Geology of sediment core retrieval [3p 58] from Sotrant, Mormugao,Goa

A Dissertation Report for

GEO-651 Dissertation

Credits: 16

Submitted in partial fulfilment of Master's Degree

MSc in Applied Geology

by

ROSHNI RAJU PUJARI

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Under the Supervision of

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School of Earth, Ocean and Atmospheric Sciences

Applied Geology

GOA UNIVERSITY

April 2024

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MAY 2024

Examinedby: Seal of the School

DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, GEOLOGY OF SEDIMENT CORE RETRIEVAL [3P58] FROM SOTRANT ,MORMUGAO,GOA is based on the results of investigations carried out by me in MSc. Applied Geology at the School of Earth, Ocean and Atmospheric Sciences, Goa University, under the Supervision of Dr. A. A. A. A. Viegas and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will not be responsible for the correctness of observations/experimental or other findings given in the dissertation.

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COMPLETION CERTIFICATE

This is to certify that the dissertation report GEOLOGY OF SEDIMENT CORE RETRIEVAL FROM SOTRANT, MORMUGAO, GOA is a bonafide work carried out byMs. Roshni Raju Pujari undermysupervision/mentorship in partial fulfillment of the requirements for the award of the degree of Master of Sciences in the Discipline Applied Geology at the School of Earth, Ocean and Atmospheric Sciences, Goa UniversityDate:

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CHAPTER I – INTRODUCTION

PROLOGUE

Goa is located on the west coast of India, bordering the states of Maharashtra and Karnataka. It has 104 km of coastline on the Arabian Sea, After gaining independence in 1947, India requested Portugal to cede Goa. Indian troops finally captured Goa in 1961. It was later incorporated into India as part of the territories of Goa, Daman and Diu. It became a state in 1987, with Daman and Diu remaining as union territories.

Goa is primarily agricultural. Its distinctive architecture and beautiful beaches are also popular tourist destinations.Goa is been located on the coast of the Indian peninsula known as the Konkan coastal belt. Goa is mainly bordered by the state of Karnataka to the east and south, the Arabian sea of South to the west and the state of Maharashtra to the north.

Goa is located between latitudes 15°48'00" and 14°53'54" North and Longitudes 74'2013" E to 73°40'33" E. The Goa state is spread over an area of 3,702 są km and it is divided into two districts-North Goa and South Goa. Some parts are hilly terrain with the Western Ghats rising to nearly 1076 m, in the eastern part of the state. In the north, the Terekhol river separates Goa and Maharashtra. Goa's climate has been equable, with the high temperatures generally in the 80 degree and low temperatures in the 70s F throughout the whole year. The state receives about 115 inches (3,000 mm) of rainfall Tiswadi Island is between the Mandovi and Zuari rivers. The island is triangular and divides the port of Goa into a part of Aguada at the mouth of the Mandovi River in the north and a part of Mormugao at the mouth of the Zuari River in the south. Goa is located in the northwestern part of the West Dharwar Craton(WDC), where the

Shimoga-Goa upper crustal belt extends continuously to the underlying Arabian Sea and the Deccan Traps to the north. The belt below the trap is thought to continue to Narmada, where the Narmada-son lineament terminates this supracrustal belt. The Shimoga-Goa belt extends from north-northwest to south-southeast for about 250 km and its maximum width from Dharwar is about 120 km (Dessai, 2011).

Precambrian igneous rocks occur along the west coast of the South Indian Shield in the state of Goa. This also includes a series of large granitic plutonic bodies located in the northwest block of the Dharwar Craton that are derived from and emplaced in Archean gneiss basement (equivalent to peninsular gneiss). The most important of these bodies, from north to south, are Ammod Ghat, Chandranath, Dudhsagar and Canacona Granite. In some cases, dolerite dykes penetrate these granitic bodies, e.g. the Canacona granite).

A historical Precambrian evolutionary tendency could be seen in the intricate mosaic of granites, mafic rocks, and associated lithologies of the Goa region of the Dharwar craton, which is an igneous environment with extensional tectonics (Dessai, 2011).The basement gneisses Trondhjemite-Tonalite -Granitoid (TTG), and related greenstone belt rock types in Goa exhibit overall structural continuity, the lithology includes intrusive bodies and basement gneiss complexes, also the bedding planes and axial planes of folding within the related supracrustal, are used to transmit the typical Dharwar-type NNW-SSE trending structural fabric. The north-oriented rock structure is thought to be the product of a major east-west compression event in the late Alcavanan that influenced the WDC. The TTG series is a well-known group of rock types formed by the dissolution of mafic crust under intense pressure. Most Archean granitic greenstones are thought to be dominated by TTG (Condie, 1994). However, Late: Archaic regions such as the Yirgan Craton are also dominated by potassium-rich granites formed by remelting of older felsic TTG dominant crust.

Aim and Objectives:

Aim: The purpose of this study was to get acquainted with the sediment pile (Borehole No.58) retrieval data in order to study its sedimentary characteristics in relation to the significance of the paleo environment and also to examine clay mineralogy.

The specific objectives were as follows:

1. Sedimentary Characteristics Investigation**:**
    - Understand the sedimentary features of the retrieved material.
    - Explore its relevance to the paleo environment.
2. Clay Mineralogy Examination:
    - Investigate the clay minerals present within the sediment.
3. Litho-Type Determination:
    - Examine the remnants of country rock at the base of the sediment pile.
    - Utilize both megascopic and microscopic observations.
4. Mineral Identification:
    - Identify different minerals found in samples from various depths.
    - Utilize both megascopic and microscopic observations.
    -
5. Sediment Fraction Characterization:
    - Define sediment fractions for different depths.
    - Represent this information using a Perjup diagram (1988) to understand the hydrodynamic conditions.

6. Color Indexing:
    - Utilize the Munsell color chart to index the sediment hues.
7. Data Compilation:
    - Based on the generated data, prepare a comprehensive log.

This study contributes to our understanding of geological processes and environmental history.

CHAPTER II – LITERATURE REVIEW

GEOLOGY OF GOA

Goa, is a coastal state in western India, has primarily sedimentary rocks. The region is part of the Western Ghats and its geology includes laterites, shales, and iron-bearing clays. The Deccan Traps, a large volcanic province, also influences the geology. Additionally, due to its proximity to the Arabian Sea, the state has alluvial deposits that influence the landscape and soil composition. The upper crustal rocks dominate the area, underlain by the trondjemite (peninsular) rocks and penetrated by mafic, ultramafic, and granite rocks.Cretaceous Deccan traps are found only in the northeastern tip of the state. Most of the geological formations are covered by laterites, alluviums, and sands.

The supercrust that constitutes the Goa Group of Gokul et al. (1985) can be divided into two lithostratigraphic sequences: the Barcem Group and the Ponda Group. The former is mainly composed of greenstone (metabasalt) and lies on the Trondjemite gneiss bedrock of the 3,300-3,400 Ma Anmode Ghat, with a roughly developed quartz and pebble conglomerate at its base, and the Bababudan Group of WDC has lithological similarities with the lower part of the Group.

The younger sequence is dominated by clastics and has been assigned to a new stratigraphic group, formally called the Ponda Group, corresponding to the Chitradurga Group of the Dharwar Supergroup (Dessai, 2011). This group overlies the 2700-2900 Ma Chandranath granitic gneiss bedrock and has a distinct unconformity characterized by a multilayered complex of granite fragments. This conglomerate has many similarities with the Talya conglomerate, which is home to the Chitradurga Group. This formation is overlain by a drystone sequence, followed by a BIF-hosting chemogenic deposit and a deep-water turbidite sequence (claystone and greywacke combination) with intercalation of mafic volcanic rocks. The upper crustal succession is penetrated by the laminated mafic-ultramafic Bondla Complex along a major shear zone (NW-SE) that primarily controls the flow paths of northwest-flowing tributaries of the Mandovi River.

As described by the Geological Survey of India (1996), this sequence consists of the Peninsular Gneiss Complex (Archaean), the metavolcanic and metasedimentary rocks of the Goa Group (Archaean to early Proterozoic), and the mafic-ultramafic It is composed of mafic complexes and intrusive granites (Early Proterozoic)., Deccan Traps (Late Cretaceous to Eocene), laterites (Cenozoic), beach sands and estuarine alluvium (Quaternary). Discrepancies separate these groups from each other.

RESIDUAL ROCKS. LATERITES

Basic Intrusives (late)	65-56 Ma	Dolerites
Deccan Traps	67-64 Ma	Basalt
Basic Intrusives		Metadolerites
Bondla Mafic - ultramafic layered complex		Dunite-peridotite-gabbro complex and equivalents
	Vagheri Formation	Metabasalts, Argillites and Metagreywacke
Ponda Group	Bicholim Formation	Banded ferruginous Quartzite, Manganiferous Cherthala vreccia with pink ferruginous phyllite
	Sanvordem Formation	Metagreywacke, Argillites, Quartzite, Tilloid
	-----------Unconformity---------	
Barcem Group	Barcem	Metagabbro ,peridotite,talc-chlorite schist,Quartzite, Quartz-sericite-schist,Red phyllite,Quartz porphyry Massive,Schistose and vesicular metabasalt
	------------Unconformity----------	
Canacona Granite	2979 + 4 Ma	Porphyritic potassic granite
Chandranath Granite Gneiss	2700-2900 Ma	Granodiorite
Anmode Ghat Trondhjemite gneiss	3300-3400 Ma	Basement; Trondhjemite - tonalite-granodiorite

Table No.1.: Revised lithostratigraphic classification of supracrustal rocks from Goa (Dessai, 2011)

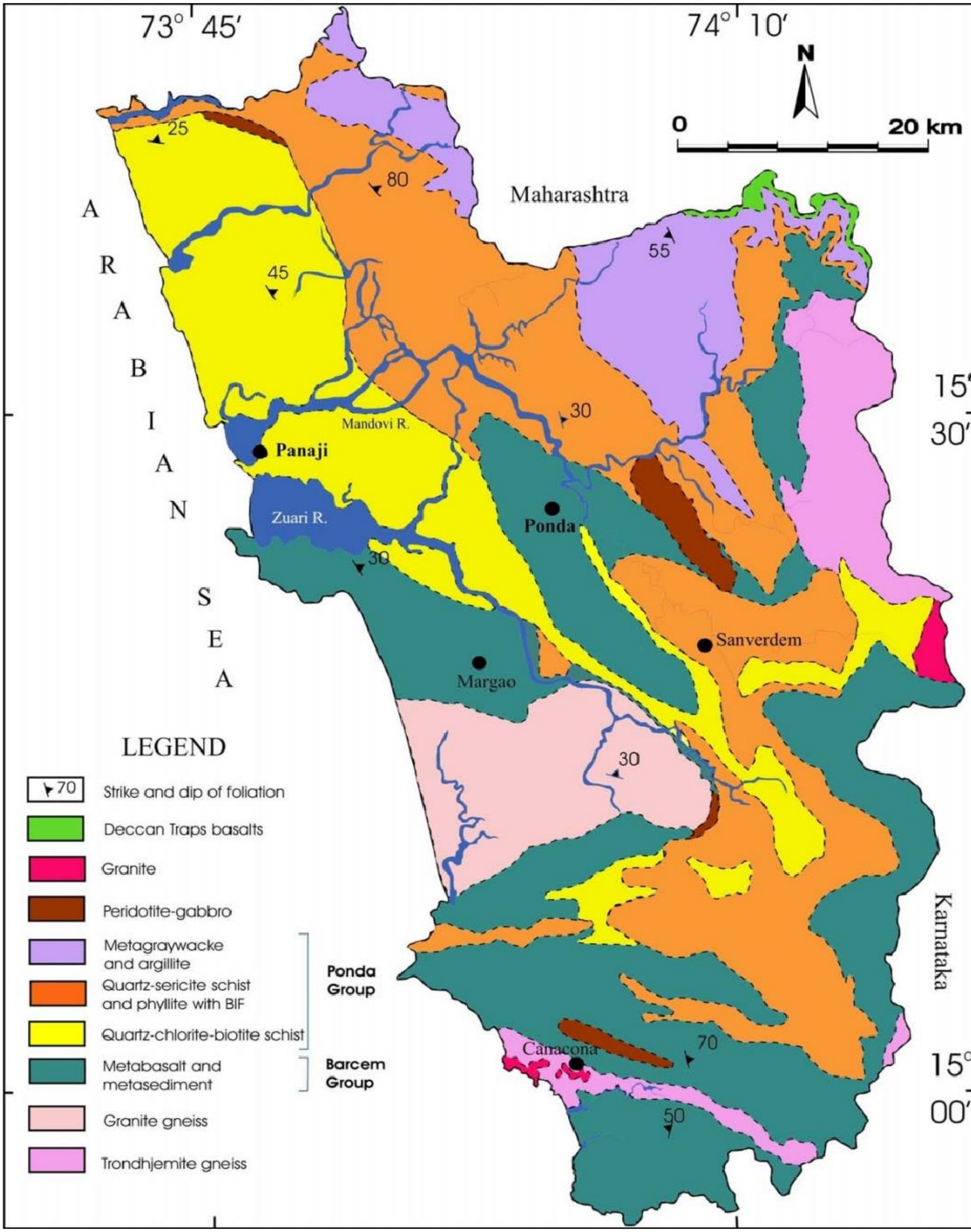


Figure 1: Geological map of Goa [Dessai, 2011]

Barcem Group: TTG acts as a basement for rocks of the Barsem Group with a thickness of over 2000 m. Metasedimentary and metavolcanic rocks form the Barcem Group. Basic and acidic lavas, agglomerates, and tuffs are examples of volcanic rocks. Quartzite, quartz sericite schist, quartz chlorite schist, and phyllite form subsedimentary rocks. In some areas phyllite deposits are observed. The basalt is vesicular and has a slate-like appearance in places. Plagioclase that has become sausserite and pyroxene that has become uralite form basalt. In Canacona, non-vesicular basalts are found in the south and in the area around Tisku (Usgao) to Dharbandora in central Goa. metabasalts are found along the northern margins of Barcem, and Vagon.

