SCHOOL OF EARTH, OCEAN AND ATMOSPHERIC SCIENCES

M.SC. PART II APPLIED GEOLOGY

GOA UNIVERSITY

TALEIGAO, Goa 403206

Exam

Roll No.:21P045018

CERTIFICATE

This is to certify that Mr. Soumya P. Parab has satisfactorily completed the course of field work for M.Sc. in Applied Geology.

Experiments conducted are pertaining to paper GLC-122 Geological Field Training. Practical prescribed by the University for Part II class, during the academic year 2022-2023.

Faculty members in-charge

DEAN

SEOAS

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

GEOLOGICAL FIELD REPORT

ON

GUJARAT AND RAJASTHAN

GOA UNIVERSITY

BY

SOUMYA PARAB

20P045018

STUDENT OF SCHOOL OF EARTH, OCEAN AND ATMOSPHERIC SCIENCES

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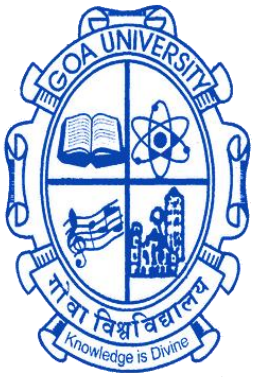

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ACKNOWLEDMENT

I would like to express my gratitude to all those who helped me through my field trip and to complete my field trip report successfully.

I am very grateful to my vice-Dean of Earth Science Dr.Anthony Arthur A. Viegas for allowing me to be part of this field trip and entire School Of Earth, Ocean and Atmospheric Sciences for all its support.

I express my huge gratitude to my teachers Dr. Anthony Viegas, Dr. Niyati Kalangutkar, Mahesh Mayekar and miss Pooja Ghadi from department of Applied Geology of Goa University, for guiding me throughout the field trip and helping me in every way possible to make it a success.

I am very thankful and appreciative of the Laboratory Assistants for providing us with all the necessary equipment required for my field trip.

A special thanks to all he pupils that I had the pleasure to be associated with me and my colleagues at various institutes such as ONGC, Physical Research Laboratory (PRL) and, Jhamarkotra Mine, for giving us vivid information about their respective firms.

Last but not the list i would like to thank all my classmates for the help they have provided and my family for their constant love and support.

INDEX

Introduction

Geology (from Ancient Greek(ge) 'earth', and (logia) 'study of, discourse') is a branch of natural science concerned with Earth and other astronomical objects, the rocks of which it is composed, and the processes by which they change over time. Modern geology significantly overlaps all other Earth sciences, including hydrology. It is integrated with Earth system science and planetary science.

Geology describes the structure of the Earth on and beneath its surface, and the processes that have shaped that structure. Geologists study the mineralogical composition of rocks in order to get insight into their history of formation. Geology determines the relative ages of rocks found at a given location; geochemistry (a branch of geology) determines their absolute ages. By combining various petro logical, crystallographic and paleontological tools, geologists are able to chronicle the geological history of the Earth as a whole. One aspect is to demonstrate the age of the Earth. Geology provides evidence for plate tectonics, the evolutionary history of life, and the Earth's past climates.

Geologists broadly study the properties and processes of Earth and other terrestrial planets. Geologists use a wide variety of methods to understand the Earth's structure and evolution, including field work, rock description, geophysical techniques, chemical analysis, physical experiments, and numerical modeling. In practical terms, geology is important for mineral and hydrocarbon exploration and exploitation, evaluating water resources, understanding natural hazards, the remediation of environmental problems, and providing insights into past climate change. Geology is a major academic discipline, and it is central to geological engineering and plays an important role in geotechnical engineering.

Geology of India

India's geography is diverse. Various locations of India include rocks from various geologic periods, dating back to the Eoarchean Age. Several of the rocks have been significantly distorted and changed. Additional deposits include newly deposited alluvium that has still not gone through diagenesis. Mineral deposits of various types can be found in abundance throughout the Indian subcontinent. Even India's fossil record, which includes stromatolites, invertebrates, animals, and plant fossils, is astounding. India's geographical area of land is divided into three parts: the Deccan Traps, Gondwana, and Vindhyan.

The Deccan Traps cover practically the whole state of Maharashtra, as well as a small portion of Gujarat, Karnataka, Madhya Pradesh, and Andhra Pradesh. After breaking away from the rest of Gondwana, the Indian Plate travelled over a geologic hotspot, the Réunion hotspot, which triggered widespread melting beneath the Indian Craton.The melting broke through the craton's surface in a gigantic flood basalt event, forming the Deccan Traps. It is also believed that the Reunion hotspot triggered the split of Madagascar and India. The Gondwana and Vindhyan include within its fold parts of Madhya Pradesh, Chhattisgarh, Odisha, Bihar, Jharkhand, West Bengal, Andhra Pradesh, Maharashtra, Jammu and Kashmir, Punjab, Himachal Pradesh, Rajasthan and Uttarakhand. The Gondwana sediments form a, unique sequence of fluviatile rocks deposited in Perm Carboniferous time. The Damodar and Sone River valleys along with Rajmahal hills in eastern India, Contain a record of the Gondwana rocks.

The Indian Craton was originally a part of the Pangaea supercontinent. At the period, India's south west coast was connected to Madagascar and southern Africa, while its east coast was connected to Australia. Rifting led Pangaea to split into two supercontinents, Gondwana (to the south) and Laurasia (to the north), around 160 million years ago (to the north). The Indian Craton remained connected to Gondwana until the supercontinent began to break apart around 125 million 5 years ago (ICS2004). The Indian Plate then moved northward towards the Eurasian Plate at the fastest known rate of any plate. The Indian Craton was originally a part of the Pangaea supercontinent. At the period, India's south west coast was connected to Madagascar and southern Africa, while its east coast was connected to Australia. Rifting led Pangaea to split into two supercontinents, Gondwana (to the south) and Laurasia (to the north), around 160 million years ago (to the north). The Indian Craton remained connected to Gondwana until the supercontinent began to break apart around 125 million 5 years ago (ICS2004). The Indian Plate then moved northward towards the Eurasian Plate at the fastest known rate of any plate. The Himalaya Ranges and the Tibetan Plateau in South Asia were formed by the closure of this ocean, which generated the Alps in Europe and the Caucasus range in western Asia. Parts of the Asian continent are deforming westward and eastward on each side of the orogen due to the current orogenic event. Simultaneously with this collision, the Indian Plates ruptured onto the neighboring Australian Plate, forming the Indo-Australian Plate, a new bigger plate. The Archaean Period (prior to 2.5 billion years ago) was distinguished by the cooling and solidification of the earth's upper crust, which is reflected by the exposure of gneisses and granites, particularly on the Peninsula. The Aravalli Range is a remnant of the Aravali Delhi Orogen, an early

Proterozoic orogeny that linked the two older portions of the Indian Craton. It stretches for almost 500 kilometers from its northern end to lonely hills and rocky ridges in Haryana before concluding near Delhi.

