SCHOOL OF EARTH, OCEAN AND ATMOSPHERIC SCIENCES

GOA UNIVERSITY

Exam: Roll No:

LABORATORY CERTIFICATE

This is to certify that Mr. /Ms. ---- Pradnesh Pednekar. ----
has satisfactorily completed the course of practical for M.Sc in Applied Geology.

Experiments conducted are pertaining to paper --
Practicals prescribed by the University for --class, during the academic year 20 - 20 .

DEAN
SEOAS

Faculty member in-charge

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

Inward No. ________
Date: ________
To whom sent ________

GUJARAT AND RAJASTHAN

FIELD REPORT

By Pradnesh Pednekar Pednekar

Goa University

Msc Applied Geology Part 2 (Student)

Table of Contents

Abstract

I am grateful to Dr Anthony Viegas, Dr Niyati Kalangutkar, Professor Mahesh Mayekar, Dr Pooja Ghadi, and all other faculties of earth science department, Goa University. Because of them this field trip could not be possible and also I appreciate the help received from the laboratory assistant Ms. Heena for providing material required for the field trip. I would like to express my gratitude towards my fellow classmates for helping me during these 10 days and giving me an update of what happened.

Also, I would like to thank my family members for their support, constant words of encouragement and also financial support.

Introduction

Our department of applied geology, Goa university had organized 10 Days of field trip to Gujarat and rajasthan. This field trip is a part of our Master's programme and is essential for a geology student to become Great in field related work. For this to be happen we were meant to take Various geological equipment which is clinometer compass and Brunton compass to take structural data like strike direction, dip Direction, dip amount etc, hand lens for mineral identification, Toposheet to have an idea where we are, and hammer to break the rock Sample. The area which we were having field work is Gujarat and Rajasthan. We visited several places, took the structural data, started to interpret, like what is this lithology, where it should be placed on the stratigraphic column, how it was formed, what led to its current situation, what is the rock, what is the environment of deposition and so on.

We spent 4 days in Ahmedabad, Gujarat and 3 days in Udaipur, Rajasthan. In Gujarat we first had a visit to Lothal which was an ancient city having a port which was for trading Indian goods or spices to western or Arab civilization. Second day we went to PRL which is a physical research laboratory. Third day we went to a dinosaur nesting site located in Balasinor, where we saw eggs and various types of skeletal remains. Fourth day we visited ONGC GGS Montera. In Rajasthan, the first thing we visited was a phosphate mine. On the second day we went to Chittor near the river bed of Berach and Gambiri . And on the third day we went to the marble quarry.

Geology of Gujarat

Gujarat is a state in India with a total size of roughly 1,96,000 square kilometres. It is located between North Latitude 20°10° and 24°50° and East Longitude 68°40° and 74°40°. Gujarat offers a diverse range of rock kinds, all of varying ages. In contrast to the 2500 million-year-old Aravallies in the northeast, the unconsolidated alluvium and beach material in the region's central and western regions are only a few thousand years old. The state contains all three significant lithological types: igneous, sedimentary, and metamorphic.

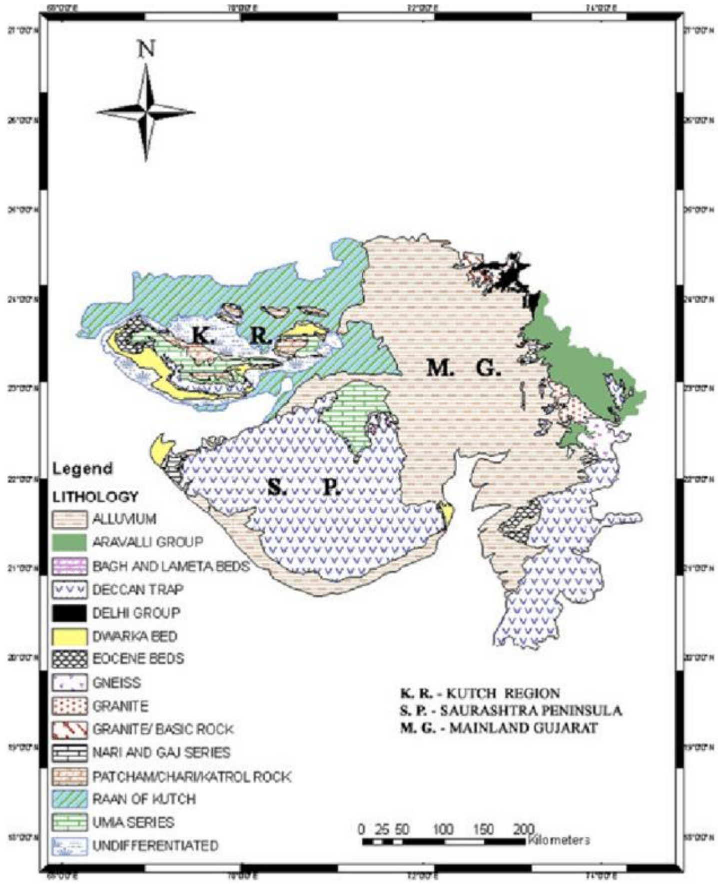

Fig 1: Geological map of Gujarat

Physiographically the state of Gujarat comprises the following three distinct zones.