Ponda Group: The Ponda Group is highly clastic dominated and is correlated with the rocks of the Chitradurga Group of the Dharwar SuperGroup (Dessai, 2011).

Sanvordem Formation: It is made up of three Formations Sanvordem, Bicholim and Vagheri overlying the Barcem Formation is the Sanvordem Formation of the Ponda Group. It is supported by a Chandranath granite gneiss basement. It is composed of mudstone, metaconglomerate (tiloid), and metagraywacke. Quartz, chlorite, and biotite schist are sometimes used to describe its lithology. It is 1200m thick Metagraystone consists of elongated lens-shaped quartz blocks and pebbles of various sizes surrounded by a schist matrix consisting primarily of chlorite. The upper part of the Sanvordem Formation is composed of thin-bedded claystones, and the associated macrolayers contain minor slump folds. Claystones are often penetrated by sandstone banks several centimeters thick. The upper part of the Sanvordem Formation shows distal turbidites, whereas the lower part shows proximal high-flow density deposits.

Bicholim Formation: Above the Sanvordem Formation is the Bicholim Formation. It is composed of small impure limestones often called calcareous phyllite, ferromanganese-bearing phyllite, banded iron-bearing quartzite, quartz-chlorite amphibole schist, and ferromanganese-bearing phyllite. It can be traced from Naibag in the north (2 km northeast of Pernem) to Salgini in the south, running the entire length of Goa (185 km). Banded hematite quartzite (BHQ) acts as a promoter for iron ore deposits. The actual thickness of the formation is often about 1,400 m. (Dessai, 2011).

A mafic dyke completely transformed into clay minerals crosses his BHQ. Banded magnetite quartzite (BMQ) and BHQ form as inclusions within phyllite. In some cases, the BHQ is further interspersed with talc-chlorite shales and pyrite-bearing carbonaceous shales. In North Goa, the BHQ is thick and iron-rich, while in South Goa, the BHQ is thinner and occurs as discontinuous bands or lenses within the phyllites. BHQ consists of alternating layers of hematite and magnetite, which are laminated thinly. On the other hand, the southern region is rich in magnetite, and the northern region is rich in hematite. BHQS exhibit a number of important sedimentary features, including: Layered iron oxide and silica, mesobands and microbands (chert), and transverse and interferometric waves. For example, in the boreholes beneath the manganese-bearing phyllites of Sonshi, rare lime deposits associated with the phyllites are found.

Vagheri Formation: In the Ponda Group, the Vagheri group is the highest and youngest Group. Metagreywacke and associated metabasalt form this structure. Northeast. The exposure of Valpoi is the best. The rocks exhibit a graded layered structure, with fine-grained greywacke (sandstone) exhibiting layered structures including flow waves and meandering layering. Metagraywackes contain metabasalts that appear as lens-like deposits and sill-like structures. The underside of the sandstone is often covered with foot prints.

Gokul et al. (1985) in the upper crust of this region he recognized three stages of folding. The first phase, F1, produced WNW-ESE foliation, which is dominant in South Goa. The emplacement of the Chandranath granite in southern Goa is explained as co-tectonic with this folding phase. The second phase, F2, is predominant in north and east Goa. The folds belonging to this stage have a northwest-southeast trend, are double-bottomed, and their southwest branches are frequently overturned. The density of foliation and folds decreases toward the west, indicating a decrease in orogeny in this direction. Potassic granite enclaves that occur along or across the eastern boundary of the province beneath the trondjemite gneiss may have syntectony during this second folding stage. The last folding stage, F3, was relatively weak and led to the development of a synclinal structure in northeastern Goa (Gokul, 1985; Gokul et al., 1985).

PHYSICAL FEATURES OF RELIEF AND STRUCTURE

Geographically, Goa is very similar to the neighboring states of Maharashtra and Karnataka. In physical geography, it is divided the state into three geographical divisions. These are the mountainous region formed by the Sahyadri Mountains in the east, the plateau region of low- and medium-low river basins, and the coastal plain. With an average altitude of 800 m, the Sahyadris range covers an area of approximately 600 km^2. The dominant mountains of this range include Sonsoghad, Vagheri, Mollemchogor, and Katrankimauri. Almost all the rivers in Goa originate from this region. The central region of Goa has plateaus ranging from 30 to 100 m above sea level that extend over the central region of the state. The Mandovi and Zuari rivers flow through most of the plains. Rivers with shallow basins include the Chapora in the north. These basins have alluvial near their coasts, forming fertile agricultural areas. Other major rivers flowing through the state include Baga, Mandovi and Zuari .

GEOMORPHOLOGY

The Western Dharwar Craton,part of the Archean-Proterozoic granite-greenstone belt of western peninsular India, is overlain in its northern region by the Late Cretaceous-Early Cenozoic (64-67 Ma) Deccan Trap. A fairly uniform macrotopographic landscape was formed by the exposure effects of pre-Decanian basement and lavas. This terrain extends from west to east along most of the western tip of the peninsula.

●Konkan-Kanara Lowlands: A low-lying coastal area characterized by short rivers flowing to the west.

●Western Ghats: Continental-scale coast-parallel cliffs, usually 600 to 1000 meters in height Western Ghats: Continental-scale coast-parallel cliffs, usually 600 to 1000 meters in height. • Summit zone of the Western Ghats: Isolated raised mesas of basaltic terrain or narrow zones of ridges and domes of cratonic basement.

●Karnataka Plateau and Maharashtra Plateau: These are vast plateau regions with a height of 600 to 800 meters, characterized by a gentle eastern slope and long rivers flowing to the east or southeast.

On the eastern side of the main slope are numerous rivers that empty into the Bay of Bengal, 800 to 1,000 kilometers away. The Western Ghats serve as a major drainage divide for much of peninsular India. Although rivers rarely cross this barrier in the Deccan region, there are instances where rivers have crossed this barrier between 14° and 15°N latitude and at some other less important but important locations further south. In places where this has happened, such as the Jog Falls (74°49'E - 14°13'N) in northern

Karnataka, the ghats fall in a series of breathtaking waterfalls, thereby cascading down the fast-moving Konkan. It fills the geographically limited catchment area of the river. However, most of the rivers that cross the coastal lowlands originate near or at the surface of the Western Ghats in the Deccan Traps and Pre-Deccan subsurface areas, deeply dissecting the lateritic belt, but it forms a mosaic of discrete geological formations. (Sriram and Prasad, 1979).

In Goa, the development and expansion of drainage channels has further fragmented the laterite zone into a mosaic of smaller 'plateau' sections over time (Sriram and Prasad, 1980; Figure 1). Occasionally, twists (or changes in slope) occur at the base of the Ghats escarpments, 20-40 km downstream of major rivers and estuaries that cut through lateritic plateaus (Tilacol, Chapora, Mandvi, Zuari,)., Chapora, Mandovi, Zuari,) (Dixit, 1976; Brückner, 1989). As a result, despite the relatively narrow tidal range typical of the coasts of this region of western India, the tides extend deep inland (several tens of miles). Dissected laterite-covered plateaus, also known as plateaus, are important geomorphological features of the coastal region of Goa. The most prominent and important specimens are found along the northern coastal region of Goa between 15°10'N and 15°45'N (north of the Tiracol River), where it enters the state of Maharashtra and has a prominent basaltic topography.

The plateaus are encountered at:

- Harmal - Keri plateau and Mandrem Morjim plateau in Pernem taluka.
- Mapusa - Porvorim, Verem and Aguada Plateau in Bardez Taluka.

• Dona Paula Taleigao, Bambolim, Kadamba and Merces Plateau in Tiswadi Taluka.

• Plateaus of Madkai and Kundai in Ponda taluka.

•Sada-Dabolim Plateau in Mormungao Taluka.

• The highlands of the Quepem and Plateau of Canacona Taluka.

These plateaus regularly connect with each other and with the bare hills further east. Some of these plateaus are elongated and follow the north-northwest-southeast trend of the Dharwar-Barcem and Sanvordem Formations. These plateaus are bounded in the west by coastal plains, streams and tidal flats of large estuarine rivers (Chapora, Mandovi, Zuari, etc.) or their tributaries, and by extensive valleys and estuaries. River drainage is the best developed.

The typical elevation of a tableland ranges between 50 and 80 m. above sea level where it is found along the coast (such as the Mormugao Plateaus), and it increases gradually inland to over 100 m. above sea level. The tablelands are heavily lateralised throughout a large portion of their extent. and they are often capped by a hard duricrust that is typically 5-10 m thick and represents the topmost zone of the surviving lateritic weathering profile. The lower layer of the weathered profile is less hardened beneath the duric crust and is therefore susceptible to preferential erosion when exposed by quarries or road cuts. These lower layers were preferentially separated from the more sclerotic upper layers near the boundaries of some plateaus (Bruckner 1989).

This resulted in topographic uplift at the edge of some plateaus and cracking and fragmentation of the overlying indurated laterite layers. These separated duricrust fragments were eventually distributed on nearby slopes through subsequent mass disposal processes, resulting in debris accumulation on foot slopes. Some of the steep slopes of the plateau have developed secondary (i.e. allochthonous) footslope ferricrite over time due to the lateritized clay and lateritic detritus that cover them. Where plateaus reach the coast similar lateritic weathering processes occur.The cliffs surrounding Cape Dona Paula (15°27'N, 73°47'E) and north of Anjuna Beach (15°35'N, 73°44'E) are 20 to 20 m high and formed by marine erosion. Once again, marine erosion preferentially removes the lower, softer layers of the landscape, and the curvature extends seaward from the cliff edge 20 to 100 meters inland. Where chunks of the earth's crust have loosened, huge boulders can be found along coastlines, potentially leaving sandy beaches semi-flooded. At a depth of 10-15 m beneath coastal sands and clays, excavations can expose layers of hard laterite. These are probably allochthonous lateritic debris from an earlier erosional episode that affected the nearby coastal plateau, which was subsequently covered by coastal sediments as a result of relative sea level rise. The Tiracol and Chapora rivers in northern Goa have at least two levels of riparian terraces at an altitude of less than 40 m, consisting mainly of lateritized pebbles. They are thought to have been formed by river incision, as they lie beneath high (60–70 m) authigenic laterites on a nearby plateau (Bruckner 1989). This suggests that deforestation, development of ferroconcrete terraces, and subsequent re-cementation are ongoing processes that continue to transform and impact the once vast Konkan laterite zone.

SEA LEVEL CHANGES

Repeated changes in sea level have led to the development, deterioration of various coastal landforms. The west coast of India is often classified as a flooded coast by Ahmed (1972). Numerous landforms, such as sea cliffs, sandstone platforms, rocky headlands, tidal flats, anastomosing drainages, and laterites, form the flooded coastline at depths of 20–30 m below mean sea level. On the other hand, the presence of wide sandy beaches, offshore rocky islands, sea caves, beach rocks, and coastal terraces confirms the recent formation of the coast (Dessai 2018).

This coast was classified as a ria coastline by D'Souza (1968) and is characterized by extensive estuaries and represents a coastline consisting mainly of emergence and partial flooding. Given that the current sea level was established in the mid-Holocene, the coastal morphology mainly shows evolutionary features associated after the Flemish Transgression (Goudie, 1973). Mid-Holocene sea level fluctuations are clearly visible along the coast of Goa. It arose during the late Quaternary period, as indicated by the 1–12 m high shelf edge ridge (7.5 and 110,000 years ago; Nair and Hashim, 1980; Rao and Nair, 1992). It may represent a paleocoastline that fell into the sea. level. It is well known that during the Late Quaternary the sea level was 6090 meters lower than the present.