The Himalayas contain early Paleozoic rocks composed of southerly derived material eroded from the crystalline craton and deposited on the Indian platform. As Pangea began to split apart during the Jurassic, massive grabens occurred in central India, filling with Upper Jurassic and Lower Cretaceous sandstones and conglomerates. By the Late Cretaceous, India had split from Australia and Africa and was making its way northward towards Asia. Before the Deccan eruptions, uplift in southern India caused the nearby Indian Ocean to become sedimented at this time. These rocks are exposed in Tamil Nadu and in the southern Indian coastal region of Pondicherry. The Deccan lava flows, one of the largest volcanic activities in earth history, occurred at the end of the Mesozoic. The sea, which spans an extent of much more than 500,000 sq . kms, represents the last break from Gondwana.

Figure No. 01: Geological map of India

Geology of Gujarat

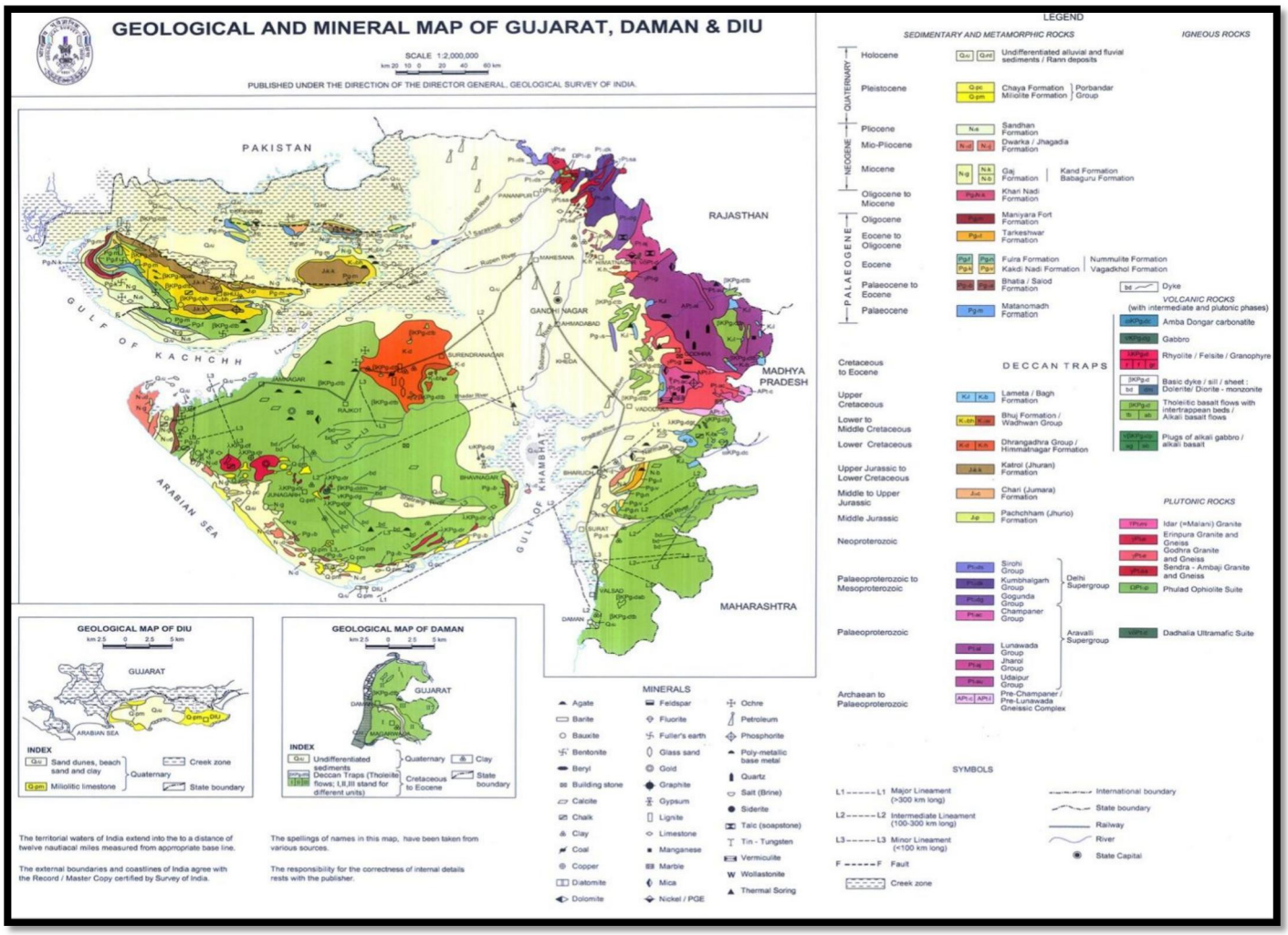

Figure no.2: Geological map of Gujarat, India

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: ignious, sedimentary, and metamorphic.

Geology controls the features of the land-mass and is well marked by dividing Gujarat state physiographically into the following three distinct geographical units: (a) Main land Gujarat, (b) Peninsular Gujarat (the Saurashtra), and (c) Kutch.

(a) Main land Gujarat: The well-known and agriculturally productive alluvial basin of Gujarat runs 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. Its width is about 121 kilometres. 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 morphology as a result of the differential weathering of horizontal lava flows.

(b) (b) Peninsular Gujarat (the Saurashtra): 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 emerges 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 gradually towards the peninsular boundary before blending into the coastal lowlands. Seashore sedimentary rocks resemble a low, level land.

(c) Kutch: The Gulf of Kutch, the Great Rann to the south, the Little Rann to the southeast, and the Arabian Sea to the southwest isolate the Kutch mainland, giving the area its name. The middle portion of Kutch is a table-land with slopes on all 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 is made up of quite decent soil and was created by sediments deposited along the northern edge of the main land. The Rann is a dry bed remnant of a sea arm that formerly connected Sind to the Narmada rift and divided Kutch from the rest of the mainland.

