SCHOOL OF EARTH, OCEAN AND ATMOSPHERIC SCIENCES
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LABORATORY CERTIFICATE

This is to certify that Mr./Ms. Vighnesh Shenvi Bhende
has satisfactorily completed the course of practical for M.Sc. in Applied Geology.

Experiments conducted are pertaining to paper Geological field training
Practical prescribed by the University for Semester IV
class, during the academic year 2022-2023.

DEAN

SEOAS

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REPORT ON THE GEOLOGICAL FIELD TRAINNING CARRIED OUT IN GUJARAT & RAJASTHAN

Submitted by

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2022-2023

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ACKNOWLEDGEMENT

I would like to express my deep and sincere gratitude towards Professor Dr. Niyati Kalangutkar (Programme Director), Associate Professor, Applied Geology, School of Earth, Ocean and Atmospheric for planning this field work and giving us an opportunity to carry out field work at Gujarat. I am highly grateful for her guidance, encouragement and support throughout the fieldwork.

I would like to thank Prof. (Ms.) Pooja Ghadi, Assistant professor, applied geology, SEOAS, Goa university and Prof. (Mr.) Mahesh Mayekar, Assistant professor, applied geology, SEOAS, Goa university, for their invaluable guidance, care and support throughout this field work. Their dynamism, vision, sincerity and motivation have deeply inspired us. It was a great privilege and honour to work under their guidance.

I am extremely grateful for what they have offered us. I am extremely grateful to Mr. Gaurav Kumar for guiding us through ONGC, Ahmedabad, Gujarat, India

I would also like to thank Mr. Dahyabhai Gorabhai Chauhan for guiding us at dinosaur fossil park, Rayoli. I would also like to thank my parents for their love, and sacrifices for educating and preparing me for my future. Lastly, I would like to thank my classmates for their love, understanding, and continuing support and co-operation throughout this field work.

1.0 INTRODUCTION

1.1 General Introduction of Gujarat State

The state of Gujarat is located in the west coast of India. It lies between Latitude 20°10°N to 24° 50°N and Longitude 68° 40°E to 74° 40°E. It is bounded by the Arabian Sea in the west and south-west, Pakistan in the north-west, Rajasthan in the north and north-east, Madhya Pradesh in the east and Maharashtra in the south east. The state of Gujarat comprises an area of approximately 1,96,000 sq.km. Geologically Gujarat provides a wide variety of rock types of different ages. Whereas the Aravalli in the NE is 2500 million years old. The unconsolidated alluvium and beach material in its Central and Western parts, are of recent past. All the important lithological types igneous, Sedimentary and Metamorphic occur within the state of Gujarat.

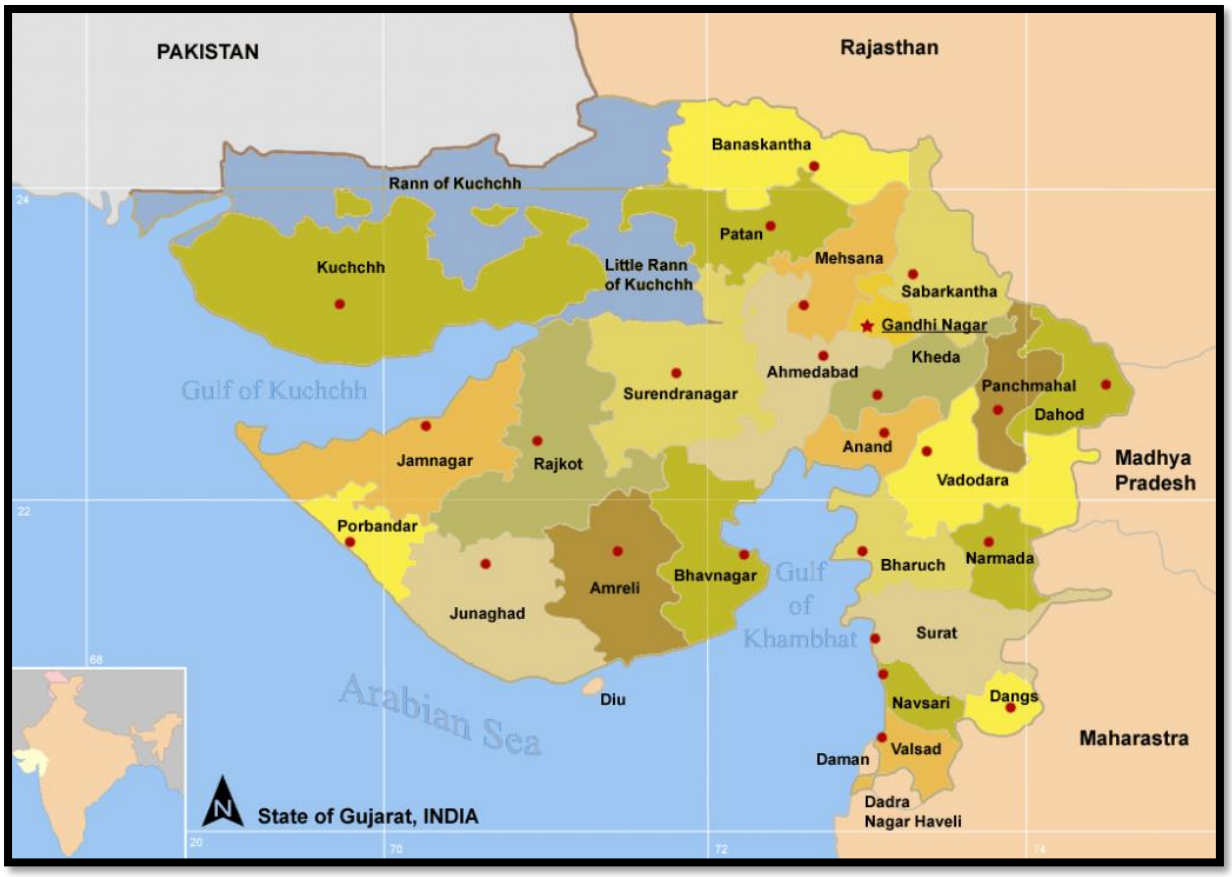

Fig 1: *Map of Gujarat (Source: Shah et Al 2002)*

1.2 Geomorphology of Gujarat

According to Kulkarni (1985) Geomorphologically, the State is divided into three distinct divisions namely Gujarat-Mainland, Saurashtra-Kathiawar Peninsula and Kutch Peninsula.

a) Gujarat-Mainland

This is agriculturally rich alluvial basin that rises from the estuarine tracts between Narmada and Tapi rivers, and extends 250 miles (402 km) northwards merging into the desert plains of Rajasthan and therefore the Rann of Kutch. It's roughly 75 miles (121 km) wide. The eastern border of the basin is bounded by Aravali, Vindhya, Satpura, and Sahyadri hill ranges. The topography of the land is clearly controlled by the geological formations. The eastern part of the south Gujarat bordering the alluvial tract features a typical Deccan trap scenery up to Narmada valley. The hills are formed by circumdenudation leaving wide plateau at top, and a step like feature due to horizontal lava-flows and their differential weathering. Trap topography within the Narmada valley is, however, different; hills are hogback shaped, as many of them are composed of wide and long dolerite dykes. The Areas which are occupied by sedimentaries of Baghs or lametas in patches, form table lands with low hills along north of Narmada. North and NE a part of the State is occupied by quartzites, phyllites and schists. Quartzites being hard and immune to weathering action, form steep narrow ridges with serrated tops arranged along the strike, while valleys and plains are occupied by phyllites and schists, these being soft. Granites typically form low to high hills with loose boulders of huge dimensions standing insitu. Thus, granite country can easily be recognized from a distance.

b) Saurashtra-Kathiawar Peninsula:

The Saurashtra is bounded by Gujarat plains within the East and NE, by gulf of Kutch and tiny Rann on the north, and on the SE by the Gulf of Cambay. The Arabian Sea borders the whole southern seaboard. The Central a part of the region forms an elevated table land, from where most of the rivers rise and flow radially. The terrain generally slopes gently towards the peninsular margin to merge into the coastal plains and therefore the great alluvial tract stretches to NE and east. The sedimentary rocks along the coast form almost a low flat country. On account of several radially intruded basic dykes cutting through traps, there are low and straight hill ranges running parallel, a characteristic feature of this country.

c) Kutch Peninsula

The mainland of Kutch is isolated by the good Rann of the north and east, Little Rann on the SE, Gulf of Kutch on the south and rest by the Arabian Sea. The central portion of Kutch forms a table-land sloping on all sides, the form of the region is sort of a tortoise and hence the name. In general, there are three hill ranges, trending almost east-west. North-flowing rivers disappear within the Rann; others join the ocean. The Banni is made by sediments deposited by northern border of the most land. The Rann may be a dry bed of the remnant of an arm of the ocean, which formally connected the Narmada rift with Sind and separated Kutch from the main-land.

During the historic times, the Indus and therefore the Saraswati of Vedic times flowed into the sea here. It's now a saline desert for the greater part of the year and marshy during the monsoon when a huge sheet of water inundates it. The Rann is split into two, viz., Great Rann and tiny Rann; they are doing not differ from one another except in size. When dry, the surface is roofed by a layer of salt and shingle. It consists of fine silt and clays. It doesn't support any vegetation except during a few small raised areas where some water is out there.