1) Mainland Gujarat

2) Saurastra and

3) Kachchh

Rocks from the Precambrian, Mesozoic, and Cenozoic eras are exposed in Gujarat. Around 49% of Gujarat's overall land is made up of hard rocks, with the remaining portion being covered by Quaternary sediments. Precambrian metamorphosed rocks with accompanying intrusives, sedimentary rocks from the Mesozoic and Cenozoic eras, and the traps and flows that make up the Cretaceous Eocene Deccan volcanic make up the hard rock.

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 roughly 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 northeastern 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.

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.

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.

Stratigraphic and age

Group	System	Rock Type	Localities	Age in millions of years
Quaternary	Recent and subrecent	Alluvium, Blown sand, Silts of Rann and Banni, Tidal flats and raised beaches.	Alluvial plains of Gujarat, Rann, Banni & Coastal deposits.	0.01
	Pleistocene	Miliolites	(i) Saurashtra coast from Gopnath northwards extending beyond Porbandar. (ii) Kutch area.	1
Tertiary or Kainozoic	Pliocene	Dwarka beds, Manchhar beds, Gypsiferous clays and sandy foraminiferal limestones.	Dwarka, Okha, Piram Island, Kutch.	12
	Miocene	Gaj beds-Highly fossiliferous clays and limestones. Agate bearing conglomerates. Kand 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	Himatnagar, Kapadvanj, Balasinor, Parabia, Dohad, Gabat, Narmada valley,	110

		(sand-stones, Lime-stones and shales).	Gora, Surpan Vanji, etc.	
		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.	

Fig 2: Stratigraphy of Gujarat

Field work

Day 1

Lothal

Fig 3: lothal

Lothal is an archaeological site located in the state of Gujarat, India, that dates back to the Indus Valley Civilization. The site is famous for its well-planned urban layout, advanced engineering systems, and its location on the banks of the Bhogava River, which once made it an important center of trade and commerce.

The importance of Lothal as a trading center is evidenced by the discovery of artifacts from different parts of the world, including West Asia, Mesopotamia, and Egypt. The city was also an important center for bead making, shell working, and metallurgy. The Harappans were known for their sophisticated metallurgical techniques, and Lothal was no exception. The city had a furnace for copper smelting and a factory for the production of bronze objects.

Here are some of the different types of buildings found in Lothal:

Dockyard: Lothal had one of the world's earliest and most sophisticated dockyards, built around 2400 BCE. The dockyard was built using large blocks of sandstone, with interlocking grooves and wooden dowels to hold them in place.

Fig 4: Dockyard

Warehouse: The city had a large number of warehouses, used for storing goods that were traded with other civilizations. The warehouses were built with brick walls and had a flat roof, with a central courtyard for ventilation.

Fig 5: Warehouse

Citadel: The citadel was the fortified area of the city, used for defense purposes. The citadel was surrounded by walls made of mud bricks and had four gateways. It was also home to the ruling class of the city.

Residential buildings: The houses in Lothal were built using mud bricks and had several rooms, including a kitchen, a living room, and a bedroom. The houses had flat roofs and were designed to stay cool in the hot climate.

Public buildings: The city had several public buildings, including a public bath, a granary, and a marketplace. The public bath was a large structure with several rooms for bathing and relaxation.

Overall, the buildings in Lothal demonstrate the advanced architectural skills and urban planning techniques of the Indus Valley Civilization.

In terms of geology, Lothal is situated in an alluvial plain that was formed by the deposition of sediments by the Bhogava River. The plain is made up of fine-grained sand, silt, and clay, with occasional pockets of pebbles and gravel. The alluvial deposits are relatively recent, dating back to the Holocene period, which began around 11,700 years ago.

The geology of Lothal has played an important role in the development of the city's infrastructure. The alluvial plain provided a stable and flat surface for building, which made it easier to construct the city's streets, buildings, and drainage systems. The soil in the region is also fertile and well-suited for agriculture, which would have been a major source of food for the city's inhabitants.

One of the most impressive engineering feats of the Indus Valley Civilization at Lothal is the city's sophisticated dockyard. The dockyard was built using a combination of brick, stone, and timber, and included a system of canals and sluice gates that allowed ships to enter and exit the dock even during high and low tides. The dockyard was strategically located at the confluence of two channels of the Bhogava River, which would have allowed ships to enter and exit the city even during the dry season when water levels were low.