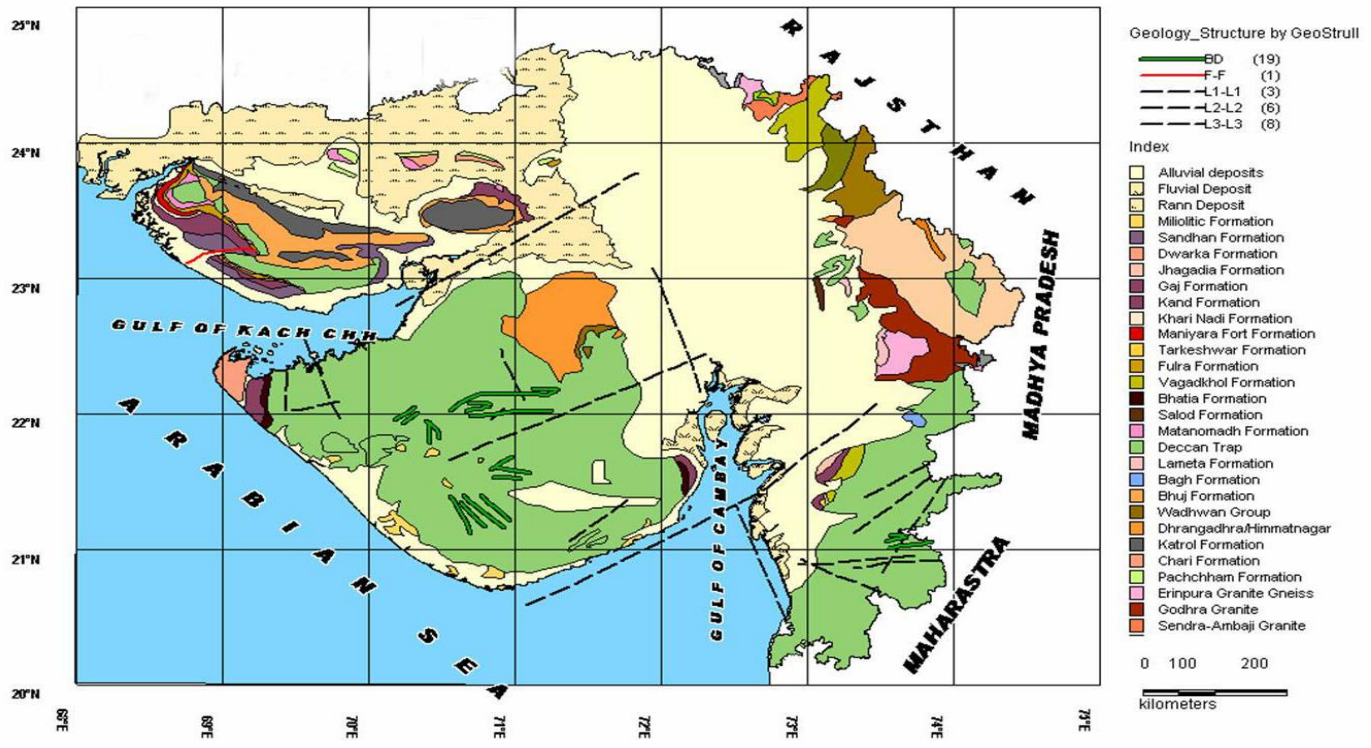

Figure no. 3

Figure No. 4: **Litho-Stratigraphic Table of Gujarat Region**

Era	Period	Epoch	Super group/ Formation	Locality	Age in Million Years
CENOZOIC	QUTAERNARY	HOLOCENE	Undifferentiated sediments/Rann deposits	Alluvial plains of Gujarat, Rann, Banni & Coastal deposits	0.01
		PLEISTOCENE	Chhaya formations/ Miliolite formation	(1)Saurastra coast from Gopnath northwards extending beyond Porbandar	1
				(2)Kachchh area	
	TERTIARY	PLIOCENE	Sandhan Formation		
		MIO-PLIOCENE	Dwarka Formation Jhagadia Formation	Dwarka Okha Jhagadia	12
		MIOCENE	Gaj Formation Kand Formation Babaguru Formation	Piram Island,Saurastra coast,Kachchh Jhagadia,Kand near Ankaleswar	25
		OLIGOCENE	Maniara Fort Formation	Kachchh	40
		OLIGOCENE-MIOCENE	Kharinadi Formation	Kachchh	
		EOCENE-OLIGOCENE	Tarkeswar Formation	Tarkeswar (Surat dist.)	
		EOCENE	Fulra Formation Kakadinadi Formation Nummulitic Formation Vagadkhol Formation	Kachchh	60
		PALEOCENE-EOCENE	Bhatia Formation Salod Formation	Jamnagar Bharuch,Surat,Valsad, KhedaSabarkantha, Kachchh, Saurastra	
		PALEOCENE	Matanomadh Formation	Kachchh	
MESOZOIC-CENOZOIC		CRETACEO-EOCENE	Deccan Trap	Parts of Sabarkantha, Panchmahals, Vadodara, Bharuch, Surat & Major parts of Valsad and Dangs, Major parts of Saurastra, Small parts of Kachchh	110
MESOZOIC		UPPER CRETACEOUS	Lameta Formation Bagh Formation	Kheda,Panchmahal,Narmada,Sabarkantha, Vadodara	
		LOWER-MIDDLE CRETACEOUS	Wadhavan Group	Saurastra	
			Bhuj Formation	Kachchh	
			Dhrangadhra Group	Saurastra	
		LOWER CRETACEOUS	Himmatnagar Formation	Sabarkantha	
		JURASSIC CRETACEOUS	Katrol (Jhuran) Formation	Kachchh	150
		UPPER JURASSIC	Chari (Jumaran) Formation		
		MIDDLE JURASSIC	Pachchham (Jhurio) Formation		
PROTERO-ZOIC		NEOPROTEROZOIC	Syn-to-Post Delhi intrusives	Palnpur,Danta,Ider,Modasa, Taranga, Dharoi,Virpur, Wanakbori,Godhara	
		PALEO-MESO-PROTEROZOIC (Delhi Super group)	Sirohi Group	Banaskantha	1500
			Kumbhalgarh Group	Danta,Ambaji,Palanpur	
			Gogunda Group	Khedbrahma,Shamalaji	
		PALAEO-PROTEROZOIC (Aravalli Super group)	Champaner Group	Chhotaudaipur,Shivrajpur, Jambughoda	
			Lunavada Group	Modasa,Shamlaji,Lunavada, Baria	
			Jharol Group	Modasa,Shamalaji	
			Udaipur Group	Northen parts of Gujarat	
ARCHAEAN PROTERO-ZOIC			Pre-Lunavada Gneissic Complex	Kanjeta-Nadatod,Chhotaudaipur	4000
			Pre-Champaner Gneissic Complex	Jetpur,Sabarkantha,Panchm-ahal,Banaskantha,Vadodara	

