SCHOOL OF EARTH, OCEAN AND ATMOSPHERIC SCIENCES

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LABORATORY CERTIFICATE

This is to certify that ~~Mr.~~ /Ms. Yukti Garg
has satisfactorily completed the course of practical for M.Sc in Applied Geology.

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DEAN
SEOAS

Faculty member in-charge

Dr. Anthony Viegas
Vice Dean (Academic),
School of Earth, Ocean
& Atmospheric Sciences,
Goa University,
Goa - 403 206.

REPORT ON THE GEOLOGICAL FIELD TRAINING CARRIED OUT IN GUJARAT AND RAJASTHAN

Submitted by

Yukti Garg

MSc II (Applied Geology)

Seat No. 21P045029

Applied Geology,

School of Earth, Ocean and Atmospheric Science,

Goa University,

Taleigao Plateau, Goa, India

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GLC 122 Geological field training


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INTRODUCTION

1.1. GENERAL INTRODUCTION

Gujarat is a state in India's western region. By both size and population, it is the ninth-largest state in India. The state is bordered to the west by the Arabian Sea, to the northeast by Rajasthan, to the east by Madhya Pradesh, and to the south by Maharashtra. Gujarat, which is in western India, has a total size of 196,024 square kilometres. The state boasts a vast coastline of about 1,600 kilometres along the Arabian Sea. There are two significant gulfs along the coastline: the Gulf of Kutch and the Gulf of Khambhat. Gujarat's northern region has the vast salt desert known as the Rann of Kutch. A flat, desolate landscape with scant vegetation and seasonal salt marshes define this region. This region floods during the monsoon season, creating a saltwater lake. The Western Ghats stretch along the state's southern border with Maharashtra, providing a mountainous landscape. Girnar, which is close to the city of Junagadh and has an elevation of 1,156 metres, is the highest peak in Gujarat. The main rivers that run through Gujarat are the Sabarmati, Mahi, Narmada, and Tapi. These rivers drain into the Arabian Sea from the neighbouring states of Rajasthan, Madhya Pradesh, and Maharashtra. Temperatures in Gujarat often range from 10°C to 50°C, making for a hot and dry climate. Most of the state's rainfall occurs from June to September, during the monsoon season. Temperatures in the Rann of Kutch are notoriously harsh, soaring above 50°C in the summer and falling below freezing in the winter. Gir Forest National Park, Blackbuck National Park, Marine National Park, and Vansda National Park are just a few of the national parks and animal sanctuaries that Gujarat is home to. Many wildlife species, including as lions, tigers, leopards, deer, and migratory birds, call these protected areas home.

The Indian state of Rajasthan is situated in the country's north. It is the largest state in terms of area in India and borders Punjab to the northwest, Pakistan to the west, Gujarat to the southwest, Madhya Pradesh to the southeast, and Uttar Pradesh to the northeast. Rajasthan occupies an area of 342,239 square kilometres and is situated in the northwest of India. The Thar Desert, which covers roughly 61% of the state's total area, makes up the majority of its arid and semiarid terrain. The desert area, sometimes known as the "Great Indian Desert," is one of India's most hostile geographical areas. The state is divided into two parts by the Aravalli Range: the desert region in the west and the hilly region in the east. Guru

Shikhar, which rises to a height of 1,722 metres in the Aravalli Range, is the highest peak in Rajasthan. Many rivers, including the Chambal, Banas, Luni, and Sabarmati rivers, drain the state. But most of the time, these rivers are seasonal, and they dry up in the summer. Rajasthan has extremely high summer temperatures of 50°C and extremely low winter temperatures of 0°C. The state experiences extremely little rainfall, with the majority of it falling from July through September, during the monsoon season. Rajasthan is home to a vast and diverse diversity of flora and animals despite its harsh environment. A variety of wildlife species, including tigers, leopards, elephants, and deer, may be found in the state's national parks and wildlife sanctuaries, which include Ranthambore National Park, Sariska Tiger Reserve, and Keoladeo National Park. Rajasthan's economy is mostly focused on agriculture; the state is one of India's top producers of wheat, barley, mustard, and other commodities. Together with oil and natural gas, Rajasthan also boasts abundant mineral resources, including marble, granite, and other stones.

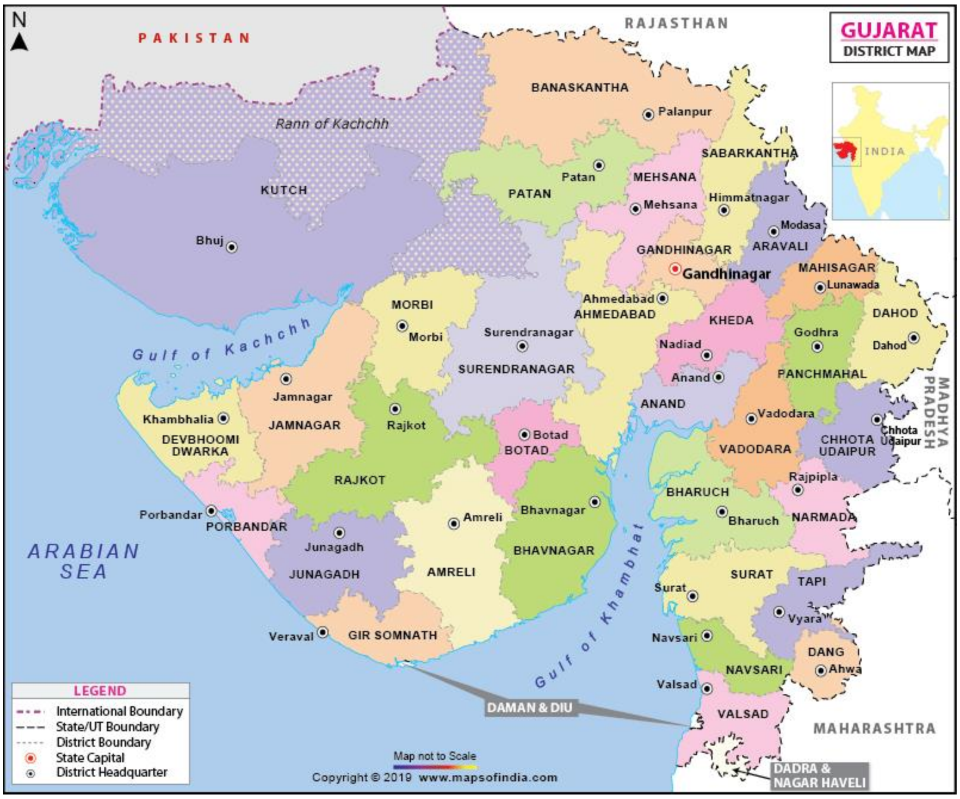

Fig. District map of Gujarat

(source: https://www.mapsofindia.com/maps/gujarat/gujarat.htm)