The Dapoli and Cansaulim clays overlying the laterite at submerged levels (BP 3.5–2.6 ka; Kumaran et al., 2012) may have been deposited under fluvial-lacustrine and/or lagoonal conditions corresponding to this transgressive stage. Similar occurrences of clayey and muddy deposits containing carbonaceous and plant debris occur in wells in different parts of Goa, including Taliegao, Tivim, Goa University Campus, Dabolim Station, and Sangod Iron Ore Mines near Sanvordem.These are supported by fossilized beach rocks present 4–6 m above the MSL near Korlai-Borlai and other locations along the Konkan coast of northern Goa (Dessai 2018). The presence of shell beds within the tidal reaches of the Chapora, Mandovi, Zuari, and other rivers may indicate paleo-oceanic inlets associated with sea-level fluctuations between approximately 2.3 and 1.5 ka BP. (e.g. Bruckner, 1989; Karlekar, 1996). It is believed that tidal flats were formed in this area of the west coast, probably due to sea level changes during this period. Beach rocks, crushing platforms, sea canals, sea caves and other related structures at Anjuna (1.5 meters above MSL) and Bogmalo (2.5 meters above MSL) at elevations higher than present sea level can also be linked to Aguada. Paleodunes (stable dunes) are further evidence that water levels were significantly higher than they are today. However, the discovery of silicified wood in calcareous aeolianite 6.5 m below the dune surface (e.g. Kale, 1983) suggests that sea level may be 1.5 to 2.5 m below sea level today.Aeolianite and beach rock combine to cause changes in water levels. The current sea level is approximately the same as the sea level 60,000 years ago. But we are now seeing localized sea level rise in several places along the west coast, particularly in Goa. These sea level changes can be caused by neotectonic activity and/or changes in the eustatic base level (Dessai 2018).

Unfortunately, the overall knowledge of Quaternary deposits in India is poor and there is no reliable information about early Quaternary sea levels. However, the end of the Pliocene was marked by a strong retreat that led to the end of the Tertiary marine deposits, and with the advent of the Quaternary the strata (along the west coast) show a transition to continental. As already mentioned, it is quite possible that the so-called Pliocene fluvial-marine/fluvial deposits in various basins are the oldest Quaternary deposits. There is little evidence of high coastlines during the Early Pleistocene, and sea levels appear to have been primarily falling and only slightly fluctuating throughout most of the Pleistocene, forming a thick succession of mixed-environment sediments. On the coast, there is little genuine information about older Pleistocene marine strata and, according to Bruckner 1992, Even on the West Coast, no one has reported any undisputed Lower Pleistocene marine strata. It was not until the Middle Pleistocene that the first major exceedance occurred, when sea levels rose to nearly 25 meters, and this high sea level was reached during the Great Interglacial. The "Last Ice Age" was a period of decline when the sea level dropped to about 150 meters. By 11,000 BC to 400 BC, degenerative conditions prevailed, and at the beginning of the Holocene, sea levels began to rise again. It is believed to have reached its maximum height between 6000 and 4000 BC, reaching around 6 to 8 meters along the coast of India. This Holocene sea level rise was punctuated by a series of cessations or small declines.

Table No.02: Summary of the geomorphological evolution of Goa [after Dessai 2018]

Palaeopian	Age	Process/lithology
	Mid-/Early-Holocene	Sea level 1.5-2.5 m below MSL/Clays with carbonized plant remains/Colva fossil wood
	Late-Pliocene/Pleistocene	Low sea level (60-90 m below MSL), shelf- edge ridges, rapid rise in sea level, river terraces, Sea-Level Laterites, Coastal Laterites
	Mid-Miocene/Early Pliocene	Low-Level Laterites
	Mid-Miocene	Transgressive cycle/shales with carbonaceous streaks e.g. Ratnagiri carbonaceous shales
Unconformity		
	Late Oligocene/Early Miocene	Intermediate-Level Laterites
	Late Oligocene	Seaward tilt with marine transgression
Mollem	Unconformity	
	Early Oligocene	Downwarping of the crust, submergence of Bombay High platform
	Late Eocene	Marine transgression Tarapur and Telwa shales
Unconformity		
Anmode	Mid Eocene	In-land lagoon Formation/change in drainage/ dissection of High-Level laterites/continental sediments-organic black shales e.g. Cambay shales
	Late Palaeocene/Early Eocene	Partly inland partly offshore basin Formation/terrigenous clastics on eastern flank of Laccadive ridge, High-Level Laterites

PREVIOUS STUDY

Suspended sediment dynamics on a seasonal scale in the Mandovi and Zaari estuaries. central west coast of India, (Kessarkar et al. 2011). Clay minerals in identification of provenance of sediments of Mandovi estuary, Goa, west coast of India, (Bukhari and Nayak, 1996). Physico-chemical quality of Mandovi and Zuari estuarine systems of Goa, west coast of India, (Singh, and Usha. 2009), Geochemistry of the suspended sediment in the estuaries of the Mandovi and Zuari, central west coast of India (Kessarkar et al. 2011). Estuarine and marine geology (2011-2015), (Rae et. al 2016), Major and trace metals in suspended and bottom sediments of the Mandovi and Zuari estuaries, western India distribution source, and pollution (Renjan, and Keviarkar, 2017). Textural characteristics of sediments of Mormugao Bay, Central West coast of India (Rao, 1973). Sources and fate of organic matter in suspended and bottom sediments of the Mandovi and Zuari estuaries, western India Shona and Murali, 2015. Assessment and analysis of Precambrian basement soil deposits using grain size distribution (Layade et al. 2019). The triangular diagram used for classification of estuarine sediments: a new approach (Perjup, 1988). Sediment transport patterns, Hydrodynamic conditions and Clay mineral distributions at Coleroon River Estuary, East Coast of India(Senapathi et al. 2014).

LITERATURE REVIEW:

Geochemistry and Grain size distribution analysis of nearshoresea bottom sediments,west coast of india: (S.Sathish et al. 2018),

Grain size distribution analysis were carried out for nearshore bottom sediments off Vengurla. The main objective of this study was to know the geochemistry, grain size distribution and its association with hydrodynamic conditions, to identify the sources and transport pathways of the marine sediments. Influences of current and source rocks are essential for mineralogical composition and particle size distribution in nearshore region. XRD analysis was done to know the mineralogical composition of the samples. The XRD analysis of the bottom sediments shows the minerals like antigorite, calcite, kaolonite, periclase, muscovite, penobsquisite, bementite, quartz, arrojadite and, iron oxide, were identified. The wind direction and speed are changes from 300-360° and 0-5m/s respectively average wind speed is 1.2m/s.The maximum current speed at Vengurla is 0.34m/s. As a result of grain size analysis, find sand,silt and clay wereobserved and it was demonstrated that there is a very good relationships between the wave energy and grain size distribution in the nearshore region. It was observed that the wave energy takes on a major role for transportation and deposition of sediments in Vengurla coast.

Depositional mechanisms from the size analysis of clastic sediments (BK Sahu, 1964).

The problem of distinguishing between different mechanisms or processes and different depositional environments based on the size of distribution of coarse clastic sediments (gravel, sand, silt, clay and their fossilised equivalents) is investigated using statistical methods. It has been multivariate discriminant analysis is used to determine multiple discriminant functions with significance levels to distinguish the grain size properties.

Grain Size Analysis of Some Beach Sands from the Indian Coasts: (Gautam kumar Das, 2009).

The beaches of the Indian peninsula, along the coast of 8129 km, attracts thousands of tourists every day due to the impassable and ferocious sea waves, with different types of waves and only a compact bottom, The mean value of coastal sediments is greater than 2.5 phi (Md > 2.5 phi) and the graphic mean size is greater than 2.3 phi (Mz > 2.3 phi). Grain size analysis indicates that all collected sediments belong to the coastal environment, as stated in the graphical representation of Moiala and Weiser (1977) and Friedman (1967). Textural analysis of these beach sand is 1.

Assessment and Analysis of Precambrian Basement Soil Deposits Using Grain Size Distribution. (Layade et al. 2019).

The grain size distribution of soil samples from the Precambrian basement within the textural properties, decreased transportation history and all the numerical assessments using statistical parameters.in this study fourteen samples were collected from the study area and were subjected to the sieve analysis in the laboratory for the determination of the grain size distribution. The statistical parameters studies the graphic mean, skewness, sorting and kurtosis. The result of the analysis of the samples ranged from coarse to fine-grained samples, moderately and poor sorted, positively and negatively skewed and the kurtosis also show leptokurtic as the most dominant which indicates that samples are poorly distributed and moderately sorted at the centre of the grain size distribution. These results also indicates that the geological environment of the soil samples could also be responsible for the poorly sorting and moderately sorting exhibited by the samples deposited in the particular study area.

CHAPTER III – METHODOLOGY

STUDY AREA

Latitude: 15°23´16"N

Longitude: 73°55´11"E

The study site is situated on the slope of the plateau along the Cortalim Margao route NH66 at Sotrant, cortalim is a village in Mormugao taluka near Thane, South Goa. Thr area is on the slope of plateau at height of above 35m. The site is approachable by all weather road. The study area is located 19 km away from Panjim on the Panjim Margao highway route through NH66, the study area is located approximately 14 km away from Margao on the Margao-Panjim highway route NH66.

Pole No: 3P 58

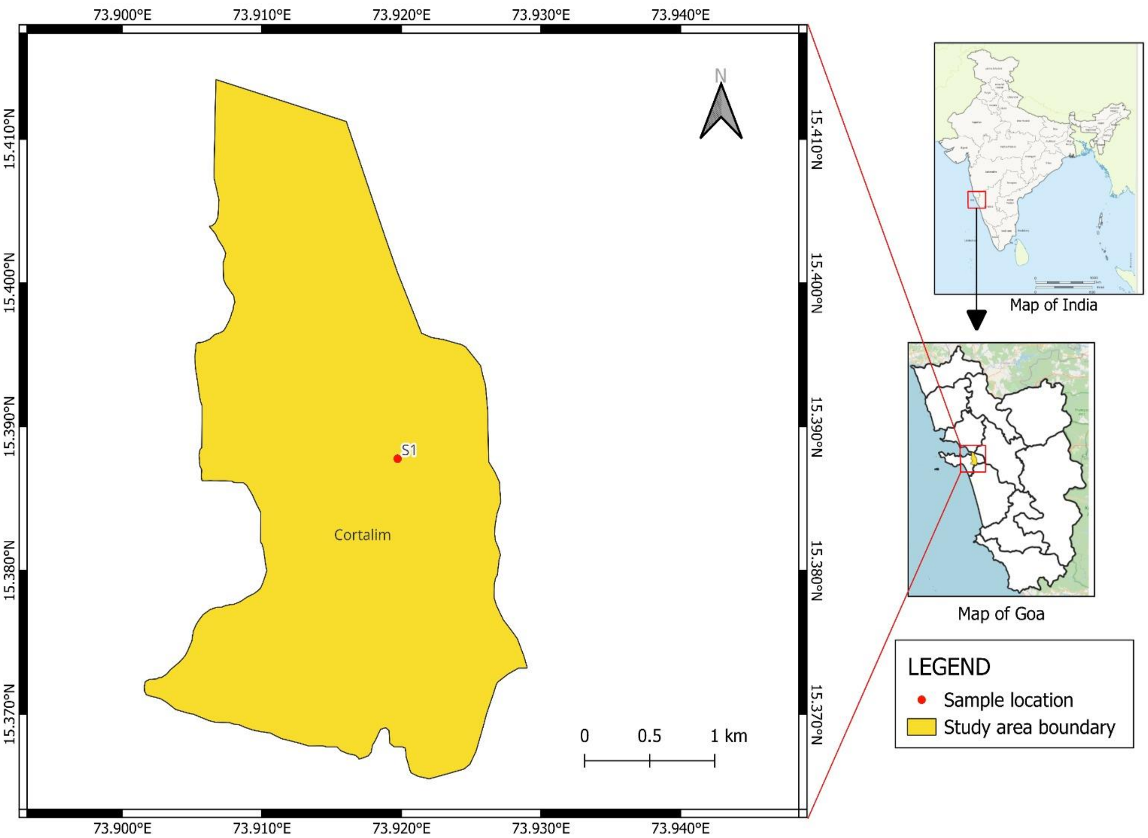


Figure No.02: Location shown in map of Goa

GRAIN SIZE

The term "grain size" refers to the diameter of individual grains of fossilized grains in sediments or clastic rocks. This term can also be used to describe other particulate materials. This is different from crystallite size, which refers to the size of a particle or single crystal within a particle. A single particle can form many crystals. Very small colloidal particles, rocks, clays, silts, sands, gravels, and rocks are examples of particulate materials. Sediment grain size provides important information regarding the factors causing sediment erosion/transport and the velocity of the flow. Poorly sorted sediments are formed by several depositional processes (such as gravity flows and debris flows), whereas well-sorted sediments are formed by wind and waves that are selective and can transport only certain particle sizes. Therefore, studying the grain size of sedimentary rocks allows us to understand the processes that lead to their formation (Folk, R.L. 1980). The physical properties of sediments can be described using various criteria such as surface roughness, shape, size, roundness, sphericity, and structure. Particle size is measured by the diameter of a sphere of similar volume. All of these characteristics play an important role in describing and evaluating suitability. Sediment particles come in a variety of sizes. They are broadly divided into rocks (256,000), boulders (256,000 to 64,000), pebbles (64,000 to 4,000), sands (2000 to 63), silts (63 to 4), and clays (2004). One of the most significant characteristics of sediment is its grain size distribution. (Sam Boggs, 2009).

