# SCHOOL OF EARTH, OCEAN AND ATMOSPHERIC SCIENCES

# GOA UNIVERSITY

Exam:

Roll No: 21P045013

## LABORATORY CERTIFICATE

This is to certify that ~~Mr.~~ /Ms. MERIN JOSE C

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

Experiments conducted are pertaining to paper GLC-122 GEOLOGICAL FIELD TRAINING

Practicals prescribed by the University for MSc. APPLIED GEOLOGY class, during the academic year 2022-2023

Faculty member in-charge

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# REPORT ON THE GEOLOGICAL FIELDWORK CARRIED OUT IN ANDAROUND GUJARAT AND RAJASTHAN

**Submitted by**

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## CERTIFICATE

This is to certify that Ms. MERIN JOSE C has satisfactorily completed the course of field work pertaining to Paper GLC- 122: Geological Field Training for MSc in applied Geology as prescribed by Goa university for MSc part II class, during the academic year 2022-2023.

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CONTENT

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**GEOLOGY OF INIDA**

The geology of India is diverse. Different regions of India contain rocks belonging to different geologic periods, dating as far back as the Eo archean Era. Some of the rocks are very deformed and altered. Other deposits include recently deposited alluvium that has yet to undergo diagenesis. Mineral deposits of great variety are found in the Indian subcontinent in huge quantity. Even India's fossil record is impressive in which stromatolites, invertebrates, vertebrates and plantfossils are included. India's geographical land area can be classified into theDeccanTraps ,Gondwana and Vindhyan. The Deccan Traps covers almost all ofMaharashtra, apart of Gujarat, Karnataka, MadhyaPradesh and Andhra Pradeshmarginally. During its journey northward after breaking off from the rest ofGondwana, the Indian Plate passed over a geologic hotspot, the Réunion hotspot, which caused extensive melting underneath the Indian Craton. The melting brokethrough the surface of the craton in a massive flood basalt event, creating theDeccanTraps. It is also thought that the Reunion hotspot caused the separation ofMadagascar and India. The Gondwana and Vindhyan include within its fold partsof Madhya Pradesh, Chhattisgarh, Odisha, Bihar, Jharkhand, West Bengal, AndhraPradesh, Maharashtra, Jammu and Kashmir, Punjab, Himachal Pradesh, Rajasthanand Uttarakhand. The Gondwana sediments form a unique sequence of fluviatilerocks deposited in PermoCarboniferous time. The Damodar and Sone river valleysand Rajmahal hills in eastern India Contain a record of the Gondwana rocks. TheIndian Craton was once part of the super continent of Pangaea. At that time, whatis now India's south west coast was attached to Madagascar and southern Africa, and what is now its east coast was Attached to Australia. During the JurassicPeriod about 160Ma(ICS 2004), rifting caused Pangaea to break apart into twosuper continents, Namely Gondwana (tothesouth) and Laurasia (to the north). The Indian Craton remained attached to Gondwana, until the super continent began to rift apart about in the early Cretaceous, about 125 million years ago (ICS2004). The Indian Plate then drifted northward towards the Eurasian Plate, at a pace that is the fastest known movement of any plate. It is generally believed that the Indian Plate separated from Madagascar About 90 Million years ago (ICS2004), however some biogeographical and geological evidence suggests that the connection between 5 Madagascar and Africa was retained at the time whenthe Indian Plate collided with the Eurasian Plate about 50 Million years ago (ICS2004). This orogeny, which is continuing today, is related to closure of the Tethys Ocean. The closure of this ocean which created the Alpsin Europe and the Caucasus range in western Asia, created the Himalaya Mountains and the Tibetan Plateau in South Asia. The current orogenic event is causing parts of the Asian continent to deform westward and Eastward on either side of the orogen. Concurrently with this collision, The Indian Plates utured on to the adjacent Australian Plate, for minga new larger plate, the Indo-Australian Plate. The earliest phase of tectonic evolution was marked by the cooling and Solidification of the upper crust of the earth's surface in the Archaean Era (prior to 2.5 billion years) which is represented by the exposure of gneisses and granites especially on the Peninsula. These form the core of the Indian Craton. The Aravalli Range is the remnant of an early Proterozoic orogeny called the Aravali-Delhi Orogen that
joined the two older segments that make up the Indian Craton. It extends approximately 500 kilometres (311mi) from its northern end to isolated hills and rocky ridges into Haryana, ending near Delhi. Early Paleozoic rocks are found in
the Himalayas and consist of southerly derived sediment seroded from the crystalline craton and deposited on the Indian platform. During the Jurassic, as Pangea began to rift apart, large grabens formed in central India filling with Upper Jurassic and LowerCretaceous sandstones and conglomerates. By the Late Cretaceous India had separated from Australia and Africa and was moving northward towards Asia. At this time, prior to the Deccan eruptions, uplift in southern India resulted in sedimentation in the adjacent Indian Ocean. Exposures of these