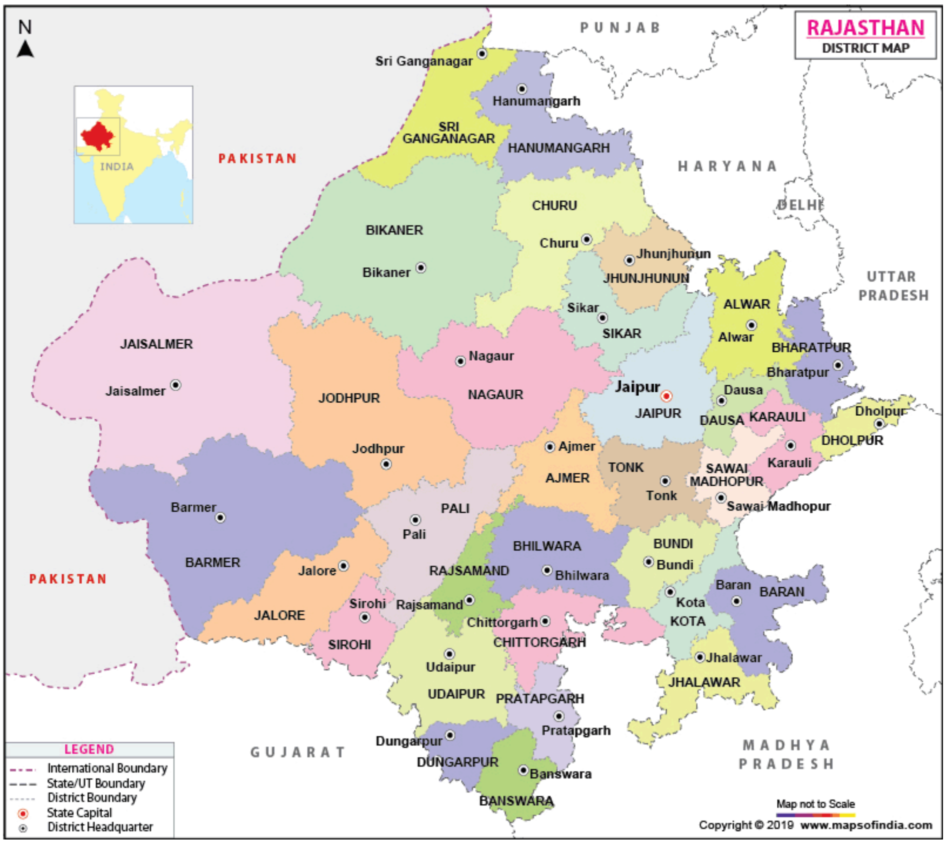

Fig. District map of Rajasthan

(source: https://www.mapsofindia.com/maps/rajasthan/rajasthan.htm#)

1.2. GEOLOGY AND GEOMORPHOLOGY OF GUJARAT

GEOMORPHOLOGY: Gujarat is a state located in western India and has a diverse geomorphology consisting of a variety of landscapes such as hills, plateaus, plains, and coasts. The state's geomorphology has been shaped by various geological processes such as tectonic movements, erosion, sedimentation, and volcanism. The Saurashtra Peninsula, located in the western part of Gujarat, is characterized by a hilly terrain with several plateaus and valleys. The region has been shaped by various tectonic movements and is believed to have undergone several phases of upliftment and subsidence. The region is also home to several volcanic features such as lava flows, volcanic cones, and ash deposits. The Rann of Kutch, a vast saline desert located in the northern part of Gujarat, is one of the unique geomorphic features of the state. The region is believed to have formed due to tectonic movements that resulted in the subsidence of the area and the subsequent flooding by the Arabian Sea. The region is characterized by a flat and barren landscape with several salt pans and is also home to several wetlands that support a diverse range of flora and fauna. The state's coastline, stretching over 1600 km along the Arabian Sea, is characterized by a variety of geomorphic features such as beaches, cliffs, and estuaries. The coastline has been shaped by various processes such as erosion, sedimentation, and sea-level fluctuations. The Gulf of Kutch, located in the northwestern part of the state, is one of the unique features of the state's coastline and is characterized by a shallow and narrow inlet with several islands and mangrove forests (Joshi et. al. (2017)).

Kulkarni et. al. (1985) divided the state into three distinct divisions geomorphologically. They are namely, Gujarat-Mainland, Saurashtra-Kathiawar Peninsula, and Kutch Peninsula.

A) Gujarat-Mainland: The well-known and agriculturally productive alluvial basin of Gujarat spans 250 miles (402 km) northward before merging with the desert plains of Rajasthan and the Rann of Kutch. It rises from the estuary tracts between the Narmada and Tapi rivers. It is around 121 kilometres (75 miles) broad. The Sahyadri, Vindhya, Satpura, and Aravali hill ranges form the basin's eastern boundary. Geological formations undoubtedly influence the topography of the terrain. Up till the Narmada river, the eastern portion of the south Gujarat region bordering the alluvial tract displays classic Deccan trap scenery. The hills are created by circumdenudation, which leaves a broad plateau at the summit and creates a step-like appearance as a result of the differential weathering of the horizontal lava flows. Nevertheless, the topography of the traps in the Narmada valley is different; the hills there are formed like hogbacks because many of them are made of long and wide dolerite dykes. Table lands with low hills are formed to the north of the Narmada in locations where Baghs or lameta sedimentaries are present in spots. Quartzites, phyllites, and schists are found in the state's northern and north-eastern regions. Since they are strong and resistant to weathering, quartzites form steep, narrow ridges with serrated tops grouped along the strike, whereas phyllites and schists, which are soft, are found in valleys and plains. Granite terrain is immediately identifiable from a distance because granites often form modest to high hills with loose boulders that are enormous in size and standing in place. The main drainage is westerly or south-westerly and includes the Gulf of Cambay-draining rivers Tapi, Narmada, Mahi, Sabarmati, and others. The Tapi and Narmada have chosen to follow faulted planes or rift valleys during their courses. Rainfall is significant in the south but lessens to 20 inches (100 cm) in the north (51 cm). Possibly formerly joined, the Rann of Kutch and the Gulf of Cambay are now separated by Nal Lake, which is located southwest of Ahmedabad.

B) Saurashtra-Kathiawar Peninsula: The Gulf of Cambay borders the Saurashtra on the SE, the Gulf of Kutch and Little Rann on the north, and the Gujarat lowlands on the east and NE. The entire southern seaboard is bordered by the Arabian Sea. The majority of the rivers rise and flow radially from a high table land in the region's centre. The vast alluvial tract extends to the NW and east, and the landscape typically descends gently towards the peninsular boundary before blending into the coastal lowlands. Seashore sedimentary rocks resemble a low, level land. A distinctive feature of this region is the parallel alignment of low, straight hill ranges caused by a number of radially intruded basic dykes passing through barriers. The rainfall varies from 20 to 50 inches (51 to 127cm), the highest being in the central portion.

