GRAIN SIZE ANALYSIS AND COARSE FRACTION STUDIES OF MARINE SEDIMENTS

Dissertation report submitted to
ADIKAVI NANNAYA UNIVERSITY
In the partial fulfilment of the requirements for the award of degree of

MASTERS OF SCIENCE IN GEOLOGY

Submitted by

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DEPARTMENT OF GEOSCIENCES
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ADIKAVI NANNAYA UNIVERSITY

RAJAHMUNDRY – 533 296, A.P.

DEPARTMENT OF GEOSCIENCES

DECLARATION

I hereby declare that the project work presented in this report, entitled "**Grain Size analysis and Coarse Fraction studies of Marine Sediments"** that is being done and submitted by me in partial fulfilment for the award of M.Sc., Geology in the Department of Geosciences, Adikavi Nannaya University, Rajahmundry, Andhra Pradesh. This work has not been submitted for the award of anydegree or diploma of any other university.

Rajahmundry,

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DEPARTMENT OF GEOSCIENCES

CERTIFICATE

I hereby declare that the project work presented in this report, entitled "**Grain Size analysis and Coarse Fraction studies of Marine Sediments"** is a bonafide record of work carried out and submitted by **Mr. Jakka Rama Krishna (2182930005)** in partial fulfilment of the requirement for the course of Master of Science in Geology.

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ABSTRACT

As a part of partial fulfillment of M.Sc. degree in Geology, a project work on Grain Size Analysis and Coarse Fraction Studies of Marine Sediments has been carried out at Marine and Coastal Survey Division, Geological Survey of India, Visakhapatnam. The sediments were collected during the cruise carried out using Research Vessel Samudra Ratnakar at continental shelf and continental slope of Nagapattinam, Tamil Nadu. Gravity corer was used for sample collection of Gravity core GC-10, GC-34 and Vibro corer was used for sample collection of Vibro core VC-30, VC-30/1 and VC-30/2. Chemical and physical treatments of the samples were carried out for doing wet sieving, dry sieving with the help of instruments like particle size analyzer, electric sieve machine, Magnetic stirrer etc. Data outputs retrieved from the grain size analysis shows Slightly Gravelly sand and Silty clay sediments with Strongly fine skewed to coarse skewed and Leptokurtic (GC-10, GC-34, VC-30/1, VC-30/2) and Platykurtic (SR 083 VC-30) nature of sediments noticed, which indicates medium energy conditions for VC-30, VC-30\1, VC-30\2, low energy conditions for GC-10 and medium to high energy conditions for GC-34 prevailed in the study area. The composition of sediments are mainly biogenic with 70-80%, the biogenic materials present are mainly Bolivina, Uvigerina, Trochammaina Inflata. The terrigenous materials mainly present are Quartz with angular to sub angular shape and minor Authigenic sediments are Phosphatic infillings in the shell fragments.

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1. INTRODUCTION

Geological Survey of India (GSI), founded in 1851, is a government of India organization under the Ministry of Mines. Since inception, it has grown into a repository of geo-science information required in various fields in the country and at the same time has also attained the status of a geo-scientific organization of international repute. With an aim to increase the visibility in the society as well as to enhance activities of GSI for greater collaboration with academia, the Ministry of Mines has taken up an initiative in the name of "BHUVISAMVAD" by the virtue of which, it conducts several interactive sessions as well as collaborative trainings and internships with the students of various educational institutions located in their field areas. This dissertation work was carried out under the "BHUVISAMVAD" programme in collaboration with M&CSD (Marine & Coastal Survey Division), OP: EC-II, Geological Survey of India, Visakhapatnam, as a part of partial fulfillment of M.Sc. Degree in Geology, Adikavi Nannaya University, a project work titled "Grain Size analysis and Coarse Fraction Studies of marine sediments of Nagapattinam, Tamil Nadu" has been carried out at Operation East Coast-II, Marine and Coastal Survey Division, Geological Survey of India, Visakhapatnam by studying grain size parameters and coarse fraction studies of two Gravity cores and 3 Vibro cores. The Grain Size analysis of a sediment can be used for describing the Mean, Median, Mode, Standard deviation, Kurtosis, Skewness. The coarse fraction study of sediments is used for describing the composition of the sediments. Hence to study the Grain Size analysis and coarse fraction study of sub-surface sediments of Nagapattinam, five sediment cores GC-10, GC-34, VC-30, VC-30/1 and VC-30/2 were taken for study, which were collected by Geological Survey of India during the cruise SR-083 on board RV Samudra Ratnakar, from the continental shelf and slope of Nagapattinam.