Geology of Rajasthan

Rajasthan makes up the Indian Shield's northwesterly portion. The State exposes numerous lithological and tectonic units with ages ranging from the Archaean to the Recent. Let's first look at geology in general to understand concepts in geology before delving into the specifics of the geology of Rajasthan. A uninterrupted geological series of rocks from the oldest Archaean Metamorphic, exhibited by the Bhilwara Super-group (>2500 million years ago), to more recent alluvium and wind-blown sand exists in Rajasthan. The state's geological sequence reveals the coexistence of the oldest rocks, from the Pre-Cambrian epoch, along with the most recent alluvium as well as wind-blown sand. The Sandmata Complex, Mangalwar Complex, and Hindoli Group of the Bhilwara Super group are the basement rocks that make up the central and southern plains. Their main composition is granulite-gneiss, amphibolites, metapelite, paragneiss, calc-silicate rocks, greywacke (the older granite-greenstone belt), and metavolcanic, met greywacke (the younger granite-greenstone belt). They are Archaean in age.

Several lead, zinc, and copper deposits are identified in the lower Proterozoic supracrustal rocks of the Bhilwara Super-Jahajpur, group's Rajpura-Dariba, Pur-Banera, and Sawar Groups, which rest on the basement rocks of the Mangalwar Complex. The Aravalli fold belt (Aravalli Super-group) as well as the Delhi fold belt (Delhi Super-group) occupy the southern and south-eastern, and southwestern and north-eastern, Rajasthan, respectively. The Aravalli Super-group is represented by metamorphosed and complexly folded clastic sediments with minor chemogenic and organogenic assemblages with interlay red basic volcanic, whereas the Delhi Super group comprises mainly carbonates, metavolcanics, metasammites and metapelite, intruded by magmatic rock of Phulad Ophiolite Suite and syn-orogenic granites of Sendra-Ambaji, Baraith, Dadikar, Harsora, etc. These belts contain a number of basic metal deposits as well as other minerals.

The Upper Proterozoic Malani Igneous Suite and the Erinpura Granite pluton are made up of solitary hillocks in western Rajasthan. The massive sedimentary stretch known as the Vindhyan is juxtaposed against the rocks of the Bhilwara Supergroup along the Great Boundary Fault in eastern Rajasthan. The northern and northwestern regions of the state contain Upper Proterozoic-Early Cambrian Marwar Supergroup rocks that are overlain by Mesozoic and Paleozoic Period sedimentary rocks. These rocks include a large number of industrial mineral resources.

The Deccan Traps are only found in the south-eastern region of the state, near Chittorgarh and Banswara. Cenozoic rocks can be found in the Barmer and Jaisalmer basins in the west and on the GanganagarPalana shelf in the north. Rajasthan's Thar Desert is made up of Quaternary deposits of aeolian and river origin.