C) Kutch Peninsula: The Great Rann in the north and east, Little Rann in the southeast, the Gulf of Kutch in the south, and the Arabian Sea isolate the Kutch mainland. The term Kutch derives from the region's tortoise-like shape in the centre, which forms a table-land with steep sides. Generally speaking, there are three hill ranges that almost trend east-west. Some rivers that travel northward in the Rann join the sea, while others vanish. The Banni (made-up land), which has rather good soil, was created by sediments deposited along the northern edge of the main land. The amount of rain falls very erratically, ranging from a few to 35 inches; on rare occasions, it can reach 45 inches (115 cm), as it did in 1967. The Rann is a dried-up portion of the bed of a former sea arm that once connected Sind to the Narmada rift and divided Kutch from the main land. The Indus and the Saraswati rivers from the Vedic era once poured into the sea here. The majority of the year, it is now a saline desert, and during the monsoon, when a massive sheet of water inundates it, it is marshy. The Rann is split into two groups: the Big Rann and the Little Rann. Other than size, they are identical to one another. A salt and shingle coating covers the surface once it has dried. It is made mostly of clays and fine silt. Apart for a few little raised spots with access to some fresh water, it is devoid of any flora.

GEOLOGY: The State of Gujarat has a long coastline (approx. 1550 km) from Sir Creek in the north-west to Umargao in the south-east, which forms nearly one-third of the Indian coastline. The coastal tract borders the Kachchh Peninsula, the Saurashtra Peninsula and the Central Plains of Gujarat. The south-eastern part is occupied by the Deccan Plateau whereas the southwestern part forms the Saurashtra (Kathiawar) Peninsula. In the north-east the conspicuous hill chains represent the southward continuation of the Aravalli Range. The Kachchh Peninsula and the Rann of Kachchh occupy the north-western part of the State. The area extending in north-south direction and lying between Aravalli Range and Saurashtra-Kachchh Peninsulas is covered by a alluvial tract. The State exposes a wide variety of lithological assemblages belonging to Precambrian, Mesozoic and Cenozoic Eras and is endowed with rich mineral wealth. Extensive exploration leading to the production of oil and natural gas in Ankleshwar, Khambhat and Kalol have put Gujarat prominently on the country's oil map. Minerals of commercial significance found in the State are those of base metals, lignite, bauxite, bentonite, dolomite, fireclay, fluorite, fuller's earth, kaolin, ball clay, limestone, chalk, calcareous sand, quartz and silica sand. Gujarat is the only State where potash is produced as a by-product in the process of manufacturing common salt from brine. The geology of Gujarat State is characterized by hard rock terrain represented by Precambrian metamorphites and associated intrusives; sedimentaries of Jurassic, Cretaceous and Tertiary Periods and the traps/flows of Deccan Volcanics of Cretaceous-Eocene age. The Precambrian metamorphites, viz. the rocks belonging to Aravalli Supergroup and the Delhi Supergroup occupy the NE part of Gujarat, adjacent to Rajasthan and Madhya Pradesh. The Aravallis are overlain by the Delhi Supergroup of rocks (Palaeoproterozoic-Mesoproterozoic), the two having been separated on the basis of an unconformable relationship, structural discordance and associated volcanic activities.

Rocks of these Supergroups are confined to the north-eastern part of Gujarat, in Sabarkantha and Banaskantha districts. These Supergroups are composed of metasedimentaries and are characterized by extensive magmatism. The magmatic activities recorded in the Aravalli Supergroup include an early phase represented by the rocks of Phulad Ophiolite Suite and a syn- to late orogenic phase of magmatism represented by several granitic activities such as Sendra-Ambaji granite and gneiss, Godhra granite and gneiss, Erinpura granite and gneiss and Idar granite. After the close of Proterozoic Era a great hiatus in geological record from Cambrian to Triassic is recorded in Gujarat. The Mesozoic sequence ranging from Middle Jurassic to Lower Cretaceous is represented by fossiliferous sediments that occur in parts of Kachchh, Sabarkantha, Panchmahals, Surendranagar, Kheda, Vadodarà and Rajkot districts. The close of the Mesozoic Era witnessed a major volcanic activity in the form of widespread outpouring of lava in parts of Saurashtra, Kachchh, southern Gujarat and eastern parts of Panção mahals and Vadodara districts. The Deccan Trap volcanic activity continued from Cretaceous to Eocene with at least four different phases of eruption. It is of interest to mention that older volcanics of basaltic composition have been intersected at the base of Dhrangadhra Sandstone at Lodhika. These older volcanics fall in the alkali basalt field of TAS diagram. The occurrence of older traps below Mesozoic sediments was also indicated earlier at Dhanduka, 150 km NE of Lodhika. The Deccan Traps are overlain by the Tertiary rocks, which occur all along the coastal area in Saurashtra in Khambhat (Cambay) basin and in parts of Kachchh. The Khambhat basin contains Eocene and Oligocene sediments having oil/gas producing horizons. There are more than 22 oil/gas fields in the State. The Quaternary sediments comprise alluvium, miliolite, coral reefs, calcareous sand etc. (Prakash et. al. (2012)).

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 fromGopnath 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 formations.	Saurashtra coast, Kutch.	25
	Oligocene	Tarkeshwar clays.	Tarkeshwar (District:Surat) and Kutch.	40
	Eocene	Nummulitic limestones and clays.	Tarkeshwar area and Kutch.	60
	Paleocene	Madh series-Supratrapean.	Kutch.	
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 sand-stones, Lameta (lime-stones). Bagh beds(sand-stones, Lime-stones and shales).	Himatnagar, Kapadvanj, Balasinor, Parabia, Dohad, Gabat, Narmada valley, Gora, Surpan Vanji, etc.	110
		Songir sandstones, Nimar sandstones,Wadhavan sandstone (Infratrappeans), Bhuj and Umia series sandstones	Songir.Near pavagadh. Wadhavan,Dhrangadhra,Bhuj etc.	
	Jurassic	Katrol series, Chari series, Patcham series (sand-stones, shales and lime-stones).	Kutch.	150
	Purana (Algonkian & Part of Cambrian)	Erinpura granite (Post- Delhi).	Palanpur, Danta, Idar, Modasa, Taranga, Dharoi, Virpur, Wanakbori, Godhra, etc.	1500
		Delhi System-Alwar quartzites, schists, and calc-gneisses, calc- schists of Ajabgarh series.	Parts of Sabarkantha and Banaskantha, and Mehsana Districts.	
Archaean or Azoic		Aravali System-Mica-schists, Phyllites, quartzites, etc.	Sabarkantha, Panchmahals, Baroda, Banaskantha.	4000
		Banded gneissic complex.	Baroda District.	

