SCHOOL OF EARTH, OCEAN AND ATMOSPHERIC SCIENCES

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LABORATORY CERTIFICATE

This is to certify that Mr. /Ms. Aleena K.A

has satisfactorily completed the course of practical for M.Sc in Applied Geology.

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REPORT ON THE GEOLOGICAL FIELDWORK CARRIED OUT IN AND AROUND GUJARAT AND RAJASTHAN

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GEOLOGY OF GUJARAT

The state of Gujarat comprises an area of approximately 1,96,000 sq.km and is enclosed within North Latitude 200 100 to 240 500 and East Longitude 680 400 to 740 400 . Geologically Gujarat provides a wide spectrum of rock types of different ages. Whereas the Aravalli's in the NE is as old as 2500 million years, the unconsolidated alluvium and beach materials in its central and western parts, date back to a few thousand years only. All the important lithological types Igneous, Sedimentary and Metamorphic occur within the state. Geomorphologically the state of Gujarat comprises the following three district zone: **a) Mainland Gujarat, b) Saurastra and c) Kachchh**. The Gujarat state exposes rocks belonging to the Pre- Cambrian, Mesozoic and Cenozoic era. The hard rocks cover about 49% of the total area of Gujarat, the rest being occupied by sediments of Quaternary period. The hard rock comprises Pre Cambrian metamorphosed and associated intrusive, sedimentary rocks of Mesozoic and Cenozoic eras and the traps/ flow constituting Deccan volcanic of Cretaceous Eocene age.

Gujarat Mainland is agriculturally rich alluvial basin of Gujarat 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 the Rann of Kutch. It is roughly 75 miles (121 km) wide. The eastern border of the basin is bounded by Aravalli, Vindhya, Satpura and Sahyadri hill ranges. The topography of the land is obviously controlled by the geological formations. The eastern part of the south Gujarat bordering the alluvial tract has a typical Deccan Traps scenery up to Narmada valley. The hills are formed by circumdenudation leaving wide plateau at top, and a step like feature because of horizontal lava – flows and their differential weathering.On north of Narmada, areas which are occupied by sedimentaries of Baghs or lametas in patches, from table lands with low hills. Granites typically form low to high hills with loose boulders of

large dimensions standing insitu; thus, granite exposure can easily be recognized from a distance.

Saurashtra – Kathiawar Peninsula is bounded by Gujarat plains in East and NE, by gulf of Kutch and little Rann on the north, and on the SE by the Gulf of Cambay. The Arabian Sea borders the entire southern seaboard. The Central 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 the great alluvial tract 6 stretches to NE and east. The sedimentary rocks along the coast form almost a low and straight hill ranges running parallel, a characteristic feature of this 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.

Kutch Peninsula is the mainland of Kutch is isolated by the Great 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 shape of the region is like tortoise. In general, there are three hill ranges, trending almost east-west. North – flowing rivers disappear in the Rann; others join the sea. The Banni (made up land) is formed by sediments deposited by northern border of the mainland and is composed of fairly good soil. The Rann is a dry bed of the remnant of an arm of the sea, which formally connected the Narmada rift with Sind and separated Kutch from the main-land. The Rann is divided into two, which are Great Rann and Little Rann; they do not differ from each other expect in size.