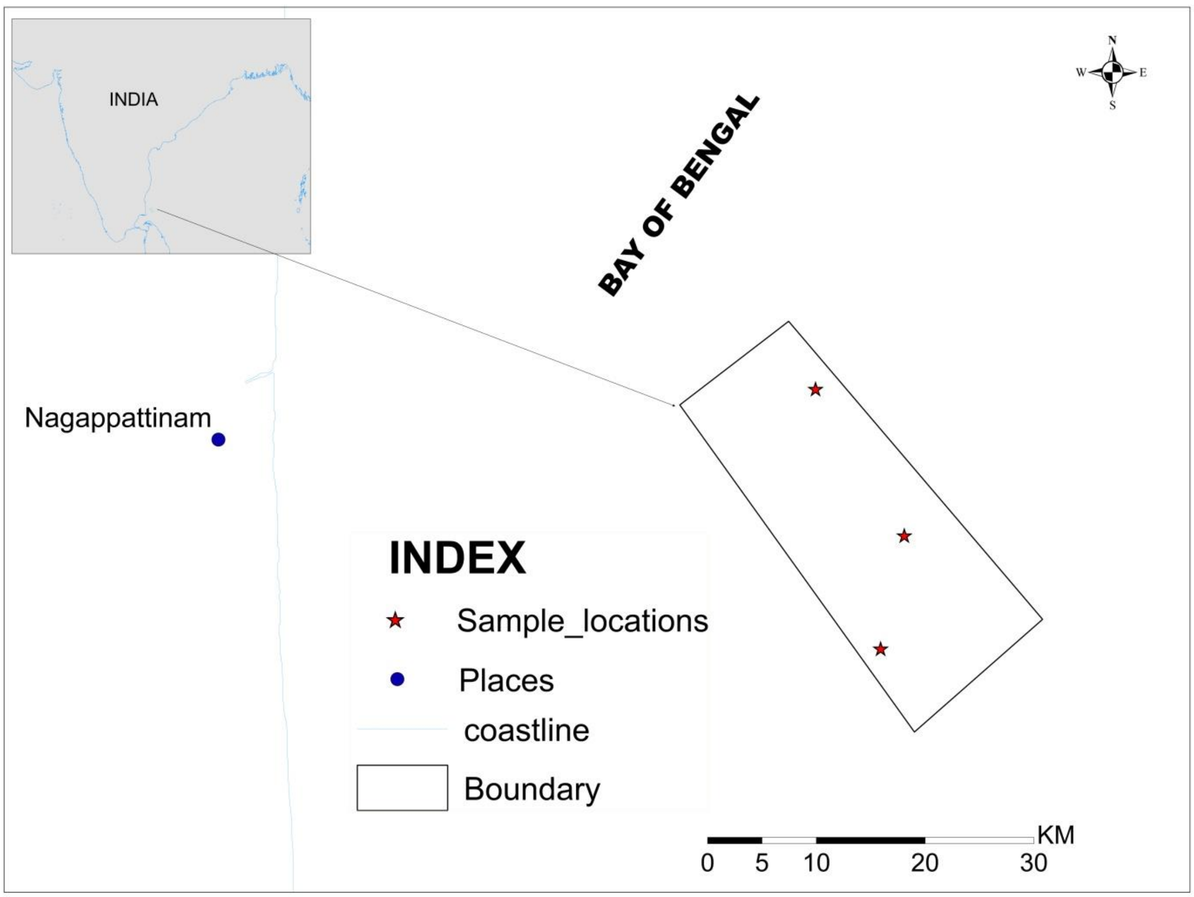
1.1 OBJECTIVE

The main objectives of the present study are

1. To understand the Statistical parameters, Depositional environments and energy conditions of subsamples of Gravity core GC-10, GC-34 and Vibro cores VC-30, VC-30/1 and VC30/2.
2. To understand the composition of sediments (Coarse Fraction).