rocks occur along the south Indian coastat Pondicherry and in TamilNadu. At the close of the Mesozoic one of the greatest volcanic eruptions in earth's
history occurred, the Deccan lava flows. Covering more than 500,000 square kilometres (193,051 sq mi) area, the sea mark the final break from Gondwana.

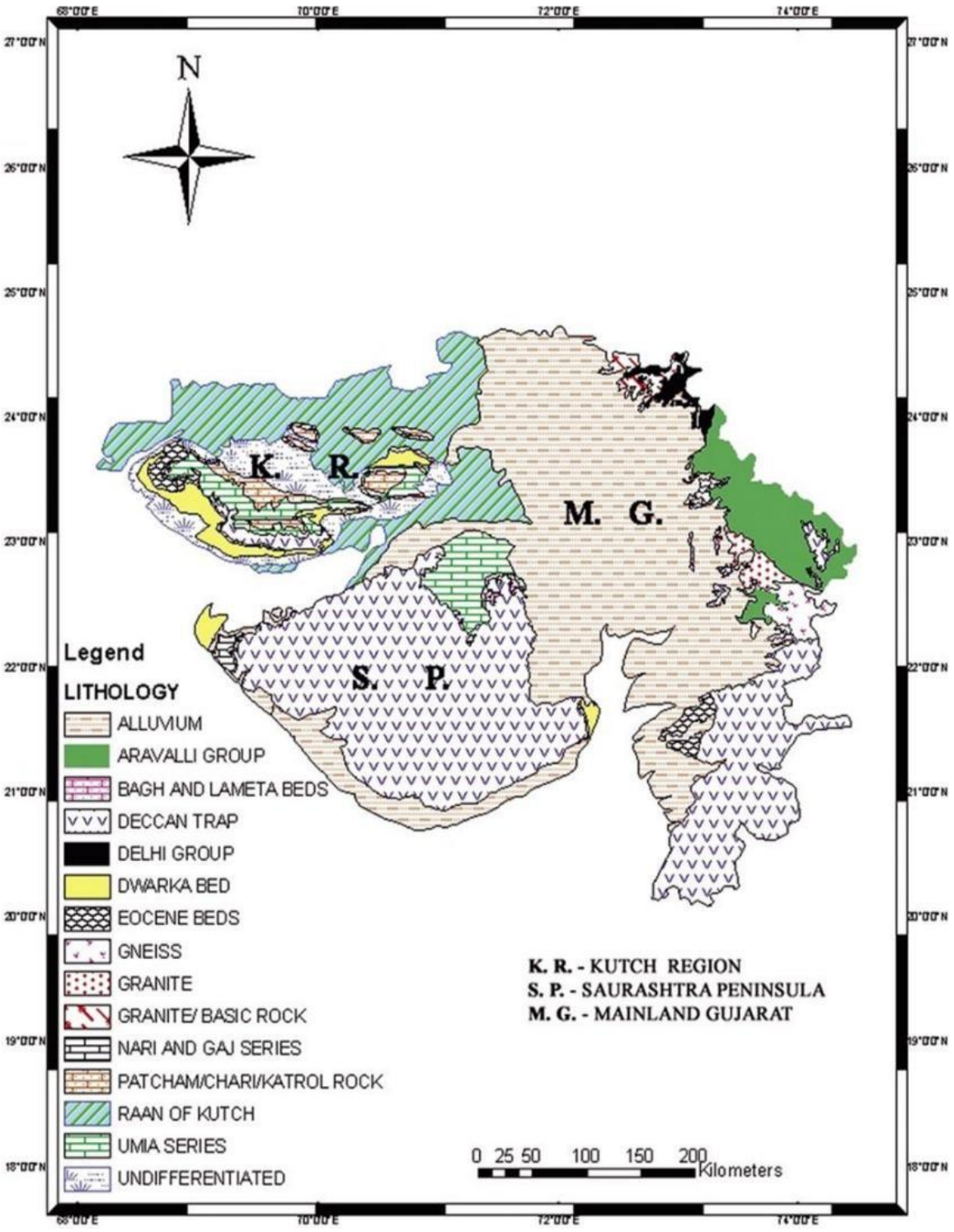
**GEOLOGY OF GUJARAT**

The state of Gujarat comprises an area of approximately 1,96,000 sq.km and is enclosed within North Latitude $20^0$ $10^0$ to $24^0$ $50^0$ and East Longitude $68^0$ $40^0$ to $74^0$ $40^0$. 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 (121km) 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 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.




ARCHEANS: These are the oldest groups of rocks forming the basement for late formations. Detailed formation under this group is Banded Gneissic Complex, are highly intricate and varied gneissic complex; they are mostly of igneous origin, but on account of interfoliar injection, they have a general northerly foliation strike, and are continuous with gneissic complex of central Mewar. These are occurred around Chhota Udepur, Bodeli and east of Sankheda. Aravalli systems are metamorphic and have been affected by tectonic forces forming folds. Basal conglomerates impure calcareous facies generally dolomitic in composition, quartzite, phyllites, slates and schists are the rocks under this system

MESOZOIC: The rocks under Delhi system are metamorphosed and undergone deformation, having been folded. The rocks are quartzite, phyllites and mica schists, calc- schist and calc gneisses, calciphyres, limestones and marble. The strike is roughly north- south and NNE-SSW. In Post-Delhi system, Erinpura granites were first recorded. A broad belt from Bariya taluk to Lunawada taluk, trending SE-NW is occupied by granites around Godhra in Panchmahals district; this extends further across the Mahi River in Balasinor taluk in west, the Kalol taluk in South. A small out-crop of granite occurs NE of Pavagadh.