Table 1: Geology of Gujarat (Kulkarni et.al. (1985))

1.3. GEOLOGY AND GEOMORPHOLOGY OF RAJASTHAN

GEOMORPHOLOGY: Rajasthan is a state located in the north-western part of India and is known for its diverse landscapes, ranging from vast deserts to rugged terrains. The state's geomorphology has been shaped by various geological processes such as tectonic movements, weathering, erosion, and sedimentation.

One of the major geomorphic features of Rajasthan is the Aravalli Range, which runs through the state and is one of the oldest mountain ranges in the world. The range is believed to have formed during the Proterozoic era and has undergone several tectonic movements over millions of years. As a result, the range is characterized by several structural features such as anticlines, synclines, and faults (Singh & Singh, 2015). The range has also played a significant role in shaping the state's drainage system, as several rivers and streams originating from the range flow through the surrounding plains.

The Thar Desert, also known as the Great Indian Desert, covers a significant portion of Rajasthan and is one of the unique geomorphic features of the state. The desert is characterized by sand dunes, rocky outcrops, and barren lands. The desert landscape has been shaped by aeolian processes such as wind erosion, transportation, and deposition. The desert is also home to several ephemeral rivers and streams that originate from the Aravalli Range and drain into the Indus river system (Singh & Singh, 2015).

Another significant geomorphic feature of Rajasthan is the Chambal River, which flows through the state and is a major tributary of the Yamuna River. The river has carved deep gorges and canyons through the rocky terrain and has deposited sediments in the surrounding plains, resulting in the formation of alluvial deposits (Singh & Singh, 2015). The river is also home to several unique flora and fauna species, including the critically endangered gharial, a species of crocodile.

In addition to the above features, Rajasthan is also home to several other geomorphic features such as hills, plateaus, and valleys. The state's geomorphology is complex and has been shaped by various geological processes over millions of years.

GEOLOGY: Rajasthan forms north-western 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 south-eastern plains. They are Archaean in age and comprise in general, granulite-gneiss; amphibolite, metapelite, paragneiss, calc-silicate rocks and greywacke (the older granite-greenstone belt) and metavolcanic, metagreywacke (the younger granite greenstone belt) respectively. 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 south eastern, 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 volcanics, whereas the Delhi Supergroup comprises mainly carbonates, metavolcanics, metasammites and metapelites, intruded by magmatic rock of Phulad Ophiolite Suite and syn-orogenic granites of Sendra Ambaji, 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 ChittaurgarhBanswara 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. The geological investigations have been continuing in the state for more than a century. However, there are some problems which need to be resolved. Scientific efforts are on to unravel such geological complexities. Recent investigations have brought out important mineral deposits in the State. To list, a few are : the lead-zinc deposits of Agucha and Pur-Banera in Bhilwara district, Kayar-Gugra deposit in Ajmer district, Dariba Rajpura-Bethumbi deposit in Rajsamand district; gold in Jagpura-Bhukia belt in Banswara district; limestone in Jaisalmer and Chittaurgarh districts; potash in Ganganagar-Nagaur basin etc.

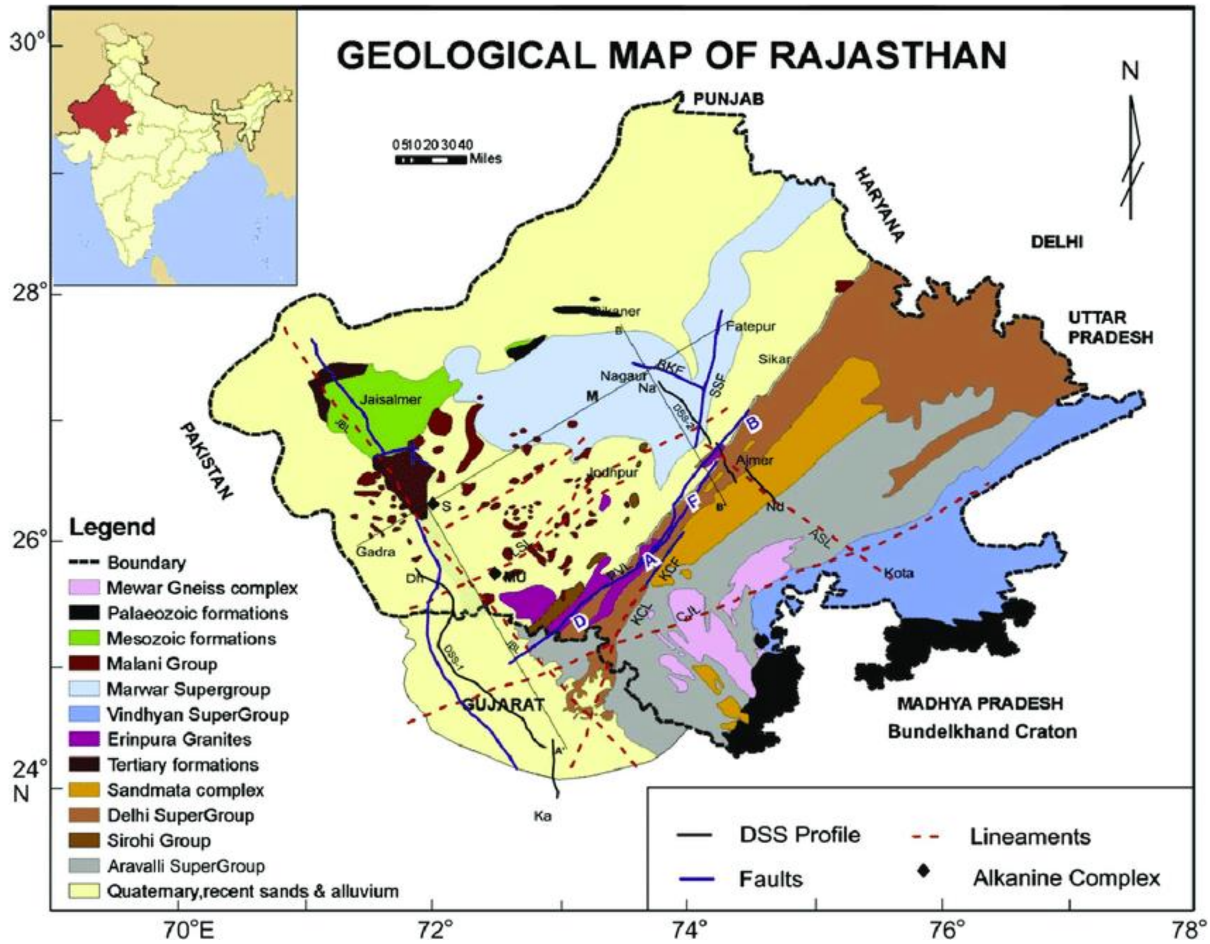

Fig. 2. Geological map of Rajasthan (Kilaru et. al. (2013))

1.4. AIMS AND OBJECTIVES

The aim was for students to understand the industrial aspect of geology.