1.2 STUDY AREA

The Gravity core samples GC-10, GC-34 and Vibro core samples VC-30, VC-30/1 and VC30/2 were collected from the continental shelf and slope of Nagapattinam, Tamil Nadu. VC-30, VC-30/1 and VC-30/2 was collected from a water depth of 206 m and has a core length of 4.66 m. GC-34 was collected from a water depth of 266 m and has a core length of 3.72 m. GC-10 was collected from a water depth of 80.28 m and has a core length of 2.59 m. Each core was sub-sampled according to colour, texture and presence of shells, etc. 3 subsamples were generated from VC-30 and one subsample form each cores GC-10 and GC-34 were studied for textural parameters and coarse fraction studies.



1.3 GEOLOGY OF THE AREA

The outer shelf of Nagapattinam, Tamilnadu is characterized by a thin veneer of authigenic sediments represented by vardine, glaucony, and phosphatic sediment (Vaz, 2000). Hard rugged karstic surfaces have been recorded of Chennai and Nagapattinam (Vaz, 1995). In the outer shelf of Chennai where water depth is 100-225m, phosphatic algal nodules and rock fragments were reported (Narassatta, 1997). The sediments comprise relict clayey sand, ooids, carbonate skeletal matter and phosphatic nodules. Relict sediments in the outer continental shelf without overlying recent sediments indicate low rate of sedimentation (Rao, 1999). The NE-SW trending Ariyallur-Puducherry depression which comprises sediments of Upper Cretaceous to Eocene may extend NE into the offshore domain. Phosphorite deposit of the Uttathur formation is a part of the extensive Cauvery basin (southernmost part of the basin along the eastern margin of Peninsular India) sediments formed during the Cretaceous. It is a tectonic depression with an area extent of 25,000 km^2 and an almost equivalent area extending into the offshore waters of the Bay of Bengal up to 200m isobath.

1.4 STRUCTURE AND TECTONICS OF THE AREA

Continental shelf is wider from north of Pondicherry upto Chennai. The continental slope is relatively steeper (1:6 to 1:8) of Chennai and Pondicherry. The floor of the continental slope occurs at a depth of 3000 m in the southern part but decreases to less than 2000 m in the north. Topographic high is observed at the foot of the continental slope and is broad over the south than in the north where it is recorded as sharp peak. The relief of the topographic high varies from a few tens of meters to 300 m and based on the geophysical data, is interpreted as the edge of the continental crust (Murthy et al., 1993). Lineaments have played an important role in shaping the shelf-slope morphology apart from the other geological processes (Murthy et al., 2002). Narrowing of the shelf and steep gradient in the vicinity of Nagapattinam was explained by Thakur and Kumar (2007) in their studies. Magnetic and gravity signals from the offshore indicate existence of granulite and the shelf edge invariably exposes the hard rock Charnockite extending from the land to offshore. Gravity high is observed mainly in the outer continental margin which may be due to the presence of high-density crustal materials/shallow bedrock. The low gravity in the inner continental shelf is due to the presence of thicker sedimentary deposits. Linear trends of dyke intrusions identified landward of Continental-Oceanic Boundary (COB) from magnetic data, which might represent the rift-phase volcanism associated with the evolution of ECMI. Such intrusives of Chennai and Visakhapatnam to Chilka Lake were demarcated from the magnetic data by Murthy (2015), the nature and extent of these intrusives and their relation to the land is yet to be studied in detail. These intrusions are associated with very high amplitude magnetic anomalies reaching at places nearly 1500 nT. The Chennai shelf represents the non-basinal part of the ECMI. The non-basinal areas provide an excellent record of relict strandlines related to eustatic sea level changes with associated rugged sea bed morphology and other subsurface hazards like buried channels, neotectonic faults etc.

2. INDIA AND ITS SURROUNDING OCEANS

2.1 ARABIAN SEA

Arabian Sea is the northwestern part of the Indian Ocean, covering a total area of about 1,491,000 square miles (3,862,000 square km) and forming part of the principal sea route between Europe and India. It is bounded to the west by the Horn of Africa and the Arabian Peninsula, to the north by Iran and Pakistan, to the east by India, and to the south by the remainder of the Indian Ocean. To the north the Gulf of Oman connects the sea with the Persian Gulf via the Strait of Hormuz. To the west the Gulf of Aden connects it with the Red Sea via the Bab el-Mandeb (Bab al-Mandab) Strait. It has a mean depth of 8,970 feet (2,734 meters).