Millimeters (mm)		Micrometers (µm)	Phi (ϕ)	Wentworth size class	
	4096		-12.0	Boulder	Gravel
	256		-8.0	Cobble	
	64		-6.0	Pebble	
	4		-2.0	Granule	
	2.00		-1.0	Very coarse sand	Sand
	1.00		0.0	Coarse sand	
1/2	0.50	500	1.0	Medium sand	
1/4	0.25	250	2.0	Fine sand	
1/8	0.125	125	3.0	Very fine sand	
1/16	0.0625	63	4.0	Coarse silt	Silt
1/32	0.031	31	5.0	Medium silt	
1/64	0.0156	15.6	6.0	Fine silt	
1/128	0.0078	7.8	7.0	Very fine silt	
1/256	0.0039	3.9	8.0	Clay	Mud
	0.00006	0.06	14.0		

Table No. 3: Wentworth grain size scale for siliclastic sediment

Wentworth's particle size distribution is consistent with the natural properties of the sediment; Recognized grain composition limits for sediment properties and grain composition. First reason for recommending this standard conversion from Wentworth particle size to Φ value. This classification method facilitates graphical representation, statistical analysis, and geological interpretation. Converting Wentworth grain size to Φ value results in a simple arithmetic series relationship.

Since the grain size is evenly spaced, logarithmic coordinate paper is no longer required for drawing. Direct measurements are also compared on the map. This is very useful for geological interpretation of the Φ-value classification method and allows you to use traditional mathematical tools for statistical sorting and also the particle size analysis data. In particular, calculation of particle size parameters is easy to performed and carried out. The basic laws of mathematics are then used to describe the particle size distribution of the sediment like mean, root mean square error, skewness, kurtosis, mode. ISO 14688-1:2002 specifies basic principles for identifying and classifying soil based on soil material and mass

The most commonly used properties of soil for technical purposes in ISO 14688-1, applies to natural products, in-situ soils, similar man-made materials in-situ, and soils relocated by humans.According to Stokes law, the force resisting a spherical body in a viscous fluid is inversely proportional to the sphere's velocity, radius, and fluid viscosity.

Settling Velocity by stokes law is given by: $V = gd^2(p_S-p_U)/18_u$

where V=Velocity of settling particle

D=Diameter of settling particle

g=Acceleration due to gravity

p_s=Density of settling particle

p_u=Density of water

U=Dynamic viscosity of fluid

Stokes' law applies to particles with particle sizes between 0.002 mm and 0.2 mm and a maximum Reynolds number of up to 1. Stokes' law applies under the following conditions: Particles must be solid, smooth, and spherical. The density of the particles must be uniform. The particles must be sufficiently large (>0.001 mm) compared to the liquid molecules so that the thermal (Brownian) motion of the liquid molecules does not affect the particles. Particles must not interfere with each other during their fall. Stokes' law is used in falling ball viscometers, where a ball of known density descends through a vertical tube.

CLAY MINERALOGY

Clay is a soft, freely bound, fine-grained natural rock or earth material less than 0.005 mm in diameter, consisting essentially of clay particles.Clays are primarily inorganic substances, with the exception of peat, mud and some soils. which contain large amounts of organic/natural substances. Clay particles are elongated by weathering and erosion of rocks including earth, ceramic clays, shales, glacial clays (which contain large amounts of debris and transported clay), and the mineral group feldspar (known as the "mother of clay"). It is formed over a period of time. During weathering, the feldspar content is distorted by hydrolysis processes, resulting in the formation of clay minerals such as kaolinite (the main mineral of kaolin clay) and smectite (the chief mineral of bentonite clay). Clays can combine with one or more clay minerals even in the presence of small amounts of quartz (SiO2), metal oxides (Al2O3, MgO), and organic materials. The plasticity of clay is based on particle size, shape, and moisture content, and when dried or fired it becomes hard, hard, cohesive, and non-plastic. Plasticity and hardness are strongly influenced by the chemical composition of the materials contained in the clay.

The particular wavelength is specific to the target (Cu, Fe, Mo, Cr). Filtering using a foil or crystal monochromator is required to generate the chromatic X-rays needed for diffraction. Copper is the most common target material for the crystal diffraction with 1.5418 A Cu-Ke radiation. These X-rays are focused and directed towards the sample. As the sample and detector rotate, the intensity of the reflected X-rays is recorded. If the shape of the incident X-rays hitting the sample satisfies the Bragg equation, constructive interference and intensity peaks will occur. The detector records this X-ray signal, processes it into a count rate, and outputs it to a device such as a printer or computer monitor. The geometry of an X-ray diffractometer is called a goniometer, where the sample is in the path of a collimator that is used to maintain an angle and rotate the sample. For typical powdered fuels, data is collected at angles between 5° and 70° (the angles present in an X-ray scan). The Laue equation is an equation developed by Von Laue that describes diffraction on three-dimensional structures. W. L. Bragg created a simpler and more understandable mathematical solution. Although the derivations eliminated some unneeded complexity, his final quations are equally as valid as Von Laue's.

Traditional X-ray diffraction studies assume that n is 1 in Bragg's law. The first-order diffraction occurs on a plane d away at the same angle, and the second-order diffraction occurs on a plane twice as far apart, so the two cannot be distinguished. When we talk about X-ray diffraction, we use the highest order that is the first order. Another application of Bragg's law is diffraction. In traditional X-ray diffraction studies, the incident X-ray beam hits the sample from different angles, producing different d values. This corresponds to the Bragg equation and causes diffraction. After diffraction, the x-ray beam moves away from the central beam at an angle of 20°. Diffraction happens at a variety of 20 angles because a crystal comprises numerous atom-filled planes that are all distributed unevenly. The majority of modern X-ray machines use the detector, which measures X-ray intensity, moves rough the complete range of angles from close to 0 to some high angle while the sample is at a Fred pace (although it may rotate).

IDENTIFICATION OF MINERALS FROM XRD DATA

X-ray diffraction (XRD) is a powerful tool for identifying minerals based on the XRD pattern of their crystal structure. The process of identifying minerals from XRD data typically involves the following steps:

Data Collection: XRD data is collected from the sample using a diffractometer that measures the intensity of X-rays diffracted by the mineral's crystal lattice.

Peak identification: Analyze XRD patterns are analysed to identify peaks that correspond to different crystalline levels within the mineral lattice. Each mineral has a unique set of peaks that can be used to identify the mineral.

Mineral identification: The identified peaks are compared to a database of XRD patterns of known minerals, such as the International Center for Diffraction Data (ICDD) database. Databases can be searched for matches to observed peak positions and intensities.

Verification: Once a potential match is found, a comparison confirms the identity. Additional properties such as chemical composition, optical properties, and physical properties. Quantitative analysis: Using methods such as Rietveld purification and quantitation phases, the intensities of peaks can be used to determine the relative abundance of different minerals in a sample.

Overall, XRD is a powerful tool for mineral identification, but requires careful sample preparation, data collection, and analysis to obtain accurate and reliable results.

SAMPLING

Borehole retrievals were obtained from Dilip Buildcon Company, which constructed the new eight lane Zuari bridge.

Sample Preparation

25 g of each sample was weighed in a 250ml beaker. Little water is added and it is kept for soaking. The soaked samples have been crushed gently by using a glass rod. After crushing 100ml of 6% hydrogen peroxide was added with constant stirring and heated at 40°C for 1 hour. The sediments were allowed to settle before being decanted to the bare minimum Distilled water was used to clean the sample. Each sample should get 40 ml of 2M sodium carbonate, which should be added while stirring continuously. Each sample should be decanted and cleaned with distilled water three to four times. The aforementioned procedures were carried act in order to remove the samples' respective organic matter, silica concentration, and altines. The saline-free samples have been decanted to a minimum of water, and 250 ml of 10% adium hexametaphosphate has been added. The samples have been mixed, and they have been allowed to sit for at least two hours. Later, they pass through a sieve with a 230 mesh size. In pre- weighed 100 ml beakers, the sieved sand fraction is collected and dried in the oven later they were sieved for grain size analysis. The solution of the sieved sample is collected in 1 litre-sized measuring cylinder. The samples are vigorously agitated and allowed to settle in peace for 20 seconds, 4 minutes, 28 seconds, and 3 hours, 41 minutes later, 20 cm, 10 cm, and 5 cm of sample are pipetted out, accordingly. Preweighed beakers are used to collect the sample, which is then dried in the oven. The beakers are weighed for grain

size calculations after drying. For XRD examination, the samples are further ground. Below is the procedure for making slide for XRD analysis. For the XRD analysis Rigaku Xray machine had been used. The process used to place the sample for analysis ia as follows:

• After drying obtained a few tenths of a gram of clay mineral

•Grinded the sample to a fine powder

•Placed into a sample holder smear uniformly onto a glass slide, assuring a flat upper surface pack into a sample container sprinkle on double sticky tape.

•Care must be taken to create a flat upper surface and to achieve a random distribution lattice orientations for creating an oriented smear.

• For analysis of clays which require a single orientation, specialized techniques for preparation of clay samples are given by USGS.

• For unit cell determinations, a small amount of a standard with known peak positions (that do not interfere with the sample) can be added and used to correct peak, positions.

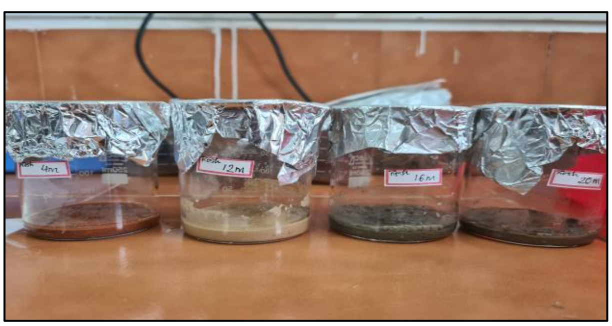


Figure No.03 : Samples kept for soaking

Figure No.04: Samples kept for settling in 1000 ml volumetric beakers

Figure No.05: Sieve Analysis

Figure No.06: 10 ml solution pipetted out for XRD analysis

Figure No.07: Clay Samples kept for drying

Petrography

Hard rock specimens of 20m and 21m depth, which constitute the basement were studied megascopically. One sample from the depth of 20m, as well as each from the depths of 21 m. Thin sections were obtained, viewed and investigated. The slide was examined with a Nikon ECLIPSE E200 microscope, using a 4X lens.

Figure No.08 : Nikon ECLIPSE E200 microscope

CHAPTER IV- ANALYSIS AND CONCLUSIONS

GRAIN SIZE DATA

Samples from drilled cores encompassing the whole sediment column, including the Zuari estuary basement, were taken from the slope of Sotrant. The pipette method was used to determine grain size by making a solution out of 25gm of dry material

ls. The information gathered is listed below.