In Cretaceous system, Lameta beds are lenticular outcrops from narrow fringes along the base of the Deccan trap. These beds are fresh water deposits, consisting of a conglomeratic formation with a siliceous or calcareous matrix at the base, overlain by earthy to massive limestones with cherty and chalcedonic stringers and veinlets. It is mottled with limonite.

spots. The thickness of these formations comes to above 15ft (5m). Bagh beds are the products of marine transgression in the cretaceous age. It consists of calcareous rocks underlain by beds of sandstone, below which conglomerates are found. Marine fossils are usually found in the uppermost limestones. The thickness is normally up to 70 ft. (21m) but in Narmada valley, it is over 1000 ft.(305m). Nimar Sandstones occur SE of Pavagadh hill and were used in the construction of the Champaner Fort at the foot of Pavagadh. The rocks are pinkish sandstone with jasper pebbles associated with ferruginous conglomeratic beds containing pebbles of quartz and calcedon.

The Deccan Traps covers large area along the eastern margin of the state extending from its southern tip of Narmada; further these are scattered patches cropping out from alluvial tract of Gujarat near Kalol and Timba in Panchmahals Dist., Kapadvanj in Kaira Dist., and near Dhansura in Ahamedabad Dist. Trap comprise lava flows of amygdaloidal trap, porphyritic trap, basalt, etc. Pavagadh a mass of trap, is known to be central type eruption unlike usual fissure type, and is an example of magmatic differentiation. Other rock types in Pavagadh are pumice, pitchstone, rhyolite, felsites, quartz m- andesite etc.

TERTIARIES: The rock of this group occur between mouths of Tapi and Narmada rivers, forming a fringe along the edge of deccan traps. The basal beds of nummulitic limestone and ferruginous clays belong to Eocene, while the overlying rocks of Kand formation (yellow limestone), ferruginous sandstones, and agate bearing conglomerate are upper Gaj of Miocene age. Laterite occurs in areas near Kapadvanj as well as Tarkeshwar. Being oil bearing, the Eocene, Oligocene and Miocene formations of Tertiaries are very important.