The Arabian Sea was formed within the past roughly 50 million years as the Indian subcontinent collided with Asia. The Arabian Basin is separated from the Gulf of Oman Basin by the Murray Ridge, a narrow, seismically active submarine ridge that extends northeast to southwest to meet the Carlsberg Ridge. West of Murray Ridge is the Malian subduction zone, an area where the ocean floor sinks below the adjacent continental crust. Deep submarine canyon has been cut by the Indus River, which also has deposited an abyssal (i.e., deep-sea) cone of thick sediments some 535 miles (860 km) wide and 930 miles (1,500 km) long. The continental shelf is narrow along the coast of the Arabian Peninsula and is even narrower along the Somali coast. No true coral reefs are found along the Arabian coast. Terrigenous (i.e., land-derived) deposits cover the major part of the continental slope to a depth of about 9,000 feet (2,700 meters) Below this, deposits consist of the calcareous tests (shells) of Globigerina (a genus of protozoans belonging to the Foraminifera order), while basins below 13,000 feet (4,000 meters) are covered by red clay. Authigenic (i.e., formed in place) ferromanganese nodules have been discovered in the Arabian basin, and polymetallic sulfides have been found. Petroleum and natural-gas deposits have been discovered in the Arabian Sea on the continental shelf of the coast of India to the west and northwest of Mumbai (Bombay) and have been intensively exploited. Extensive small-scale fishing is carried on in the Arabian Sea, particularly of the east coasts of Africa, the Arabian Peninsula, and west coast of the Indian subcontinent. Commercial fishing also is undertaken by larger vessels. India, Pakistan, Sri Lanka, Iran, Oman, Yemen, France, the United Arab Emirates, South Korea, Japan, and the Maldives are the principal fishing countries.

2.2 INDIAN OCEAN

Indian Ocean covers approximately one-fifth of the total ocean area of the world. It is the smallest, geologically youngest and physically most complex of the world's three major oceans. It stretches for more than 6,200 miles (10,000 km) between the southern tips of Africa and Australia, without its marginal seas, has an area of about 28,360,000 square miles (73,440,000 square km). The Indian Ocean's average depth is 12,990 feet (3,960 m) and its deepest point in the Sunda Deep of the Java Trench, of the southern coast of the island of Java (Indonesia) is 24,442 feet (7,450 m). Ocean basins are characterized by smooth, flat plains of thick sediment with abyssal hills (i.e., features that are less than 3,300 feet high) at the bottom flanks of the oceanic ridges. The Indian Ocean's complex ridge topography led to the formation of many basins that range in width from 200 to 5,600 miles (320 to 9,000 km). The oceanic ridges consist of a rugged, seismically active mountain chain that is part of the worldwide oceanic ridge system and stillcontains centers of seafloor spreading in several places. Most striking is the aseismic (virtually earthquake-free) Ninety East Ridge, which is the longest and straightest in the world ocean. The immense load of suspended sediments from the rivers emptying into the Indian Ocean is the highest of the three oceans, and nearly half of it comes from the Indian subcontinent alone. Those terrigenous sediments occur mostly on the continental shelves, slopes, and rises and they merge into abyssal plains. The immense load of suspended sediments from the rivers emptying into the Indian Ocean is the highest of the three oceans and nearly half of it comes from the Indian subcontinent alone. Those terrigenous sediments occur mostly on the continental shelves, slopes, and rises and they merge into abyssal plains. The ocean floor is composed of basalt in various stages of alteration. The principal authigenic (ocean-formed) mineral deposits are phosphorites, ferromanganese crusts, ferromanganese nodules and hydrothermal metalliferous sediments.