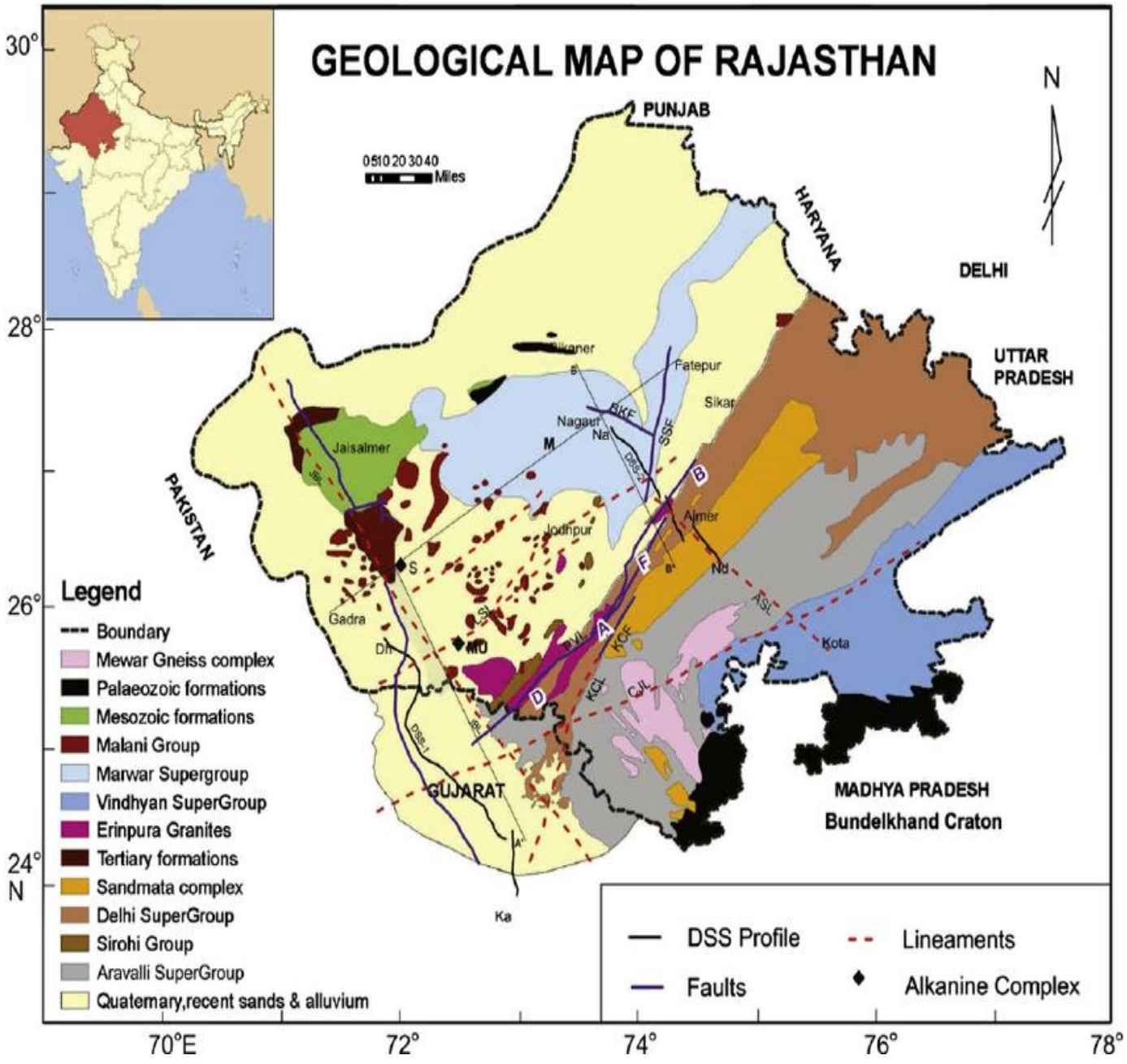

Figure no.5: Geological map of Rajasthan

Field visit: Day:01

Date: 22nd January 2023 | Sunday

Lothal: Archaeological Remain Of A Harappan Port-Town

Latitude: 22° 31’ 18” N

Longitude: 72° 14’ 58” E

Lothal, one of the most mesmerizing remnants of Harappan civilisation, is an ancient mound excavated by Prof. S.R.Rao which unearthed several remains of Harappan town datable to circa 2500-1900 B.C with area of 64752 square meters. Lothal lies on the eastern flank of the Kathiawar Peninsula, which is part of the Saurashtra Block. The Saurashtra Block is a tectonic block that is part of the Indian subcontinent, surrounded to the west by the Arabian Sea and to the east by the Indian mainland. The geology of the Saurashtra Block is complicated, with a wide range of sedimentary and metamorphic rocks present.

The entire settlement was divided into Acropolis and Lower town, protected by mud brick wall, with all amenities including drains and portable water. The Lower town was subdivided into commercial centre and residential sector. A cemetery and the most vivid remain is a large tank identified as dock and a warehouse located at southwest of citadel, was scientifically designed and constructed of fine burnt bricks to withstand current and water thrust, known for its water locking device. The excavations at Lothal Yielded a variety of articles including beads, seals, shells, ivory, copper and bronze, tools, animal and human figurines, weights, etc. Prosperity of this town largely depended on its overseas trade of items where discovery of objects of Persian Gulf origin and terracotta figurines of gorilla and mummy indicate a strong overseas contact. As suggested by Prof. Rao Lothal which was primarily known as port, the modern silted creek extending up to Lothal depicted the ancient river used by Harappan people. Where creek joins the river Bhogavo towards south but can be seen today only as far as Saragwala, south of Lothal.

World's major ancient civilizations flourished near river banks and deltaic sea coasts. The reason behind is the easy availability of water, a vital requirement of human beings. However, this choice of sites with easily available water has also cost dear to them. The change of river courses and sea level fluctuations led to the devastation of well-established civilizations. The existence of foraminifera is very essential in understanding Lothal's geological history. Foraminifera are microscopic sea creatures that secrete a calcareous shell and are frequently employed as bioindicators in paleoenvironmental investigations. The foraminifera discovered in Lothal indicate that the area was formerly a marine environment, with the Indus River delta close.

The above information helped me analyse and understand the historical and scientific significance of the Indus valley civilization along with human-environment interaction.

Figure no. 6: Pot Furnace

Figure no. 7: Bead Factory

Figure no. 8:

Figure no. 09: Well in

Figure No. 10: Drainage system

Field visit: Day:02

Date: 23rd January 2023 | Monday

Physical Research Laboratory

Latitude: 23°02′8″N

Longitude: 72°32′33″E

The Physical Research Laboratory is a National Research Institute for space and allied sciences, primarily funded by the Government of India's Department of Space. PRL conducts fundamental research in a variety of fields, including physics, space and atmospheric sciences, astronomy, astrophysics and solar physics, and planetary and geosciences. Dr. Vikram Sarabhai established the Physical Research Laboratory on November 11, 1947. The laboratory began modestly at his home, with studies on cosmic rays. The Geosciences Division of India's Physical Research Laboratory (PRL) is a major scientific organization devoted to the study of the earth and its different components. It is one of the country's largest and most prominent institutions dedicated to geosciences. The PRL Geosciences Division, based in Ahmedabad, Gujarat, has been critical in furthering our understanding of the earth's structure, composition, and dynamics. The division is home to a group of highly skilled and experienced researchers who study on a variety of earth science topics such as seismology, geodynamics, geodesy, atmospheric science, oceanography, and paleo-climate.

Dr. Sanjeev Kumar (Geo-science Professor) explained us the focus of the research lab and briefly told about the working of the laboratory. The Geosciences Division of PRL has a wide range of research facilities and state-of-the-art equipment that are used to conduct cutting-edge research. We thank the faculty for guiding us around the labs of the PRL.

- **MC-ICPMS:** The term "multi-collector inductively coupled plasma mass spectrometry" refers to a powerful analytical technology utilised for high accuracy isotopic analysis of a variety of elements. MC-ICPMS is a highly sensitive and precise analytical technique utilised in a variety of applications ranging from examining the geochemistry of rocks to evaluating trace elements in biological materials.

  Working of MC-ICPMS:

  1. Sample introduction: A small amount of sample material is introduced into an inductively coupled plasma (ICP) source, where it is vaporized and ionized.
  2. Ionization: The ions produced in the ICP are extracted and focused into a beam, which is then sent through a series of magnetic fields. The magnetic fields cause the ions to bend, and the degree of bending depends on their mass-to-charge ratio (m/z)

3. Separation: The ion beam is separated into its various isotopes by a mass spectrometer. This allows the different isotopes of an element to be measured separately.
4. 4 Detection: The ion beam is then directed towards a detector system which consists of multiple collectors, each of which collects a specific isotope of interest. By measuring the isotopic ratios of the different collectors, the relative abundances of the different isotopes can be determined with high precision.

Overall, MC-ICPMS is a highly sensitive and precise analytical technique that is used in a wide range of applications, from studying the geochemistry of rocks to analyzing trace elements in biological samples.

- **TIMS:** The term "thermal ionisation mass spectrometry" (TIMS) refers to a strong analytical technique utilised for high accuracy isotopic analysis of a wide range of elements. TIMS is a highly sensitive and precise analytical technique utilised in a variety of applications ranging from examining the geochemistry of rocks to analysing trace elements in biological samples.

  Working of TIMS:

  1. Sample introduction: A small amount of sample material is loaded onto a filament, which is then heated to a high temperature. The heat causes the sample to vaporize and form ions.
  2. Ionization: The vaporized sample is ionized by bombarding it with electrons. The ionized sample is then accelerated through a series of electric fields and sent towards a mass spectrometer.
  3. Separation: The ion beam is separated into its various isotopes by a mass spectrometer. This allows the different isotopes of an element to be measured separately.
  4. Detection: The ion beam is then directed towards a detector system which measures the number of ions hitting it. By measuring the isotopic ratios of the different ions, the relative abundances of the different isotopes can be determined with high precision

- TIMS is frequently used to determine the isotopic ratios of elements with low natural abundance, such as uranium and lead.
- Overall, TIMS is a highly sensitive and precise analytical technique utilised in a variety of applications ranging from examining the geochemistry of rocks to analysing trace elements in biological materials. TIMS is frequently used to determine the isotopic ratios of elements with low natural abundance, such as uranium and lead.