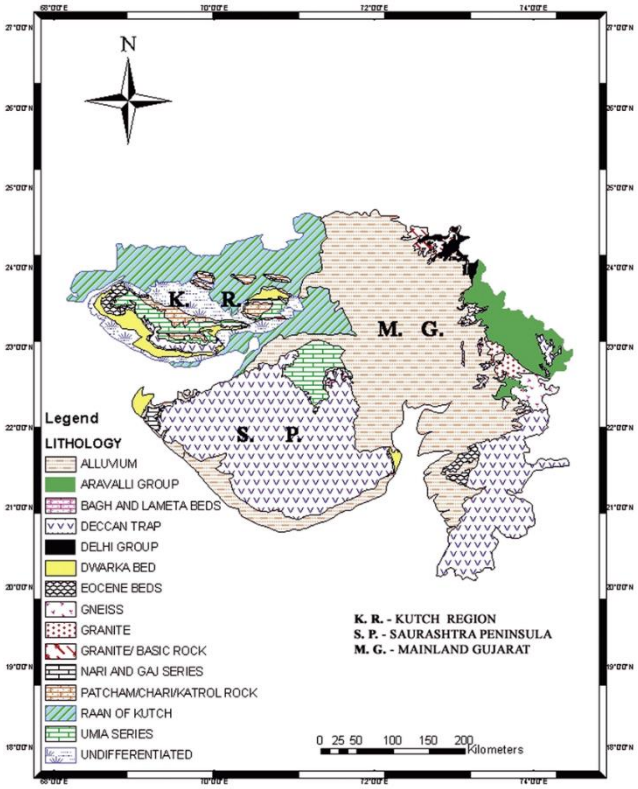

Fig 2: *Geological Map of Gujarat (source: Merh 1995.)*

1.3 General Geology of Gujarat

The Gujarat state exposes rocks belonging to the Precambrian, Mesozoic and Cenozoic age. The hard rocks cover about 49% of the entire area of Gujarat, the remainder being occupied by sediments of Quaternary age. The hard rock comprises pre-cambrian metamorphosed and associated intrusive, sedimentary rocks of Mesozoic and Cenozoic eras and therefore the traps/flows constituting Deccan volcanic of Cretaceous Eocene age. the various geological formations occurring in various parts of Gujarat are shown within the "Geological Map of Gujarat" (**Fig 2**). Generalised stratigraphy of Gujarat is given in **Table 1**.

Group	*System*	*Rock Type*	*Localities*	*Age in Millions of years*
Quaternary	Recent and subrecent	Alluvium, blown sand, Silts of Rann and Banni. Tidal flats and raised beaches.	Alluvial plains of Gujarat, Rann, Banni & Coastal deposits.	0.01
	Pleistocene	Miliolites	(i) Saurashtra coast from Gopnath northwards extending beyond Porbandar. (ii) Kutch area.	1
Tertiary or Kainozoic	Pliocene	Dwarka beds, Manchhar beds, Gypsiferous clays and sandy foraminiferal limestones.	Dwarka, Okha, Piram Island, Kutch.	12
	Miocene	Gaj beds-Highly fossiliferous clays and limestones. Agate bearing conglomerates. Kand formation.	Saurashtra coast, Kutch	25
	Oligocene	Tarkeshwar clays.	Tarkeshwar (District:Surat) and Kutch.	40
	Eocene	Nummilitic limestones and clays.	Tarkeshwar area and Kutch.	60
Secondary or Mesozoic	Cretaceous Eocene	Deccan traps with inter trappeans.	Parts of Sabarkantha, Panchmahals, Baroda, Broach, Surat and major part of Bulsar and Dangs Districts. Major part of Saurashtra and small part of Kutch.	
	Cretaceous	Himatnagar sandstones, Lameta (limestones). Bagh beds.	Himatnagar, Kapadvanj, Balasinor, Parabia, Dohad, Gabat, Narmada valley.	110

		Songir sandstones, Nimar sandstones, Wadhavan sandstone (infratrappeans), Bhuj and Umia series sandstones.	Sogir, Near Pavagadh. Wadhavan, Dhangaadhra, Bhuj etc.	
	Jurassic	Katrol series, Chari series, Patnam series (Sand-stones, shales and lime-stones).	Kutch	150
	Purana (algonkian & Part of Cambrian)	Erinpura granite (post-Delhi). Delhi System-Alwar quarzites, schists, and calc-gneisses, calcschists of Ajabgarh series.	Palanpur, Danta, Idar, Modasa, Taranga, Dharoi, Virpur, Wanakbori, Godhra, etc. Parts of Sabarkantha and Banaskantha, and Mehsana districts.	1500
Archean or Azoiz		Aravali system-Micaschists, Phyllites, quarzites, etc. Banded gneissic complex.	Sabarkantha, Panchmahals, Baroda, Banaskantha. Baroda district.	2700

Table 1: Lithostratigraphic classification of Gujarat (Kulkarni 1985)

1.4 General Introduction of Rajasthan State

The State of Rajasthan has a square-shaped outline having north-south and east-west trending diagonals. The southernmost point of the State lies a little south of the Tropic of Cancer; whereas the 30°12' latitude touches the northernmost point of the State. The western and the eastern ends of the State are limited by 69°35′ and 78°17' longitudes respectively. The north-south diagonal line, measuring 869 km, is little longer than the east-west line. The territorial boundary of the State is 5920 km long, out of which about 1074 km is the international boundary with Pakistan. Rajasthan, which is the largest state in India, has a total surface area of 3,42,239 sq. the country. About 50 per cent of the State's surface area is desert-like arid-zone, approximately 3/4th of which is under the cover of sand dunes.

The entire State is devoid of any perennial drainage system. Several seasonal rivers, originating from the Aravalli Mountains, drain about half the area of the State. The entire western half is either free of even ephemeral drainage pattern, or has developed local internal drainage system. A number of water divides, separating the drainage to the Bay of Bengal from that to the Arabian Sea, pass through the State. This is an indication of block-wise uplift, tilting and down sagging of parts of the terrain during post-Jurassic periods.

Although the city of Jodhpur is specifically known as the 'Sun City', the entire State seems to enjoy generous sunshine for the major part of a year. Cloudy days are very restricted even in considerably wet areas. There are mentions of four-month long rainy season ("chomasa") in the folk songs of Rajasthan. This, however, is a feature of the yesteryears, some forty or fifty years ago. Records indicate that the rainfall in some parts of the State used to be double of the present-day precipitation. There are records of about 100 cm of rainfall in the Udaipur-Zawar region in the past.

Compared to that Udaipur now receives between 35 to 50 cm annual rainfalls. Much of the western Rajasthan, that includes the Thar Desert, falls under the arid zone with 10 to 30 cm annual rainfall. The rainfall is not only low but the pattern is also very erratic. Because of the special orographic situation, the Mount Abu region receives a very high annual rainfall, averaging over 160 cm.

Fig 3: *Map of Rajasthan (source: https://free-printablemap.com/wp-content/uploads/2018/10/filemap-rajasthan-dist-7-div-wikimedia-commons-with-political-map-of-rajasthan-state.png)*

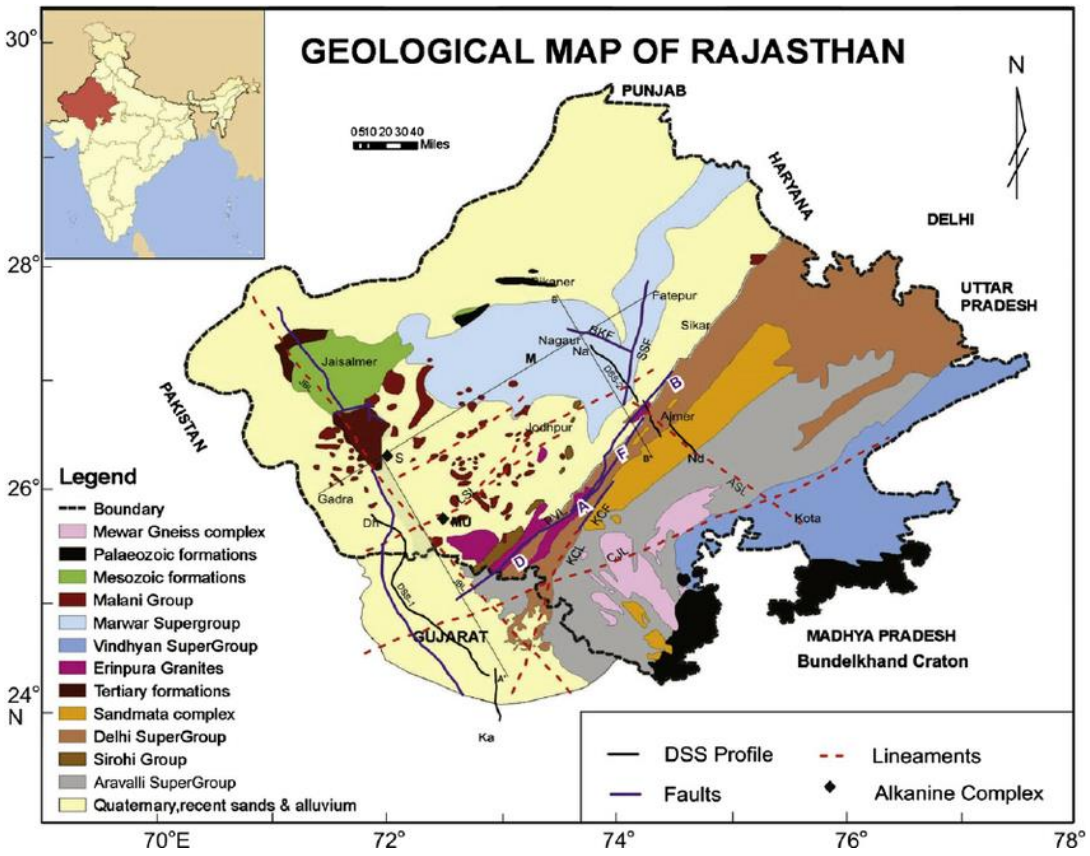

Fig 4: *Geological Map of Rajasthan (source: Kilaru, Suman & Goud, Dr & Rao, V. (2013). Paper.)*

1.5 Geomorphology of Rajasthan

Based mainly on the physiographic character, the State of Rajasthan can be conveniently divided into four main geomorphic segments from west to east (Fig. kilometres. This is about 10.75 per cent of the area of 1.2). These are:

1. The Plains of Thar Desert
2. The Aravalli Mountains
3. The Eastern Plains
4. The Uplands of Harauti and Malwa.

1. The Plains of Thar Desert

Extending westward from the western flank of the Aravalli Mountains is the Thar Desert, which continues into the adjoining parts of Pakistan in the west, and Kachchh in the south. The total surface area of the desert is around 2,00,000 sq. km; almost two-third of which lies in Rajasthan. In the east, the desert is bounded by the Aravalli Mountains. In fact, the mountain range forms a barrier to the advancement of the desert to the central Indian region. North of Ajmer, the situation is different where the mountain range breaks up into a series of highly worn-out hills. Flat sand- and silt-covered valleys stretch out between isolated hills. Intense sand movements are noticed through these expansive 'wind gaps in the region south of Delhi and Agra. In the north and northwest, the Thar Desert imperceptibly mingles with the dry plains of Punjab. The southern part of the Thar Desert, which includes parts of Kachchh in northern Gujarat and southwestern Rajasthan, constitutes the typical tropical desert. The northern part stretches into the subtropical zone.