2.3 BAY OF BENGAL

Bay of Bengal is the large but relatively shallow embayment of the northeastern Indian Ocean, occupying an area of about 839,000 square miles (2,173,000 square km). It lies roughly between latitudes 5° and 22° N and longitudes 80° and 90° E. It is bordered by Sri Lanka and India to the west, Bangladesh to the north, and Myanmar (Burma) and the northern part of the Malay Peninsula to the east. The bay is about 1,000 miles (1,600 km) wide, with an average depth of more than 8,500 feet (2,600 m). The maximum depth is 15,400 feet (4,694 m). A number of large rivers-the Mahanadi, Godavari, Krishna, and Kaveri (Cauvery) on the west and the Ganges (Ganga) and Brahmaputra on the north-flow into the Bay of Bengal. The Andaman and Nicobar groups, which are the only islands, separate the bay from the Andaman Sea. The Bay of Bengal is bordered to the north by a wide continental shelf that narrows to the south and by slopes of varying gradient on the northwest, north, and northeast, all cut by canyons from the rivers. Most important are the Ganges-Brahmaputra, Andhra, Mahadevan, Krishna, and Godavari canyons. These were former estuaries when the shoreline was at the margin of the continental shelf during the Pleistocene Epoch (about 2,600,000 to 11,700 years ago). The deep floor of the bay is occupied by a vast abyssal (deep-sea) plain that slopes to the south. The fan of sediments of the Ganges River is the widest (8 to 11 km) and thickest in the world. The bay itself was formed as the Indian subcontinent collided with Asia within roughly the past 50 million year. Sediments in the Bay of Bengal are dominated by terrigenous deposits from the rivers, derived mainly from the Indian subcontinent and from the Himalayas. Calcareous clays and oozes are found near the Andaman and Nicobar Islands and a top the Ninety East Ridge. The amount of organic matter present in the continental-shelf sediment of the northern part of the east coast is poor compared with the world's average for near shore sediments. Petroleum and natural-gas discoveries have been made in the Bay of Bengal, notably offshore of the Godavari and Mahanadi deltas. The bay has a geologic setting similar to that of the Indus River basin and the western margin of the Indian Peninsula. Hydrocarbon resources in the Bay of Bengal generally are located in deep areas, as compared to those in the Arabian Sea. There are placer deposits of titanium of northeastern Sri Lanka and rare earths of northeastern India. Heavy mineral sands occur around Nagapattinam (in Tamil Nadu state) on the southeastern Indian coast, near Chennai (Madras) and in coastal areas around Vishakhapatnam. They consist of ilmenite, garnet, sillimanite, zircon, rutile, and manganite.

3. SEDIMENTS AND SEDIMENTARY ENVIRONMENTS

A sedimentary or depositional environment is an area of Earth's surface where large volumes of sediment accumulate. All environments of deposition belong to one of three settings: terrestrial, coastal (or marginal marine) and marine Sedimentary environments display great complexity and almost infinite variety. Variations in environmental factors such as climate, latitude, surface topography, subsurface geology, and sediment supply help determine the characteristics of a sedimentary environment, and the resulting sedimentary deposits.

3.1 TERRESTRIAL ENVIRONMENTS

Water, wind, and ice erode, transport, and deposit terrigenous sediments on land Geologists recognize five common terrestrial sedimentary environments: stream, lake, desert, glacial, and volcanic Streams are the most widespread terrestrial sedimentary environment. Because they dominate landscapes in both humid and arid climates, stream valleys are the most common landform on Earth. Streams naturally meander and coarse-grained sediments accumulate along the inside of meanders where water velocity decreases, forming sand and gravel bars. When flood-water overflows a stream's banks, fine-grained sediment accumulates on the land surface, or floodplain, adjacent to the channel Coarser sediment collects on the channel banks during floods, forming a narrow deposit called a levee Sorting, rounding and sediment load generally increase downstream. Where a stream rapidly changes from a high to low slope on land, for example at the base of a mountain, gravel, sand, silt, and clay form a sediment pile called an alluvial fan Where a stream flows into standing water its sediments produce a deposit called a delta. Deltas are usually finer grained than alluvial fans. In both alluvial fans and deltas, grain size rapidly decreases down slope. Most lakes form from water contributed by one or more streams as well as precipitation directly into the lake. As it arrives at a lake, stream velocity drops very rapidly, depositing the coarsest sediment at the lake-shore and forming a delta. Farther from shore, as the water continues to lose velocity, finer and finer grained sediment falls to the lake bottom. Only in the deepest part of the lake is water movement slow enough to permit the finest grained sediment to accumulate. This produces thin layers of clay. Hence, grain size generally decreases from the lakeshore to its center. Deserts develop where rainfall is too sparse to support abundant plants. Contrary to popular belief, most deserts are not vast seas of sand. Instead, they consist mostly of a mixture of gravel and sand. However, the sand may be eroded away, or deflated, by the wind leaving behind a layer of gravel called desert pavement or regs. The deflated sand is later heaped into piles downwind, producing dunes. Despite the prevalence of regs and dunes in deserts, water is nonetheless the most important agent of erosion. Alluvial fans are common at the base of mountains. Dry lake beds, or playas, and salt deposits, or sabkhas, resulting from lake evaporation, commonly occupy the adjacent valley floor. From around two million years ago to about ten thousand years ago the Pleistocene epoch, or Ice Age- glaciers deposited sediments over large areas at mid- to high-latitudes. These glacial ice deposits, called till, are characterized by a wide range of sediment sizes (geologists refer to sediment comprised of a wide range of particle sizes as being poorly sorted). They generally are thick, widespread sheets or narrow, sinuous ridges. Ice melt water forms thick, well-sorted, and widespread layers of sediment called stratified drift. Though volcanism involves igneous processes, many terrestrial volcanic deposits are sedimentary in origin. These volcaniclastic, or pyroclastic, sediments form when ash, cinders, and larger volcanic materials fall to the ground during eruptions. Running water often modifies volcaniclastic sediments after deposition. They also may move downhill as a mudflow, or lahar, when saturated with water. Generally, volcano-clastic sediments form thin lobe-shaped deposits and widespread sheets, which thicken toward the volcanic source.