DAY 1

A visit to our ancestors, Archaeological remains of Harappan Civilisation, Lothal

(22˚31’18”N 72˚14’58”E)

The ancient mound 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 floods by a 13 m thick mud brick wall, on the western side. The Chief lived in the acropolis, where houses were built on 3 m high platform and provided with all the civic amenities including paved baths, underground drains and a well for potable water. The lower town was subdivided into two sectors. The main commercial centre in which craftsmen lived and the other is residential sector. 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 has 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.

This location holds the beauty of the earliest civilisation of Harappan which dates back to 5200-4800 year ago. As we enter, we see the dried river of connecting Sabarmati river and gulf of Khambat. It is believed that this river provided a commute to traders from the other parts of the world. As we enter, we also notice a well which had bricks that were narrower inward and broader outward. As we enter the city, we first see the upper city. This also had the dockyard and warehouse. It was approximately 2-3 m higher than the entire the city. There were twin human fossils found in the upper city. The upper city was walled, had a systematic drainage, common bath area, multiple toilets and hot water system like a geyser. All the drains had slope to stop it from flooding and overflowing. The upper city was at a higher level than the lower city. As we enter the lower city, we first visit the bead factory, in front of which was chullah or Bhatti used to make the terracotta beads or steatite, banded agate, amethyst beads. As we proceeded further into the city, a well organised market was observed. But this market had two parts to it, again at different elevations. The higher elevation had the actual market and the lower was the stay for the labourers. Steatite microbeads and seal were found. These seals would represent the visiting kingdoms. Since sea level regression has taken place, the sea is now 50 kms away from this city. This place was first discovered around 1954-55.

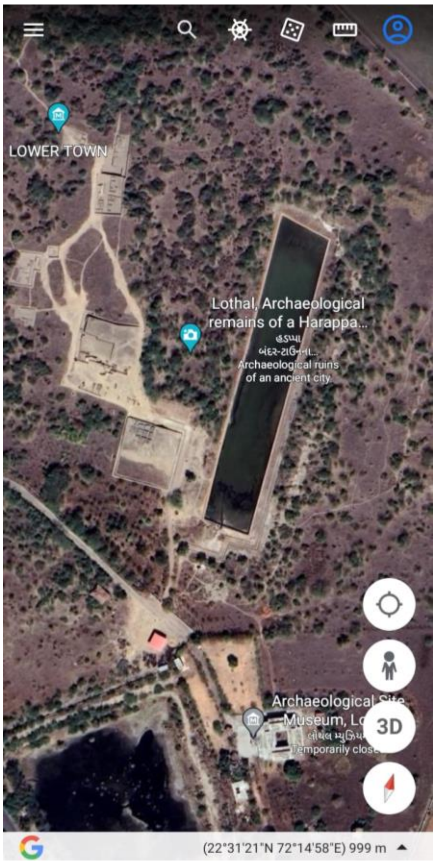

Fig 3. Satellite image of the site

Fig 4. chullah for bead making

Fig 5. factory

Fig 6. the river next to the city.

Fig 7. warehouse

Fig 8. common bath area with gyeser in the upper city.

Fig 9. the upper city stay area

Fig 10. market area

Fig 11. stay for the labourers

DAY 2

A peek into the research world, Physical Research Laboratory

(Amrutvarshini vav (stepwell) Paanchkuva (23°01′30″N 72°35′50″E); Shaking towers or Minarets; PRL (23°02′8″N 72°32′33″E)

Firstly, we visited the Amrutvarshini vav (stepwell) Paanchkuva. Ahmedabad. It's a three storied well which was completed in 1723. It was built by Raghunathdas, diwan to Haider Quli Khan. It is more than 50 feet deep. The rocks used appeared to be sandstone. Next, we visited the Shaking towers or Minarets, next to the gateway of the Ahmedabad railway station. The original name of the mosque is not known, but the minars can be dated stylisitcally to the late fifteenth or early sixteenth century. At this time, Ahmadabad was the thriving capital of the Muslim sultanate of Gujarat. Their brick surfaces are covered in elaborate floral and geometric motifs in relief and they are further ornamented by the presence of cantilivered balconies at intervals which divide the towers visually into storeys.

Later in the afternoon we visited Physical Research Laboratory. Known as the cradle of Space Sciences in India, the Physical Research Laboratory (PRL) was founded in 1947 by Dr. Vikram Sarabhai. As a unit of Department of Space, Government of India, PRL carries out fundamental research in selected areas of Physics, Space & Atmospheric Sciences, Astronomy, Astrophysics & Solar Physics, and Planetary & Geo-Sciences. We were introduced by the head of the department, Dr. Sanjeev Kumar. He explained us what was the responsibility of the geoscience division in terms of research. The department's research interest include Solid Earth Geochemistry, Geomorphology and Tectonics, Paleoclimate Studies, Hydrology, Aqueous Geochemistry, Oceanography and Paleooceanography, Biogeochemistry and Aerosol Chemistry. We then visited 4 laboratories.

The first equipment and the third equipment we saw was a Multi-collector Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS). Multi-collector Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS) is an advanced analytical technique used to determine isotopic compositions of various elements with high precision and accuracy. The principle of MC-ICPMS involves the ionization of a sample in an inductively coupled plasma source (ICP), which generates a high temperature plasma that breaks the sample into ions (Tang et. al. 2019). These ions are then extracted into a mass spectrometer, where they are separated based on their mass-to-charge ratio (m/z) by a mass analyzer, such as a magnetic sector or quadrupole. In a traditional mass spectrometer, the ions are collected at a single detector, providing information on the isotopic ratios of a single element. However, in an MC-ICPMS, the ions are collected at multiple detectors, each with a different mass resolving power. This allows for the simultaneous analysis of multiple isotopes of different elements. The MC-ICPMS is highly sensitive and has a very low detection limit, making it useful for analyzing trace elements and isotopes in a variety of fields, including geology, environmental science, and biology. The precise measurement of isotopic ratios in MC-ICPMS is achieved by carefully controlling and monitoring various instrumental parameters, such as the ion beam intensity, the mass resolution, and the stability of the detectors. By measuring the isotopic ratios of different elements, MC-ICPMS can provide important insights into the origin, evolution, and processes of a variety of natural and artificial materials. The third equipment was the same but with a higher resolution.