The geology of the region also played a role in the city's decline. Over time, the Bhogava River changed course, and the city's once-thriving port was left stranded several kilometers inland. Without easy access to the river, the city's trade and commerce declined, and the population gradually abandoned the site. Lothal was abandoned around 1900 BCE, and the reason for its decline is not known. However, it is believed that the city may have been destroyed by natural calamities like floods or earthquakes. The discovery of a large number of human skeletons in the city suggests that the inhabitants may have died due to an epidemic.

Day 2

PRL (Physica; Research Laboratory)

Fig 6: PRL campus

The Physical Research Laboratory (PRL) is a national research institution in India that focuses on fundamental research in space and planetary sciences, astronomy, astrophysics, geosciences, and atmospheric sciences. It was founded in 1947 by Vikram Sarabhai, a renowned physicist and industrialist, who is widely regarded as the father of the Indian space program. PRL is located in Ahmedabad, Gujarat, and is a part of the Indian Space Research Organisation (ISRO).

The research activities at PRL are divided into five departments: Astronomy & Astrophysics, Planetary Sciences, Geosciences, Atmospheric Sciences, and Theoretical Physics. The Astronomy & Astrophysics department studies the origin and evolution of stars, galaxies, and the universe as a whole. The Planetary Sciences department focuses on the study of planets, asteroids, and comets in our solar system and beyond. The Geosciences department studies the Earth's crust, mantle, and core, and their interactions with the atmosphere and the biosphere. The Atmospheric Sciences department studies the physical and chemical processes that govern the Earth's atmosphere, including weather patterns, climate change, and air pollution. The Theoretical Physics department supports the other four departments by providing theoretical insights into the physical processes that underlie their research.

PRL has made significant contributions to the Indian space program over the years. In the 1960s, PRL played a key role in the design and development of India's first satellite, Aryabhata, which was launched in 1975. PRL has also contributed to the design and development of several other Indian satellites, including the Indian Remote Sensing (IRS) series, the Indian National Satellite (INSAT) series, and the Mars Orbiter Mission (MOM).

There are various instruments which were shown during our visit. These are used to get the age of the particular sample and its composition.

One of such lab contains a graphitization process which covers the sample with a graphite layer. This facility is used to prepare high-purity graphite samples for Radiocarbon measurements in the AMS. Can handle both organic samples (EA) and inorganic samples (CHS)

IRMS- Isotopic Ratio Mass Spectrometer Laboratory

Fig 7: IRMS- Isotopic Ratio Mass Spectrometer Laboratory

IRMS measures the isotopic ratios of elements in a sample, which can provide information about the sample's origin, age, and environmental conditions.

The IRMS laboratory is a specialized facility that houses the equipment and expertise needed to conduct these measurements. The laboratory typically consists of several key components, including a mass spectrometer, a gas chromatograph, and various sample preparation and analysis instruments.

The mass spectrometer is the heart of the IRMS laboratory. It is a highly sensitive instrument that measures the mass-to-charge ratio of ions in a sample. In IRMS, the mass spectrometer is used to measure the isotopic ratios of elements in a sample. Specifically, it measures the relative abundances of different isotopes of a given element, such as carbon-12 and carbon-13.

To prepare a sample for analysis in the mass spectrometer, it must first be converted into a gas. This is typically done using a gas chromatograph, which separates the different components of the sample based on their physical properties. The gas chromatograph is equipped with a special column that can separate the different isotopes of a given element, allowing them to be analyzed separately in the mass spectrometer.

In geology, IRMS is often used to date materials based on the isotopic ratios of certain elements. For example, researchers can analyze the isotopic ratios of carbon in organic materials like bones or wood to determine their age. This process, known as radiocarbon dating, relies on the fact that the ratio of carbon-14 to carbon-12 in a sample changes over time as the carbon-14 undergoes radioactive decay.

In addition to dating, IRMS can also provide information about the environmental conditions in which a sample was formed. For example, the isotopic ratios of oxygen in ice cores can provide information about past climate conditions, while the isotopic ratios of sulfur in rocks can provide insights into ancient ocean chemistry.

Electron Probe Micro Analyser (EPMA)

Fig 8 : Electron Probe Micro Analyser (EPMA)

Electron Probe Micro Analyser (EPMA) is an analytical tool that is used for the determination of the chemical composition of a sample by measuring the X-rays produced when a high-energy electron beam interacts with the sample. The EPMA can provide spatially resolved elemental maps and quantify the elemental composition of a sample with high accuracy and precision. This technique is used in a wide range of scientific fields, including geology, materials science, and environmental science.

Work with WDS technique and it works by bombarding of small sample analytical area by focused electron beam and collection of x-ray photons.