3.2 COASTAL ENVIRONMENTS

Where the land meets the sea, interplay between terrestrial and marine processes causes sedimentary environments to be complicated. In areas where wave energy is low and the tidal range (the difference between high tide and low tide) is also low, terrestrial processes usually dominate. For example, sediments flowing into the sea from a river will form a well-developed triangular shaped deposit known as a delta. If wave energy is high and tidal range low, the river's sediments will be reworked into a beach or barrier island. However, if tidal range is high, tidal currents flood the river mouth daily, forming a drowned river mouth, or estuary, with scattered sand bars. In coastal areas far from rivers, the nature of the coast changes rapidly. The balance between tidal and wave processes influences coastal character. The higher the tidal range, the more important tidal processes become. In wave-dominated areas, currents flowing parallel to the shoreline move sand along the coast, producing barrier islands and beaches for long stretches. If a barrier island protects the coast, channels, or tidal inlets, pass between the islands and allow tidal currents to flow from the open ocean into the bay behind the island. Landward from the bay, a tidal marsh will occur. When high tide approaches and tidal currents flow landward, the marsh will be flooded. As the water level drops toward low tide, tidal currents flow seaward, exposing the marsh to the elements. If no barrier island is present, coasts are simple with only a few river mouths and coastal marshes to break the monotony of long stretches of beach. Where tidal range is high, strong tidal currents dominate coastal processes. Tidal sand flats occur below low tide level. These are generally covered with large ripples to small sand dunes. Between the low tide and high tide marks, ripples are abundant on a mixed sand and mud flat. A mud flat, backed by a tidal marsh, forms above the high tide mark. Landward of the low tide level, tidal creeks cut through the deposits as well.

3.3 MARINE ENVIRONMENTS

Sediments may accumulate and be preserved virtually anywhere in the oceans. Consequently, marine sedimentary environments are numerous and widespread. As we travel from the surface of the ocean downward to the seafloor, water pressure increases by 1 atm for every 10m of depth. Temperature is relatively stable in the deep ocean. Water depth also plays a major role in shaping these environments. For simplicity, marine environments can be divided into two broad groups: shelf and deep oceanic Shelf environments range in depth from low tide level to depths of 425 ft (130 m), typical for the outer edge of the continental shelf. The deep sea is the lowest layer in the ocean, existing below the thermocline and above the sea bed, at a depth of 1000 fathoms or more.

3.3.1 CONTINENTAL SHELF ENVIRONMENT

A continental shelf is a portion of a continent that is submerged under an area of relatively shallow water known as a shelf sea. The continental shelves are covered by terrigenous sediments that is, those derived from erosion of the continents. However, little of the sediments are from current rivers; some 60-70% of the sediments on the world's shelves is relict sediment, deposited during the last ice age, when the sea level was 100-120m lower than it is now. Continental shelves teem with life because of the sunlight available in shallow water, in contrast to the biotic deserts of the oceans' abyssal plain. The pelagic environment of the continental shelf constitutes the neritic zone, and the benthic province of the shelf is the sublittoral zone. The average width of continental shelf is about 45 mi (75 km). Shelf sediments generally decrease in grain size with increasing distance from shore. This occurs for two reasons:

(1) Greater distance from sediment sources

(2) Decreasing sediment movement (transport) with increasing water depth.