Figure no.11: Statue of Dr. Sarabhai at PRL

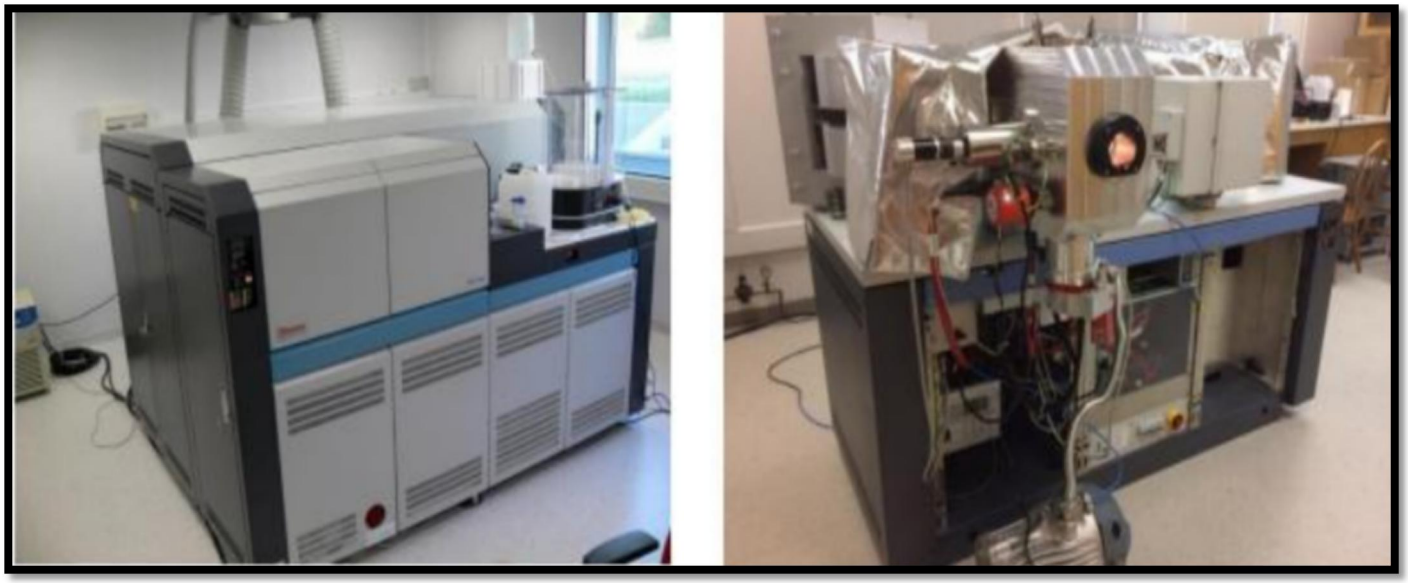

Figure no. 12: MC-ICPMS & TIMS Machines at PRL

Field visit: Day:03

Date: 24th January 2023 | Tuesday

[Location 1]

BALASINOR (MARUTI TEMPLE)

Latitude: 22°97’07’’ N

Longitude: 73° 34’ 64’’E

The Aravalli supergroup is 2.5 billion years old. The general direction of Aravalli sediment is NE-SW.The Aravalli craton's closing phase is characterised by large-scale granitic activity. The majority of Granitic masses intruded between 730 and 830 Ma, as demonstrated by a cluster of Rb-Sr ages. Godhra granite is one of the granitic intrusions that occurred during the Aravalli craton's last phase. The Champaner and Lunavada groups of the Aravalli supergroup have been invaded by Godhra granite. The Aravalli craton encompasses practically the whole state of Rajasthan, as well as parts of Gujarat, Madhya Pradesh, and the outskirts of Delhi and Haryana.

The area was a little higher up, where there were granite domes. The granites are 925- 945 million years old, with no paleozoic sequence in the Gujarat stratigraphic table. The topography of granite includes tors and domes. Tors are enormous, rounded granite rocks that grow as a result of erosion and weathering. The occurrence of exfoliated domes generated, by rock expansion contribute via temperature changes. The rock is greyish in colour, with grain sizes ranging from medium to coarse. It is crystalline in form, with feldspar and quartz minerals serving as fundamental minerals and biotite serving as an accessory mineral. Many locations in the rock revealed separated quartz and biotite pieces. Plagioclase euhedral crystals can also be found orientated in a specific orientation. The rock type is plutonic felsic igneous rock.Grey Granite is the name given to this stone.

A shear zone passing through the foliation was also seen.

Figure No. 15

Figure No. 16

Figure No. 14: Godhra Granite with Xenoliths

Field visit: Day:03

Date: 24th January 2023 | Tuesday

[Location 2]

Raiyoli in Balasinor

Latitude: 23° 05’ 62’’ N

Longitude: 73° 34 35’’ E

Raiyoli, in Balasinor, is one of Asia's most notable dinosaur sites. The Raiyoli Dinosaur Fossil Park is a dinosaur museum and fossil park located in Balasinor, Gujarat, India. It is also known as the Balasinor Dinosaur Fossil Park. The park is situated about 80 km from Ahmedabad and covers an area of approximately 72 acres.The fossilised bones of a dinosaur with a unique skull crest, Rajasauras Narmadensis, were unearthed here. Rayoli is well-known for discovering the Rajasaurus Dinosaur, a regal dinosaur from the Narmada River. It was 30 feet long, 9 feet tall, and weighted around 3-4 tonnes. The Raiyoli Dinosaur Site was discovered in 1981, and the fossils found there date back more than 65 million years. The park also contains a dinosaur fossil interpretation centre. The park's rocks are home to fossils. It is also said to be the third largest Dinosaur Fossil Site in the world. It has over 10,000 dinosaur fossils, including bones, eggs, and other remains that were found during excavations conducted by the Geological Survey of India (GSI) and the Gujarat Ecological Education and Research (GEER) Foundation.

The Raiyoli Dinosaur Fossil Park is a well-known tourist destination in Gujarat, attracting visitors from all over the world. It offers visitors a once-in-a-lifetime opportunity to observe India's rich and diversified geological history and to explore the ancient world of dinosaurs.