Principle:

The principle of EPMA is based on the interaction of high-energy electrons with a sample, which produces X-rays with a specific energy. When the electrons are accelerated towards the sample, they collide with the atoms in the sample, causing the emission of secondary electrons and X-rays. These X-rays are characteristic of the elements present in the sample and are used to determine the chemical composition of the material.

Instrumentation:

The EPMA consists of an electron gun that produces a beam of high-energy electrons. The electron beam is focused onto the sample using a series of electromagnetic lenses, and the X-rays produced by the interaction of the beam with the sample are collected using an energy-dispersive spectrometer (EDS) or wavelength-dispersive spectrometer (WDS). The EDS or WDS can be used to detect and quantify the X-rays produced by the sample, which are characteristic of the elements present in the material.

Applications:

EPMA has a wide range of applications in many scientific fields. In geology, EPMA is used to determine the mineral composition of rocks and soils. EPMA can provide spatially resolved elemental maps of rocks and minerals, which can be used to understand their formation and evolution. In materials science, EPMA is used to determine the composition of materials such as ceramics, metals, and polymers. This information can be used to optimize the properties of the material for specific applications. In environmental science, EPMA is used to determine the composition of pollutants in soil and water samples.

Laser Ablation - Inductively Coupled Plasma Mass Spectrometer (ICPMS)

Laser ablation-inductively coupled plasma mass spectrometry (LA-ICP-MS) is a powerful analytical technique that allows for the determination of elemental and isotopic composition of solid materials.

The technique involves the use of a laser to vaporize and ablate small amounts of a sample material, which is then carried by a stream of inert gas into an inductively coupled plasma (ICP). The ICP is a high-temperature plasma generated by an electrical discharge, which ionizes the sample vapor and creates a plasma of ions and electrons.

The ions produced in the ICP are then analyzed by a mass spectrometer, which separates them according to their mass-to-charge ratio and detects them using a detector. By measuring the isotopic and elemental composition of the ions produced in the ICP, LA-ICP-MS can provide precise and accurate measurements of the chemical composition of the sample material.

LA-ICP-MS has a wide range of applications, including geological studies, environmental analysis, forensic investigations, and material science. It can be used to analyze a wide range of solid materials, including rocks, minerals, metals, and biological tissues. The technique is particularly useful for analyzing samples with complex matrices or low concentrations of elements, as it allows for the detection of trace elements and isotopes at very low levels.

Day 3

Balasinor

Fig 9: Dinosaur park, Rayoli

Dinosaur Park, Rayoli Balanisor is a paleontological park located in the Indian state of Gujarat. The park is known for its impressive collection of dinosaur fossils and replicas, as well as for its efforts to educate visitors about the prehistoric world and the importance of conservation.

The park is situated in the Balasinor region of Gujarat, which is known for its rich deposits of dinosaur fossils. The region was once part of a large floodplain that existed during the Late Cretaceous period, about 65 million years ago. The floodplain was home to a variety of dinosaurs, including sauropods, theropods, and ornithopods, whose fossils have been found in the region.

The dinosaur park covers an area of about 72 acres and contains several attractions for visitors. One of the main attractions is the Dinosaur Fossil Park, which is a collection of fossils that have been excavated from the region. The park contains several fossil sites, each of which represents a different period in the region's history. Visitors can see fossils of dinosaur bones, teeth, and footprints, as well as fossils of other prehistoric animals and plants.

Another attraction at the park is the Dinosaur Museum, which houses a collection of dinosaur replicas and models. The museum contains life-sized models of several dinosaur species, including the Tyrannosaurus rex, Stegosaurus, Triceratops, and many others. The models are displayed in various poses, such as feeding, fighting, and resting, and are accompanied by information about the dinosaur's anatomy, behavior, and habitat

In Rayoli Balasinor, several types of dinosaur fossils have been discovered, including:

1. Rajasaurus: a large carnivorous dinosaur that lived during the Late Cretaceous period, about 70 million years ago.
2. Titanosaur: a group of long-necked herbivorous dinosaurs that lived during the Late Cretaceous period.
3. Abelisaurids: a group of carnivorous dinosaurs that lived during the Late Cretaceous period, and are known for their short arms and powerful jaws.
4. Stegosaurids: a group of herbivorous dinosaurs that had distinctive bony plates on their backs and spiked tails. They lived during the Late Jurassic and Early Cretaceous periods.
5. Sauropods: a group of long-necked herbivorous dinosaurs that lived during the Jurassic and Cretaceous periods. They were among the largest land animals that ever lived.

Day 4

ONGC GGS MONTERA

Oil and Natural Gas Corporation Limited (ONGC) is an Indian multinational oil and gas company. It is one of the largest companies in India and is responsible for producing 70% of India's crude oil and natural gas. ONGC GGS Motera is one of its most important production facilities, located in Gujarat, India.