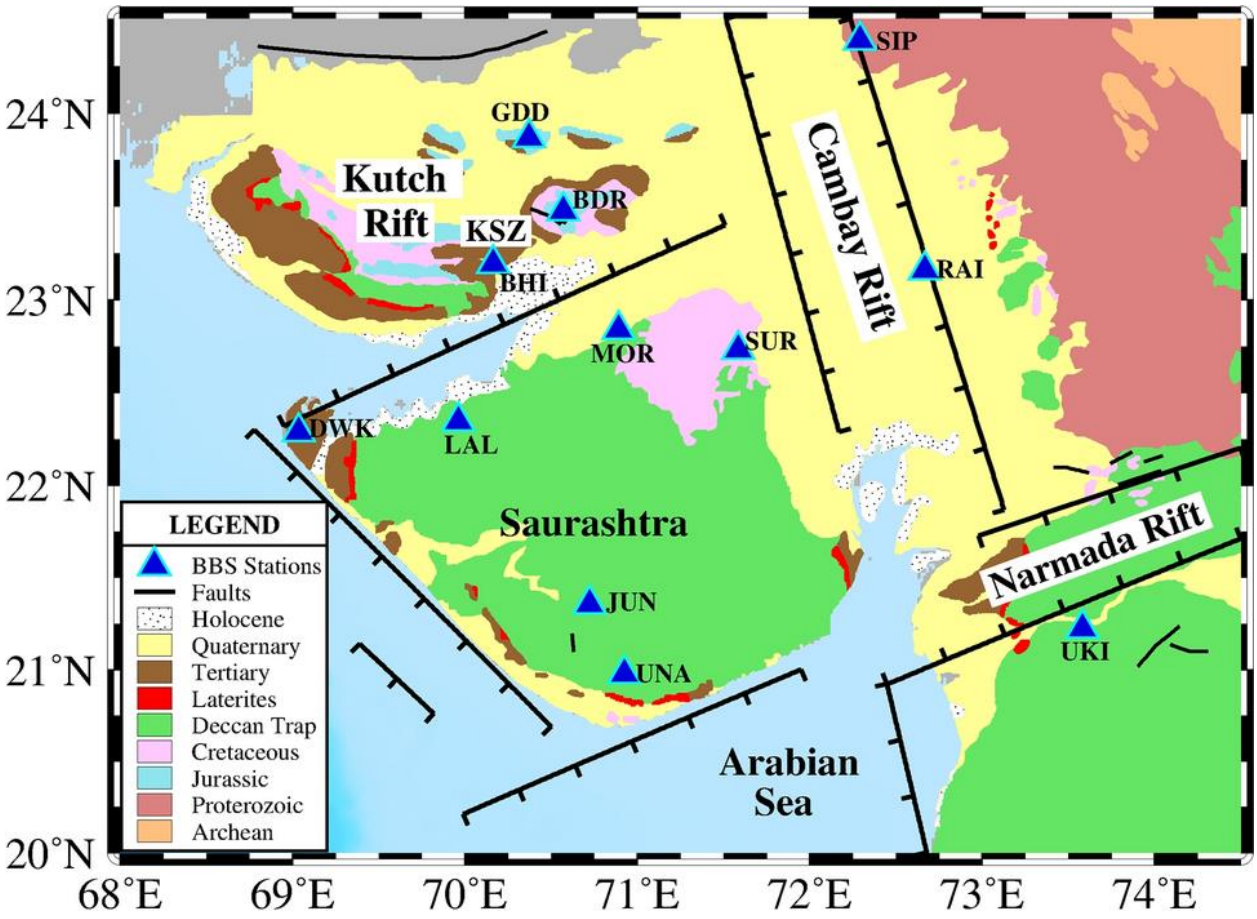

Figure 1: lithological map of Gujarat

Lithostratigraphic table of Gujarat

Group	System	Rock Type	Localities	Age in millions of years
Quaternary	Recent and subrecent	Alluvium, blown sand and Silts of Rann and Banni, Tidal flats and raised beaches.	Alluvial plains of Gujarat, Rann, Banni & Coastal deposits.	0.01
	Pleistocene	Miliolites	1)Saurashtra coast from Gopnath onwards extending beyond Porbandar. 2)Kutch area.	1
Tertiary or Kainozoic	Pliocene	Dwarka beds, Manchhar beds, Gypsiferous clays and sandy foraminiferal limestones.	Dwarka, Okha, Piram Island and 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	
	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 (limestones). Bagh beds (sandstones, Limestones and shales). Songir sandstones, Nimar sandstones, Wadhavan sandstone (Infratrappeans), Bhuj and Umia series	Himatnagar, Kapadvanj, Balasinor, Parabia, Dohad, Gabat, Narmada valley, Surpan Vanji, etc. Songiri near pavagadh. Wadhavan, Dhrangadhra, Bhuj etc.	110

Secondary or Mesozoic	Jurassic	Katrol series, Chari series, Patcham series (sand-stones, shales and limestones.	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		Aravalli system-Mica-schists, Phyllites, quartzites, etc.	Sabarkantha, Panchmahals, Baroda, Banaskantha.	4000
		Banded gneissic complex	Baroda District.	

FIELD OBSERVATION

DAY 1

Date: 22/1/23

Location: Lothal

LATITUDE- $22^0 31'18"$ NE

LONGITUDE- $72^0 14'58"$

Lothal was one of the southernmost sites of the ancient Indus Valley civilisation, located in the Bhal region of the Indian state of Gujarat. Construction of the city is believed to have begun around 2200 BCE.

Archaeological Survey of India , the official Indian government agency for preservation of ancient monuments, discovered Lothal in 1954. Excavation work in Lothal commenced on 13 February 1955 and continued till 19 May 1960. According to the ASI, arguably Lothal had the world's earliest known dock, which connected the city to an ancient course of the Sabarmati river on the trade route . This trade route stretched between Harappan cities in Sindh and the peninsula of Saurashtra where the surrounding Kutch desert of today was a part of the Arabian sea.

The National institute of oceanography in Goa discovered foraminifera (marine microfossils) and salt, gypsum crystals in the rectangular structure clearly indicating that sea water once filled the structure and it was definitely a dockyard.

TOWN PLANNIG

A flood destroyed village foundations and settlements (c. 2350 BCE). Harappans based around Lothal and from Sindh took this opportunity to expand their settlement and create a planned township on the lines of greater cities in the Indus valley.[15] Lothal planners engaged themselves to protect the area from consistent floods. The town was divided into blocks of 1- 2m high (3–6 ft) platforms of sun-dried bricks, each serving 20–30 houses of thick mud and brick walls.

The city was divided into a citadel, or acropolis and a lower town. The rulers of the town lived in the acropolis, which featured houses with paved bathing platforms, underground

and surface drains (built of kiln-fired bricks) and potable water well. The acropolis also housed the towns warehouse, with a ramp down to the basin, on the towns eastern flank. The lower town was subdivided into two sectors. A north–south arterial street was the main commercial area. It was flanked by shops of rich and ordinary merchants and craftsmen. The residential area was located to either side of the marketplace. The lower town was also periodically enlarged during Lothal's years of prosperity.

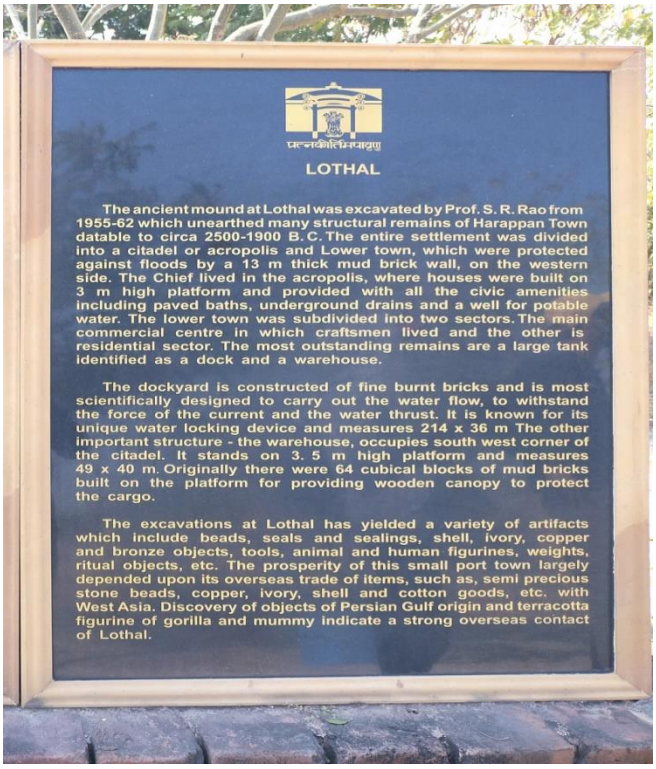

Figure2: History of Lothal

Figure 3: Bathing platform and communal drain, acropolis

Figure 4 and 5: The bathroom-toilet structure of the ruler's house in Lothal

Figure 6: warehouse of lothal

Figure 7: main well

Figure 8: An ancient well, and the city drainage canals

Figure 9: bead factory

Figure 10: Pot furnace at lothal

Figure 11: market at lothal

Acropolis and lower town

The town center of Acropolis was the political and commercial heart of Lothal measuring at 127.4 metres (418 feet) east-to-west by 60.9 metres (200 feet) north-to-south. There were three streets and two lanes running east–west, and two streets running north–south. The four sides of the rectangular platform on which houses were built are formed by mud-brick structures of 12.2–24.4 metres (40–80 ft) thickness and 2.1–3.6 metres (6.9–11.8 ft) high.[51] The identified bathing platforms are located in the acropolis, and part of mostly two-roomed houses with open courtyards. The bricks used for paving the bathing platforms were polished to prevent seepage. The pavements were lime-plastered, and edges were wainscoted (wooden panels) by thin walls. The ruler's residence was 43.92 square metres (472.8 square feet) and hosted a 1.8 square metres (19 square feet) bathing platform with contiguous squat latrine which was also connected to an outside drain that discharged into the dock. The lower town marketplace was on the main north–south street 6–8 metres (20–26 ft) wide. Built in straight rows on either side of the street are residences and workshops, although brick-built drains and early period housing has now disappeared. The street maintained a uniform width and did not undergo encroachment during the reconstructive periods after deluges. There are multiple two-roomed shops and workplaces of coppersmiths and blacksmiths.