Though considered as plain lands, the desert region as such has locally rugged topography having an average elevation of about 225 m above the mean sea level. (Fig. 1.3). The general slope is towards west and south. In the west, the average elevation drops to about 150 m^1 close to the India-Pakistan boundary. The westerly slope continues up to the Indus valley. In the south the desert almost reaches the sea level in the Rann areas of Kachchh in northern Gujarat.

Based on a number of physical parameters, particularly the topography, development of sand dunes, hydrological factors including rain fall, and the nature of vegetation, the Thar Desert has been divided into (i) Marusthali, a sensu stricto sand desert, whichforms a rim along the western boundary of the State of Rajasthan, and (ii) Bagar, an arid zone with fewer sand dunes.

The Marusthali is characterised by a low surface relief, general elevation between 200-250 m or so, extensive development of sand dunes, and below 25 cm annual rainfall. In such a forlorn territory, not even an ephemeral drainage system exists.

The Marusthali covers the districts of Barmer, Jaisalmer, Bikaner, as well as the western part of Jodhpur and Churu. About 90 per cent of western Rajasthan has a cover of aeolian sands. In parts of the region around Jaisalmer, Barmer and Bikaner, the Marusthali is virtually dune free and rocky. Rocky pavements in these regions are littered with wind- worn rock pieces of different shapes and sizes. Such a landscape can be witnessed in regions around Pokaran

(26°55': 71°09'), Phalodi (27°09′: 72°22′) and Jaisalmer. Sand dunes are generally not a part of the panorama of such areas. Instead, the rocky desert tract displays various types of erosion topography. Near Chohatan (25°25′ 71°01′), there are spectacularly sculptured granitic knolls resulting from wind erosion. The scenario at Barmer is characterised by the typical 'bornhardt type' residual hills. In some parts, raised rocky pavements with scarp faces appear as 'hamadas', which is the Arabic name for high-level structural plains, similar to a mesa.Tilted 'hamadas" appear as cuestas with steep facing escarpments. The areas of rocky pavement are also characterised by the presence of saline playa depressions as near Pokaran, Phalodi and Jaisalmer.

Barring the rocky parts, the Marusthali is characterised by the monotony of vast expanse of sand, which is broken to some extent by the variation in the morphology of dunes. There are a variety of dune forms. Based on the morphology and relative stability, the dunes have been classified into (i) old dissected dunes of indeterminate type and sand shields, (ii) stabilised parabolic, longitudinal and transverse dunes, and (iii) active small-scale barchan and low longitudinal ridge dunes. The dunes in the southern portion of the Jaisalmer-Barmer tract are compound parabolic types showing rake-like arrangements of dune arms. Westward these dunes gradually grade to wind erosion. The Bagar lands of western longitudinal types. An expanse of barchanoid ridges Rajasthan can be divided into second order sub-regions occupies the southwestern part of the Marusthali. having different geomorphological characteristics. Crescent shaped dunes comprising transverse, barchanoid and type barchans occur at several places. Between Barmer and Jodhpur the dunes are dominantly parabolic. Northward these dunes grade to longitudinal and crescent shaped sand bodies.

In contrast to the Marusthali, the Bagar lands have relatively higher surface relief with fewer sand dunes, higher annual rainfall, and steppe-type vegetation. The average height of the region ranges between 300 to 500 m. In the eastern part, the Bagar forms the piedmont west of the Aravalli Mountains. The upland of Jalore-Siwana lies over 300 m, with the maximum height, 834 m, at the Siwana Hills. The upland occurs between the drainages of the Luni and Sukri. There are also many small scattered and isolated 'inselberg'-like hillocks in the western edge of the Bagar. Granitic rocks in these outcrops occur as typically rounded bodies showing evidence of wind erosion. The Bagar lands of western Rajasthan can be divided into second order sub-regions having different geomorphological characteristics. These are: -

(i) Luni-Sukri Basin
(ii) Nagaur-Shekhawati Region
(iii) Ghaggar Plain

(i) Luni-Sukri Basin: A number of short streams originating from the Aravalli Mountains in the east drain the Bagar lands. The most important river flowing in the region is the Luni. Originating from the Aravalli Mountains, southwest of Ajmer, the Luni flows in the southwesterly direction. The important tributaries of the Luni are the Sukri and the Jawai. In rainy seasons, the combined seasonal affluent of the Luni-Sukri-Jawai River System is discharged partly in the respective channels, and the rest in the Rann of Kachchh in the south.

In the southern parts of the Luni-Sukri Basin, the general subdued topography is broken by a few sand hills. Further south, there are evidences of a large palaeo-delta complex of combined rivers of Luni and its tributaries fringing the northern border of the Great Rann of Kachchh (Roy and Merh, 1977). The size of the delta is intriguingly large, which led some authors to think that it could even be the delta of the extinct Saraswati River.

(ii) Nagaur-Sekhawati Region: The Luni and Sukri River Basins are the only major tract of alluvial plains in the Rajasthan Bagar. North of the fluvial tract lies a vast upland, called the Nagaur Upland, constituted partly of horizontally bedded sandstones of Marwar Supergroup, and partly of a large pediplain which can be traced from east of Nagaur. The average height of the Nagaur Upland is 400 m. North of it lies the Shekhawati region, which is an undulating sandy terrain of longitudinal sand dunes, interdunal flats, and isolated low-lying hills with fringing pediments. The region south of Nagaur town and the Merta Road is relatively free from sand dunes. The Nagaur- Shekhawati Region is also a belt characterised by internal drainage and linear deflated areas between sand ridges. There are number of salt-soaked narrow playa depressions in this part of the Bagar. The important ones occur at Khatu (2707 74°21′), Kuchaman (27°09': 74°52′), Didwana (27°24′: 74°34′), and Degana (26°50': 74°20').

Unlike the alluvial plains of the southeast, the northern part of Nagaur- and Bagar-Shekhawati tract shows wider dune covered areas and much fewer ephemeral streams originating from the Aravalli Mountains. Some older dunes are dissected by rills and gullies. Parabolic dunes are a common feature, while the longitudinal and transverse dunes are relatively rare. In some parts of the Bagar-Shekhawati, calcareous substratum is exposed at a height of 450 m above the mean sea level.

(iii) The Ghaggar Plain: The northernmost Bagar region covers large areas in the Ganganagar and Hanumangarh Districts. The region is known as Ghaggar Flood Plain, which comprises dry, wide valleys of the Ghaggar River. The dry valley, which passes through Hanumangarh, Suratgarh (29°29' : 73°53′) and Anupgarh (29°12': 73°13'), is believed to be the beds of the legendary Saraswati River. The river, which is now extinct, had a perennial flow of water from the Himalayan glaciers. The dry channels of Drishadvati in the Nohar-Bhadra areas in Hanumangarh District are considered to be a once-flourishing tributary of the Saraswati. Presently, relief features, which normally characterises the much the area is under the process of increasing agricultural younger mountain chains, like the Appalachians in the activities. The pressure of excessive land use coupled eastern North America, or the Urals that joins Europe with low rain in the region has led to development of with Asia. fresh dunes of barchan type in place of alluvial sands.

2. The Aravalli Mountains

The Aravalli Mountains, which crosses the state of Rajasthan diagonally for a distance of about 800 km, lies east of the Thar Desert. It is a typical ensialic mountain range of olden Proterozoic rocks having an age span between 2500 and 850 million years from today. The Archaean rocks, which form the foundation of the mountain, have a history of one billion years; the oldest rocks are believed to have originated earlier to 3300 million years ago. Although Heron (1953)

described the Aravalli Mountains as 'being perhaps the oldest mountain range in the world', it is doubtful if the present relief can be ascribed entirely to the Precambrian orogenesis.

References to the Aravalli Mountains are traceable in ancient literatures as a mountain that stands askew to the east-west trending Himalaya and the Vindhyan ranges (known as the Satpura Mountains in geological literatures). The mountain not only prevented the sand movement to the east, but also formed a formidable of Fermor (1930) that the Aravalli crustal block is a barrier for the ancient people to cross over particularly horst between the Great Boundary Fault in the east in the southern part. In spite of being an ancient and the Sirohi-Tosham line (Sirohi Lineament) in the geomorphic 'welt', the mountain has very prominent relief features, which normally characterises the much younger mountain chains, like the Appalachains in the eastern North America, or the Urals that joins Europe with Asia.

In plan view, the Aravalli Mountains has been likened somewhat like two fans joined handle to handle' (Heron, 1953). The central part of the common handle is less than 10 km wide. This description of the Aravalli Mountains matches quite well with the features appearing in the satellite imageries.

Heron's (1953) description of the main component of the geomorphic mountain as a syncline or synclinorium ("Main Delhi Syncline") is naively simplistic. Detailed studies subsequent to the publication of the Heron's classical memoir helped in erecting an evolutionary history comprising three successive Proterozoic cycles of basin evolution, magmatism, metamorphism and tectonic inversion, on an Archean basement.

Geologically, the Aravalli crustal block shows a rectangular plan with straight western boundary. The eastern boundary against the plateaus of Harauti and Malwa, made of Vindhyan rocks and Deccan basalt respectively, is curved with gentle westerly convexity.