SAMPLE	SAMPLE ID	GRAVEL %	SAND %	SILT %	CLAY %
4 m	3P58_4 m	---------	41.27	1.97	56.77
12 m	3P58_12 m	---------	12. 69	0.6	86.7
16 m	3P58_16 m	---------	44.56	3.424	52.01
20 m	3P58_20 m	3.84	45.308	1.184	49.67

Table No.4: Grain Size Data [Percentage]

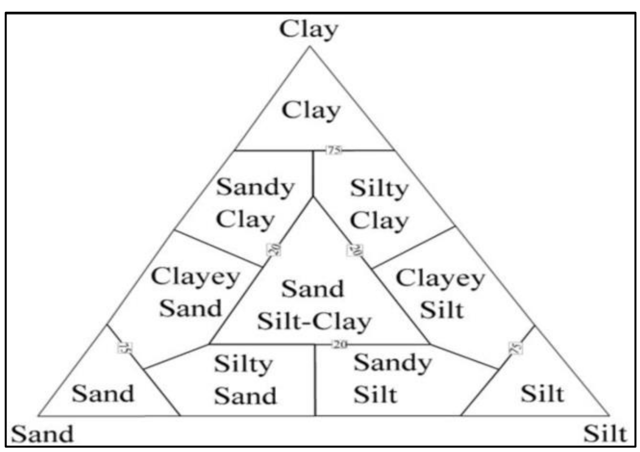
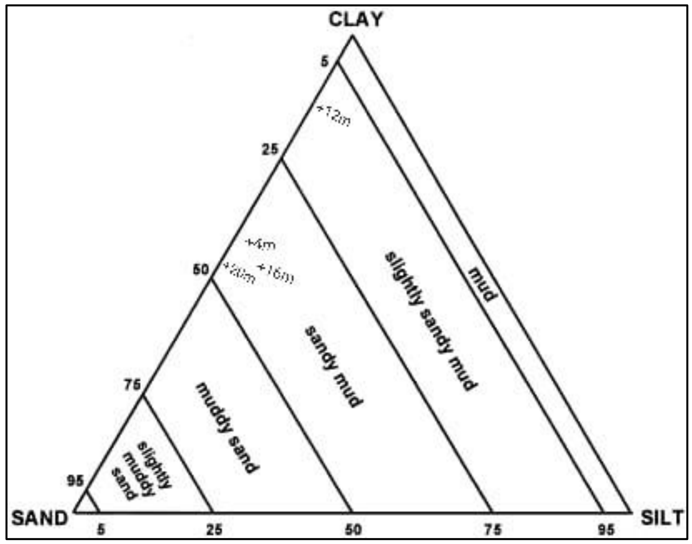
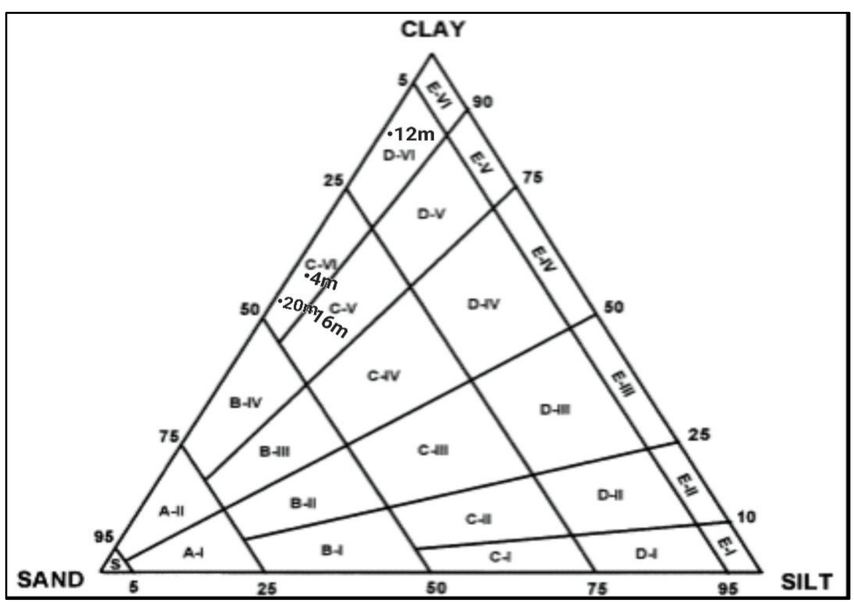


Diagram showing sand-silt-clay texture

As mentioned above (Shepard (1954)) classification of sediment types. Sediment type classification is based on relative percentages of each size component.



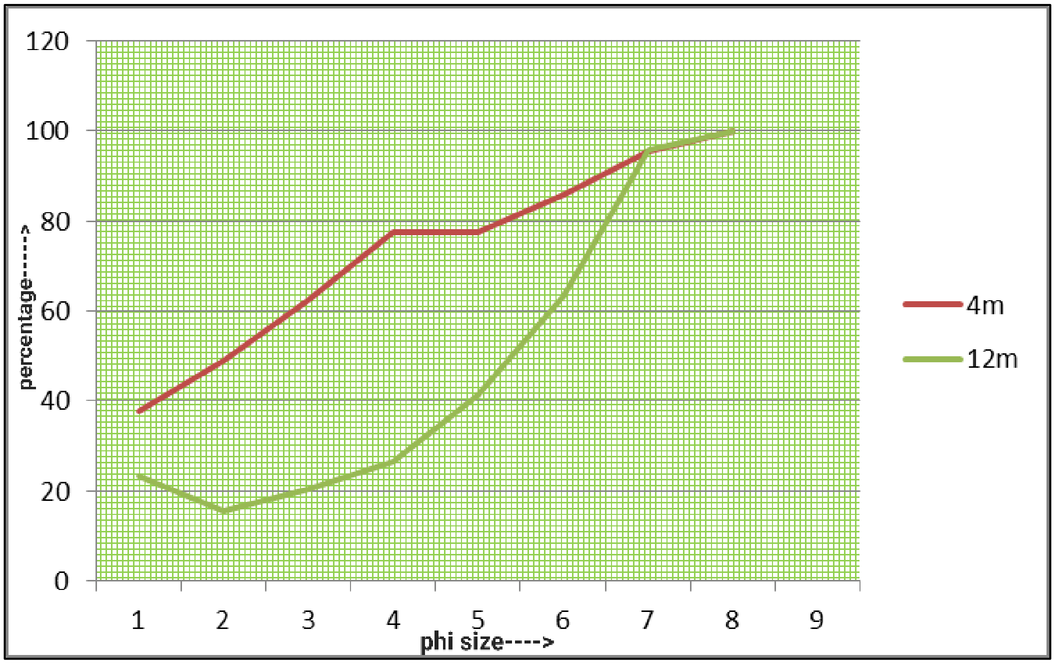
Ternary diagram for sand-silt-clay mixture (after Flemming,2000)



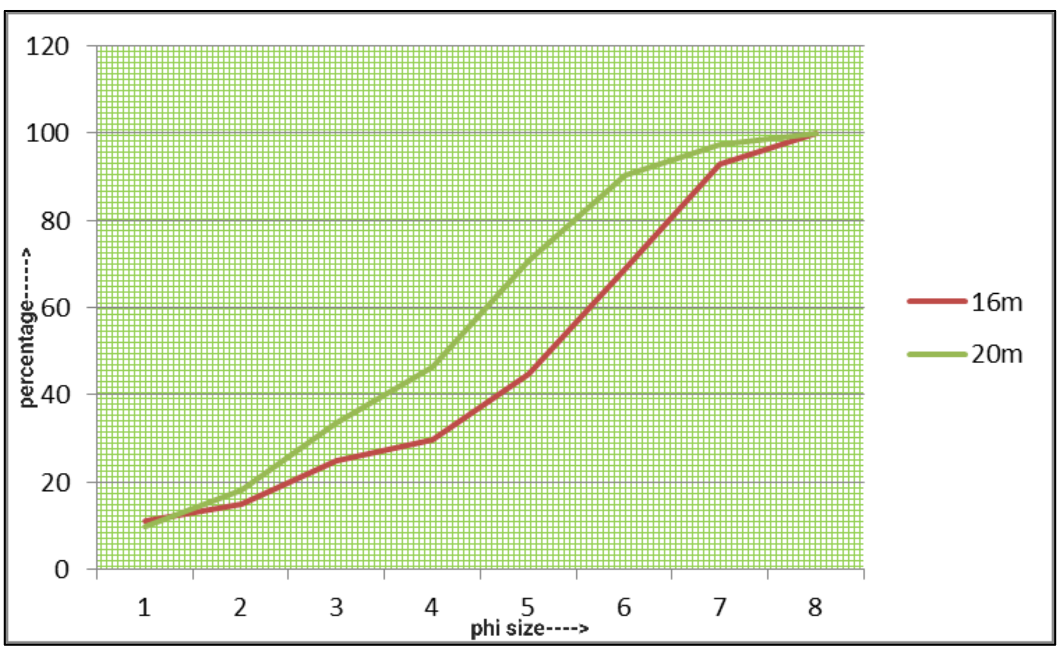
Ternary diagram showing hydrodynamic condition (Perjup 1988)

Sample ID	Code	Textural class name
3P58_4 m	C- VI	Clayey Sandy mud
3P58_12 m	D- VI	Clayey slightly Sandy mud
3P58_16 m	C- V	Clayey Sandy mud
3P58_20 m	C- VI	Clayey Sandy mud

Table No.5: Descriptive terminology of the three- component sand- silt- clay sedimentary system illustrated in graph no. 2 (after Flemming, 2000).



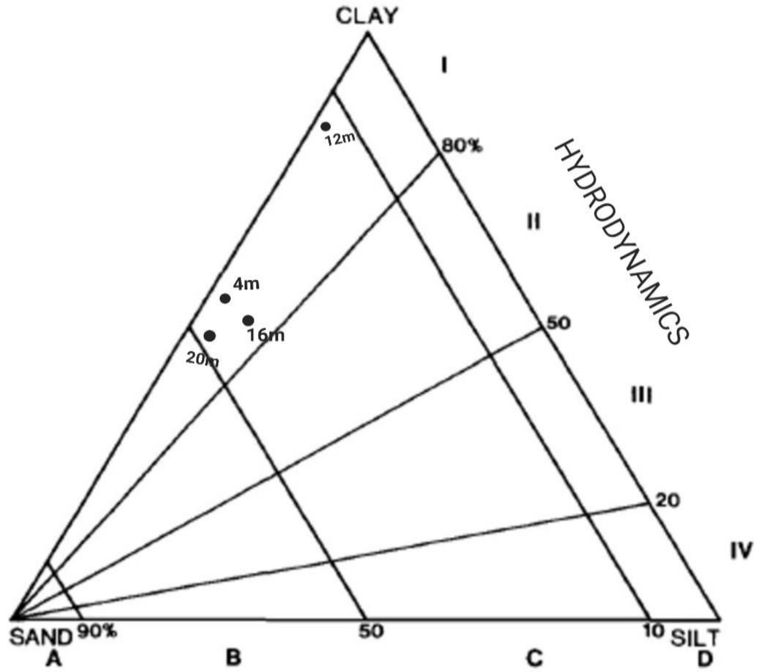
Graph No.1



Graph No.2

Sample ID	Mean	Standard Deviation	Skewness	Kurtosis
3P58_4 m	1.40 Medium	1.36 Poorly sorted	0.39 Positively skewed	0.59 Very platykurtic
3P58_12 m	2.47 Fine	1.19 Poorly sorted	-0.57 Strongly negative skewed	1.23 Leptokurtic
3P58_16 m	2.52 Fine	1.20 Poorly sorted	-0.46 Strongly negative skewed	0.97 Mesoplatykurtic
3P58_20 m	2.10 Fine	1.04 Poorly sorted	-0.31 Negatively skewed	0.90 Platykurtic

Table No.6: Graphical grain size parameters for sediment sample.



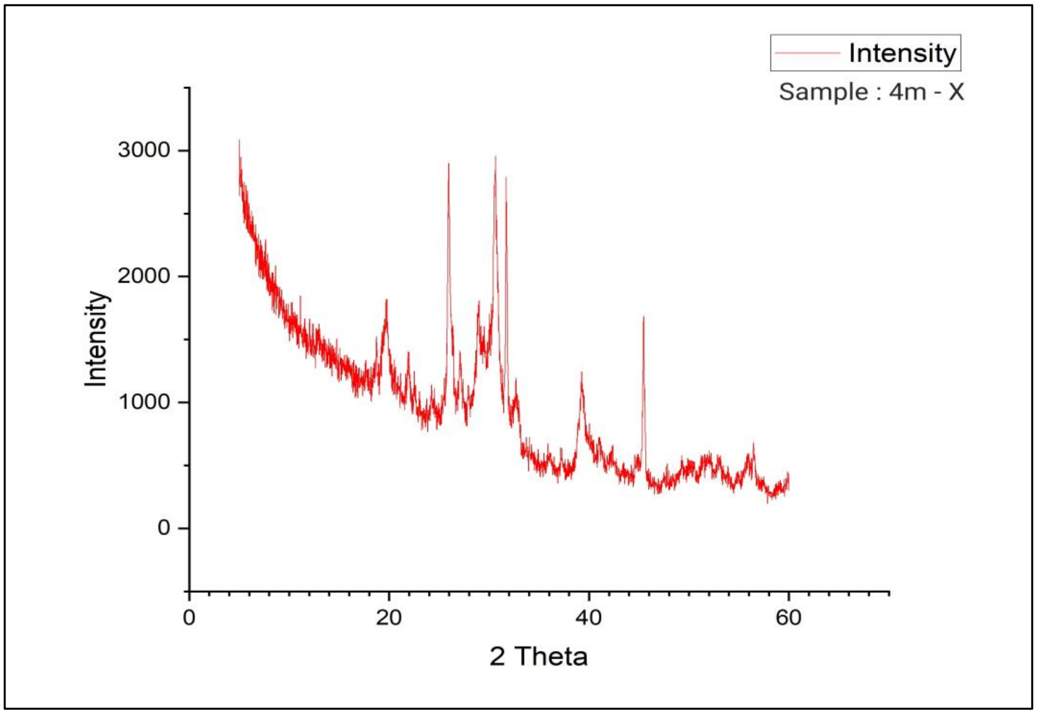
Pejrup's Diagram (1988) classification of hydrodynamic conditions.