Figure 12: lower town

Bead factory at Lothal

The bead factories(fig:9),situated where the 8th street of the commercial area and the 5th street of the residential area meet, comprised the main industry of the Harappans. They probably settled (or their culture came) to the Gulf of Cambay region because of its agate and precious stone resources. The bead factory, which performs a very important economic function, possesses a central courtyard and eleven rooms, a store, and a guardhouse. There is a cinder dump as well as a double-chambered circular kiln

with stoke-holes for fuel supply. Four flues are connected with each other, the upper chamber and the stokehold. The mud plaster of the floors and walls are vitrified owing to intense heat during work. The remnants of raw materials such as reed, cow dung, sawdust, and agate are found, giving archaeologists hints of how the kiln was operated.[53] A large mud-brick building faces the factory, and its significance is noted by its plan.Four large rooms and a hall, with an overall measurement of 17.1 by 12.8 metres (56 ft × 42 ft). The hall has a large doorway and a raised floor in the southern corner of the building.

DOCKYARD

The trapezoidal, burn brick, structure is located on the east of the town and away from the main river channel, to possibly avoid deposition of silt. The north–south length averages 215 metres (705 feet), and east–west width of 35 metres (115 feet). An inlet approximately 7 metres (23 ft) wide and 0.9 metres (3.0 ft) in depth survives in the north of the structure, and a 1 metre (3.3 ft) square sluice gate or spillway, that appears could have been dammed by a wooden gate, exists in the south face of the structure. When the river changed its course in 2000 BCE, a canal approximately 7 metres (23 feet) wide and 2 kilometers (1.2 miles) long, was dug to the new river course.

Facilitating the movement of cargo was a mud brick wharf, 220 metres (720 feet) long, built on the western arm of the dock, with a ramp leading to the warehouse and acropolis, built on a packed mud platform, original 4.26 metres (14.0 feet) in height (Now it is 3.35 metres or 11.0 feet.) on the south western flank of the basin. The warehouse was originally built on sixty-four cubical blocks, 3.6 metres (12 feet) square, with 1.2-metre (3.9-foot) passages, and based on a 3.5-metre (11-foot) mud-brick podium. The pedestal was very high to provide maximum protection from floods. Brick-paved passages between blocks served as vents, and a direct ramp led to the dock to facilitate loading. The warehouse was located close to the acropolis, to allow tight supervision by ruling authorities. Despite elaborate precautions, the major floods that brought the city's decline destroyed all but twelve blocks, which became the makeshift storehouse.

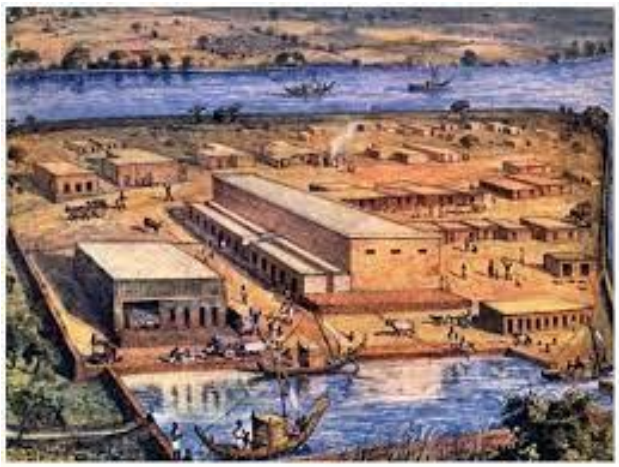

Figure 13: dockyard

Figure 14: dockyard at present

DAY 2

LOCATION 1: Amrutvarshini Vav step well

Latitude -23.02495^{0}N

Longitude -72.5972^{0}E

Panchkuva, literally *five wells*, area derived its name the five wells in the area. Amritavarshini vav was completed in 1723 as per Devanagari and Persian inscription (Vikram Samvat 1779/A.H. 1135) in the stepwell. It was built by Raghunathdas, diwan to Haidar Quli Khan, who was the governor of Gujarat during his stay in the city in 1721–1722 for charitable purpose.

parsely ornamented, Amriavarshini Vav is notable for its L-shaped plan and has simple design. It has three storeys and is more than 50 feet deep. The bracing arches have different shapes at the two storeys and in the *kuta* (pavilion tower) before the well shaft. It was declared a protected monument in 1969 and was conserved in 1999. It was recharged later by digging in 2004.