Heron (1953) quotes with approval that suggestion of Fermor (1930) that the Aravalli crustal block is a horst between the Great Boundary Fault in the east and the Sirohi-Tosham line (Sirohi Lineament) in the west. The concept received weighty support from the interpretation of gravity data by Glennie (1932), Mathur (1969), Quereshy (1964) and Reddy and Ramakrishna (1988a). physiographycally, the ‘Aravalli Horst’ is made up of western mountains (Aravalli Mountains) and eastern upland plains of Banas and Mahi basins.

The Aravalli Mountains can be subdivided into the following geographical belts:

i. Alwar Hills,
ii. Eastern shekhawati hills including Sambhar Basin,
iii. Central Aravalli (Merwara) Hills,
iv. Mewar Hills, and
v. The Abu Block

(i) Alwar Hills

The northern 'fan' of the Aravalli Mountains covers the districts of Jaipur, Alwar and Dausa. The eastern most hills, the Bayana-Lalsot Hills, continue as discontinuous rows of hills up to Tonk in the south.

There are several prominent, intricately patterned ridges of quartzite amidst a flat country of phyllite and calcareous rocks. In certain instances, high quartzite ridges enclose low, soil covered, flat grounds of granitic bed rocks. Altogether, the geometry is comparable to the ancient Roman 'amphitheatres'.

The average elevation of quartzite ridges of the Alwar Hills is between 550 to 670 m from the mean sea level. Isolated high peaks, which rise higher than 700 m are that of Bairath (710 m) in the Alwar District, Babai (792 m) and Kho (978 m) in the Jhunjhunu District and Raghunathpur (1051 m) in the Sikar District. Highly dissected and eroded hills, which have been lowered down to about 100 m or less, occur in the northern and northeastern regions, i.e., towards Delhi and Bharatpur respectively. These isolated, subdued hills gradually merge with the Great Plains of Ganga and Yamuna.

(ii) Eastern Shekhawati Hills including Sambhar Basin

The Aravalli ranges from east of Sikar up to Ajmer present a different landscape from that of the Alwar Hills. Physiographically, the region is known as the Sambhar Basin, which occupies the most depressed part of the eastern Shekhawati Hills. A characteristic feature of the belt is the internal drainage system, which is entirely captive to the depression forming the saline lake of Sambhar (Fig. 1.9). The region is characterised by subdued topography with low hills, plastered with blown sands. The wide and flat valleys, which separate the low hills, at places, run for several kilometres. With an average height of 400 m, the Sambhar is the largest saline lake in Rajasthan. It is about 25 km long along east-west direction. The width varies from 4.5 km to about 16 km. The Sambhar is a very shallow lake; maximum depth of water during rainy season is about one metre. The lake virtually dries up leaving a small central puddle of mud and brine during the summer months.

(iii) Central Aravalli (Merwara) Hills

The central part of the Aravalli Mountains is also known as Merwara Hills. This is the thinnest part of the mountain, which forms the common "handle" of the two fans' of the Aravalli Mountains. From near Gugra, north of Ajmer, parallel rows of flat-topped hills and steep valleys extend southward up to the important pass, Desuri-ki-Nal. The Aravalli Mountains in this stretch is virtually impregnable, having only a few passes to cross over the mountain. South of Ajmer, the mountain is breached by the Sagarmati River, which forms wide plain areas along its course through the mountain. The mafic rocks are the main component of the bold and precipitous hills on the western flank of the mountain. By contrast, the eastern side, which exposes dominantly calcareous rocks, shows higher degree of levelling. The average level of the central Aravalli tract is 550 m. There are only a few peaks that rise above 800 m. Taragarh (855 m) is the highest point in the neighbourhood of Ajmer. In the southern part, a peak near Goram Ghat stands at 935 m above the mean sea level. Mainly from the topographic stand point, Sen and Sen (1983) made a comparison of the relief of the central Aravalli tract with the Basin and Range Province of North America.

(iv) Mewar Hills

Reliefwise the highest elevation of the Aravalli Mountains is in the triangular area lying south of Desuri-ki-Nal. Known as the Mewar Hills, this high-hilly tract is bounded by the Eastern Mewar and Chappan plains in the east, Cambay Graben in the south, and the extension of the Kui-Chandravati Fault in the west. The northern part of the triangle between the Fort of Kumbhalgarh (25 05': 73°35') and Gogunda (24°46' 73°32′) is a region of high elevation, locally called the Bhorat Pathar (plateau). Lying at a level of nearly 1000 m, the plateau has a steep and precipitous western fall. There are a number of peaks, which rise over 200 m above the average 1000 m level. The highest peak of the Bhorat Pathar is the Jarga Parvat rising to 1316 m. This is the second highest point in Rajasthan after the Guru Shikhar (1722 m) in Mount Abu. The Fort of Kumbhalgarh is perched majestically at 1075 m high overlooking the plains of western Rajasthan Bagar. The Bhorat Pathar is made of several subparallel bold ridges of quartzite separated by valleys underlain by phyllite and calcareous schists.

From south of Gogunda, sets of subparallel ridges branch in the southwesterly, southerly, and southeasterly directions. The southwesterly branch of the southern Mewar Hills runs straight up to the Gujarat border where the ridges undergo abrupt truncation. Because of this, the highly mountainous Aravalli landscape is taken over by the low- lying alluvial plain of Cambay Graben. The abrupt termination of Aravalli ridges is a major geomorphic feature that also constitutes the southern boundary of outcrops of the Precambrian rocks of Rajasthan. Another prominent feature in the geomor- phology of this part of the Aravalli ranges is the presence of number of circular and semicircular relief features, possibly related to intrusions that shoved astride the tectonic pattern of the host rocks.

The middle branch of the Aravalli ridges, which runs more or less in the north-south direction, makes its appearance from east of Gogunda. These are very prominent ridges of quartzites in a milieu of phyllites, all belonging to the Aravalli Supergroup. All the ridges of the Aravalli Mountains described earlier, geologically belong to the Delhi Supergroup. The angular relationship between the two trails of the Aravalli Mountains that run southwesterly and southerly respectively, marks an important tectonic feature presumably representing the trace of unconformity between two geological formations. The angular relationship appears very prominently in thr satellite imageries. The ridges trend southward up to Kherwara (23 59: 73°37') and Rishabdev (24°05': 73°42′), where from starts a gradual southeasterly swing of the bold quartzite ridges. On a plan view, the ridges assume queer patterns particularly in the region between south of Dungarpur and Lunavada (23°32′: 73°35') in northern Gujarat. The ridges become more subdued until these get covered under Deccan basalts in the east. The highest elevation in this part of the Mewar Hills is in the region west and northwest of the city of Udaipur, where there are a number of peaks rising above 900 m. The highest point is 1073 m near Jharol (24°24’:73°29').

The most easterly trail of ridges, which runs in southeasterly direction, starts from the upland north of Udaipur. The city itself is surrounded by chains of hills. The valley where the city of lakes is situated is called Girwa[1]. The continuity of southeasterly ridges, which are traceable beyond Salumbar, is breached at the Jaisamand Lake. Some hills in the neighbourhood of Jaisamand Lake rise up to 820 m, whereas the highest level of lake water stands at 300 m.

These easterly and terminal Aravalli ridges present a bold geomorphic outline bordering the Eastern Plains of Banas and Mahi Basins.

(v) The Abu Block

The hill mass of Abu is a high rising, isolated tableland (Fig. 1.6a) in the Aravalli Mountains separated by the main ridges of the Southern Mewar Hills by a wide northeast-southwest running valley. At 1722 m above the mean sea level, the Gurushikhar is not only the highest point in the Abu Block but also in the entire Indian shield north of the Nilgiri Mountains. From distance, the Abu Block appears as a raised tableland, which is about 19 km long and about 6 km wide. With an average height of 1200 m above the mean sea level, the Abu Block stands much higher above the shoulders of the surrounding hill ranges on its either side. Its northern and western falls are extremely precipitous. Whereas the outlines of the eastern and the southern margins are ill defined because of the presence of a number of spurs and highly incised valleys. Granitoids being the dominant rocks of the Abu Block, produced many fanciful and curious forms having smooth surfaces. Many of these are balanced precariously on narrow pivots. Another typical erosion feature is the development of rounded and subrounded cavernous depressions on the steep cliff faces of rocks indicating dominance of wind erosion in this region.

3. The Eastern plains

Lying east and southeast of the Aravalli Mountains is the Eastern Plains of granite gneisses, granitoids, paragneisses, mica schists and phyllites. Heron (1953) quotes Rudyard Kipling who had described region as 'the stony plains of Mewar'. The entire plain is divided into northern Mewar Plain and the southern Chappan Plain. The dividing line of the two plains is an important water divide of the Indian shield. The divider runs east-west (more precisely, ESE-WNW) through the 'girwa" of Udaipur and south of the Udaisagar Lake.

The Great Boundary Fault, separating the Aravalli Horst' from the Vindhyan Plateau, forms the eastern boundary of the Mewar Plain. The Aravalli ranges in the west form the most formidable western boundary the Mewar Plain. The Mewar Plain, particularly in the southwestern part is truly a 'stony plain' with a little cover of alluvial sand. Mainly because of this, the region in local dialect is known as 'banjarbhumi (sandy infertile land with shrub coppice). The thickness of the alluvial cover increases to north and east. The whole of the Mewar Plain is dotted with numerous dwarfed hills and ridges. The two most prominent ones are the Sandmata Hill (817 m) and the Quartzite 'dome' of Amet (968 m). both situated close to the western boundary of the plain. In the north, the Mewar Plain gets blended with the Plains of Ganga.

Originating from the Bhorat Pathar, the Banas River flows almost through the centre of the Mewar Plain. Its important tributaries are the Berach, Kothari, Khari, Dhund and Moral. Flow of the river in the Mewar Plain indicates a north northeasterly gradient of the basin. This may be interpreted as due to the general northerly tilt of the block of the crust that underlies the Mewar Plain.

