern part are covered with basalts. Mainly consisting of lava flows, the traps show the usual varieties, viz. dark, grey, compact, porphyritic, amygdaloidal, etc.

In the Girnar and Osham hills of Junagadh, besides the usual dolerite and basalt, there are lamprophyre, limburgite, monchiquite, olivine-gabbro, porphyrite, andesite, monzonite, nepheline-syenite, granophyre, rhyolite, obsidian, and pitchstone, which have been studied and described by a number of workers (Krishnan, 1925; Chatterjee, 1960; Subba Rao, 1964).

Mathur and others (1926) who mapped the Girnar hills in detail suggested that the basaltic flows of

this area were domed up by later intrusives representing the result of differentiation. The domed portion of the flows has been eroded away in the centre, exposing an intrusive mass of diorite-monzonite below.

In the Gir forest of Saurashtra, there occur some dykes of olivine-dolerite and masses of granophyre and rhyolite.

In parts of Saurashtra where borings have been put down through the traps, very basic types like limburgite and ankaramite are found inter-bedded with normal basalts.

It is thought that the basalts of Saurashtra are the extensions of Gujarat traps, and these extend northwards in Kutch. However, it is not unlikely that some feeders from the Saurashtra region itself, were responsible for the formation of basalts. The eruption in Saurashtra was perhaps partly of central type, and it would appear that several eruptive vents, viz. those of Baroda, Dhank, Osham and Girnar hills lie on the important Narmada dislocation trend.

Dolerite dykes

A number of dykes are encountered in the trap country. Mostly these dykes consist of coarse dolerites occasionally porphyritic. They almost form swarms of dykes as described by Auden (1949). Their general trend is variable quite often east-west; sometimes they run north-south or NW-SE and cut across others. Around the plutonic mass of Girnar and Gogat Chamardi, these dykes show a more or less radial disposition.

TERTIARIES:

The Tertiary succession in Saurashtra begins with Miocene period, the formations of Eocene and Oligocene age being absent. Outcropping at the western end of the Peninsula, these Tertiaries are exposed as small disconnected outcrops on the fringe of coastal alluvium round the southern limits of the trap area. These beds are almost horizontal and are much obscured by recent deposits and cultivation. In the absence of any deeply cut sections no succession has been made out, but the aggregate thickness of the Tertiaries must amount to few hundred metres.

Gaj Beds: These Gaj formations are prominently seen near Okhamandal as well as south of Bhavnagar in the coastal region. Also quite a few isolated patches of these rocks occur along the margin of traps and laterites and some inliers in alluvium are there in the coastal region. Resting over the Deccan traps, these Miocene formations equivalent to the Gaj Beds of Sind, are seen consisting of variegated clays, marls and impure limestones. These are fossiliferous and a large number of Bryozoa, Corals, Echinoids, Lamellibranchs, Gastropods, and Cephalopods have been reported from it.

Gogha Bess: In the eastern part of the Peninsula near Bhavnagar, thinly bedded grits, conglomerates and sandstones occur near Gogha at the western tip of the Gulf of Cambay. These are considered to be of Mio-Pliocene age.

Piram Beds: The island of Piram near Bhavnagar is well known for its mammalian fossils of Middle Siwalik age (Pliocene). The Piram beds overlie the Gaj beds disconformably, on the east coast and Piram Island.

Dwarka Beds: In the northwestern corner of Saurashtra, around Dwarka, these beds of probable Pliocene age overlie the Gaj beds. These consist of gypsiferous clays, silts, and sandy forminiferal limestones.

QUATERNARY:

Pleistocene

Saurashtra has a very well developed Pleistocene formation represented by an oolitic arenaceous limestone containing the foraminiferal shells (Miliolite). Almost all along the coast, except in the north-western corner, this marine limestone known as 'Miliolite limestone' or 'Miliolite', attains a thickness of over 30 m. This foraminiferal limestone is found in inland areas also, as far as on Chotila hill (357.5 m elevation), Junagadh, etc. and this fact provides clear proof of the elevation of coast in recent times.