The second equipment we were explained to was a Thermal Ionization Mass Spectrometer (TIMS). Thermal Ionization Mass Spectrometry (TIMS) is a highly precise and accurate analytical technique used to measure the isotopic composition of elements. TIMS is commonly used in a variety of scientific disciplines, including geology, nuclear physics, and environmental science. The basic principle of TIMS is to ionize a sample by heating it to a high temperature in a vacuum, and then to separate and detect the ions using a mass spectrometer (Faure et. al. 2016). This technique can be used to measure the isotopic composition of a wide range of elements, including uranium, thorium, and lead. One of the key advantages of TIMS is its high precision and accuracy. TIMS can measure isotopic ratios with a precision of better than 0.1% and an accuracy of better than 0.01%. This makes TIMS an ideal technique for measuring isotopic ratios in a variety of samples, including rocks, minerals, and environmental samples. Another advantage of TIMS is its ability to measure very low concentrations of isotopes. This is important for applications such as nuclear forensics and environmental monitoring, where the detection of trace amounts of isotopes can be critical. However, TIMS is a complex and expensive technique that requires highly skilled operators and careful calibration. As a result, it is typically only used in specialized laboratories.

The next two equipments we were explained were Isotope Ratio Mass Spectrometer (IRMS) and Gas Chromatography Mass Spectrometer (GCMS). Isotope Ratio Mass Spectrometer (IRMS) and Gas Chromatography Mass Spectrometer (GCMS) are two powerful analytical techniques used to measure the chemical and isotopic composition of samples. IRMS measures the ratios of isotopes in a sample, such as carbon-13 and carbon-12, nitrogen-15 and nitrogen-14, or oxygen-18 and oxygen-16 (Eiler et. al. 2013). This technique involves separating the isotopes by converting the sample into a gas and then ionizing and separating the isotopes using a magnetic field. IRMS can be used in a wide range of applications, including studying the origin and age of rocks, studying the carbon cycle in the environment, and determining the authenticity of food and beverage products. GCMS, on the other hand, is used to separate and analyze complex mixtures of organic compounds. It involves separating the components of a sample using gas chromatography and then analyzing the components using mass spectrometry (Fraga et. al. 2015). GCMS is a highly sensitive technique that can identify and quantify trace amounts of compounds in a sample. It has many applications, including drug testing, environmental monitoring, and food analysis. Both IRMS and GCMS are highly specialized techniques that require skilled operators and careful calibration. They are also expensive to operate, and typically only used in specialized laboratories. However, they are powerful tools for understanding the chemical and isotopic composition of samples and have a wide range of applications in scientific research and industry.

Lastly, we also saw an old glass system for preparation of sample for Carbon dating.

Sanjeev sir, Kumar sir, Kadlagi sir and Goswami sir explained us all these equipments.

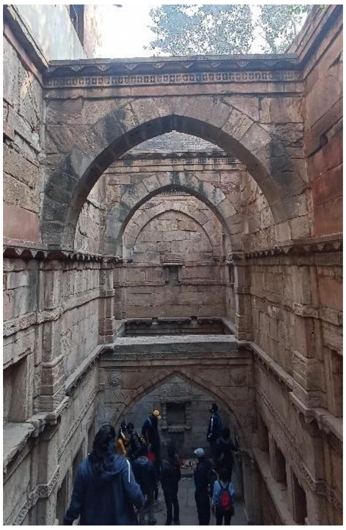

Fig 12. entrance to the Amrutvarshini vav Paanchkuva

Fig 13. one of the minarets

fig 14. PRL entrance

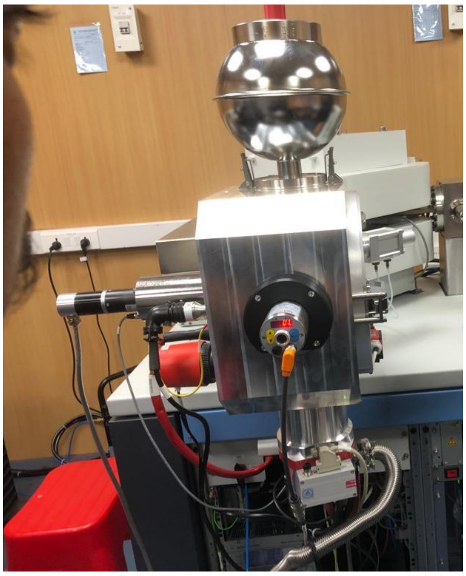

Fig 15. TIMS

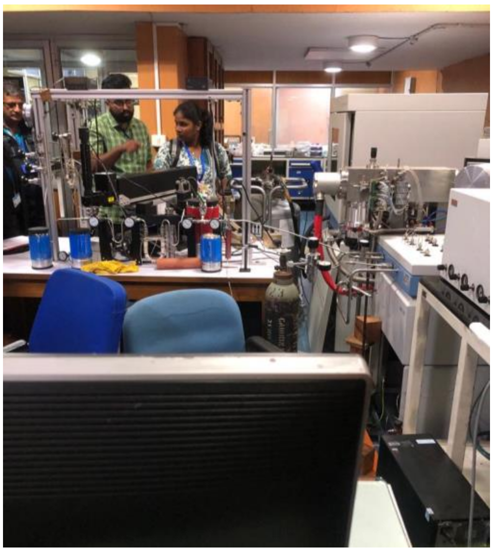

Fig 16. IRMS & GCMS

DAY 3

Tour to the Mesozoic era

SPOT 1: 22°97'07'' N, 73 34' 64'' E

This place is called Raiyoli. The granites here belong to Godhra granite (925-950mya). It is 4 km from Balasinor town. The structures observed here are tors of granites. They age back to Neoproterozoic. In the stratigraphy of Gujarat, paleozoic succession was not recorded. The rocks directly date from archean to Mesozoic. These Mesozoic rocks are part of infratrappeans which are broadly divided into 3 categories the oldest Himamnagar sandstone, Bagh beds and Lameta beds. Aravalli craton covers almost entire state of Rajasthan, part of Gujarat, Madhya Pradesh and fringes of Delhi and Haryana.