ONGC GGS Motera is a gas gathering station that processes natural gas from the Cambay Basin. It is located near Ahmedabad in the Indian state of Gujarat. The gas gathering station is a part of the Ahmedabad Asset of ONGC, which includes 10 other oil and gas fields.

The Cambay Basin is one of the oldest sedimentary basins in India and is located in the western part of the country. The basin is known for its rich reserves of oil and gas. The gas produced from the basin is rich in methane, making it suitable for industrial and domestic use.

ONGC GGS Motera was commissioned in 1997 and has a processing capacity of 7 million cubic meters per day (mcmd). The gas gathering station is designed to process natural gas from several oil and gas fields in the region, including the North Kathana and South Kathana fields. The gas produced from these fields is transported to the GGS Motera facility through pipelines.

The gas processing facility at ONGC GGS Motera consists of several components, including gas dehydration units, gas sweetening units, gas compressors, bath heater and storage tanks. The gas produced from the fields is first dehydrated to remove any moisture present in it. The gas is then sweetened to remove impurities such as hydrogen sulfide and carbon dioxide. The sweetened gas is compressed and stored in storage tanks before it is transported to customers through pipelines.

Compressors are used to increase the pressure of natural gas, which allows it to be transported efficiently through pipelines. They use a 2nd stage compressor in this facility that had been recently upgraded due to efficiency.

Bath heater

The bath heater operates by heating the fluid in a bath of hot oil or glycol, which is then circulated through a heat exchanger. The heat from the hot oil or glycol is transferred to the hydrocarbon fluid, increasing its temperature to the required level. The heated fluid is then transported through the pipeline to the destination.

Bath heaters are crucial for maintaining the fluid's viscosity and reducing its density, making it easier to transport. In addition, heating the fluid also reduces the risk of damage to the pipeline, as it prevents the formation of hydrates, which can cause blockages and damage to the pipeline.

Overall, the function of the bath heater in ONGC is to ensure that the crude oil and natural gas are transported efficiently and safely by heating them to the appropriate temperature, thus preventing any issues that may arise from the fluid's low temperature during transportation.

Water injection plant

Water injection is a secondary recovery technique used in the oil and gas industry to increase the production rate of hydrocarbons. In an oil reservoir, there is a natural pressure gradient that helps to push the oil and gas towards the production wells. However, over time, this pressure gradient can decrease, and the production rate can decline. To counter this, water injection plants are used in ONGC to inject water into the reservoir to maintain the pressure gradient and increase the production rate of hydrocarbons. The water is injected into the reservoir through injection wells that are drilled specifically for this purpose.

The injected water helps to displace the oil and gas towards the production wells, where it can be extracted. The water injection plant also helps to increase the recovery factor of the reservoir by pushing out more oil and gas than would otherwise be recoverable through natural production methods.

Overall, the function of a water injection plant in ONGC is to enhance the production rate and recovery factor of an oil reservoir by maintaining the pressure gradient and displacing hydrocarbons towards the production wells.

Test separator

The function of a test separator in ONGC is to separate the mixture of fluids that are produced from the well during the testing process. The test separator is designed to separate the oil, gas, and water, and measure the flow rate and properties of each fluid separately. This allows ONGC to accurately determine the amount of oil, gas, and water that can be produced from the well.

In addition to separating the fluids, the test separator may also be used to measure the pressure and temperature of the fluids, which are important parameters for determining the properties and potential production of the well. The test separator is a critical piece of equipment in well testing operations, and its accurate operation is essential for determining the viability and productivity of a well.

ONGC GGS Motera is a critical facility for ONGC's operations in the region. The gas produced from the fields in the region is transported to the facility, where it is processed and made ready for distribution to customers. The facility also plays a critical role in the production of natural gas, which is an essential fuel for industries and households in India.

Geology of Rajasthan

Rajasthan is endowed with a continuous geological sequence of rocks from the oldest Archaean Metamorphic, represented by Bhilwara Supergroup (>2500 m. y.) to sub-recent alluvium & wind blown

Sand.