The Chappan Plain lies east of Udaipur, south of the water divide, which change over to a low flat plain in the south. The Chappan is a region of rocky badlands. In contrast to the relief in

the northern level ground, the Chappan in its northern part is a deeply dissected rocky terrain characterised by a maze of intricately oriented shallow valleys. Heron (1953) described this plain as a 'tangled wilderness of shallow valleys'. The dominant rocks in the terrain are granitoids and gneisses. In contrast to the fact that the region exposes the oldest rocks of the Aravalli terrain, the topography appears to be quite young and immature. The plain is dissected by the drainage of the Som and Mahi Rivers, which flow to the Gulf of Cambay. The fall of the country, which is between 8 to 12 m per km, is much steeper than that in the Mewar Plain. In the southern part of the Banswara District, the rocky Chappan gives way to an alluvial plain having 150-300 m average elevation.

4. The Uplands of Harauti and Malwa

East of the Mewar Plain, separated by the Great Boundary Fault, is the Harauti Upland (or Plateau). This is the westernmost fringe of the Great Vindhyan Plateau. Made dominantly of sandstones and the river system of the State can be conveniently limestones, the upland looks like an escarpment running in a northeast-southwest direction. In the south, near Chittaurgarh, there are a number of north- south trending folds, of which the anticlines occur as linear ridges separating subparallel flat lying, 'synformal' valleys.

Only a part of the Malwa Plateau, which lies south of Harauti Upland, is in Rajasthan. The Malwa is a part of the Deccan Plateau, which characteristically shows flat topped hills of lava flows. The landscape of the Malwa region is characterised by basaltic uplands littered with pieces of dark grey basalt. The Malwa of this region forms the western part of the Upper Mahi Basin. It is rugged and dissected terrain where the high banks of rivers are strewn with dark grey boulders of basalts. Because of this, the region bears a gloomy and dirty look.

1.6 General Geology of Rajasthan

Rajasthan occupies 3,42,239 sq km area covering 10.74% of the Indian Territory and is the largest State of India. The State is located within 23 03'-30 12'N and 69 29'-78 17'E. The northwestern part of the State is occupied by the Thar Desert covering 32% area of the total area. The Aravalli hill range extending from Delhi in the northeast to the plains of north Gujarat in the southwest, divides the State into two unequal parts. The area to the east of the hills is covered by the eastern plains and the Vindhyan plateau. Rajasthan forms northwestern part of the Indian Shield. The rock sequences of the region cover a time span of about 3500 to 0.5 Ma. The State exposes a variety of lithological and tectonic units ranging in age from Archaean to Recent times. The basement rocks - the Sandmata Complex, Mangalwar Complex and Hindoli Group of Bhilwara Supergroup - occupy central and southeastern plains. They are Archaean in age and comprise in general, granulite-gneiss; amphibolite, metapelite, paragneiss, calc-silicate rocks and greywacke (the older granitegreenstone belt) and metavolcanic, metagreywacke (the younger granitegreenstone belt) respectively. The Lower Proterozoic supracrustal rocks of the Jahazpur, Rajpura-Dariba, PurBanera and Sawar Groups of Bhilwara Supergroup rest on the basement rocks of the Mangalwar Complex and host a number of lead, zinc and copper deposits. The Bhilwara Supergroup of rocks is intruded by the Untala-Gingla Granite, Berach Granite, basic and ultramafic bodies. The Lower Proterozoic supracrustal rocks of the Jahazpur, Rajpura-Dariba, Pur-Banera and Sawar Groups of Bhilwara Supergroup rest on the basement rocks of the Mangalwar Complex and host a number of lead, zinc and copper deposits. The Bhilwara Supergroup of rocks is intruded by the Untala-Gingla Granite, Berach Granite, basic and ultramafic bodies. The Proterozoic fold belts, viz., the Aravalli fold belt (the Aravalli Supergroup) and the Delhi fold belt (the Delhi Supergroup) occupy the southern and southeastern, and south-western and north-eastern Rajasthan respectively. The Aravalli Supergroup is represented by metamorphosed and complexly folded clastic sediments with minor chemogenic and organogenic assemblages with interlayered basic volcancics, whereas the Delhi Supergroup comprises mainly carbonates, metavolcanics, metasammites and metapelites, intruded by magmatic rock of Phulad Ophiolite Suite and syn-orogenic granites of SendraAmbaji, Bairath, Dadikar, Harsora, etc. A number of base metal deposits are located in these belts as also other minerals. The isolated hillocks of western Rajasthan constitute the Upper Proterozoic Malani Igneous Suite and the Erinpura Granite pluton. Eastern Rajasthan is characterised by the vast sedimentary stretch constituting the Vindhyans, which is juxtaposed against the rocks of the Bhilwara Supergroup along the Great Boundary Fault. The northern and north-western parts of the State exhibit Upper Proterozoic-Early Cambrian (?) rocks of the Marwar Supergroup which are overlain by sedimentary rocks of different ages of Palaeozoic and Mesozoic Era. Many industrial mineral deposits are found in these rocks. The Deccan Traps are restricted to the south-eastern part of the State in Chittaurgarh Banswara area. The Cenozoic rocks are manifested in Barmer and Jaisalmer basins in the west and Ganganagar-Palana shelf in the north. The Quaternary sediments of aeolian and fluvial origin constitute the Thar Desert of Rajasthan

1.7 Regional Geology

Growth of the Precambrian crust in the north western part of the Indian Shield evolved through accretion of several sedimentary sequences, which were deposited at intervals around a nucleus of gneissic rocks; here it is a heterogeneous rock assemblage known as the Banded Gneissic Complex (3500 my.) and the Berach Granite, as a result of tectonic changes and subsequent marine transgressions and regressions. The oldest sedimentary sequence which overlies the gneissic basement with a profound erosion unconformity is the Aravalli Supergroup. The Raialo, the Delhi, and the Vindhyan Supergroups are the successively younger sedimentary units. The field visit regions mostly covered the rock sequences belonging to the Vindhyan Supergroup and the Aravalli Supergroup.

(i) Aravalli Supergroup

The Aravalli craton is located in the north-western part of peninsular India, bounded on the north by the Himalaya Mountain chain, the Cambay graben in the southwest, and the Narmada-Son lineament on the south and southeast. Young sediments cover the western boundary and may extend farther into Pakistan. Rocks of the Aravalli craton are quite different from the Dharwar and other cratons of the Indian shield. They consist mostly of Proterozoic phyllites, graywackes, quartzites, and carbonates, with minor mafic and ultramafic schists. Stromatolites are common in the carbonates and are associated with phosphorite deposits. Banded-iron formations are almost totally absent from the Aravalli craton but common in other cratonic blocks of the Indian shield. Major structures of the Aravalli craton include the Great Boundary fault on the eastern edge of the Aravalli-Delhi belt, the Delhi-Haridwar ridge, and the Faizabad ridge, which is an extension of the Bundelkhand massif under the Indo-Gangetic Plain. The Aravalli-Delhi belt contains a large number of granitic rocks emplaced over a wide range of time from 3.5 billion to 750 million years ago. Ages of the Aravalli Supergroup range between 2.5 and 2.0 billion years.

Aravalli Orogen		
South Delhi Supergroup		
Gogunda Group	Siliciclastic dominated	1.2-1.0 Ga[3], <1.0 Ga[5]
Kumbhalgarh Group	Mixed siliciclastic-carbonate	< Ga[5]
North Delhi Supergroup		
Ajabgarh Group	Mixed siliciclastic-carbonate	<1.74 Ga[5]
Alwar Group	Siliciclastic dominated	<1.76 Ga[6], <2.1 Ga[5]
Raialo Group	Mixed carbonate-siliciclastic	<2.3 Ga[5]
Aravalli Supergroup		
Upper Aravalli Group		
Lakhawali Formation	Siliciclastic dominated	
Kabita Formation	Carbonate dominated	
Debari Formation	Siliciclastic dominated	<1.67 Ga[4]
Middle Aravalli Group		
Tidi Formation	Siliciclastic dominated	
Bowa Formation	Siliciclastic dominated	<1.73 Ga[4]
Mochia Formation	Mixed carbonate-siliciclastic	
Udaipur Formation	Siliciclastic dominated	1.6 Ga[3], <1.80 Ga[4]
Lower Aravalli Group		
Jhamarkotra Formation	Carbonate dominated	1.7 Ga[3]
Delwara Formation	Mafic volcanics and sandstone	<2.45 Ga[4]
----------Unconformity----------		
Sandmata complex	Gneisses, granitoids and Charnockites	2.9-1.7 Ga[2]
Banded Gneissic Complex	TTGs and granitoids	3.31-2.49 Ga[1]

Table 3*- Stratigraphic Sequence of the Aravalli Supergroup*

(ii) Vindhyan Supergroup

The Vindhyan Supergroup is the thickest Precambrian sedimentary succession of India and the duration of its deposition is one of the longest in the world. The importance of the Vindhyan sequences lies in the notion that because of its vastness in time and space they contain important information on the evolution of the Earth's atmosphere, climate, sedimentary cover and life. The Vindhyan basin is bounded to the west by the Aravalli Mountains along the Great Boundary Fault but is believed to continue uninterrupted beneath the Gangetic alluvial plain beyond the present northern outcrop limit and below the Deccan Traps in the southwest. The rocks of the Supergroup are exposed in two sectors: Rajasthan in the west and Son valley in the east. The Vindhyan strata are unmetamorphosed and mostly undeformed. However, there exist largescale folds in the Son valley and several post depositional faults in Rajasthan. The Vindhyan Supergroup is composed mostly of low dipping formations of sandstone, shale and carbonate, with a few conglomerates and volcaniclastic beds, separated by a major regional and several local unconformities. It is generally believed that the Vindhyan basin was a vast intra-cratonic basin formed in response to intraplate stresses.