The samples' sand fraction varies, with a minimum proportion of of 16% and a maximum percentage of 45.88%. Likewise, the clay fractions range from 20.0% and a maximum percentage of 50%, respectively. Table 5 provides a textural classification of each sample. The, sample with slightly sandy mud is sample 2. In Table 6, the terms mean, standard deviation, skewness, and kurtosis are classified according to their values and descriptions. From 1 to IV, hydrodynamic conditions get more intense, according to the ternary diagram (Perjup 1998). As can be observed in graph no. 4, all samples fall under category I, which had hydrodynamic conditions that were calm-and moderately strong. Textural roughness is displayed in Categories A through D with respect to increasing sand fraction.

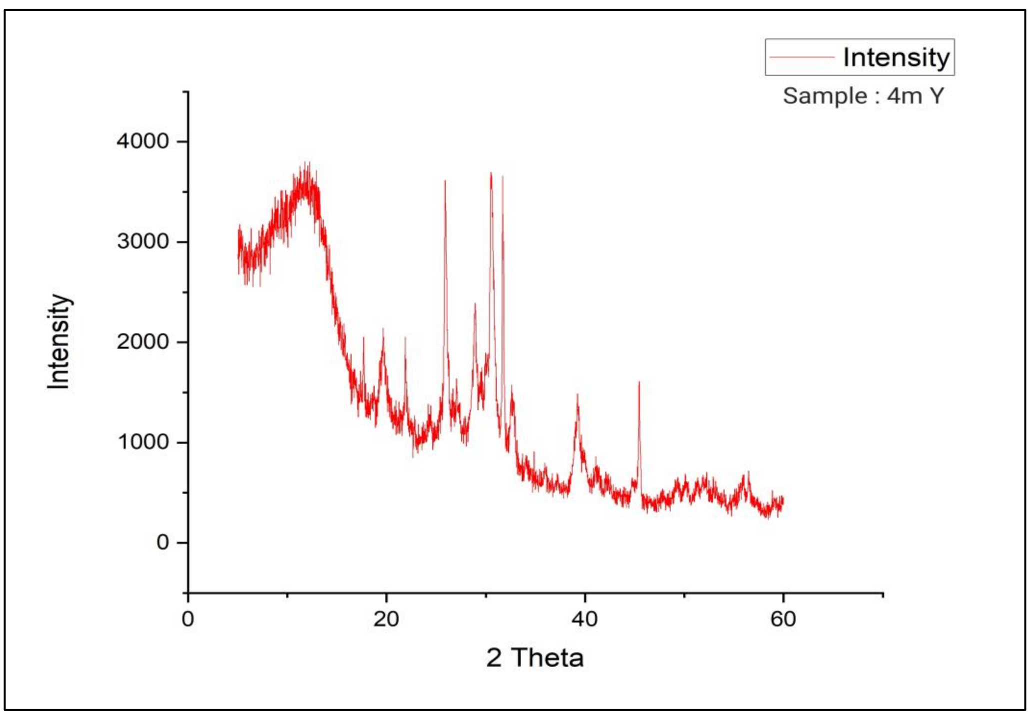
Clay Mineralogy

Using a Rigaku X-ray diffractometer with a copper source, X-ray diffraction patterns were discovered for 12 samples. Prepared sample slides were put in the diffractometer. The analysis of each sample took 15 minutes.

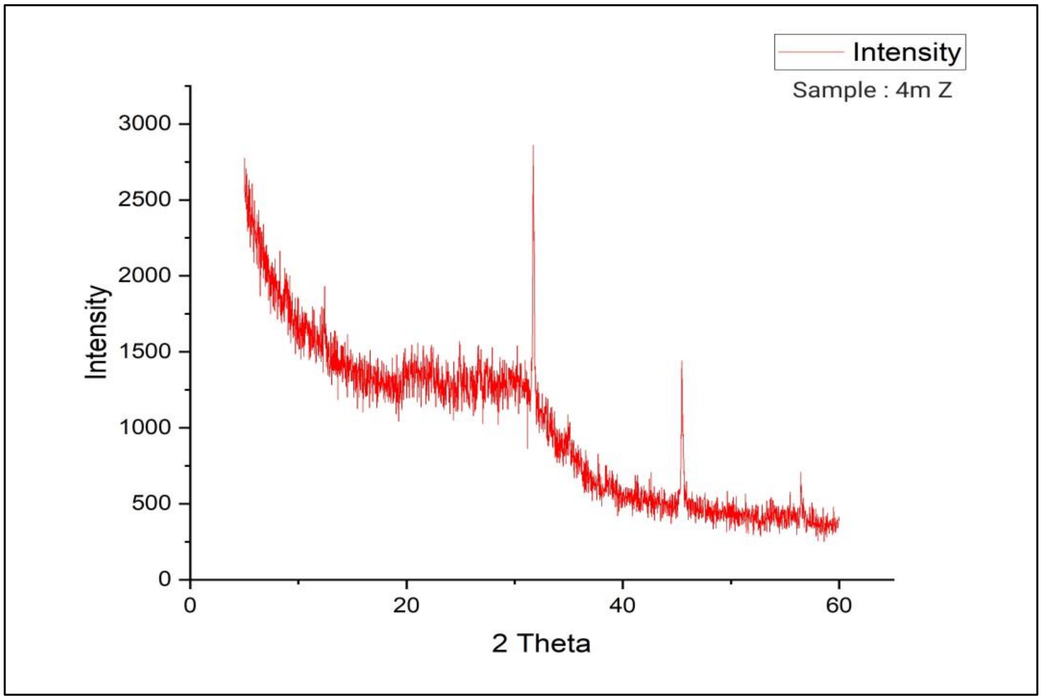
Figure No.09 and 10; XRD (RIGAKU) MACHINE AT GOA UNIVERSITY.