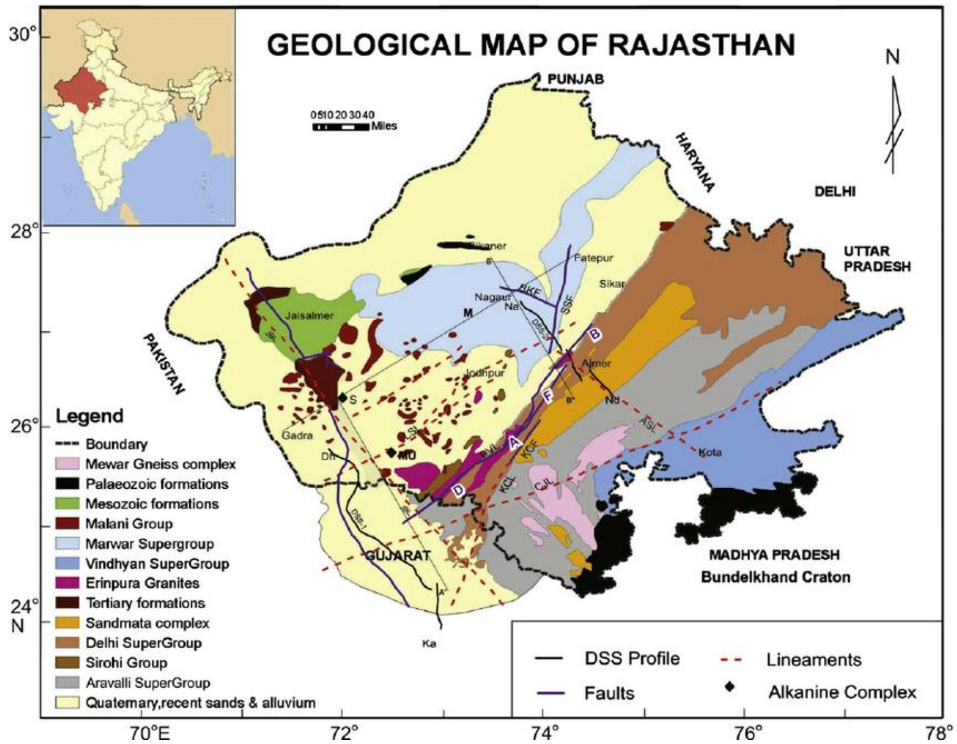

Fig 10: geological map of Rajasthan

The geological sequence of the state is highly varied and complex, revealing the co-existence of the most ancient rocks of the Pre-Cambrian age and the most recent alluvium as well as windblown sand. 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 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.

GEOLOGY

- **Archaean**
  - BHILWARA SUPERGROUP
    - Sand Mata Complex, Mangalwar Complex, Hindoli Group
- **Proterozoic**
  - BHILWARA SUPERGROUP
    - Rajpura-Dariba Group, Pur-Banera Group, Jahazpur Group, Sawar Group; Ranthambor Group
  - ARAVALLI SUPERGROUP
    - Debari Group, Udaipur Group, Bari Lake Group, Kankroli Group; Jharol Group, Dovda Group, Nathdwara Group; Lunavada Group
  - DELHI SUPERGROUP
    - Railo Group; Alwar Group, Ajabgarh Group, Gogunda Group, Kumbhalgarh Group, Sirohi Group; Punagarh Group, Sindreth Group
  - VINDHYAN SUPERGROUP
    - Lower Vindhyan Group, Upper Vindhyan Group
  - MALANI IGNEOUS SUITE
  - MARWAR SUPERGROUP
    - Jodhpur Group, Bilara Group, Nagaur Group
- **Palaeozoic**
- **Mesozoic and Cenozoic**
  - Deccan Traps; Tertiary Alkaline Complex; Sedimentaries; Quaternary

Fig 11: Stratigraphy and age

The isolated hillocks of western Rajasthan constitute the Upper Proterozoic Malani Igneous Suite and the Erinpura Granite pluton. Eastern Rajasthan is characterized by the vast sedimentary stretch constituting the Vindhyans, which is juxtaposed against the rocks of the Bhilwara Supergroup along the Great Boundary Fault.

The northern and north-western parts of the State exhibit Upper Proterozoic-Early Cambrian rocks of the Marwar Supergroup which are overlain by sedimentary rocks of different ages of Palaeozoic and Mesozoic Era. Many industrial mineral deposits are found in these rocks. The Deccan Traps are restricted to the south-eastern part of the State in Chittaurgarh-Banswara area.

The Cenozoic rocks are manifested in Barmer and Jaisalmer basins in the west and Ganganagar-Palana shelf in the north. The Quaternary sediments of aeolian and fluvial origin constitute the Thar Desert of Rajasthan.

Day 6

Spot 1:

Jhamarkotra Opencast Mine

Fig 12: Jhamarkotra Opencast Mine

Jhamarkotra Opencast Mine is a large phosphate rock mine located in the Udaipur district of Rajasthan, India. It is one of the largest open-pit phosphate mines in the world, with an estimated reserve of over 150 million tonnes of rock. The mine is operated by the Rajasthan State Mines and Minerals Limited (RSMML), a state-owned mining company.

The Jhamarkotra mine was discovered in 1968, and commercial mining operations began in 1983. The mine is located in the Aravalli Range, which is known for its rich mineral deposits. The phosphate rock extracted from the mine is used to produce fertilizers, which are essential for agriculture.The Jhamarkotra mine is an open-pit mine, which means that the phosphate rock is extracted from an open quarry.