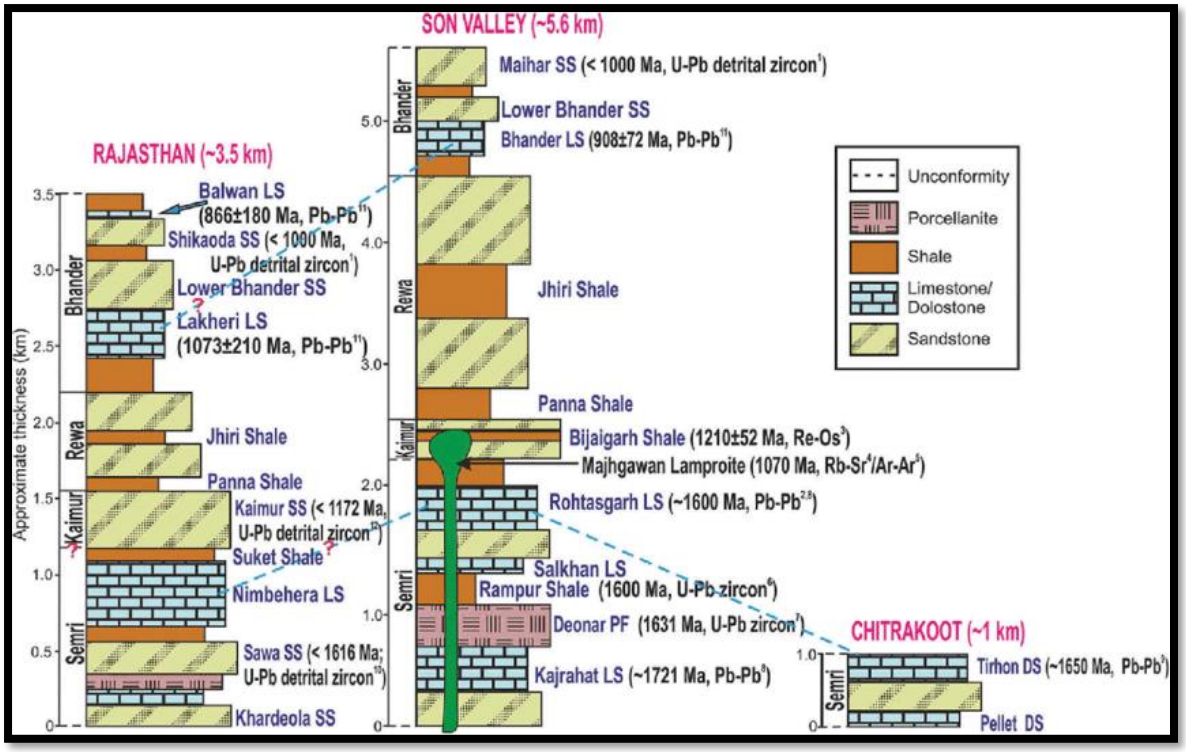

Fig 5: *- Stratigraphic logs of the Vindhyan Supergroup in Rajasthan (West), Son Valley (Southeast), and Chitrakut (Northeast).*

Day 01: 22/02/2023

Location: Archaeological remains of Harappa Port-Town, Lothal

Latitude: 22.521605

Longitude: 72.249538

The ancient mount at Lothal was excavated by Prof. S.R. Rao from 1955-62 which unearthed many structural remains of Harappan town datable to circa 2500-1900 B. C. The entire settlement was divided into a citadel or acropolis and Lower town, which were protected against flood by 13 m thick mud brick wall, on the western side. The Chief lived in the acropolis, where houses were built on 3 m thick platform and provided with all civic amenities including paved baths, underground drains and a well for potable water. The lower town was subdivided into two sectors. The most outstanding remains are a large tank identified as a dock and a warehouse.

The dockyard is constructed of fine burnt bricks and is most scientifically designed to carry out the water flow, to withstand the force of the current and the water thrust. It is known for its unique water locking device and measures 214 X 36 m. the other important structure – the warehouse, occupies south west corner of the citadel. It stands on 3.5 m high platform and measures 49 X 40 m. originally there were 64 cubical blocks of mud bricks built on the platform for providing wooden canopy to protect the cargo.

The excavations at Lothal have yielded a variety of artifacts which include beads, seals and sealings, shell, ivory, copper and bronze objects, tools, animal and human figurines, weights, ritual objects, etc. The prosperity of this small port town largely depended upon its overseas trade of items, such as, semi-precious stone beads, copper, ivory, shell and cotton goods, etc. with West Asia. Discovery of objects of Persian Gulf origin and terracotta figurine of gorilla and mummy indicate a strong overseas contact of Lothal.

Fig 6: *the dockyard.*

Fig 7: *the drainage system.*

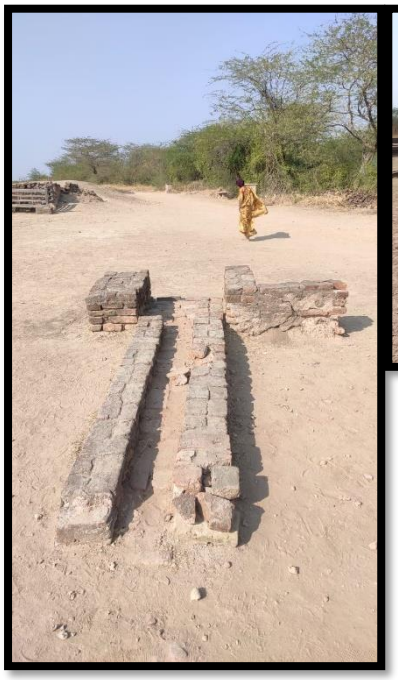

Fig 8: *the paved baths.*

Fig 9: *the warehouse.*

Fig 10: *the semi-precious bead factory.*

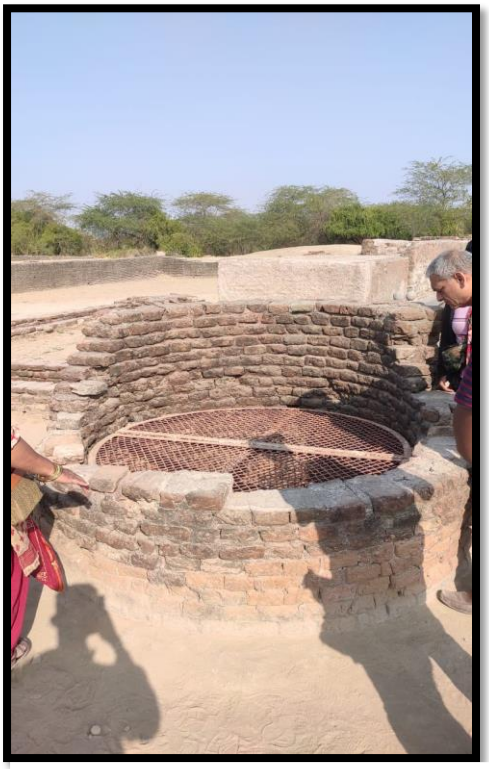

Fig 11: *a well at acropolis.*

Fig 12: *the underground drainage at acropolis.*

Day 02: 23/01/2023

Location: Physical Research Laboratory, Ahmedabad

The Physical Research Laboratory (PRL), Ahmedabad is a premier research institute engaged in basic research in the areas of Astronomy and Astrophysics, Solar Physics, Planetary Science and Exploration, Space and Atmospheric Sciences, Geosciences, Theoretical Physics, Atomic, Molecular and Optical Physics and Astro-chemistry.

This division runs several research programs, particularly aerosol chemistry, hydrology, paleoclimatology, oceanography, etc. The experimental facilities of this division incorporate accelerator mass spectrometer(AMS), aethalometer, isotope ratio mass spectrometer(IRMS), ion chromatographs, and many more.

In the geosciences field the study Studies that are particularly related to geochronology, geochemistry, glaciology, oceanography and palaeoclimatology are carried out in this department. The major focus is on studying Earth and its components' origin and evolution. Isotope geology is one of the most researched subjects. Their research is based on measurements of the abundances of radioactive isotopes, elements, etc.

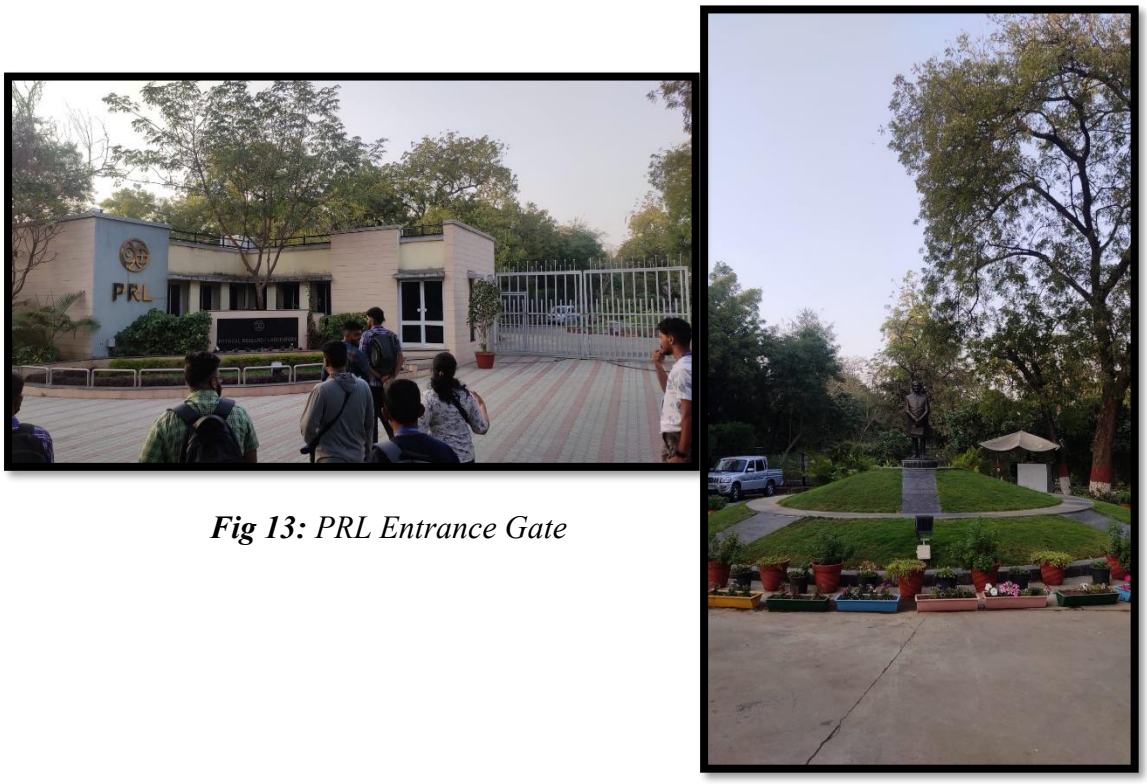

Fig 13: *PRL Entrance Gate*

Fig 14: ICP-AES inductively coupled plasma atomic emission spectrometry.