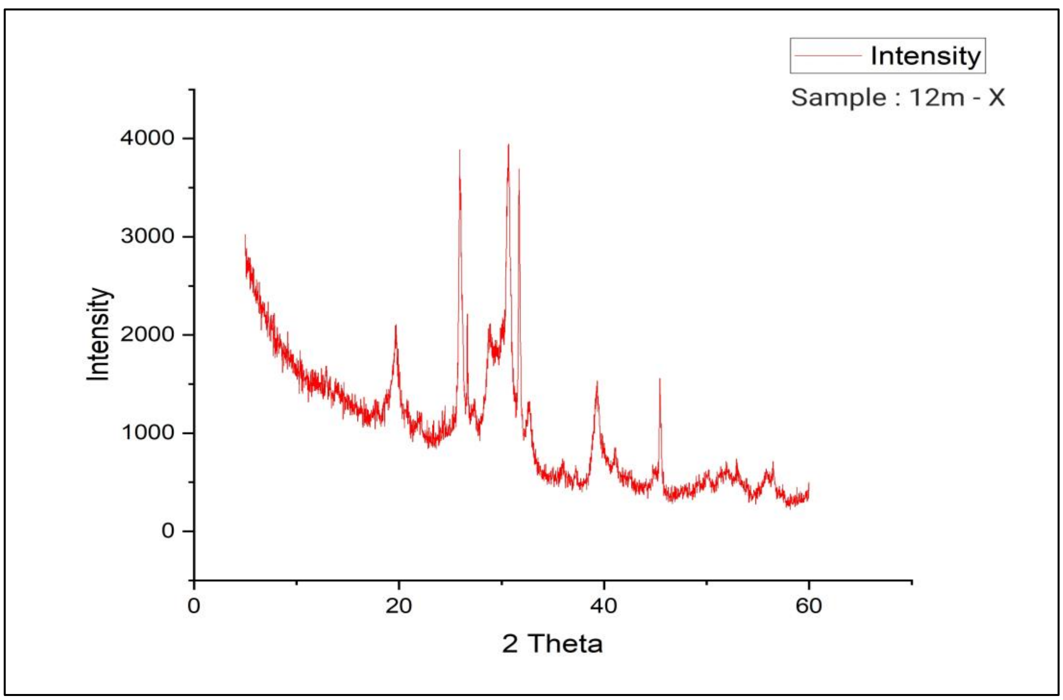
Graph No.3



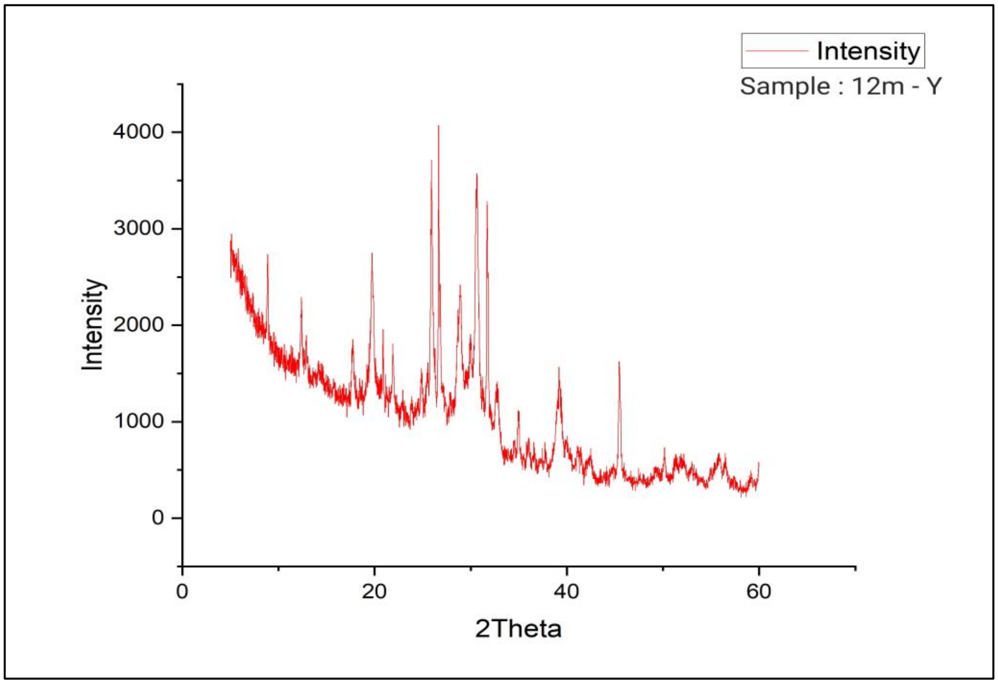
Graph No.4



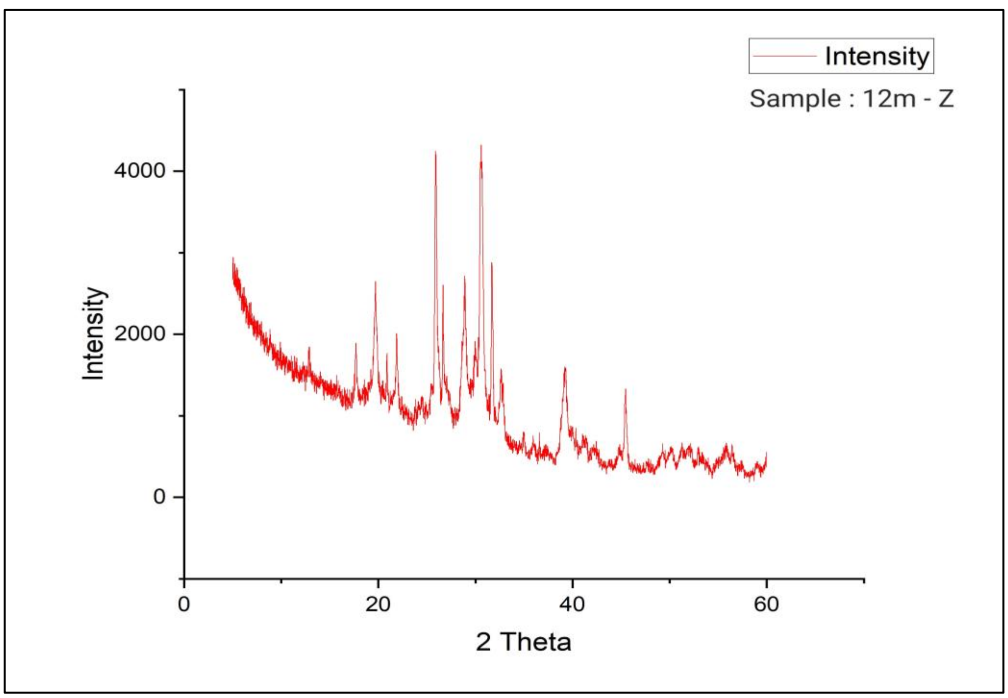
Graph No.5



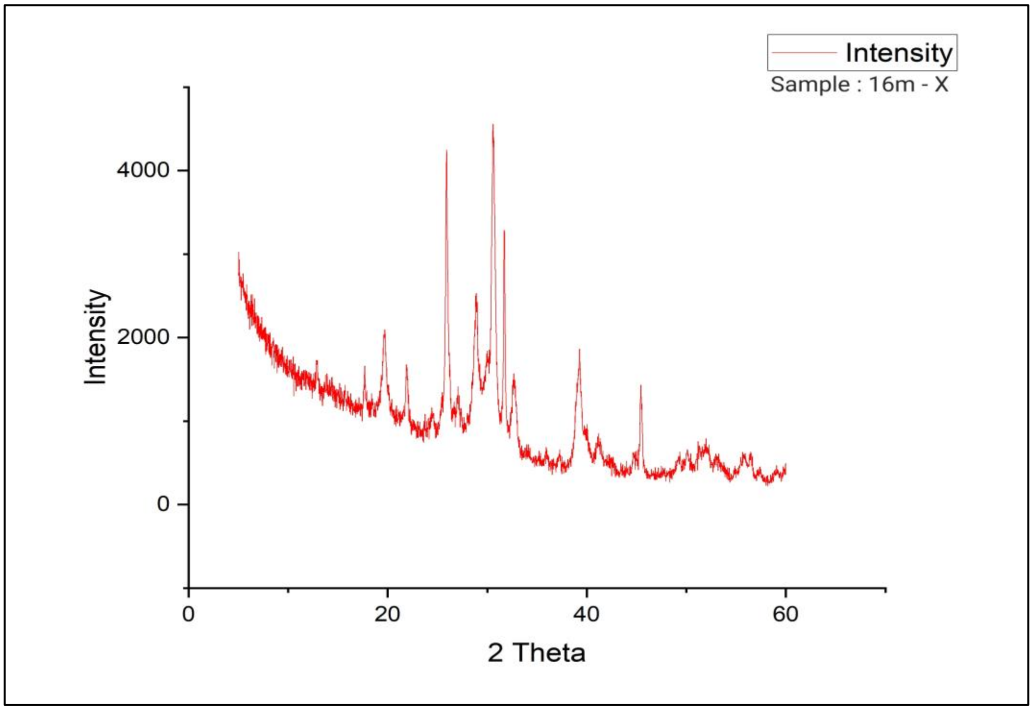
Graph No.6



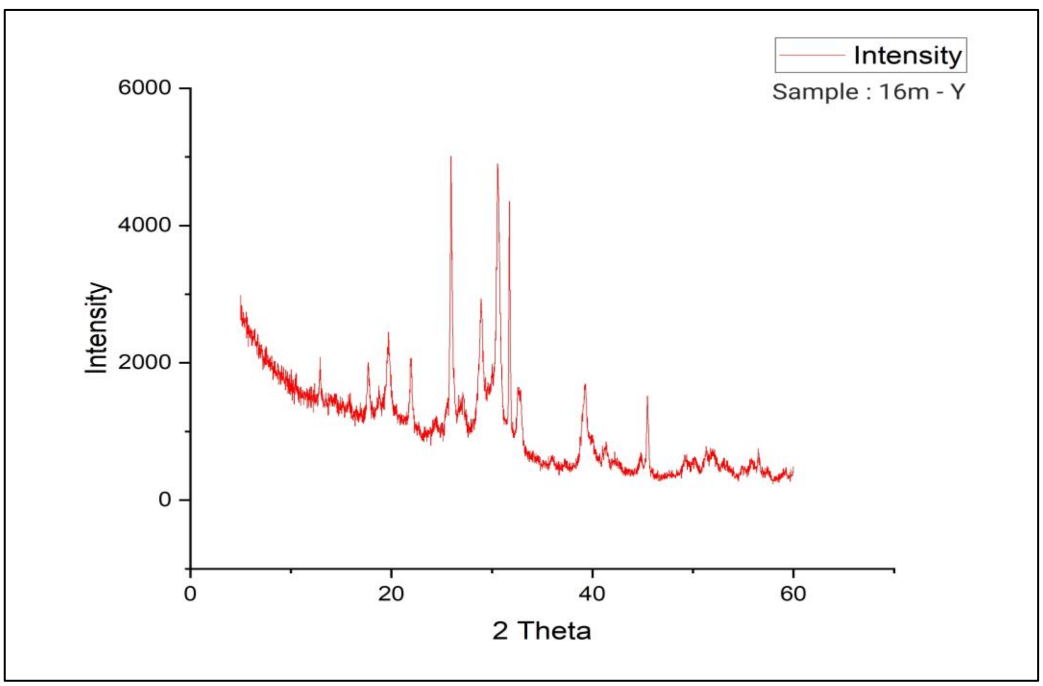
Graph No.7



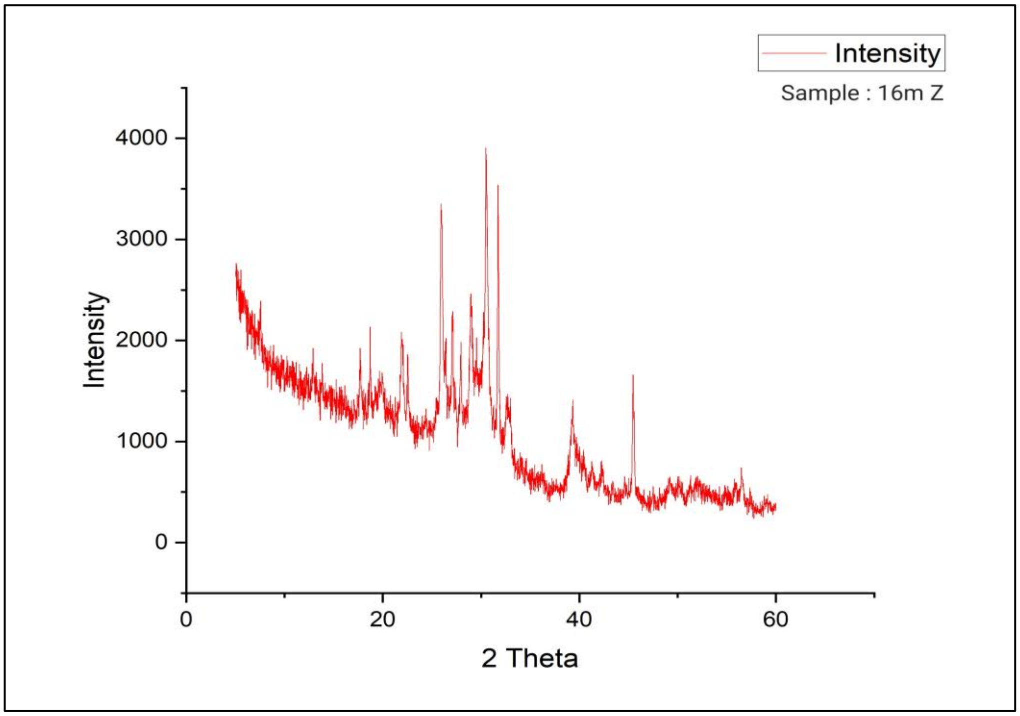
Graph No.8



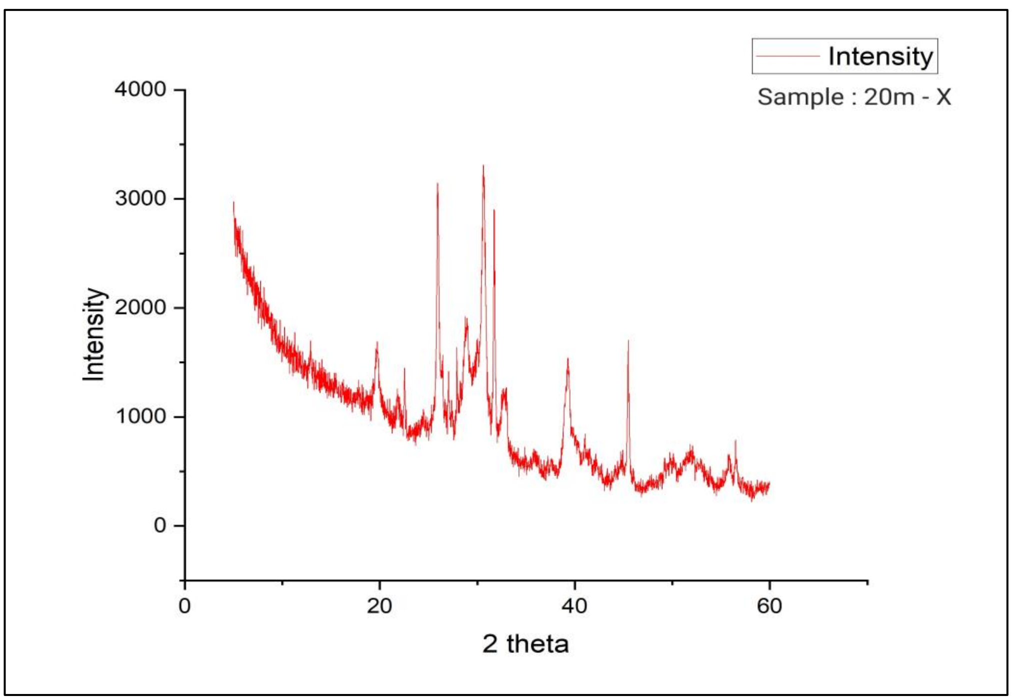
Graph No.9



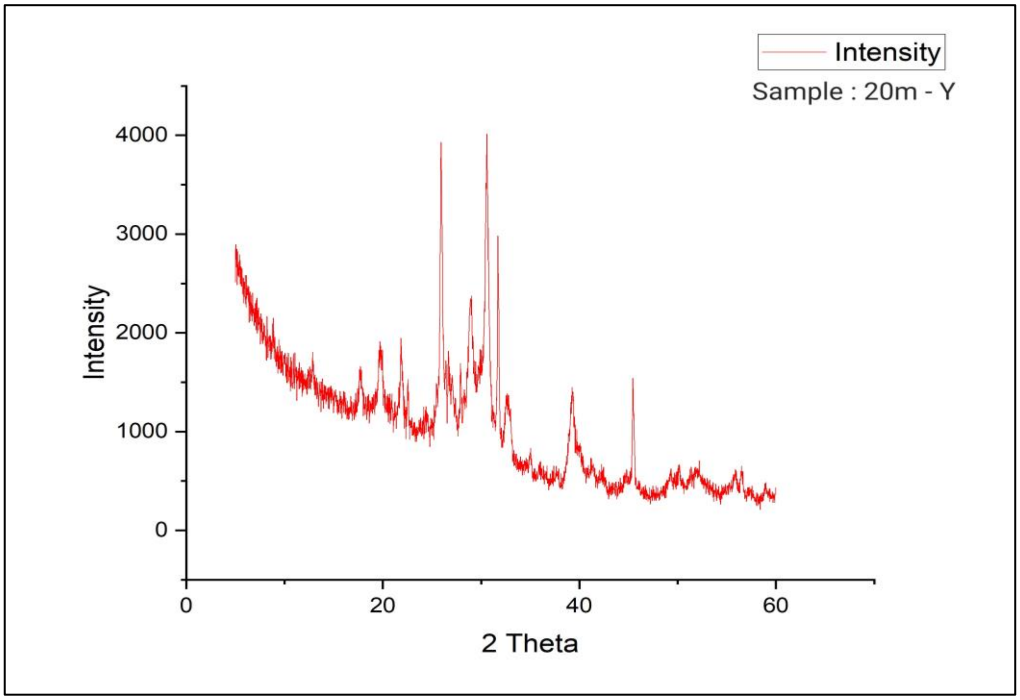
Graph No.10



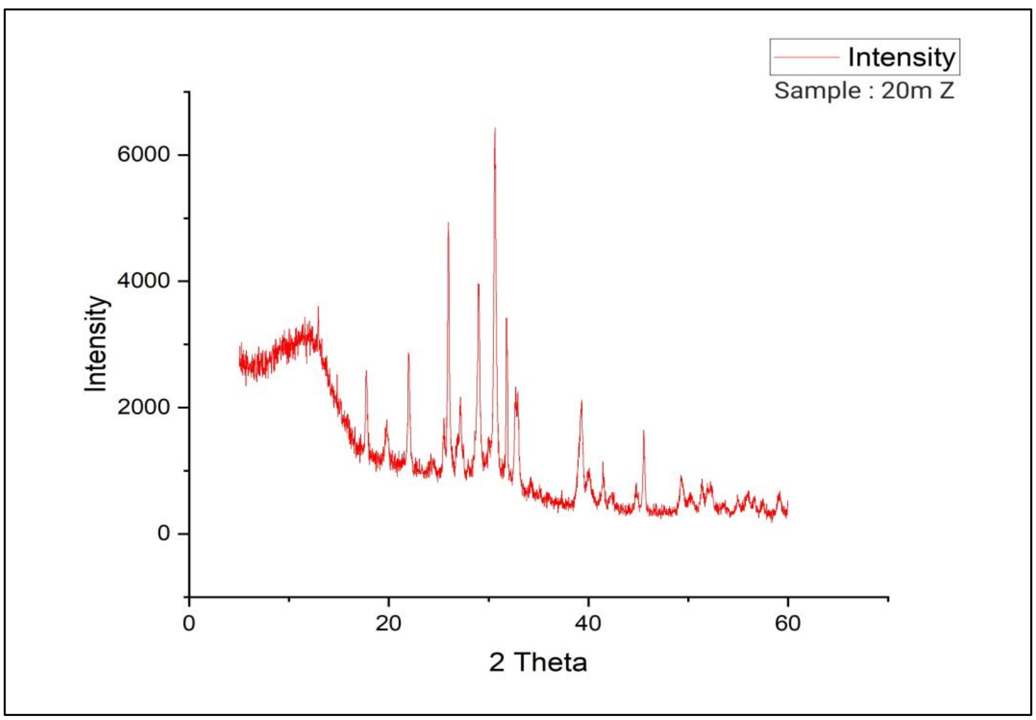
Graph No.11



Graph No.12



Graph No.13



Graph No.14

Based on the peak intensities, clay minerals were identified Results are listed in the table below.

SAMPLE ID	Clay Minerals
3P58_4m X	Kaolinite, Quartz, Illite, Montmorillonite
3P58_4m Y	Kaolinite, Quartz, Illite
3P58_4m Z	Kaolinite, Quartz
3P58_12m X	Kaolinite, Quartz, Illite, Montmorillonite
3P58_12m Y	Kaolinite, Quartz, Illite
3P58_12m Z	Kaolinite, Quartz, Illite
3P58_16m X	Kaolinite, Quartz, Illite, Montmorillonite
3P58_16m Y	Kaolinite, Quartz, Illite
3P58_16m Z	Kaolinite, Quartz, Illite
3P58_20m X	Kaolinite,Quartz,Illite,Montmorillonite,Chlorite
3P58_20m Y	Kaolinite,Quartz,Illite,Montmorillonite,Chlorite
3P58_20m Z	Kaolinite,Quartz,Illite,Montmorillonite,Chlorite

Table No.7: Identification of Clay minerals of the borehole.

02 04 06 08 10 12 14 16 18 20 22

	Munsell Code		ClayMineral
	5YR 6/4	Clayey sandy mud	Kaolinite ,Quartz ,Montmorillonite , Illite
	5Y 8/2	Clayey slightly sandy mud	Kaolinite ,Quartz ,Montmorillonite , Illite
	7/10 Y	Clayey sandy mud	Kaolinite ,Quartz ,Montmorillonite , Illite
	7/10 Y	Clayey sandy mud	Kaolinite ,Quartz ,Montmorillonite , Illite , Chlorite
	------------	Country rock	Gneiss

Figure No.11: Lithology of study area

MICROSCOPIC CHARACTERISTICS

At the depth of 21m, the rock pieces are found of which slides were made to identify the minerals. Thin section description of minerals are below:

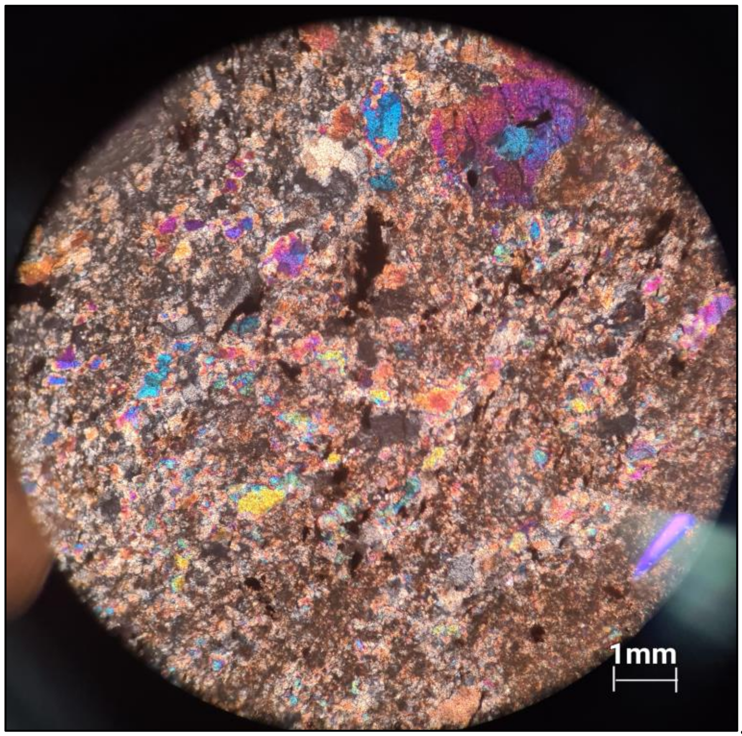


Figure No.12: Country rock-gneiss

In the thin section, the rock is medium to coarse grained and exhibit a granoblastic fabric.

The mineral is colourless, granular and has low relief and it is clear in plain polarized light; Between cross polar, it shows first order grey interference colour and at some places yellow; and sometimes exhibits undulose extinction indicating quartz mineral; which is clear indication that the rock has undergone the effect of strain.

The mineral is colourless and has low to moderate relief. Grains identified are rectangular in shape, between cross polar light, it shows first order grey to white interference colour, The extinction is inclined and it shows polysynthetic twinning; which indicates it is a plagioclase.

The mineral is colourles and has moderate relief and irregular shape; Presence of one set perfect cleavage, between cross polar, it shows second to third order bright-high interference colours. It shows parallel extinction.It is a muscovite.

A framework pattern was observed with some pleochroism in plain polarized light that is iron oxide, this is because of the Fe - oxidation in the rock, The texture observed are because of the precipitating layers within the iron oxide cementation,suggesting multiple iron precipitating events.

The mineral is colourless and has high relief, presence of cleavage, between cross polarized light, it shows second order interference colour it also shows inclined (45°) extinction therefore it is identified as clino pyroxene (Augite).

Mineralogicaly the rock consists of quartz, feldspar and muscovite and also iron oxides Quartz and feldepar are the essential minerals, the minerals are not oriented. The rock is Gneiss.

INTERPRETATION

The study area constitutes backwater sediment, and we used grain size analysis to determine the lithology, sediment mineralogy, and sequence of depositional environments. Clay mineralogy was studied and thin sections of the bedrock were used to determine the petrographic characteristics of the area.

Four available samples are taken from the sediment core at different depths 4 m, 12 m, 16 m, and 20 m for analysis. The country rock gneiss is at a depth of 21 m. According to particle size measurements, the 4m, 12m, 16m, and 20m samples have a smoother texture. The average size of a sediment is influenced by the transport medium, the source, and the energy level of the environment in which the sediment is deposited. The main tendency or average size of the deposit is called the average size, which, according to Sahu (1964), in terms of energy, it refers to the typical kinetic energy rate of the depositing agent.

The observed sorting variability can be attributed to variations in sediment flow rate and water. All samples were poorly sorted, suggesting that there were velocity fluctuations that caused turbulence, resulting in poor or very poor sample sorting.

The symmetry of the central part of the distribution is determined using skewness. This indicates symmetry or asymmetry in the sediment abundance distribution.