Recent and Sub-Recent

These include soil mantle, coastal sands, tidal flats and raised beaches. Along the south coast of Saurashtra there is very little alluvium, its place being taken by a calcareous grit which carries marine shells and

is evidently of very recent age.

Laterites: Laterite, a highly porous and red coloured rock occurs along the Deccan Trap border in discontinuous linear belts or strips; the largest one is near Bhavnagar.

KUTCH

The Kutch region shows the following stratigraphic sequence:

TABLE NO.11

Quaternary	Alluvium, Rann, blown sand, tidal flats, etc.		Recent & Sub-Recent
	Porbandar Series (15-20 m)	Calcareous and Oolitic limestones with Miliolites.	Pleistocene
Tertiary	Kankavati Series (370 m)	Pink grits with fossil wood. Grey sand-stones and clays.	Pliocene (Equivalent to Manchar).

Contd..

Khari Series (350 m)	Khari-Stage: Shales and Siltstones (340 m) Waior stage: Creamy marls and Oolites. (10 m)	Miocene
Lakhpat Series (10 - 12 m)	Marls and limestones.	Oligocene
Berwali Series (130 m)		Eocene
Babia stage (85 m)	Limestones and Ochreous and greenish clays.	Kirthar
Kakdi stage (45 m)	Limestones and shales	Laki
Madh Series (30 - 40 m)	Laterites, clays and sandstones.	Paleocene
600 m +	Deccan Trap	Cretaceo-Eocene
Cretaceous Bhuj Series (300 m ±)	Sandstones and shales.	Mid. Cretaceous (? Albian)
Umia Series including Ukra Beds (430 m ±)	Barren sandstones and shales.	Lower Cretaceous (Neocomian-Aptian)

Jurassic	Katrol series (330 m ±)	Sandstones and shales.	Kimmeridgian - Tithonian.
	Chari series (430 m ±)	Dhosa oolite, marls, and gypseous shales, limestones, golden oolites.	Callovian-Oxfordian.
	Patcham series (325 m ±) 20 ±	Coral limestone, shell limestone. Granite-cobble-Conglomerate and arkose.	Bathonian older
PRE-CAMBRIAN		Granite and metamorphic complex with intrusion of syenite.	

ARYAN GROUP:

JURASSIC SYSTEM:

The most salient feature of the geology of Kutch is the prominent development of Jurassic and Cretaceous rocks. The Tethys sea of Jurassic and early Cretaceous times is considered extending beyond the main Himalayan axis into the region of the Lesser

Himalaya and that a channel extended into Baluchistan and the Salt Range, and farther south through portions of Rajasthan into the region of Kutch, and thence westward as far as Madagascar. The basement for these Jurassic rocks as reported by Biswas and Deshpande (1968) is Pre-Cambrian syenite exposed near Khadir Island.

The Mesozoic rocks constitute one of the most well developed and complete succession in the world, and have preserved in them a valuable invertebrate faunal assemblage. The rocks mainly comprise limestones (oolitic and coralline), marls, shales and sandstones constituting Patcham, Chari and Katrol series and representing mainly marine deposits. The Jurassic invertebrate fauna consists of a rich assemblage of Ammonites, Brachiopods, Actinozoa, Lammelibranchs, Cephalopods, etc. The Cephalopod fauna enables fairly accurate correlation of these beds with corresponding zones in Europe and Africa.

The Jurassic rocks have an estimated thickness of about 1100 m, and crop out in three anticlinal

ridges trending E-W. These anticlinal ridges show transverse undulations resulting into a number of dome-like structures. Owing to an east-west fault (Katrol fault), the major part of the Jurassic sequence has been repeated. Along the northern flank, the Jurassics are cut by another E-W fault (Mainland fault), which marks the junction of these rocks with the main expanse of the Rann.

CRETACEOUS SYSTEM:

Recent intensive work in connection with oil exploration has indicated the need of some marginal modifications in the stratigraphy of Jurassics and Cretaceous in and around this region. Poddar (1959), and Richter - Bernberg and others (1963) have conclusively put the whole Umia series under the Cretaceous system on the basis of lithological and palaeontological evidences. Earlier a part of the lowermost Umia was considered as Jurassics.