Figure 15 :Right angled construction of step well

Figure 16: Inscriptions in the step well

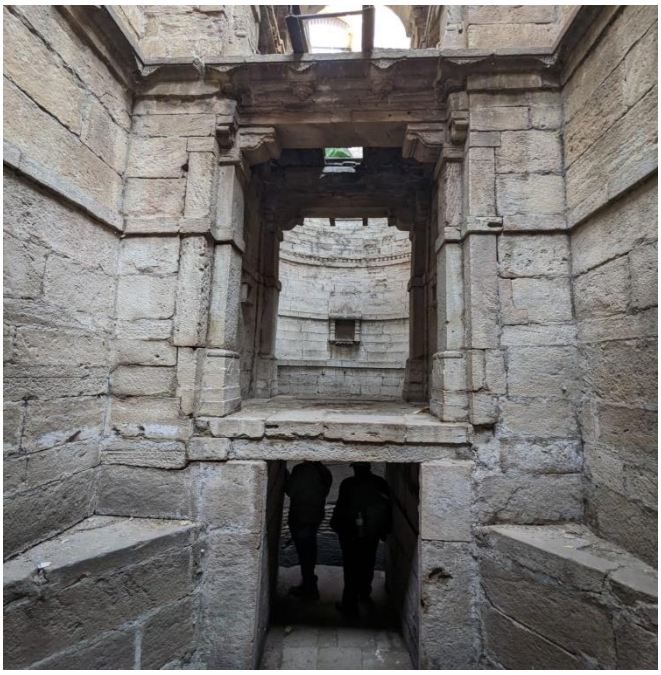

Figure 17: shaft of the well

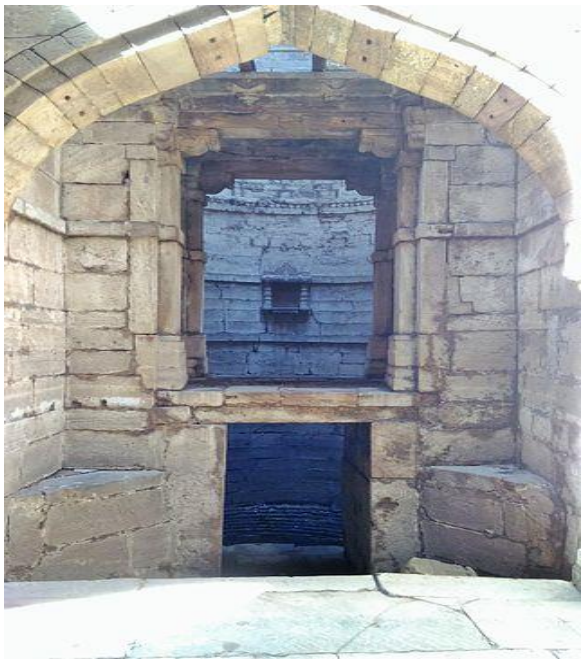

Figure 18: shaft of the well

Figure 19: well

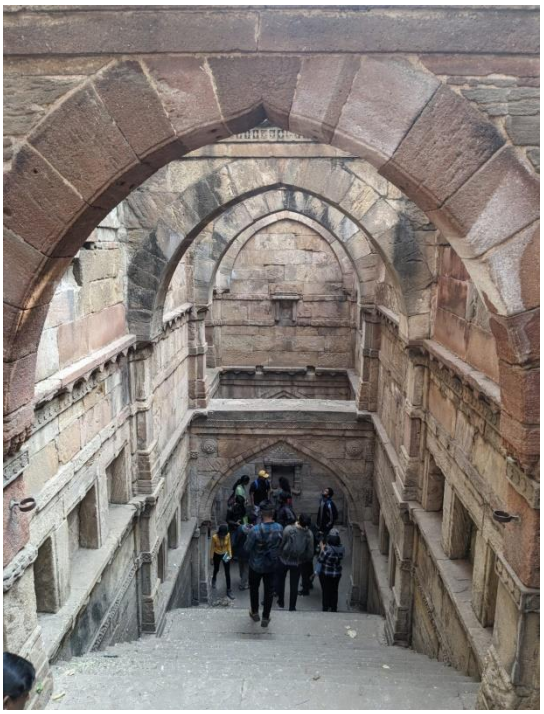

Figure 20: steps to the well

LOCATION 2: PHYSICAL RESEARCH LABORATORY

Latitude -23^{0}02′8″N

Longitude -72^{0}32′33″E

Physical Research Laboratory (PRL)

LAB -1 MC-ICPMS

MC-ICPMS stands for Multi-Collector Inductively Coupled Plasma Mass Spectrometry. It is a highly specialized analytical instrument used in geochemistry, geochronology, and environmental science.

At PRL (Physical Research Laboratory) in India, MC-ICPMS is used to measure isotopic ratios of elements such as Sr, Nd, Pb, and Hf in rocks and minerals. These isotopic ratios provide important information about the age and origin of rocks, as well as the history of the Earth's crust.

The instrument works by ionizing a sample using an inductively coupled plasma (ICP), which creates a stream of charged particles. These ions are then separated according to their mass-to-charge ratio using a magnetic field. The MC-ICPMS has multiple detectors that can simultaneously measure the isotopic composition of the same element, allowing for precise measurements of isotopic ratios.

In simple terms, the MC-ICPMS works by zapping a rock sample with a beam of charged particles, which breaks the sample down into its individual isotopes. The instrument then separates these isotopes based on their weight and measures their abundance. This information can be used to determine the age and origin of the rock.

Lab 2-The TIMS (Thermal Ionization Mass Spectrometry) lab is a specialized analytical laboratory that is dedicated to the analysis of isotopes of elements. The lab is equipped with a Thermal Ionization Mass Spectrometer (TIMS) which is used to measure the isotope ratios of a range of elements.

The TIMS lab works by first separating the element of interest from the sample matrix. This is done through a process called ion exchange chromatography or chemical separation. The separated element is then loaded onto a filament and heated to high temperatures, which causes the element to ionize and form a beam of ions.

The ions are then focused using an electrostatic lens system and passed through a mass spectrometer which separates the ions based on their mass-to-charge ratio. The resulting signal is recorded and the isotope ratios are calculated.

The TIMS lab is used for a wide range of applications including the analysis of geological samples, environmental samples, and biological samples. It is a highly precise technique, capable of measuring isotope ratios to very high accuracy, and is widely regarded as the gold standard for isotope analysis.

Overall, the TIMS lab is a powerful tool for understanding the isotopic composition of a wide range of samples, and it has important applications in fields such as geology, environmental science, and archaeology.

Lab 3-The IRMS lab at PRL (Physical Research Laboratory) is a state-of-the-art facility that specializes in isotopic analysis using Isotope Ratio Mass Spectrometry (IRMS). This laboratory is located in Ahmedabad, India, and is part of the Physical Research Laboratory, a national research institute funded by the Department of Space, Government of India.

The IRMS lab at PRL has a wide range of analytical capabilities and offers isotopic analysis of various elements, including carbon, nitrogen, oxygen, hydrogen, sulfur, and many others. The lab is equipped with several mass spectrometers, gas chromatographs, and other supporting instruments, allowing for precise and accurate measurements of isotopic ratios in a variety of samples.

Lab 4-The AMS (Alpha Magnetic Spectrometer) laboratory is a particle physics laboratory located at the Physical Research Laboratory (PRL) in Ahmedabad, India. The AMS experiment is a state-of-the-art particle detector designed to study cosmic rays and search for evidence of dark matter.

The AMS detector is mounted on the International Space Station (ISS) and has been collecting data since 2011. The laboratory at PRL serves as a regional center for the AMS collaboration and is involved in data analysis, simulation, and software development for the AMS experiment.

Overall, the AMS laboratory at PRL is an important center for research in high-energy physics and provides valuable opportunities for Indian physicists to contribute to international collaborations and participate in cutting-edge research.

Figure 21: PRL Ahmedabad

Figure 22: PRL Ahmedabad

Figure 23

Figure 24

Figure 25

Figure 26

Figure 27

Fig 23 to 27- Different Labs at PRL

DAY 3

Location 1: Godhra Granite

Classification of Aravalli Supergroup:

Aravalli Supergroup

Champaner group

Lunavada group

Jharol group

Udaipur group

Debari group

Delwara group

-----unconformity-----

Mangalwar/ sandmata complex

Mewar gneiss

Aravalli supergroup is ~2.5Ga old. General trend of aravalli t is NE-SW. The closing phase o Aravalli craton is marked with large scale granitic activity. Most of Granitic bodies have intruded in the time span of 730 to 830 Ma, as evidenced by a cluster of Rb- Sr ages. Godhra granite is one of the granitic intrusion that took place during the closing phase of Aravalli craton. Godhra granite have intruded the Champaner and Lunavada group of Aravalli supergroup. Godhra granite is porphyritic granite to granodiorite with associated pegmatite. It shows presence of feldspar, quartz, micas (biotite & muscovite) minerals. Muscoviteand biotite are present as phenocyst of appx 0.5- 5cm. MMEs were also present. Mafic magma enclaves are formed due to the process of co-genetic mixing of magma. Also perthite texture was seen.

In this location the exposed rock is coarse grained granite (Godhra granite), which exhibit exfoliations weathering. It composed of Quartz, feldspar and mica in hand specimen. 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 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. Some places granite is seen as weathered, because feldspar is standing out. 20 This granite is not showing any foliation, so o deformation occurred. Some places feldspar is aligned as stacks. Xenoliths are present which made of rich in biotite and at some places needles of hornblende are also seen. These xenoliths are aligned, some showing crenulations.