Skewness occurs when two different normal populations are mixed in varying ratios, and it suggests that coarse dominates fine and vice versa. The skewness values reveal the depositing medium's kinetic energy.4m is positively (Fine) skewed value and samples 12m ,16m and 20m are Negatively (coarse) skewed (Layade ,et.al 2019).

The percentage of clay in the mud fraction serves as a proxy for the hydrodynamic state of the depositional environment. From section I to section IV, the hydrodynamic condition becomes more turbulent. The sediment is divided into four groups. A to D, based on how much sand it contains. The triangle has been divided into 16 groups as a result. At depth of 4m and 20m the hydrodynamic code value is C-VI and at depth of 12m and 16m are D-VI AND C-V. All these samples fall in category I, indicating calm environment (Perjup 1988).

Severe leaching of crystalline metamorphosed phyllites and silicate alteration of laterites in tropical climates can lead to the formation of kaolinite. Leaching of crystalline metamorphic rocks and phyllites can lead to the formation of illite, Montmorillonite are formed by the metamorphosis of feldspar minerals. Chlorite is formed by ion exchange with other clay minerals in a diagenetic fluid environment rich in iron and magnesium,rocks due to weathering,minerals play an important role in soil composition, especially in tropical regions. It has a low pH value typical of freshwater or seawater, where a solution containing Na, Ca, Mg, and ferrous iron forms as the rock surface weathers.

At a depth of 21m crystalline rock was found which showed felsic and mafic bands in the hand specimen. As observed in the thin section the rock contains quartz, muscovite, calcic.plagioclase and iron oxides which indicates the rock is Gneiss.

The sediment pile from Sotrant, Cortalim mentioned above enables certain inferences about the palaeoenvironment circumstances during the sediment's deposition in the Zuari estuary. The study area contains laterite granules at the depth of 4m.

This sedimentation's high energy depositional periods are shown by the lithosection's sandy and then muddy horizons, which are distinctive . Given that the sediments contains organic materials, it can be inferred that they are a product of the maritime intrusions throughout this time period's depositional phases. According to Dessai (2018), the clayey sediments above the sea level laterites are identical to the Dapoli clays, which have been dated to between 3.5 and 2.6 ka BP (Kumaran et al. 2012). To establish clear controls on the kind of sedimentation and the palaeo-environments of their deposition, more work on these sediments is necessary.

RESULT

Four samples were collected from the study area, each representing a different depth of 4m,12m,16m and 20m. The basement rock is a gneiss at a depth of 21m. All the samples have smoother texture, according to the grain size measures. Samples at 4m depth is positively skewed indicating calm environment and samples at 12m,16m and 20m depth is negatively skewed indicating turbulent environment. To know the hydrodynamic condition the data are plotted of each sample. 4m,12m,16, and 20m fall into C-VI, C-V and D-VI, that falls in category I, which indicates a calm environment. The ternary diagram plots classification of the hydrodynamic parameters of the depositional environment show that the sediment underwent just one cycle of depositional settings. From XRD analysis of clay, quartz, kaolinite, illite, chlorite and montmorillonite are found. The descriptive log is the result of all this data. Palaeo-environment conditions of the study area shows presence of laterites granules at the depth of 4m. According to Dessai (2018), the clayey sediments above the sea level laterites are identical to the Dapoli clays, which have been dated to between 3.5 and 2.6 ka BP (Kumaran et al. 2012).To establish clear controls on the kind of sedimentation and the palaeo-environments of their deposition, more research on these sediments is necessary.

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M.Sc in Applied Geology

by

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Certificate

This is to certify that the record of work done by Miss. Roshni Pujari of class MSc Applied Geology Part-ll, Year 2023-2024, contained in this report has been examined and signed and that the course of fieldwork in Geology prescribed by Department of Earth Science of Goa University has been satisfactorily carried out.

Head of the Department.

Examiner's Signature :

Date:

DECLARATION BY STUDENT

I hereby declare that the data presented in this Field work report entitled, "Report on Geological field work in and around Bellary, Karnataka India" is based on the findings carried out by me in the M.Sc Applied Geology at the School of Earth, Ocean and Atmospheric Sciences, Goa University under the Supervision of Dr. Dr. A.A.A Viegas, Dr. Poornima Dhawaskar, Dr. Nicole Sequeira and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will be not be responsible for the correctness of observations/experimental or other findings given the Field report.

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