Umia, Ukra and Bhuj beds form the Cretaceous of Kutch comprising a thickness of about 730 m according to Poddar (1959). Umia series consists of variegated

sandstones, with minor bands of shales and clays; well preserved plant remains, probably of early Cretaceous age, are associated with the coal bands in the upper part of the Umia Series. Ukra Beds containing Ammonites form the uppermost part of the Umia Series. Bhuj Series consists of soft, massive, current-bedded sandstones with minor sandy shales that were deposited under predominantly fluviatile and estuarine conditions. These are of middle Cretaceous age.

DECCAN TRAP:

Basaltic rocks, which overlie the Cretaceous, are confined to central and southern half of the Kutch region, and are obviously the extension of the Saurashtra lava flows. These consist of number of flows of the usual dark grey, greenish and olive green beds, similar to the typical Deccan basaltic type. The thickness of trap in Kutch is about 760 m. Unlike in mainland Saurashtra, there are no traces of volcanic cones. Dykes of dolerite are frequently seen cutting the earlier sedimentaries in various directions,

predominantly in the N-S directions.

TERTIARIES:

The Tertiary formations fringe the entire southernmost rocky strip of the mainland Kutch and form a width of 10 to 20 km. These also border Jurassics in Patcham, Khadir and Bela, and Cretaceous and Jurassics in Wagad highland. A rather thick Tertiary succession of about 900 m is seen in the southwest near the village Waior. These Tertiary rocks are fossiliferous, and fossils belonging to a number of phylla are found. Various forms of Echinoderma, Lamellibranchs, Gastropods, Foraminifers, etc. The different series under Tertiaries as given by Bishwas (1965) are already given earlier (Table No.11).

These Tertiary formations (together with the old Mesozoics) have been involved folding movements, which began in Miocene time and continued intermittanly right upto the Pleistocene and even to Recent times. The general trend of the folding is E-W. However, unlike the Mesozoic strata the Tertiaries have escaped pronounced folding.

QUATERNARY:

Pleistocene and Recent:

Rocks belonging to this age are represented by coarse sandy limestones indentical to the Miliolite of Saurashtra. These occur as isolated patches in the trap and Jurassics like Katrol hills and Wagad region in the tract south and east of Bhuj respectively. These limestones are generally massive, show very coarse current bedding, and consist of fine calcareous oolitic tiny foraminiferal shells and sand grains and other rock fragments. Though some workers like Biswas (1965) considered these rocks as of aeolin origin, Merh and Hardas (1968) have recently suggested a marine shallow water origin.

Recent alluvium in Kutch forms 5 to 15 km broad belt all along the coast. This alluvial plain consists of a brown loam resting upon mottled clay with kankar. Some coastal sand-dunes are also present along the southwestern coast near Jakhau.

Rann of Kutch: The northern half of the Kutch region consists of the Rann. It comprises an immense marshy

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salt plain, scarcely above sea level, and extending for 300 km from east to west, and in places, as wide as 150 km from north to south. The Rann is in fact an ancient outlet of the sea, which has now dried up. It is divided roughly into two 'by the large island' of Kutch and another small island; to the north lies the Great Rann and to the south lies a similar plain on the landward side - the Little Rann. The Great Rann covers about 3000 sq.km inclusive of the Banni, a low lying tract distinguishable from the Rann by some coarse vegetation which exists upon it. The Banni area intervenes between the rocky mainland and the main Rann, and is built up by the rivers which flow from south in the Rann, depositing their load. The most of the Rann has hard and polished surface due to a thick encrustation of salt.

There is little doubt that the Rann was a gulf of the sea within recent times. Borings in the Little Rann have shown layers 2 to 3 m thick, of stiff bluish and black clay, overlying a brine bearing gritty sand. The clay contains a few Gastropod shells indicating that estuarine conditions succeed the marine conditions in Recent times.