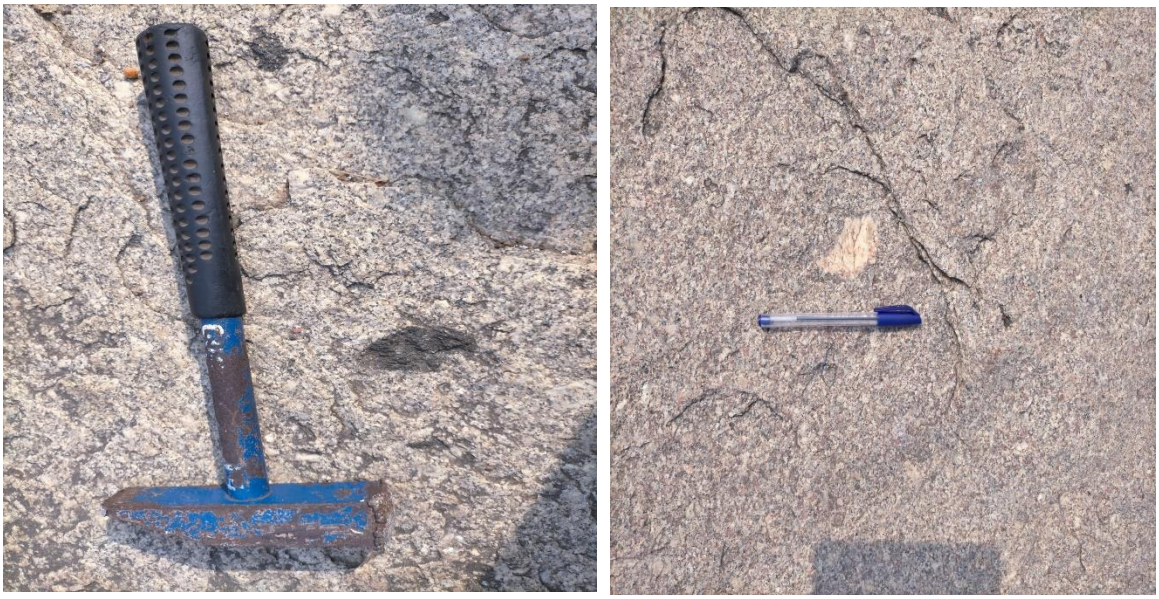

Figure 28: phenocryst in granite

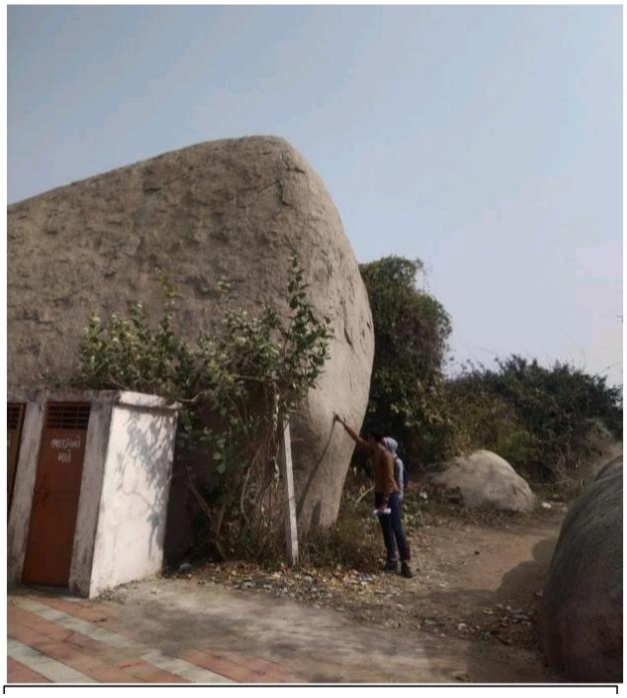

Figure 29: Tores of Godhra granite

Figure: godhra granite in handspecimen

DAY 3

DATE: 24/1/23

LOCATION 2–DINOSAUR PARK RAIOLI, BALASINOR

LATITUDE – 23.0562° N

LONGITUDE- 73.3435° E

In 1980s Paleontologists accidently came across the fossil remains and bones in the village of Rayioli in Balasinor. Since then, the place has been flooded with researchers and a number of excavations have taken place in the area the findings of which revealed the fact that there were more than 13 species of dinosaurs that thrived around 65 million years ago. The fossil park here contains life sized statues of those giant creatures and further excavations have found that a squat, thick-legged, heavy-bodied carnivorous dinosaur with a crested horn, Rajasaurus Narmandensis, King of Narmada. This creature belonged to the carnivore family of Tyrannosaurus Rex. The large tracts of sedimentary rock layers called the Lameta formation exposed in this area.

Piecing together the evidence in Raiyoli, researchers now believe that Gujarat is home to one of the largest clutch of dinosaur hatcheries in the world. At least 13 species of dinosaurs lived here, possibly for more than 100 million years until their extinction some 66 million years ago. The soft soil made hatching and protecting eggs easier for the animals. So well-protected are the fossilised eggs found here that many researchers call them the best-preserved eggs in the world after the ones found in Aix-en-Provence in France.

The town of Balasinor had no idea that it was sitting on a treasure trove of dinosaur bones and fossilized eggs. The grazing lands of the state that belonged to the Babi dynasty, had become the property of the government after the merger of states, post Indian independence. These large tracts of sedimentary rock layers called the Lameta formation, lay uninhabited and barren until one day in 1981, 2 geologists from the Geological Society of India (GSI), Dr G. N. Dwivedi and Dr D M Mohabey discovered this place by chance. They were on a systematic mapping mission and during their visit to the village of Raiyoli in Balasinor, they happened to come upon the fossilized remains of dinosaurs in their natural form. They also visited one of the cement quarries in the area and observed that the pathway to the mine manager's office was lined with

decorative spherical structures. These were thought to be limestone balls and were called cannon balls by the laborers who had found them in the surrounding.

Dr Mohabey took one of these balls to Dr Ashok Sahni, a prominent paleontologist who was visiting Ahmedabad for a conference. From the texture on the outer layer, Dr Ashok identified the object as the egg of a Sauropod dinosaur. Sauropods are quadrupedal herbivorous dinosaurs. After this discovery, a report was then sent to the GSI and the place was documented as a fossil site. Over 10,000 eggs and several bones have been said to have since been unearthed from this site, many of which are now showcased in museums attached to the offices of the Geological Survey of India in cities Kolkata, Nagpur, Jaipur, Lucknow, Gandhinagar etc Many are also missing though and are thought to have been taken away by villagers and visitors over the years. It is assumed that there are still a large number that continue to be buried both within the site and its surroundings. In 1996 there were around 50 geologists and paleontologists from around the world who were a part of a team that was touring India on field excursions and they declared that this seemed to be the third largest hatchery and fossil site in the world after the Mongolian Gobi desert and Aix en Provence in France. After the discovery of this site, another geologist Dr Suresh Srivastava and his team, conducted 2 more excavations. An area was selected and 7-8 pits were dug, from which over 400 bones were unearthed. These were sent to the paleontology division at the HQ of the GSI's western region at Jaipur and over a period of time, the bones were cleared of all debris that covered them.