These are covered by thick mantle of alluvium on the westwards. Oil is found in Eocene, Oligocene and Miocene. Saurashtra- Kathiawar peninsula in Jura- Cretaceous are the oldest formations in the Saurashtra area, and they occur in the NE corner of the region, around Dhrangdhara. Sandstone from these formations is known as excellent building stones.

Traps have occupied almost the whole of Saurashtra region expect the coastal areas and its NE corner. Traps of Saurashtra are the extensions of Gujarat and Malwa traps, and these extend northwards in Kutch. A bed of volcanic ash, made up of fragments varying in size from gravel to large lumps of a dense trap occur in the lower part of the Chotila hill. Laterites occur along the Deccan trap border in a discontinuous linear belts or strips; the largest one is near Bhavnagar. Gaj beds occur as isolated patches, at interval in coastal areas between Bhavnagar and Jamnagar along the margins of Deccan traps, were laterites in alluvium.

These comprise of limonitic limestone, sandstone, grit, conglomerate and yellowish clays and marls with gypsum. In Piram island near Bhavnagar is know for discovery of fossil mammalian bones of age Pliocene. Dwaraka beds consist of limestone and yellow earthy, marly or clayey beds, partly gypseous with iron-stained harder bands.

QUATERNERY: Miliolite limestone are also known as Porbandar stone is a finely oolitic free stone composed of remains of foraminifer. Calcite grains are found around Miliolites. Major part of Miliolites limestones is of high grade, and used extensively for the cement manufacture, as well as in chemical industry. In recent, sand dunes, consolidated shore sand,tidal mud flates, coral reefs and fresh water alluvium are present. Saurashtra region is rich in mineral wealth also.

**DAY 1:**
**LOTHAL**

Latitude : 22˚31’18”N

Longitude: 72˚14’58”E

About 80km southwest of Ahmedabad, the city that stood at this archaeological site 4500 years ago was one of the most important of the Indus Valley civilization. Lothal is a combination of two words; Loth and thal, which in Gujarati means ‘the mound of the dead’. The excavated site of Lothal is the only port-town of the Indus Valley Civilisation. The excavation started from 13 February 1955 to 19 May 1960 by the Archaeological Survey of India (ASI) to unearth the ancient city. Archaeologists believe that the city was a part of a major river system on the ancient trade route from Sindh to Saurashtra in Gujarat.

TOWN PLANNING- 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 residential area was located to either side of the marketplace. The lower town had The lower town contains a commercial and residential area. Streets running from east to west led to the residential areas with lanes allowing access to individual dwellings

DOCKYARD-A metropolis with an upper and a lower town had in on its northern side a basin with vertical wall, inlet and outlet channels which has been identified as a tidal dockyard. Satellite image show that river channel, now dried, would have brought in considerable volume of water during high tide which would have filled the basin and facilitated sailing of boats upstream. The identification of the tidal creek rough which boats would have sailed upstream, the controlled water inlet and outlet system provided in the humongous basin and the marks of flooding which ultimately resulted in rendering it non-functional provide physical evidence of the working systems of the tidal port. Dimension: width-37m, length-22m
An inlet channel 1.7 meters above the bottom level of the 4.26 meter deep tank allowed excess water to escape. Other inlets prevented siltation of the tanks and erosion of the banks. After a ship would have unloaded its cargo, the gates would have opened and allowed it to return to the Arabian sea waters in the Gulf of Cambay. The discovery foraminifera (marine microfossils) and salt, gypsum crystals (due to evaporation of seawater) in the rectangular structure clearly indicating that sea water once filled the structure

WELLS – the wells were found in both lower and upper town. The wells were paved of standard sized bricks which were trapezoidal in shape . the shorter side of approximately 4” were placed inwards and longer side of approximately 6”outwards. One of the well were
WAREHOUSE - A long wharf connected the dockyard to the main warehouse, which was located on a plinth some 3.5 meters above the ground. The first concern of the Harappan engineers might have been to ensure against floods and tides. The warehouse was divided into 64 rooms of around 3.5 square meters each, connected by 1.2 meter wide passages. Twelve of these

cubical blocks are visible today. Kiln fired bricks were unaffected by tidal waters, were used in making the passages to protect the cargo. A direct ramp led to the dock to facilitate loading.