Aravalli Supergroup

Champaner group
Lunavada group
Jharol group
Udaipur group
Debari group
Delwara group
-----unconformity-----
Mangalwar/ sandmata complex
Mewar gneiss

The Aravalli supergroup dates back 2.5 Ga. Sediment from the Aravalli has a NE-SW general tendency. Large-scale granitic activity characterises the Aravalli craton's concluding phase. A cluster of Rb-Sr ages shows that the majority of granitic entities invaded between 730 and 830 Ma. One of the granitic intrusions that happened when the Aravalli craton was closing is the Godhra granite. The Champaner and Lunavada group of the Aravalli supergroup have been invaded by Godhra granite. Porphyritic granite to granodiorite with accompanying pegmatite makes up Godhra granite. It demonstrates the presence of feldspar, quartz, and micas (biotite and muscovite). About 0.5 to 5 cm phenocrysts of muscovite and biotite are found. MMEs were also in the room. Co-genetic mixing of the magma is the process that creates mafic magma pockets. Perthite texture was also discernible.


Fig 17. Tors at Rhyoli


Fig. Godra granite with xenolith

SPOT 2: 23 05’ 62’’ N, 73 34 35’’ E (Raiyoli, Balasinor)

Here we observed the youngest, Lameta beds, limestones and subordinate sandstone. Bones were found in sandstone and clutches of eggs in limestone. In the Indian village of Balasinor, there is a dinosaur museum and fossil park called the Raiyoli Dinosaur Fossil Park. The park covers an area of about 72 acres and is located about 80 kilometres from Ahmedabad. Both India's largest dinosaur fossil deposit and one of the largest dinosaur egg hatcheries in the world are located at the Raiyoli Dinosaur Fossil Park. According to legend, dinosaurs inhabited the park 65 million years ago. Over 10,000 dinosaur fossils, including bones, eggs, and other remains, were found there during excavations conducted by the Gujarat Ecological Education and Research (GEER) Foundation and the Geological Survey of India (GSI). The park has a museum where visitors may examine life-sized dinosaur replicas, bones, and displays about dinosaur evolution.

Fig 18. Preserved dinosaur embryo

Fig 19. Dinosaur eggs

Fig 20. Leg femur of Sauropod

Fig 21. Vertebrae of dinosaur

Fig 22. life size dinosaur display in the museum

Fig 23. ammonite cast fossil in the museum

Fig 24. dinosaur skull cast fossil in museum

DAY 4

To ONGC Well site at GGS-Motera (23° 11' 31" N, 72° 59' 79" E)

On the day 4 in Gujarat, we got the opportunity to visit the ONGC's (Oil and Natural Gas Corporation LTD.) well site or collection site in GGS-Motera, Ahmedabad. Soon after the entrance, there are many detailed flow charts presented. These flowcharts had details on hazardous area class, plant layout, process flow diagram, fire fighting equipment, HSE Policy, QHSE Policy and OISD Standards. Then we met safety officer, Gaurav Kumar, who gave us the tour and explained us the process of different parts of the plant.

This installation is where we receive oil and crude. There are 59 wells in the radius of 17 kms and all are well connected. The basic steps of collection site is process → treatment → refinery. The first equipment was Booster Gas Compressor plant. It was an older version of the equipment. Its role was to increase the pressure. It has two compressors and 2 water pumps. The second equipment was a Separator Manifold and is hazardous. It is the main processing plant. Everything was controlled in the control room, SCADA (supervisory control and data acquisition). This processing plant has pipeline connected to separators, which is the third equipment. These separators have 2 lines, one for crude oil and one for gas. The main role of this equipment is to separate the violent gases. There are 3 tanks connected namely, T1, T2 and T3 and each has the capacity of 45 meter cube. Equipments are installed for controlling and monitoring the pressure. For the purpose of safety its advised to use PPE suits and follow SOP's. If any leakage is caused, it will be due to the failure of gasket. To correct this, first depressurise, then change the gasket, check for any gas using hydrocarbon detector and close again. Hydrotest and NDT test are done by private contractors. Bargum liquid is used for hydrofracturing. Insolation has been done for avoiding any gas exchange through pipes. Corrosion inhibitor is used to maintain the lifeline of the pipelines and released 2L per day. The fourth equipment was the new version of gas compressor, MOT-PSV. As the previous one, its role is also to increase the pressure. It has a 2 stage compressor working on the engine principle. It has a bath heater working on heat exchange principle to increase the mobility of the crude oil. CO2 flooding system has been installed in this plant for detecting flares and controlling the fire.

Since phones were not allowed, no photographs have been taken.

Fig 25. entrance of the GGS Motera well site

DAY 5 & DAY 6

Day 5 travelled to Udaipur from Ahmedabad.

Day 6: Visit to the mines, Jamarkotra Mines

These mines are owned by Rajasthan State Mines and Minerals Ltd. They are rock phosphate Jhamarkotra mines. The Government of Rajasthan's public sector company, Rajasthan State Mines & Minerals Ltd (RSMML), primarily manufactures and sells high-grade rock phosphate, lignite, limestone, and gypsum (non-metallic minerals) from mines spread out across Rajasthan. After rock phosphate was discovered at Jhamarkotra mines in 1969, BGL took over management of those mines (Udaipur). Rock phosphate ore mining is the main line of business for RSMML. It operates one of the biggest and most mechanised mines in the nation in Jhamarkotra, which is 26 kilometres from Udaipur. Jhamarkotra is significant since it supplies 98% of India's supply of rock phosphate. Jhamarkotra, with a capacity to handle more than 20 million tonnes of rock annually, may be India's largest open cast mine outside of the steel and coal industries. Because to the shallow and sharply dipping ore body's shape, long, narrow pits with enormous depth extension have produced very high stripping ratios with high lead and lift for waste and mineral. The 12-meter bench prevents anything that is falling from falling any further. Metasedimentary rocks of the Aravalli Supergroup contain the rock phosphate (Precambrian age). It is a byproduct of algae. The deposit has an average thickness of 15 metres and a 16-kilometer strike length. A reserve of 77 million tonnes of rock phosphate has been established based on 60,000 mt of drilling in 500 boreholes. The majority of these 17 million tonnes are graded at +30% P_2O_5, while the remaining 12 million tonnes are graded at 0-30% P_2O_5. A 1500 TPD (Tonnes Per Day) beneficiation facility has been set up to improve the low-grade phosphate ore.

13 sq km total area is under lease. In Jhamarkotra, the strike length of the phosphorite bed extends across a linear distance of 16 km, including the discontinuous outcrop. At Jhamarkotra, the phosphate bed's highest point outcrops at 600 MRL, and along the downdip direction, the phosphate has been shown to extend up to a little under 250 MRL. Angle of dip for ore body is 45–55°. The thickness of the phosphate bed is incredibly changeable and only persists over a short strike length. In Jhamarkotra, the average phosphate bed thickness of 15 km could be located along a continuous strike length of 6 km.