Finally in 2003, the Rajasaurus narmadensis was (re)born, a species that was declared to be unique to India and especially the Balasinor region. Raja or king, after the horn that looked like a crown, saurus after reptile/lizard and narmadensis after the Narmada river basin, this was a mighty creature indeed at 30 feet in length, 8 feet in height and a weight of 3-4 tons.

The main point of interest in the park is a cluster of 13 barricades that have been put up, not too far from the entrance gate. These enclose rocks embedded with various bone parts of different dinosaurs. With the help of Dr Mohabey, the parts were identified and very informative and helpful boards were put up indicating the original species of dinosaur and the location of that part in its bone structure, thus allowing the imagination to form a fathomable picture. Ulnas, sternums and vertebrae of Sauropods and Theropods and other such bones are visible and indicated in the cluster of barricade.

A visit to the fossil park will surely make you dig deep into the history of dinosaurs in Gujarat. And in order to quench your thirst for the same, state government came up with a Dinosaur Museum. The museum is spread in an area of over 25,000 sq. feet with 10 galleries spread in the basement and the ground floor depicting various forms of displays (films and exhibitions).

Figure 30 Dinosaur fossils fenced with barricades

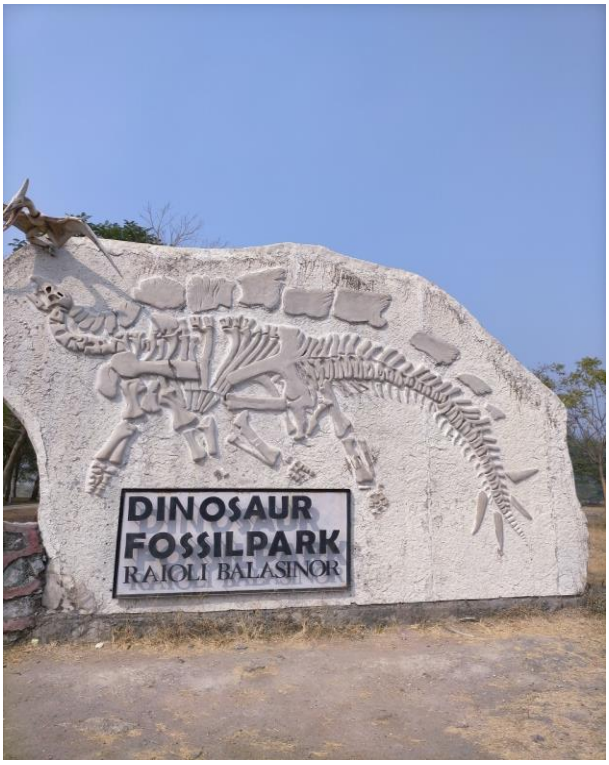

Figure 31: FOSSIL PARK RAIYOLI

Figure 32: 13 fossil cages at Raioli

Figure33: sternum in ventral view Titanosaurid sauropod

Figure 34: Hem apophysis of sauropod

Figure 35 :left femur in medial view and caudal vertebrae of sauropod

Figure 36:possible ragmentary pelvis bone of Abelisurid theropod

Figure 37: possible ragmentary pelvis bone of Abelisurid theropod

Figure 38: limb bone of sauropod

Figure 39: fossilised egg of dinosaur

Figure 40: fossilised embryo of dinosaur

Figure 41 :fossilised bone of dinosaur

DAY 4

DATE: 25/1/23

LOCATION 1: ONGC , Ahmedabad

Latitude -23.11310742^{0}N

Longitude-72.59790913^{0}E

At this location the crude oil is collected for refining from total 59 wells with the radius of approximately 17m and are connected by a pipeline. It has water injection plant with two water injection pumps. Booster gas compressor which is being used for compressing the gas. LP separator is used to separate oil and gas . This pipeline are underground which is connected to separator and then oil is received to the tank of approximately 41000 L capacity ,three tanks were present at the location .The pipeline fluid pressure is maintained by the Hydrotest.

Figure 42: At ONGC , Ahmedabad

GEOLOGY OF RAJASTHAN

Physiographically the state can be divided into four units:

(a) Aravalli hill ranges

(b) Eastern plains

(c) Western Sandy Plain and Sand Dunes and

(d) Vindhyan Scarp land and Deccan Lava Plateau

Aravalli Hill Ranges

The Aravalli ranges trending NE-SW are the oldest mountain chain in India. The elevation of these hill ranges varies from about 600 metres to over 900 metres above mean sea level (mamsl). They are composed of Bhilwara, Aravalli and Delhi Super group of rocks ranging in age from Archaean {2500 million year (my)} to Proterozoic (740 my). These ranges form a series of rugged hills with rounded surfaces. The quartzite however, stands out as scarps. Near Ajmer, these separate out southwest wards into a number of parallel ridges. At Mount Abu, the clusters of granite peaks reach a maximum height of 1722 m amsl at Guru Sikhar.

The Eastern Plains

In the plains, east of the Aravalli ranges, the altitude varies from 150m to 450m amsl. The general trend of the slope varies from place to place. In Dungarpur and Banswara districts it is mainly from north to south, in Alwar district it is from south to north and in the remaining districts, forming the central and north eastern Rajasthan, it is from west to east.

Vindhyan plateau marks the south - eastern limit.

The Western Sandy Plains and Sand Dunes

The sandy plains in western Rajasthan, forming a part of Thar Desert, are mainly occupied by

alluvium and blown sands. These plains are further sub-divided into three units:

Sandy Arid Plain (Marusthali)

Semi-arid Transitional Plain

Ghaggar Plain

The Sandy Arid Plain is a typical desert terrain. It includes the western most districts of Jaisalmer,Bikaner and part of Barmer, Jodhpur, Nagaur, Churu and Ganganagar. The line dividing the Sandy Arid Plain and the Semi-arid Transitional Plain as well as Ghaggar Plain is based on climatic parameters and water resource availability. The eastern boundaries of the Semi-arid Transitional Plain are the foot-hills and their extension on the western side of Aravalli ranges. Sand dunes are prominent and the terrain is punctuated with isolated hills of granites and rhyolites. The altitude varies from 30m to 300m amsl. The general slope is from northeast to southwest. The Ghaggar Plain consists mainly of former flood plains and aeolian deposits. Networks of canals cover the entire area. The southern and southeastern part is occupied by medium to high dunes. Nineteen of these interdunal depressions are being utilised for storing the diverted Ghaggar flood waters. The central part of the Ghaggar Plain is drained by the regulated flood waters of Ghaggar River.