DRAINAGE SYSTEM- The most unique aspect of planning during the Indus Valley civilization was the system of underground drainage. The main sewer, 1.5 meters deep and 91 cm across, connected to many north-south and east-west sewers. It was made from bricks smoothened and joined together seamlessly. The expert masonry kept the sewer watertight. A wooden screen at the end of the drains held back solid wastes.
Toilets and washrooms there were provisions for public toilets for the people of acropolis which had proper drainage system.

BEAD INDUSTRY- beads making furnaces have been excavated. made of terracotta , gold, steatite, jasper. These were made by grinding materials, rolling them on to a string, baking it solid. Finally the baked roll was sawed into required shapes and sizes.
Unique necklaces were made with microbeads of gold. Coppersmithing and pottery reached high standards of development in the lower town.
.
STEATITE SEAL- the steatite seal was found which was the evidence for trade and relations with other gulf countries.

Sea level rise and foraminifera

Foraminifers present in the shelly sediment layers in Lothal Dockyard (Cambay) are discussed as case studies of high sea stand. The results indicate the possibility of higher sea level around 6,000 years BP. Similarly sediments collected from the seafloor show a sea level approximately 100m lower than the present at around 15,000yr BP.The presence of foraminifers in the rectangular structure(dockyard), connected through open marine environment with high tidal range. . Around 4500 years B.P. (time of Lothal) sea level was higher than the present. When sea level started going down, this connection was cut off and what locked inside got evaporated and giving rise to salt and gypsum crystals

Figure 1  Remains of The Dockyard and The Warehouse

Figure 2
Remains of the well in lower town, toilets and their drainage patterns

Figure 3 Furnace , steatite seal

**DAY 2:**
**PHYSICAL RESEARCH LABORATORY**

**PRL** is unit of Department of Space ,government of India; fouded by Dr. Vikram Sarabhai in 1947. The institute carries out studies on selected areas of physics, space and atmospheric science, astronomy, astrophysics and solar physics, planetary and geosciences.

At PRL we were introduced various laboratories and latest machineries used .

- Ex Terra Lab: Multi-collector Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS)
  Hybrid mass spectrometer that combines the advantages of superior ionization of an inductively coupled plasma source and the precise measurements of a magnetic sector multicollector mass spectrometer.The instrument **uses a plasma (ICP) to ionize the elements in a sample and then measures the ions using a mass spectrometer (MS)**.
  Instrument :Neptune plus
- Chemistry lab : Thermal Ionization Mass Spectrometer (TIMS)
  It provides high precision isotope ratio measurements. Best used for uranium.
  Instrument:: triton plus
- HR-ICPMS :High Resolution Inductively Coupled Plasma Mass Spectrometer
  used for elemental analysis of solutions and solid samples. The superior ionization of inductively coupled plasma source is combined with a magnetic sector multicollector mass spectrometer resulting in ultimate sensitivity. The instrument can be used to find the trace elements within the water bodies. Each samples take almost 15minutes.
- Lighter elements mass spectrometer:
  The instrument is used for gas samples.
- Accelerator mass spectroscopy
  mass spectrometry that accelerates ions to extraordinarily high kinetic energies before mass analysis. The special strength of AMS among the mass spectrometric methods is its power to separate a rare isotope from an abundant neighboring mass. The lab was used to produce $CO_2$ from $H_2O$ in vaccum condition. Liquid nitrogen is used to collect the contaminants. ons are accelerated **by passing them through a potential difference V**
- Radiocarbon dating lab

**Figure 4 PRL**

**Figure 5 TIMS , MC-ICPMS**

**DAY 3:**
**Spot 1**

Latitude :23.0562N
Longitude:73.3421E
The location had exposed torse of granites of Neo-Proterozoic age(935+/-20 Ma). This suite of rocks is intrusive into the Lunavada and Champaner groups of rocks.The rock was identified as granites by the light colored, coarse grained rocks(approximately 2-4cms), subhedral grains that consisted of potassium feldspars, quartz, muscovite and biotite. These are compact and massive, medium grained grey in colour. The trend of these granites is N-S. Exfoliation was observed on various rocks. Mass segregations of black flaky minerals with vitreous to sub-vitreous lustre are found ,biotite are found on rocks. At places these euhedral feldspars were aligned in a particular direction which is a characteristic of magmatic flow.