Geological Setting:

Jhamarkotra phosphate deposit is hosted by the sedimentary rocks of the Proterozoic Aravalli Supergroup. The Aravalli Supergroup consists of a sequence of sedimentary and volcanic rocks that were deposited in a rift basin during the late Archean to early Proterozoic period. The sedimentary rocks of the Aravalli Supergroup are divided into three distinct units, namely, the Lower Aravalli, Middle Aravalli, and Upper Aravalli. The phosphate deposit at Jhamarkotra is hosted by the Upper Aravalli sedimentary rocks.

The Upper Aravalli rocks consist of a sequence of shale, quartzite, and limestone interbedded with dolomitic limestone and calcareous sandstone. The phosphate deposit is restricted to the dolomitic limestone unit, which is about 15-20 m thick and is overlain by calcareous sandstone. The dolomitic limestone is mainly composed of dolomite with minor amounts of calcite, quartz, and clay minerals

Fig 13 Blue green algae in dark layer in phosphate rock

The Jhamarkotra phosphate deposit is a stratiform deposit, which means that it occurs in layers or strata within the host rocks. The deposit consists of a series of horizontally bedded phosphorite layers, which are interbedded with shale, chert, and dolomite. The thickness of the phosphorite layers varies from a few centimeters to several meters.

The Jhamarkotra opencast mine has been developed on a series of parallel ridges that are oriented in a northeast-southwest direction. The ridges are separated by narrow valleys that are filled with sedimentary rocks of the Bhilwara Group. The ridges are up to 30 meters high and have a gentle slope of about 10 degrees.

The mining operation at Jhamarkotra involves the use of large-scale earth-moving equipment, such as excavators, bulldozers, and haul trucks. The overburden, which is the layer of soil and rock covering the phosphate deposit, is removed using excavators and bulldozers. The phosphate ore is then extracted using surface miners, which are specialized machines that can cut and crush the phosphate rock in situ.

Spot 2:
Jhameshwar mahadev temple, Jhamarkotra

Fi 14: Stalactites

Here we can observe stalactites that are rock formations that hang from the ceiling of a cave and are formed over thousands of years due to the slow dripping of water containing minerals. The Jhameshwar Mahadev Temple is situated inside one such cave that is made up of stalactites. The stalactites in the cave have formed intricate shapes over the centuries, creating a natural architectural wonder.

Day 7

Spot 1:

Chittor

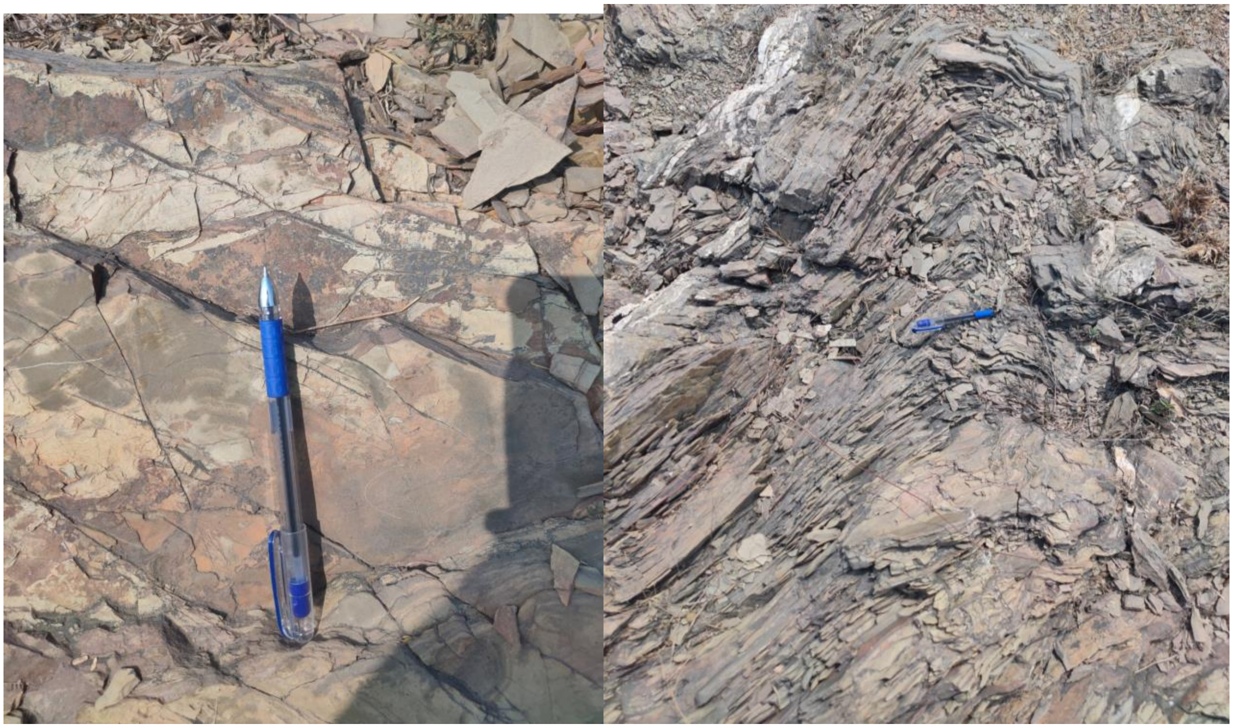

Fig 15: Suket shale can be seen in folded strata

The rocks found in Chittorgarh are primarily sedimentary rocks, which are formed by the accumulation and consolidation of sediment over time. The region is characterized by a series of hills and valleys, and the rocks found here are primarily sandstones, shales, and limestones.