Vindhyan Scarpland and Deccan Lava Plateau

The southeastern plains are locally characterised by plateau, scarp land and ravines. The Vindhyan scarpland are seen all along the Great Boundary Fault from Chittorgarh to the trijunction of Bharatpur, Dholpur and Sawai Madhopur districts. They have an average elevation of 300m to 580m amsl.The Deccan Lava Plateau is mainly confined to parts of Kota, Jhalawar, Banswara and Chittorgarh districts. The elevation ranges from 300m to over 500m amsl.

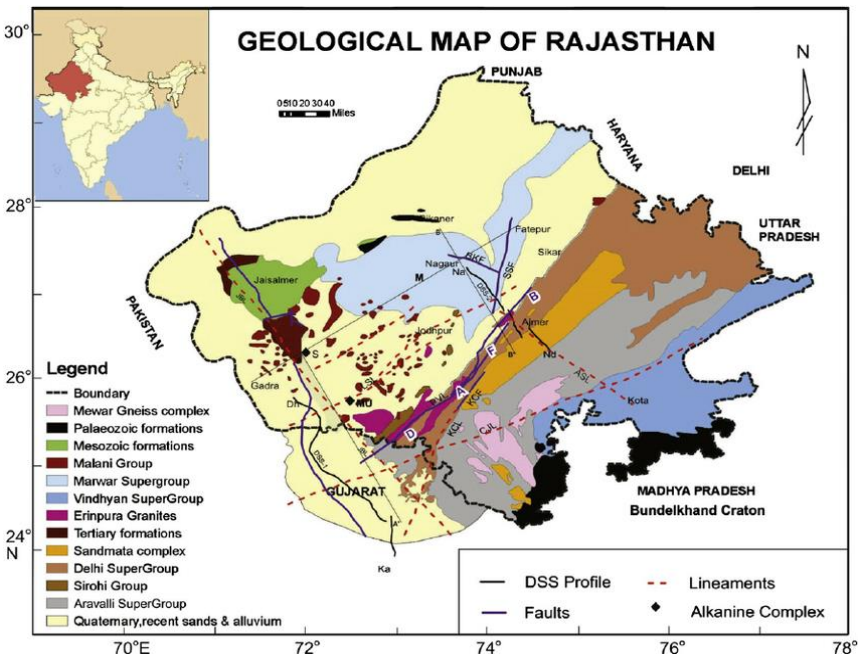

Figure 43: geological map of Rajasthan

Geological Time Scale

ERA	PERIOD	EPOCH /AGE	Million Years Ago	EVENTS
CENOZOIC *Age of Mammals* 65.5 mya - present day	*Quaternary*	*Holocene*	*Today - 0.01*	Ice Age ends Humans are dominant
		Pleistocene	*- 1.6 -*	Earliest Humans appear Ice Age begins
	Tertiary	*Pliocene*	*- 5.3 -*	Hominids (human ancestors) appear
		Miocene	*-23.7- -36.6 -*	Grass becomes widespread
		Oligocene	*- 57.8 -*	Mammals are dominant
		Eocene	*-65.5 -*	Eocene - Oligocene extinction event
		Paleocene	*- 144 -*	First large mammals appear
MESOZOIC *Age of Reptiles* 245 mya - 65.5 mya	*Cretaceous*	*Extinction of Dinosaurs*	*- 208 - - 245 -*	K-T extinction event Earth looks closer to present-day Flowering plants appear
	Jurassic		*- 286 - - 360 -*	First Birds appear Pangaea splits into Laurasia, Gondwanna Dinosaurs are dominant
	Triassic	*First Dinosaurs*	*- 408 - - 438 - - 505 -*	Pangaea cracks First mammals appear Reptiles are dominant
PALEOZOIC 570 mya - 245 mya	*Permian*	*Age of Amphibians*	*- 570 - -2500- -3800- 4600*	Permian -Triassic extinction event Pangaea forms
	Carboniferous			First reptiles appear First large cartilaginous fishes appear
	Devonian	*Age of Fishes*		Late Devonian extinction event First land animals appear First amphibians appear
	Silurian			First land plants appear First jawed fishes appear First insects appear
	Ordovician	*Age of Invertebrates*		Ordovician -Silurian extinction event First vertebrates appear
	Cambrian			End Botomian extinction event First fungi appear Trilobites are dominant
PRECAMBRIAN 4600 mya - 570 mya	*Proterozoic Eon*			First soft-bodied animals appear First multicellular life appear
	Achean Eon			Photosynthesizing cyanobacteria appear First unicellular life appear
	Hadean Eon	*Priscoan Period*		Atmosphere and oceansform Oldest rocks form as Earth cools

DAY 5

LOCATION 1: JHAMARKOTRA OPENCAST MINE

Latitude -24.4778° N

Longitude -73.8360° E

Figure 43: jhamarkotra opencast mine

Rajasthan State Mines & Minerals Limited (RSMML) is a public sector enterprise of the Government of Rajasthan and primarily engaged in Mining and Marketing of High Grade Rock phosphate, Lignite, Limestone & Gypsum (Non-Metallic minerals) through its mines located at various locations in Rajasthan. In 1969 after discovery of rock phosphate in Jhamarkotra (Udaipur), BGL took over operations at Jhamarkotra mines. The major activity of RSMML is the mining of Rockphosphate ore. It operates one of the largest and fully mechanised mines in the country at Jhamarkotra, 26 Kms. from Udaipur. Jhamarkotra plays an important role by contributing 98% of rock phosphate production of India. With an annual rock handling of about 20 million tonnes, Jhamarkotra is probably the largest open cast mine in India outside the steel and coal sectors. The geometry of the ore body i.e thin and sharply dipping had resulted in long and narrow pits with great depth extension, which involves very high stripping ratio with high lead and lift for waste and mineral. The rock phosphate occurs in metasedimentary rocks of Aravalli Supergroup (Precambrian age). It is of algal origin. The deposit extends over a strike length of 16 kms in horse-shoe shape with average thickness of 15 meters. A reserve of 77 million tonnes of rock phosphate has been proved on the basis of 60,000 mts. drilling in 500

boreholes. Out of these 17 million tonnes is of +30% P2O5 grade and rest is of 12 0 30% P2O5 grade. A beneficiation plant of 1500 TPD (Tonnes Per Day) capacity has been installed to up grade the lowgrade phosphate ore.

Extent of Jhamarkotra Deposit

Total lease area is 13sqkm2. In Jhamarkotra, the strike length of the phosphaorite bed including the discontinuous outcrop extending over a linear distance of 16 km. The highest point of the phosphate bed outcrop at 600 MRL at Jhamarkotra and along the downdip direction the extention of the phosphate has been proved upto a little below 250 MRL. Ore body dips at angle of 45-55°.The phosphate bed shows an extremely variable thickness showing persistence only over a limited strike length. Thus, in Jhamarkotra, the 15 km average thickness of the phosphate bed could be traced over 6 km of continuous strike length. In some portions, ore body shows pinching and swelling structure, hence the thickness of ore body varies from 5-35m.. For the sake of convenience in prospecting and mining the deposit has been divided into 12 blocks viz. A-Extension, A, B, C, D, E, F, G, H, I, J and K.