**Spot 2**

Latitude :23.4.12
Longitude :73.11.35
The area was highly weathered. Conglomerates and sandstones were found. Jasper clasts along with limestones were also observed. Fossils of dinosaur egg shells were found within limestone; whereas bonnes and teeth were found in sandstone.

Figure 6 xenolith with gneissic banding, plagioclase xenolith


Figure 7 Mass segregations of biotite,  exfoliation on godhra granites


Figure 8 Segregation of mica and plagioclase ,  shells of dinosaur egg

**Spot 3**
**Raioli –dinosaur fossil park**

Balasinor is located in the Mahisagar District of Gujarat and this park is the second-largest dinosaur fossil park in the world. Fossils of left femur and caudal vertebrae of Sauropods, scapula of Coracoid Titanosaurid, dorsal vertebrae Abelisaurid theropod with intermediate limb bone, were found. During the research in 1977 , 75%of two dinosaurs were found at a depth of 12 feet. In 1981 fossils of terapods (carnivorous) were found of Rajasaurus.
It is estimated that atleast 13 species had lived here , possibly 100 million years ago till their extinction.
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.

**Figure 9 Enterance of dinosaur fossil park , Fossil of an egg**

**Figure 10 Fossils of dinosaur egg**

**DAY 4:**

**ONGC –GGS, Motera**

Latitude :

Longitude:

Gas Gathering Station

The raw gas from the wellhead, undergoes various processes to meet certain specifications of pipeline quality gas. This gas station collects gas from 59wells within 17km radius within motera. The gas is collected through small diameter pipes and collected in *sperator* to separate gas and oil. From the seperators gas is transported to compressors, and oil to tank (45000L). Booster gas compressor plant –the equipment used to increase or amplify the air pressure coming from an existing compression system by passing it through additional compression stages.Water injection plant-Water injection is used in the production of oil where high pressure water is injected into the oil reservoir to increase pressure to increase oil recovery from an existing reservoir, bath heater-the crude gets cooled in wax to decrease mobility, so it increase its mobility the temperature is increased. $CO_2$flooding system –a common fire fighting system, box canopy- instruments that continuously monitor the pressure and other parameters,pipelines are insulated with rubber gaskets and gas corrosion inhibitors are provided 2L/day for their protection.

SCADA-supervisory control and data acquisition is a category of software applications for controlling industrial processes. These systems monitor the gas leakages, the ability to understand what's happening in their wells, pipelines, pumps, helps prevent blow-outs, verifies the safety of pumping and watches out for the integrity of the well-bore.

## 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 Scarpland 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 (m amsl). 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 south west 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. The 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 bythe 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.