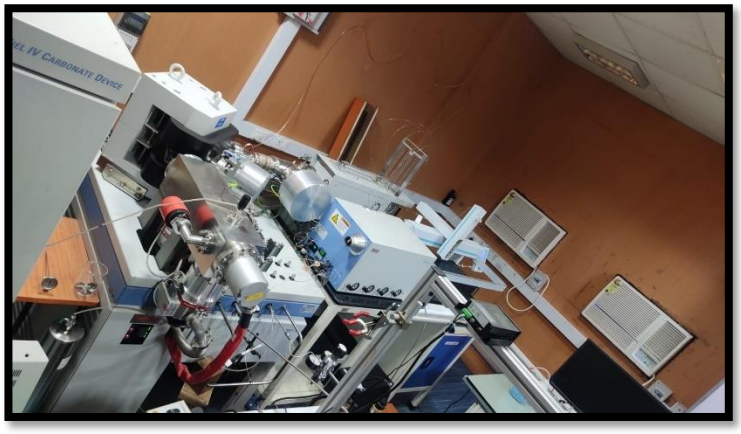

Fig 16: *TIMS*

Day 03: 24/01/2023

Location 01: Near Mahadev Temple, Balasinor

Latitude: 22.970785

Longitude: 73.346296

The outcrops are exposed as inselberg/Tors topography, which exhibit exfoliations weathering. These are compact & massive, medium grained grey in colour. The trend of these granitoids is N-S. Large phenocrysts of Feldspar of about 2-5 cm. largest phenocryst observed was 2inches. were surrounded by finer matrix mainly composed of biotite and quartz. At places these euhedral feldspars were aligned in a particular direction (trains of end-to-end touching grains) which is a characteristic of magmatic flow. The quartz and micas show segregation at places they are more weathered. The granites are more weathered along EW direction. 5cm wide exfoliation joints seen. Xenoliths of gneisses and biotites seen.

- Rock description: -
  - Colour- greyish
  - Texture- medium coarse grain, orthogonal, subhedral
  - Composition-
    - Essential- feldspar (sub-vitreous,2-set cleavage, sub-hedral)

      Quartz (7, vitreous)

    - Accessory- flaky biotite with pearly lustre as xenolith.
  - Classification- Plutonic Felsic Igneous Rock
  - Rock name- grey granite

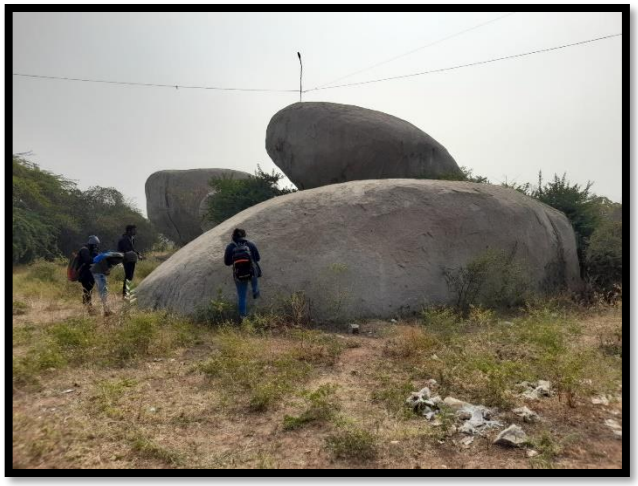

Fig 17: *torse of granite.*

Fig 18: *grey granite.*

Fig 19: *lensoidal material in granitoid.*

Location 02: Dinosaur Fossil Park, Raiyoli-Balasinor

In the year 1981 geologists from the Geological Survey of India who were surveying the area about 16 km NNE of the village Balasinor in the District Kheda, Gujarat for minerals stumbled upon remains of dinosaur bones and fossils. Some 65.5 million years ago during the Cretaceous period, the topography of Gujarat and specifically of Raioli in Balasinor was different than what it is today. The plains of the river Narmada that extended from its basin proved an ideal breeding ground for the Indian Titanosaurid Sauropods and Abelisaurid Theropods. The land proved to be the perfect hatchery for dinosaurs from the late Jurassic period to throughout the Cretaceous period are the basal part of these sections comprises the Aravalli Super Group, including quartzites and phyllites, which are further enveloped by Godhra granitoids. These sections expose an approximately 2-m thick, greenish-coloured conglomerate with numerous sauropods and theropod bones. The conglomerate is further encrusted by a 1.5-m-thick calcareous sandstone, which has also yielded a few fragmentary dinosaur teeth and bones. The topmost part of these sections is composed of the 2.5–3-mthick Lameta Limestone. These sections are some of the most productive sections for dinosaur nests and eggs and have yielded hundreds of beautifully preserved eggshell fragments belonging to five oospecies.

The **Rajasaurus Narmadensis**, an Abelisaurid Theropod Dinosaur with a single horn on its head that roamed the Narmada valley during the late Cretaceous period. This dinosaur is believed to have a massive dimension with a length of 9 meters, and a height of 2.4 meters and

weighing a staggering 4000 kilograms. The bones of the Rajasaurus were excavated and it named because of the horn on its head which gave it the appearance of wearing a crown and the fact that it thrived on the Narmada Valley.

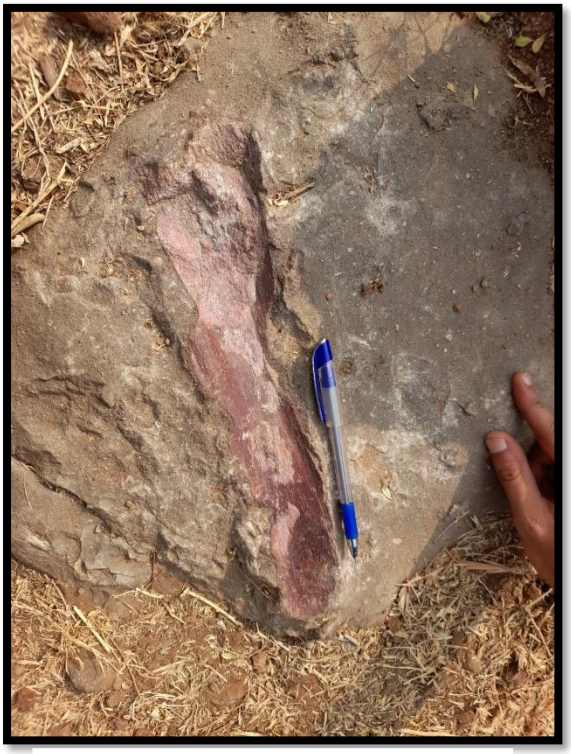

Fig 20: *a fossilised bone.*

Fig 21: *fossilised egg with embryo*

Day 04: 25/01/2023

Location: ONGC – GGS MOTERA, Ahmedabad-Gujarat

Day 4 25/01/2023

The mine code was 100180

We visited an oil and crude treatment plant which was connected to 59 oil wells in a radius of 17kms which were connected through underground pipelines. 50 to 60 thousand liters of oil and crude is being transported from this G.G.S Motera to the Kayoli IOCL Refinery.

Mister Gaurav kumar who was Safety Officer there, guided us and show us the plants which were present there.

Firstly,we went to the main processing plant where oil and gas is recieved through underground pipelines which comes to a booster gas compressor plant which passes to the low pressure seperator which seperate Oil and Gas based on the density. Which is directly stored in a tanker which is 45 cubic metres.

Based on the pressure received there are two separators present.

i. Low pressure separator

   20.60kg/cm^2

   Hydro test pressure - 9.0 kg/cm^2

   Safety valve test pressure -6.-kg/cm^2

ii. High Pressure separator

   40 kg/cm^2

   Hydro test pressure- 60 kg/cm^2

   Safety valve test pressure- 43 kg/cm^2

Through this separator, oil and gas is directly stored in the storage tank.

Corrosion inhibitor are used to prevent rusting of pipelines. 2 litres per day in each pipeline.

There are 2 new gas booster plants with high capacity. This are 2 stage compressor which makes the machine smaller in size.

The bath heaters are used to increase the temperature of crude if it gets solidifies in the pipelines which works on the idea of heat exchanges.

This new booster plant has a safety measure feature which is CO2 flooding which prevents fire.

They used SCADA software to check and maintain the pressure temperature and flow meter.

Lastly, Gaurav Sir briefly explained us the processing and working of the plant.

Fig 22: *ONGC-GGS MOTERA, Ahmedabad*

Day 06: 27/03/2023

Location: Jamarkotra Phospherite Mine, Udaipur

A large deposit of rock phosphate was discovered by the State Department of Mines and Geology, Rajasthan, in the year 1968 at Jhamarkotra near Udaipur. Nitrogen, potash and phosphorous are the three products of the mine but the rock phosphate contributes to the 90% of the phosphorous of the country and hardly 10% is imported. Some other phospherite mines are Fatasar Lake, padagaon rock phosphate mine and Kanpur rock phosphate mine. Some phosphorite is confined to algal stromatolitic columns such kind of deposits are found in Jammu and Madhya Pradesh.

The late Precambrian phosphorite deposits of the Aravalli Mountain belt occur as discontinuous outcrops within dolomitic limestone and silicified dolomite of the Aravalli Supergroup. They extend from Udaipur in the north to Jhabua in the south. (Banerjee, Basu, & Srivastava, 1980).