Grade of the Deposit 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.

Stromatolites: Stromatolite Park, Jhamarkotra, Udaipur District, Rajasthan

It is another site preserving evidences of early life on the earth. The stromatolites occurs over a strike length of 15 km in rock phosphate within Precambrian Aravalli Supergroup of rocks.

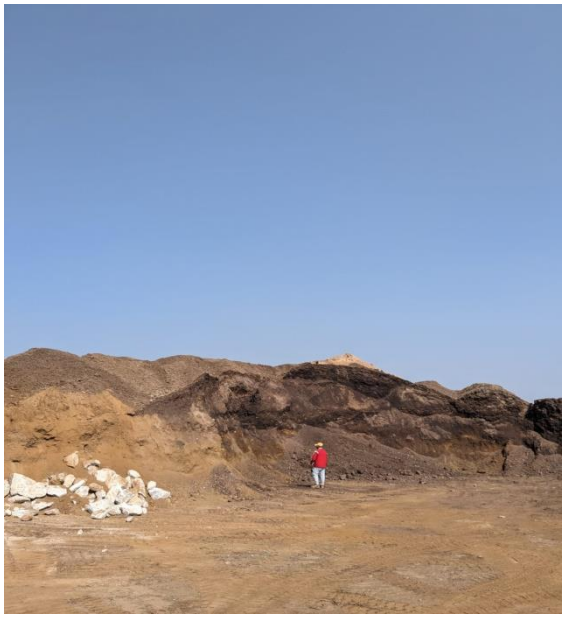

Figure 34: High grade ore

Figure 45: apatite

Figure 46: stromatolites

Spot 2 – Jhameshwar Mahadev Temple,

Jhamarkotra Stalactites are type of formation that hangs from the ceiling of caves, hot springs. They are developed downwards, grow from dripping walls and ceilings. The fundamental form is the ‘straw’ stalactite, a monolayer crystal sheath enclosing a feedwater canal and growing downwards only. Leakage from the canal may over plate the sheath, creating tapered (carrot-like) stalactites up to one metre in diameter and several 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

Figure: stalactites

DAY 6

LOCATION 1: GAMBERI RIVER BANK

LATITUDE- N 24.90380^0

LONGITUDE- E 74.623149^0

Chittorgarh district is generally characterised by undulating topography with hills belonging to the aravalli range. The district comprises of rocks of Bilwara supergroup, Vindhyan supergroup and Deccan traps.

The field area is occupied by vindhyan sediments like conglomarates and rocks of Bilwara supergroup, both separated from each other by great boundary fault. Berach River flows parallel to the great boundary fault. Bilwara supergroup is present at the west side of the river. Bilwaa supergroup is divided into 3 tectono-stratigraphic units which are Hindoli group, Mangalwar complex together with isolated mineralised belts and Sandmata complex. Hindoli group mainly consists of greywackes and phyllites. 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.

Sl no :		
1	Strike	N 50^{0}E
	Dip direction	N 140^0 E
	Dip amount	40^0
2	Strike	N 40^{0}E
	Dip direction	N132^{0}E
	Dip amount	45^0

3	Strike	N 50^0 E
	Dip direction	N 142^0 E
	Dip amount	47^0
4	Strike	N50^0 E
	Dip direction	N140^0 E
	Dip amount	52^0
5	Strike	N 55 ^{0}E
	Dip direction	N 144^0 E
	Dip amount	48^0

LOCATION 2 : EAST OF GAMBERI RIVER BANK

To the east of the river vindhyan sediments that is conglomerate rests on hindoli group by nonconformity. Matrix supported conglomerate is present. It consists of rounded to sub rounded pebbles of varying size from 2-6cm.

1	Strike	N46 ^{0} E
	Dip direction	N 140^0 E
	Dip amount	54^0

Figure 47:Suket shale,folded

Figure 48: folded shale

Figure 49:folded quartz vein in suket shale

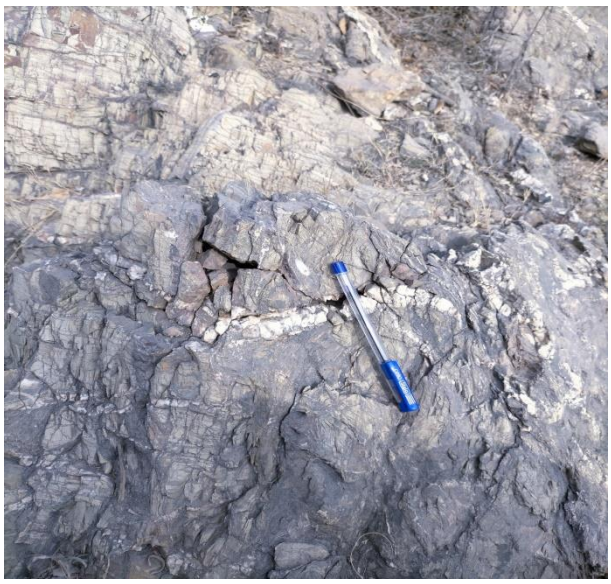

Figure 60 :folded quartz vein in shale

Figure 51: conglomerate rests on shale

Figure 52: non conformity between conglomerate and shale

LOCATION 3 : Near Chittorgarh fort

- **Lithology: Nimbara limestone**

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 and contains fossilized marine organisms, including shells and corals, which are visible on its surface. It is formed through the accumulation of calcium carbonate-rich sediment that has been compressed over millions of years, often in marine environments

Figure 53: LIMESTONE FOUND AT RIVER BANK

DAY 7

LOCATION 1: NATHDWARA

LATITUDE- N 24.9312^0

LONGITUDE- E 73.8193^0

Lithology - Marble, Schist

The marble strata were inclined with the overlying bed of schist. The schist present was heavily weathered. The marble bed which was inclined had minor crenulation folding sequence which initiated few joints present in the marble. The recrystallised silica grains in the marble suggested the following sequence have undergone contact metamorphism. The schist present had alternate augen gneiss structure with minerals like chlorite and tremolite dominating into the rock, which suggested the name of the schist as mica schist. Elongated acicular structure is also seen in the mica schist in which the needle like structure consists of tremolite.

1	Strike	N 136^0 E
	Dip direction	N222^0 E
	Dip amount	28^0
2	Strike	N134^0 E
	Dip direction	N 214^0 E
	Dip amount	26^0
3	Strike	N149^0 E
	Dip direction	N240^0 E
	Dip amount	28^0

Figure 54: EXPOSED MARBLE STRATA

Figure 55:Augen structure

Figure 56: garnet in rock sample

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