Figure No.15

Figure No.16

Figure No.17

Figure No.18: Dinosaur fossil

Field visit: Day:04

Date: 25th January 2023 | Wednesday

GAS GATHERING SYSTEM - MOTERA OIL AND NATURAL GAS CORPORATION LTD (ONGC)

Latitude: 23° 11’ 31’’ N

Longitude: 72° 59’ 79’’ E

MINE CODE: 100180

ONGC GGS Motera is a gas gathering station located in Motera, Gujarat, India, operated by the Oil and Natural Gas Corporation (ONGC). The primary function of the station is to collect and process natural gas from nearby oil fields and deliver it to various customers such as fertilizer plants, power plants, and city gas distribution networks. The gas collection process is separating natural gas from crude oil and water, compressing it to enhance pressure, and then transporting it to various users via pipes. To ensure safe and effective operations, the station is outfitted with cutting-edge technology and equipment.

ONGC GGS Motera uses advanced technology and equipment to ensure safe and efficient gas gathering and transmission. Some of the key technologies used at the station are:

1.) Gas Chromatography
2.) Compressors
3.) SCADA System
4.) Pipeline Inspection
5.) Environmental Monitoring

The oil and crude gas collection station that was linked to 59 oil wells within a 17-kilometer radius via underground pipelines. Every day, 50 to 60 thousand litres of oil and crude are transported to the Kayoli IOCL Refinery. Mister Gaurav Kumar, the plant's Safety Officer, guided us and showed us around.First, we travelled to the main processing facility, where oil and gas are received through subterranean pipes and sent to a booster gas compressor plant, where they are separated based on density. It is directly kept in a 45 cubic metre tanker.

Based on the pressure received there are two separator present.

1.) Low pressure separator 20.60kg/cm2
    Hydro test pressure-9.0 kg/cm2
    Safety valve test pressure -6.-kg/cm2

2) High Pressure separator 40 kg/cm2

Hydro test pressure- 60 kg/cm2
Safety valve test pressure- 43 kg/cm2

Oil and gas are directly stored within the storage tank via this separator. Corrosion inhibitors are used to keep pipelines from rusting. Each pipeline receives 2 liters every day. There are two new high-capacity gas booster plants. This is a two-stage compressor, which makes the machine smaller. Bath heaters are used to raise the temperature of petroleum if it solidifies in pipes, which operate on the principle of heat exchanges. This contemporary booster plant has a fire-prevention mechanism in the form of CO2 flooding. The pressure temperature and flow metre were checked and maintained using SCADA software. Finally, Gaurav Sir briefly detailed the plant's procedures and operation.

Figure No. 19: GAS GATHERING SYSTEM - MOTERA OIL AND NATURAL GAS CORPORATION LTD (ONGC)

Field visit: Day:05

Date: 27th January 2023 | Thursday

[Location 1]

Rajasthan State Mines and Minerals Limited (RSMML) Rock phosphate, Jhamarkotra Mines, Udaipur

Latitude: 24.491558°

Longitude: 73.84149°

The Jhamarkotra mines are a group of rock phosphate mines located in the Udaipur district of the Indian state Rajasthan. These mines are the largest rock phosphate mine in India and are operated by the Rajasthan State Mines and Minerals Limited (RSMML). The Jhamarkotra mines were discovered in 1986 and have been in operation since then. The rock phosphate from here used as a raw material in production of fertilizers. They are primarily engaged in Mining and Marketing of High-Grade Rock phosphate, Lignite, Limestone & Gypsum (NonMetallic minerals) through its mines located at various locations in Rajasthan.

Rock Phosphate is present as stromatolites buried in the Aravallies. The mine is an open cast mine using benches and faces with 1:16 as the ore to overburden ratio.

Blue green algae take dissolved phosphate from the water in the photic zone and then these algae when dead are buried in the sediments. This forms the low grade deposits of phosphate. When this deposits were exposed to the meteoric rain, the matrix was leached out and the high grade ore was deposited. These resulted into the high grade deposits at the bottom.

The oldest rock is Banded Gnessis complex which is of Archean age with no life remains. Overlaid by the Aravalli super group and the lower Aravallies comprising of the phosphate deposits.It was observed that the every third bence was more of the length then the first two with a constant face height so as to hold the sliding rock falls.The host rock is the Dolomite which has a dip of 55° and thickness of 5-15m.

Apatite crystalis were found in the field which was formed due to the injection in the primary rock and was of low grade. The high grade ore is of 2 types i.e. 30 % used in fertilizer industries and 31.5% used in Gujarat state fertilizers and chemicals. The low grade ore i.e. 16% is upgraded using beneficiation and more processes like Froth flotation and upgrade to 31.5% and used. This is done at Industrial Beneficiation Plant. The mine water is transported and used by the city of Udaipur .

Figure no.20: View point of Jhamarkotra Opencast Mine

Figure No. 21: Stromatolites

Figure No. 22 (a): Apatite

Figure no. 22(b): Apatite

Field visit: Day:05

Date: 27th January 2023 | Thursday

[Location 2]

Jhameshwar Mahadev Temple, Jhamarkotra

Figure No. 23: Stalactites

Stalactites are formations that cling to the ceilings of caves and hot springs.They grow from dripping walls and ceilings and develop downwards. The'straw' stalactite is a monolayer crystal sheath covering a feedwater canal and growing downwards only. Leakage from the canal can cause tapering (carrot-like) stalactites up to one metre in diameter and several metres in length. Rapid deposition on protuberances can result in the formation of a plethora of secondary formations such as crenulations, corbels, draperies, and smaller stalactites. A'column' is a stalactite-stalagmite pair that has grown together.

Field visit: Day:06

Date: 28th January 2023 | Saturday

Chittorgarh (banks of the Berech River)

Latitude: 24° 47’40” N

Longitude: 73° 51’ 71” E

[Location 1]

Rock Type – Suket Shale- Phyllite

The Chittorgarh district is distinguished for its undulating topography and Aravalli range highlands. The district is made mainly of rocks from the Bhilwara supergroup, the Vindhyan supergroup, and the Deccan traps. The field region is populated by Vindhyan sedimentary conglomerates and rocks of the Bilwara supergroup, which are separated by a large boundary fault. The Berach River follows the big border fault. The Bilwara supergroup can be found on the river's west bank. The Bilwaa supergroup is divided into three tectono-stratigraphic units: the Hindoli group, the Mangalwar complex with separate mineralised bands, and the Sandmata complex.

Greywackes and phyllites dominate the Hindoli group. These phyllites have folded into large-scale low-plunging folds that run parallel to the GBF. The increased tightness and asymmetry of the folds near the fault indicates that these are fault-related folds. They are severely compressed, with joint sets that are more closely spaced than those found away from the river and away from the GBF. There are slicken sides, indicating the presence of a fault, and quartz veins, which could be syngenetic or post-genetic.