Jhamarkotra phosphorite displays a larger spectrum of petrographic types, including algal microsphorite in a micritic of the ore in the market. The ore to overburden ration is 1:16. Groundmass, fragmental phosphatic intraclasts with recrystallized calcareous cement, and microsphorite clasts embedded in silt-sized quartz and pelitic intercalations. The mine strike length is about 16km forming a zig-zag basin and the ore body is in horse- shoe shaped striking in the E-W direction and with 5-15m thickness and 55m average depth. It is an open cast mine with bench and faces and its depth is about 180m from the original topography. The bench heigh is around 10m and face height in a sequence 7m, 7m, 12m.There are two types of the ore 1) high grade ore 2) low grade ore. The high-grade ore with P2O5 content (35- 36%) and this high-grade material supplied to the manufacture of the fertilizers. Low grade ore consist of 29% of P_2O_5. The total tonnage od the geological reservoir is 39m tonnes and mining reservoir is 18m tonnes. The tonnage and area of mining reservoir depends upon the demand.

In the area oldest basement rock is the banded gneissic complex and the Aravalli supergroup with the Jhamarkotra Formation belonging to the lower Aravalli Supergroup unconfirmably overlying the basement rock. The Jhamarkotra Formation evidences the presence of earlier life with the basin 2000-2300 m years. The shallow marine environment of the area in the geological past led the growth of algae and dissolution of the phosphate. The host ore rock is Dolomite.

Fig 23: *overview of Mining Pit*

Day 07: 28/01/2023

Location: Berach River, Chittoorgarh

Latitude: 24.903800

Longitude: 74.623149

The rocks of this spot are exposed along the banks of the river Berach. This are fine grain sedimentary rock texturally foliated and with the slaty cleavage structure. Quartz veins are concordant to the folding. The is grey coloured with red and white layers.

The rock is the Suket Shale that stratigraphically belong to the Semri Group of the Vindhyan Supergroup overlain by the Kaimur group and underlain by the Nimbara Limstones of the Semi Group.

The structural data from Table.1 shows that the area has undergone two generations of deformation that is evidenced by the presence of two generations fold with F1 fold forming syncline and anticline structure striking N500 and the F2 fold striking along N 120°. A pair of conjugate shear joints are present, J1 trending N50 and J2 trending N300. Limbs of the fold dipping in the opposite direction reveals that the area is folded.

Strike direction	Dip direction	Dip amount
N50°	N145°	45°
N210°	N240°	40°
N50°	N320°	58°
N50°	N140°	67°
N40°	N130°	58°

Table 02: *F1 fold data*

Strike direction	Dip direction	Dip amount
N220°	N40°	45°
N200°	N30°	32°
N302°	N210°	43°
N330°	N60°	41°

Table 03: *F2 fold data*

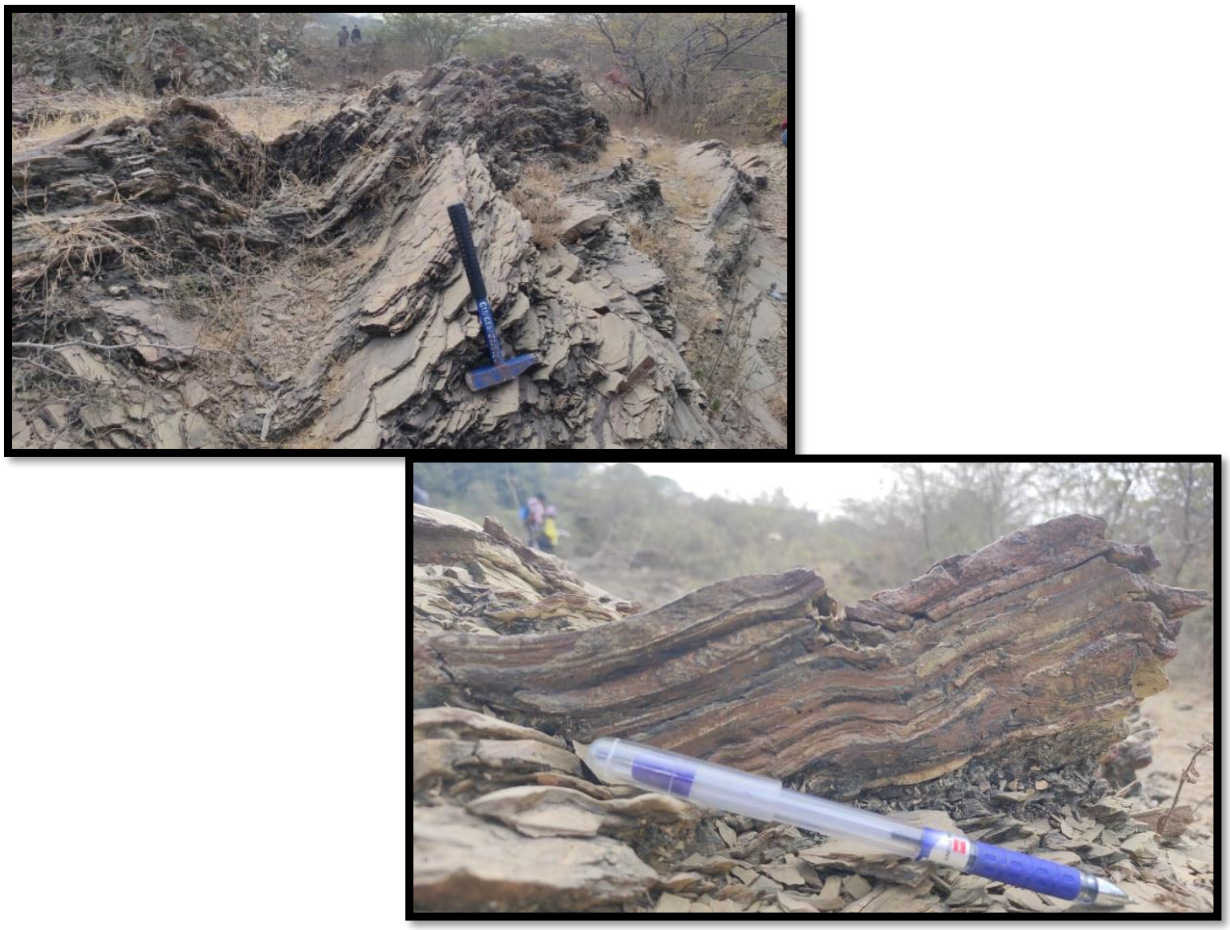

Fig 24: *folded Suket Shale*

Location: On banks of Gambhiri River, Chittoorgarh

Latitude: 24.874186

Longitude: 74.633308

Rocks are exposed along the Gambhiri river which are dipping almost vertical. They are Nimbara Limestone of the Semri Group of the Vindhyan Supergroup. These limestones are striking N 180° and Dipping N 274°. The rock is highly jointed. orthogonal joints are present trending N170° and N80°.The Nimbara Limestone is dominantly composed of micritic to microsparitic calcite that preserves largely marine isotopic and trace element signatures.

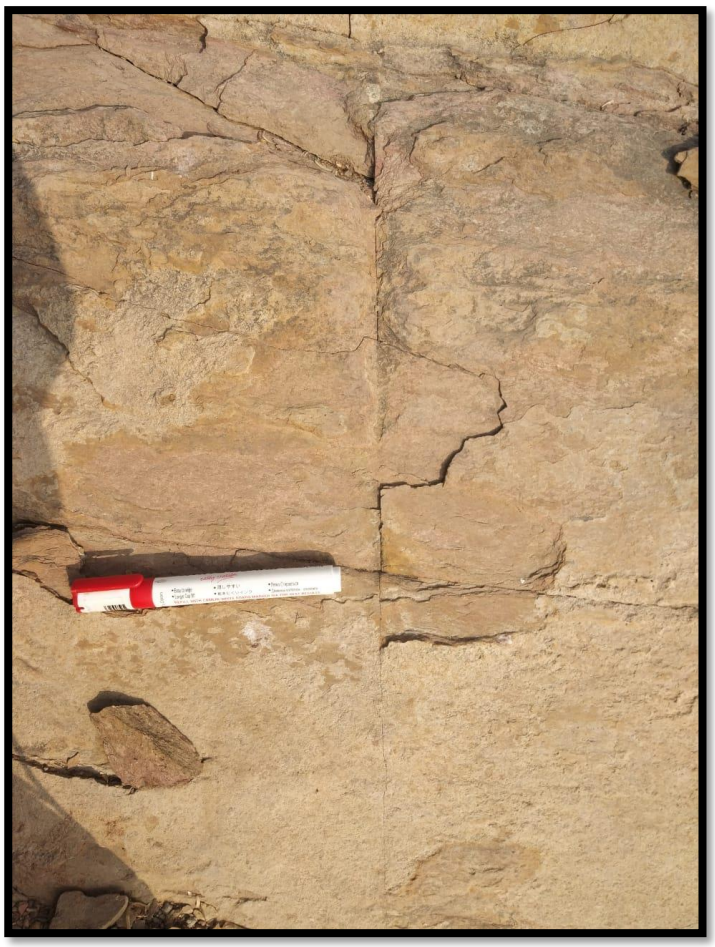

Fig 25: *Nimbara Limestone*

Day 08: 29/01/2023

Location: Nathdwara

Latitude: 25.057646

Longitude: 73.850865

The exposed rocks are in a sequence, Here the grey marble overlain by the schistose rock followed by the marble with the joint N115° passing through all three different lithology. The schistose rock is very dark in colour and defined by schistosity which are striking N130°, dipping N320° by 40°. At some spots micas are present so the rock is highly weathered Chlorite Mica Schist. Grey Marble underlain the schist is banded with grey bands, shows Porphyroblast texture with the presence of Amphibole with prismatic habit. It strikes N-S, dipping East by 26°.

Fig 26: *grey and white lamination in marble.*

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