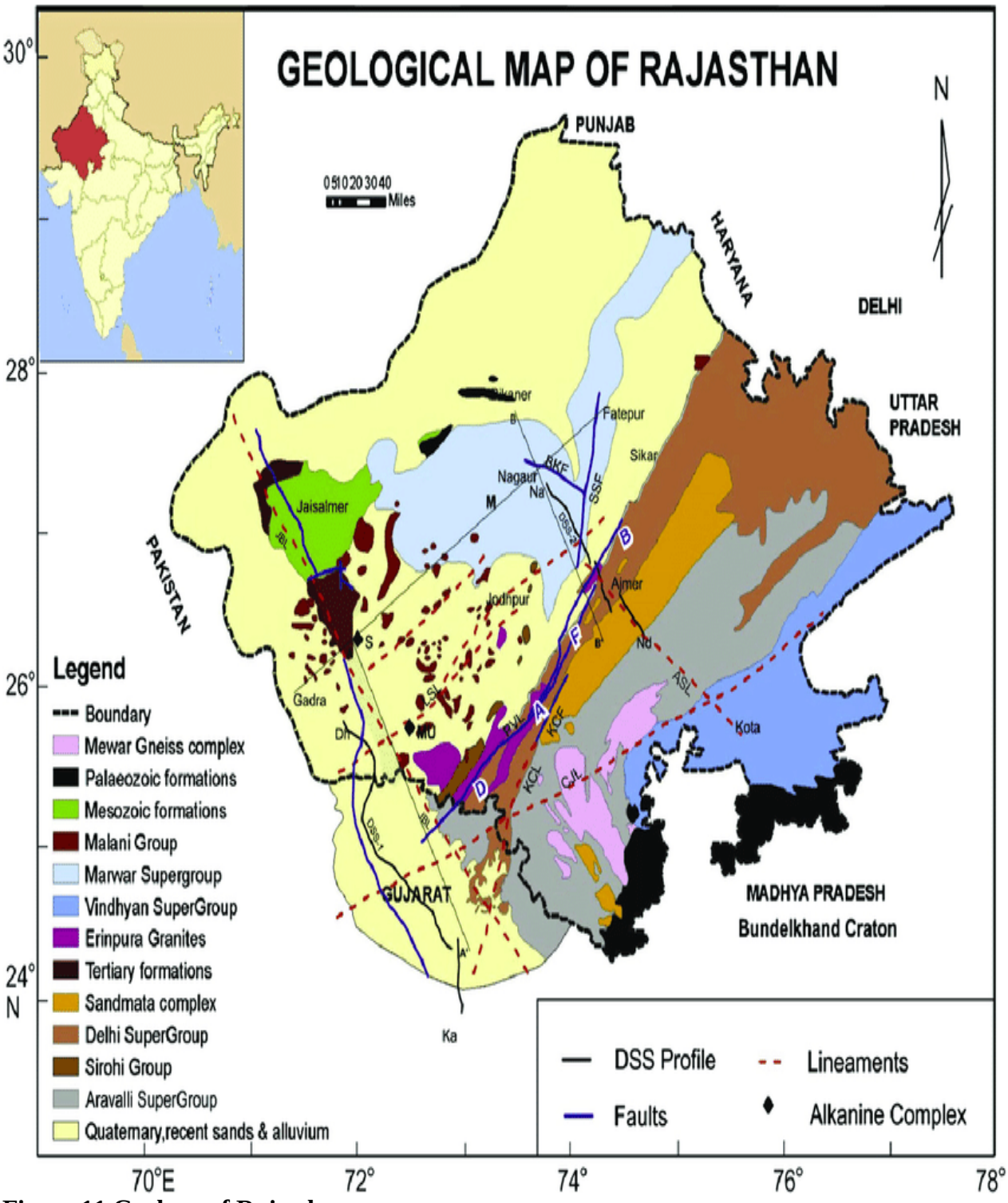



**Figure 11 Geology of Rajasthan**

**DAY 5:**
**Jamar Khotra Mines (Rajasthan state mines and minerals limited)**

Latitude :$24^0$28’21”N
Longitude:$73^0$51’34”E

The major activity of Rajathan State Mines and Minerals Limited(rsmml) is the mining of rock phosphate ore. It operates one of the largest and fully mechanised mines in the country at Jhamarkotra, 26 Kms. from Udaipur. Open pit mining is practiced. Total lease area is 13sqkm$^2$.

The area belongs to lower Aravalli supergroup , The rock phosphate occurs in metasedimentary rocks of Aravalli Supergroup (Precambrian age). 2000-2200 MYA due to sedimentation presence of blue green algae was prominent . These organisms grow in photic zone (shallow depth). During sedimentation algae dissolved phosphate in ppm which was utilized for their growth. When sedimentation stopped the growth of BGA also stopped. The phosphet of this region could be also formed due to diagenetic precipitation of apatites.

Phosphate rocks are basically diphospherous pentaoxide. The shape of ore body is horse shoe. Apatites could not be seen in secondary phosphates. There is industrial beneficiation plant where in 16% low grade is chamged to 35% high grade ore. Dark colored high grade rocks are found in D block.

Two types of ore: low grade and high grade. The low grade is found in hard form. Less than 25% of phosphate. High grade ore had more than 25%of phosphate. The host rock is dolomite. The transition from low to high grade ore might be because of meteoric rain which dissolved dolomite increasing the grade of ore. The ore body is zig-zag ;with faults and folds . the average dip is $55^0$ and thickness of 5-15km . due to high disturbance the secondary phosphates were within the cracks along with apatite. The faces were 10m each whereas the benches were 7-7-12m for safety.
The rock phosphate occurs in dolomitic limestone associated with stromatolites appearing in grey to bluish grey colour shades and in variable forms and shape. Ore to overburden ratio is 1:16.