The Chittorgarh district is part of the Aravalli mountain range, which is one of the oldest mountain ranges in the world. The Aravalli range stretches across Rajasthan, Gujarat, and Haryana, and is estimated to be over 350 million years old. The mountain range was formed as a result of tectonic activity during the Precambrian era, when the Indian subcontinent collided with the Eurasian Plate. This spot was located on the banks of the Berach river, this river was parallel to the strike direction of the rocks that were found on its banks. Readings are given below and are taken perpendicular to the river.

Site	Strike direction	Dip direction	Dip amount
A	N40°	N130°	60°
B	N40°	N149°	64°
C	N39°	N132°	53°
D	N42°	N136°	44°
E	N57°	N153°	41°

Fig 16: Multiple degree of folding

The rocks were folded signifying that there was a tectonic disturbance. This event has occurred multiple times and due to which second generation folds can be seen. Also, quartz veins had been intruded in these rocks having thickness of a few millimeters to a centimeter. But there was a case that this vein was also getting folded along with the rock and through the already folded rock, indicating that these rocks at that time were in the process of orogenic activity that can be seen throughout the topography of the area. Also it was located in the Aravalli mountain ranges.

Fold	Strike direction	Dip direction	Dip amount
Limb 1	N53°	N141°	36°
Limb 2	N205°	N295°	64°

The shale contains a high percentage of organic matter, which is responsible for the dark color of the rock. The thickness of Suket Shale varies across the region, with some areas showing a thickness of up to 1500 meters. The shale is generally overlain by sandstones and conglomerates of the Vindhyan Supergroup within Simdri group and underlain by the Aravalli Supergroup.

Spot 2

Nimbara limestone

This rock type is located on the banks of river Gambiri. Nimbara limestone is formed from the remains of marine organisms that lived in shallow seas that covered the region during the Mesozoic Era, around 66 to 252 million years ago. The limestone is primarily made up of calcium carbonate, which has accumulated over millions of years through the process of sedimentation and compaction.

Nimbara limestone is a fine-grained rock that ranges in color from light beige to dark brown. It has a high density and is known for its hardness and durability. The rock is composed of fossilized marine organisms, such as corals, mollusks, and foraminifera, which give it a unique texture and pattern.

Day 8

Upli odan marble quarry

Fig 17:Marble quarry

The marble deposits at Upli Odan are part of the Aravalli Supergroup, which is a large sequence of rocks that extends across several states in India. The Aravalli Supergroup was deposited during the Proterozoic era and consists of a variety of sedimentary and volcanic rocks, including limestone, dolomite, quartzite, and marble. The marble at Upli Odan is part of the Bhilwara Formation, which is a unit of dolomite and marble interbedded with phyllites, schists, and quartzites.

The marble at Upli Odan is known for its purity, whiteness, and fine-grained texture. It is composed of calcite, which is a mineral that forms from the precipitation of calcium carbonate from seawater. The purity of the marble is due to the absence of impurities, such as clay, silt, and sand, during the deposition of the Bhilwara Formation. The whiteness of the marble is due to the absence of iron oxide, which gives other marbles a yellow or red color. The fine-grained texture of the marble is due to the recrystallization of the original calcite crystals during metamorphism.

Fig 17: Actinolite crystal below the coin

Structural data acquired showed a large scale fold on this rock bed. This data was acquired on both the ends of the exposed marble, distance between the ends was around 50m. Is some part of the rock there was actinolite crystals present'

Site	Strike direction	Dip direction	Dip amount
A	N144°	N237°	27°
B	N139°	N227°	34°

References

Majumdar, T.. (2013). Geomorphological characteristics identification from remote sensing along with surface temperature anomaly and SAR interferometry–related studies and their correlation with earthquake occurrences in Gujarat. Natural Hazards. 69. 10.1007/s11069-013-0731-x.

https://www.rajras.in/rajasthan/geography/geology/

Kilaru, Suman & Goud, Dr & Rao, V.. (2013). Paper.

https://minedocs.com/20/Report_Rajasthan_State_Geology_Mineral_Maps_Geological_Survey_India_2011.pdf

https://www.guj-nwrws.gujarat.gov.in/showpage.aspx?contentid=1459&lang=English