The Suket Shale-Phyllite shows various stages of predominant folding from which possible readings were taken with respect to the hinge plane: **STRUCTURAL DATA**

	Limb 1	Limb 2	Limb 3
Strike Direction	**57º**	**27º**	**39º**
Dip direction	**149º**	**295º**	**132º**
Amount of Dip	**43º**	**63º**	**53º**

Joint Sets

	Strike direction
Joint set 1	**100º**
Joint set 2	**145º**

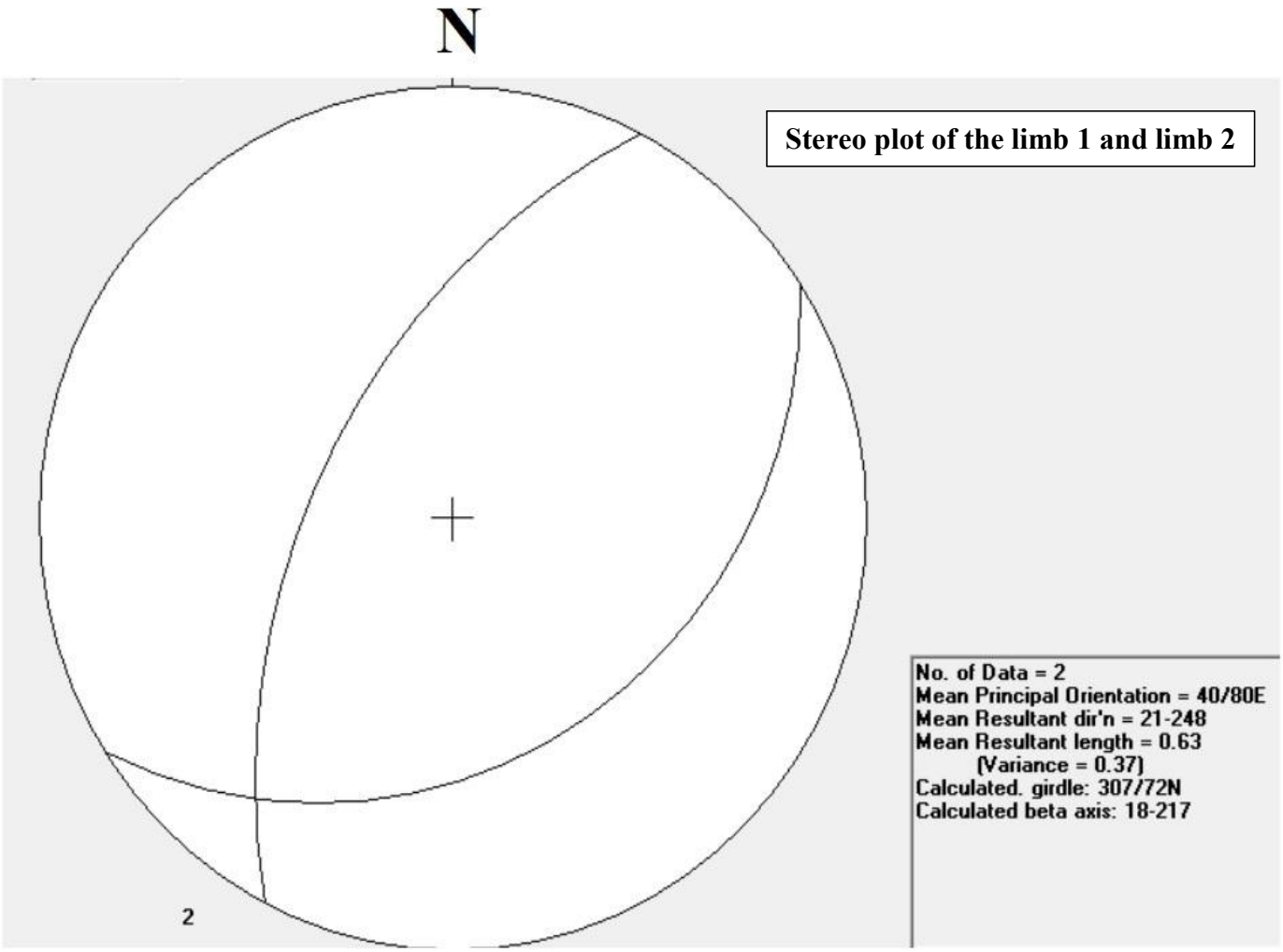

Figure No.24: Suket Shale-Phyllite

Figure No.25: Anticlinal Plunging Hinge

Figure No.26: Folding Sequence

[Location 2]

Nimbara Limestone

Nimbara Limestone is a sedimentary limestone comprised mostly of calcium carbonate. It is often found in Rajasthan's Nimbara region and is a widely used material because of its long-lasting qualities, strength, and natural beauty. This limestone is typically light grey in colour and has visible fossilised sea creatures such as shells and corals on its surface. It is generated by the buildup of calcium carbonate-rich silt squeezed over thousands of years, most often in marine environments.

The the readings of the Nimbara Limestone near Chittorgarh Fort:

STRUCTURAL DATA

Strike Direction	**6º**	**3º**	**8º**
Dip direction	**276º**	**273º**	**278º**
Amount of Dip	**40º**	**63º**	**45º**

Field visit: Day:07

Date: 29th January 2023 | Sunday

Nathdwara Limestone/Marble

Latitude: 25° 05’ 76” N

Longitude: 73° 85’ 08” E

Massive beds of marble and Mica chloride schist were observed with dips ranging from 30° to 40°. On a broader scale, the dipping beds of marble and mica chloride schist were visible. The mica chloride schist

was severely metamorphosed and worn, with Biotite visible throughout the bed. Augen structures were visible in certain spots. Marble was found to have a sinsodal structure. The marble contained Termolite and Actinolite. The marble strata were inclined with the schist bed underneath them. The schist in the area was highly worn. The sloped marble bed featured a modest crenulation folding sequence that generated a few joints in the marble. The recrystallised silica grains in the marble revealed that contact metamorphism occurred in the following order. The schist present had an alternative augen gneiss structure containing minerals like chlorite and tremolite dominating the rock, leading to the term mica schist. The needle-like structure of tremolite is also found inside the mica schist as an elongated acicular structure.

Figure no. 27: Dipping Beds

Figure No. 28: Plagioclase standing out

Figure No. 29: Augen Structure

Figure No. 29: Actinolite in Marble

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