Fig 26. Jhamarkotra mines

At Jhamarkotra deposit, generally a Bi-modal grade distribution pattern viz.+30 % (37- 38%) P2O5 designated as High-Grade Ore (HGO) and 16 to 22 % P2O5 designated as Low-Grade Ore (LGO) could be deciphered. However, at places near the contacts of the above grade of phosphate bed, some transitional zones exist which are designated as Mixed / Medium Grade Ore (MGO). The marketable grade of ore is 31.5% & 30% P2O5, but a large resource of low-grade ore also occurs in the area. Looking at great demand of phosphate fertilizer and to reduce its import, the low-grade ore is being upgraded through froth flotation in beneficiation plant.

The mineral phase of apatite, which makes phosphorite, is considered to have formed by three mechanisms (i) direct inorganic precipitation, (ii) primary biogenic precipitation, and (iii) diagenetic precipitation/replacement. Diagenetic precipitation of apatite is considered as an important mechanism involved in phosphorite formation. Apatite of this origin commonly occurs as void filling and cementing material in the associated sediments. It is said that the organic matter, which collects on the shelf regions, on decay, causes very high concentration of phosphorous below the sediment water interface, leading to precipitation of apatite. During this process carbonate constituents of the sediment are also phosphatised due to the replacement.

The open pit mining method is being followed at Jhamarkotra Mine for exploitation of the mineral. The working levels are kept dry by continuous pumping of ground water through tube wells constructed on periphery of the pit limit. The bench height in this extent of mine is given at 7m consecutively for a couple of times with alternating 12 m heighted bench. (7m,7m,12m).

Fig 27. Mineral Apatite in botryoidal form

Fig 28. High grade ore


Fig 29. Stromatolites

Jhameshwar Mahadev Temple, Jhamarkotra: Stalactites are formations that cling to the ceilings of caves and hot springs. They sprout from dripping walls and ceilings and develop downwards. The'straw' stalactite is a monolayer crystal sheath covering a feedwater channel and developing downwards exclusively. Leakage from the canal can cause tapering (carrot-like) stalactites up to one metre in diameter and many metres in length. Accelerated deposition on protuberances can add a myriad of subsidiary forms such as crenulations, corbels, drapes and lesser stalactites. A ‘column’ is a stalactite–stalagmite pair grown together.


Fig 30. Jhameshwar temple

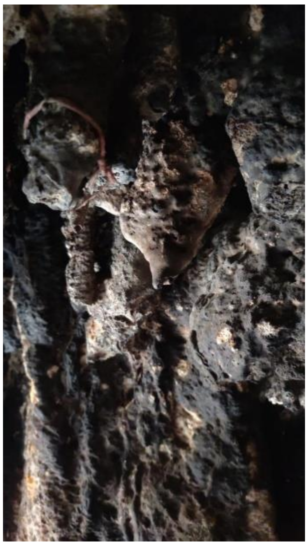
Fig 31. Stalactites

DAY 7

Study of Suket Shale & Phyllite

Spot 1 (24˚ 47' 40" N, 73˚ 51' 71" E)

The Chittorgarh district is noted for its undulating landscape and Aravalli range highlands. Rocks from the Vindhyan supergroup, the Deccan traps, and the Bhilwara supergroup make up the majority of the district. The Vindhyan sedimentary conglomerates and rocks of the Bilwara supergroup, which are divided by a large boundary fault, make up the majority of the field region. The Berach River follows the great boundary fault. On the west bank of the river, there is a supergroup called the Bilwara. The Hindoli group, the Mangalwar complex with distinct mineralized bands, and the Sandmata complex are the three tectono-stratigraphic units that make up the Bilwara supergroup. The Hindoli group is dominated by phyllites and greywackes. These phyllites haves been folded into large- scale low plunging folds trending parallel to the GBF. Increase in the tightness and asymmetry of the folds near the fault suggests that these are fault related folds. They are highly compressed and joint sets are closely spaced than the joints present away from the river that is away from the GBF. Slicken sides are observed, which indicates the presence of fault and quartz veins are also present which may be either syngenetic or post genetic. The Suket Shale-Phyllite shows various stages of predominant folding from which possible readings were taken with respect to the hinge plane. This location was next to

	Strike Direction	Dip Amount with Direction
Hinge Plane	200° N	29° N (Plunge)
Limb 1	200° N	36° E
Limb 2	125° N	54° W

Joint Sets are as follows:	
	Strike Direction
Joint Set 1	145° N
Joint Set 2	100° N

Fig 32. Sukhet Shale-Phyllite

Fig 33. anticlinal plunging fold hinge

Spot 2 (24° 52’ 59”, 74° 37’ 57”)

Nimbara Limestone is a type of sedimentary rock that is primarily composed of calcium carbonate. It is commonly found in the Nimbara region of Rajasthan, India, and is a popular building material due to its durability, strength, and natural beauty. This limestone is typically light gray in color. It is formed through the accumulation of calcium carbonate-rich sediment that has been compressed over millions of years, often in marine environments. This location was next to Gambhir river. Few possible readings were taken:

	Strike Direction	Dip Amount with Direction
Spot 1	N	40° W
Spot 2	N	64° W

Fig 34. Nimbara limestone

DAY 8

Marbles (25 05’ 76” N, 73 85 08” E)

In the Indian state of Rajasthan, limestone of the Nathwara variety can be found. It has the name of the Rajasthani town of Nathwara, which is situated in the Udaipur district. This limestone is a fine-grained, light-colored rock that mostly consists of calcium carbonate. It is frequently quarried in the Nathwara region and utilised for both aesthetic and building purposes.

Lithology - Marble, Schist

The schist bed beneath the marble strata was also inclined. There was extensively weathered schist present. A modest crenulation folding sequence started a few marble joints on the marble bed, which was inclined. The silica grains in the marble that had recrystallized indicated that the next succession had experienced contact metamorphism. It was suggested that the schist be called mica schist since it possessed an alternative augen gneiss structure and dominant minerals including chlorite and tremolite. The mica schist also has an elongated acicular structure, with tremolite making up the needle-like structure.

Marble	Strike Direction	Dip Amount with Direction
Spot 1	130° N	32° SW
Spot 2	360° N	26° E

Fig 35. Augen structure in hand specimen

Fig 36. Mica schist in between marble

SUMMARY

This field visit was to understand the different aspects of geology such as mining, petroleum, geoparks, etc. This field work took place in and around two cities of India in the states of Gujarat and Rajasthan. In Gujarat, Ahmedabad, Lothal and Balasinor were visited. Insights of historical sites, research laboratories, oil wells and geology of the area were gained. We studied the Harappan civilisation, Godhra granites, dinosaurs of India in sandstones, limestones and Lameta beds. The process involved in the collection of oil at an oil site was studied. In Udaipur, Jhamarkotra mines, one of the largest open phosphate mines were visited. Sukheth shale, Nimbara limestone and marble with mica schist were studied. Overall, this field work consisted of every aspect of geology.

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