**Figure 12 Benches and faces of the mine,  stromatolites**

**Figure 13 apatite**

**Location-2**
**Jhameshwar Mahadev temple,Jhamarkota**

Formation of stalactites. Stalactites are type of formation that hangs from the ceiling of caves, hotsprings. They are developed downwards, grow from dripping walls and ceilings.

**DAY 6:**
**Banks of Berach river**

Spot 1:

Latitude :24.9038N
Longitude:74.6231E

Suket shale belongs to semri group of vindyan supergroup. The area was highly folded and had various types of folds- Primary and secondary folds.2 Sets of joints were also observed. Quartz veins were exposed as cutting and along with the folds. The quartz veins lies east west and parallel to the fold axis. The area was also highly deformed
According to the stratigraphy ,it is described as the suket shale ;since it shows slately cleavage it could be slate. The terrain is brown-greyish color and fine platey minerals can be seen.

| STRIKE | N45E | N48E | N54E | N55E |
|---|---|---|---|---|
| DIP AMOUNT | 40 | 59 | 56 | 42 |

On the other bank of the river , unconformity was observed. conglomerate. Contact of the lithology of conglomerate and shale is observed.

STRIKE: N42
DIP AMOUNT: 47

**Figure 14Suket shale,  fold**

**Spot 3: Nimbara limestone**

**Latitude :24.8740 N**
**Longitude:74.6332E**

The outcrop was on the banks of Gambiri river. Nimbara limestone was exposed.

| | | | |
|---|---|---|---|
| STRIKE | 190 | 170 | 180 |
| DIP AMOUNT | 54 | 40 | 45 |

**DAY 7:**
**Marble schist mine**

SPOT 1
Latitude :
Longitude:

The outcrop was fully weathered and foliated.there were competent and incompetent layer : marble was sandwiched between schist. The schist could be mica chlorite schist because of the presence of flaky minerals but could not be properly identified due to weathering. Mylonitic structure were observed which were stress indicators. Certain acicular structure were found which might be tremolite or actinolite. Green colored fibrous minerals were seen-serpentine. Small garnet crystals were also seen which were less than1cm size.
The area could be a single large anticlinal fold.

| | LEFT SIDE | MIDDLE | RIGHT SIDE |
|---|---|---|---|
| STRIKE | $142^0$ | 135 | 123 |
| DIP AMOUNT | 29 | 35 | 35 |

SPOT 2
Less than 100m from the spot 1.the outcrop was less weathered and so, schistosity could be identified. Certain rocks showed augen structure , exhibited the stress direction
STRIKE: 120-140
DIP AMOUNT: 28-32

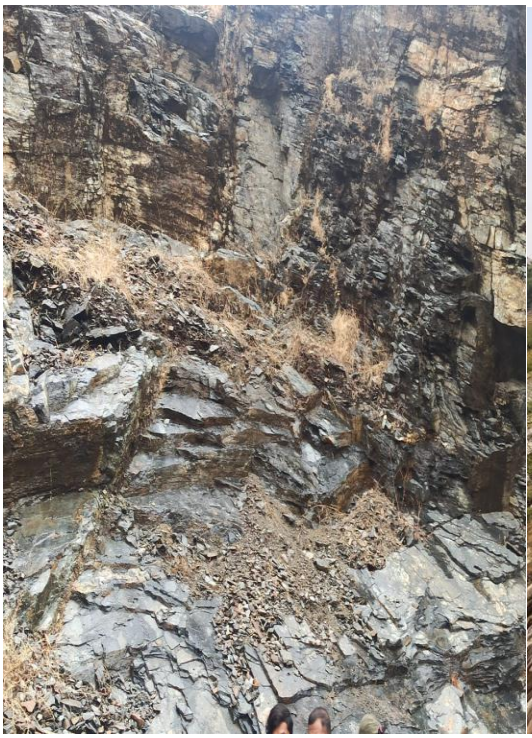



**Figure 15schistose rock ,  nimbara limestone**

**Figure 16 marble schist mine**

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