Shelf sediments vary significantly with latitude. At high latitudes, glacial ice flowing into coastal water generates icebergs, which transport large sediment loads of various sizes out onto the shelf. As icebergs melt, they drop their load. These glacio-marine sediments are generally less sorted and coarser grained than lower latitude deposits. In fact, boulders known as drop stones occur on the sea floor in deep water, hundreds of miles from shore. Occur inter-bedded. In water depths greater than 150 to 200 ft (45-60 m), even storm waves do not stir the bottom; consequently, silts and clays predominate. Scattered sand deposits are also located on outer shelf margins. During periods of lower sea level, rivers flowing across what is now the inner shelf deposited these so-called relict sediments. At low latitudes, bottom-dwelling plants and animals secrete large volumes of calcium carbonate, producing thick blankets of carbonate sediment. Perhaps the best known carbonate environment is the coral reef. Corals produce a rigid framework of carbonate rock (limestone), which is also a major source of sediment of various grain sizes. Where stream input is great, terrigenous sediments discourage habitation by carbonate-producing organisms and dilute any carbonate sediment that is produced.

3.3.2 CONTINENTAL SLOPE ENVIRONMENT

The relatively steeply sloping surface that extends from the outer edge of a continental shelf down to the continental rise. The total relief is substantial, ranging from 1 km to 10 km and ranges from 1° to 15° of slope. Along many coasts of the world the slope is furrowed by deep submarine canyons, terminating as fan-shaped deposits at the base. The world's combined continental slope has a total length of approximately 300,000 km (200,000 miles) and descends at an average angle in excess of 4° from the shelf break at the edge of the continental shelf to the beginning of the ocean basins at depths of 100 to 3,200m (330 to 10,500 feet).About one-half of all continental slopes descend into deep-sea trenches or shallower depressions, and most of the remainder terminates in fans of marine sediment or in continental rises. The transition from continental crust to oceanic crust usually occurs below the continental slope. About 8.5 percent of the ocean floor is covered by the continental slope-rise system. This system is an expression of the edge of the continental crustal block. Beyond the shelf-slope break, the continental crust thins quickly, and the rise lies partly on the continental crust and partly on the oceanic crust of the deep sea continental slopes are indented by numerous submarine canyons and mounds. Rivers deliver most of the sediments to mid-latitude shelves. Therefore, grain size routinely decreases with distance from shore; sediment sorting also tends to be good. Shallow water, near shore sediments form thick sand blankets with abundant ripple marks. As depth increases and water movement decreases, average grain size decreases, and sand, silt, and clay occur inter-bedded. In water depths greater than 150 to 200 ft (45-60 m), even storm waves do not stir the bottom; consequently, silts and clays predominate. Scattered sand deposits are also located on outer shelf margins. During periods of lower sea level, rivers flowing across what is now the inner shelf deposited these so-called relict sediments. At low latitudes, bottom-dwelling plants and animals secrete large volumes of calcium carbonate, producing thick blankets of carbonate sediment. Perhaps the best known carbonate environment is the coral reef. Corals produce a rigid framework of carbonate rock (limestone), which is also a major source of sediment of various grain sizes. Where stream input is great, terrigenous sediments discourage habitation by carbonate-producing organisms and dilute any carbonate sediment that is produced.

3.3.3 DEEP OCEANIC ENVIRONMENT

Seaward of the continental shelves, continental slopes incline more steeply, so relict and modern sediments form deposits called deep-sea fans. These are similar to alluvial fans, but generally consist of sand-to clay-sized particles with little or no gravel. Deep-sea fans form the continental rise continuous apron of sediment at the base of the continental slope. Even farther from land, the monotonous abyssal plains begin. Here mostly clay-sized sediment forms sheets up to 0.6 mi (1 km) thick. These deposits composed of sediments that settle through the water column from shallow depths thin to a feather edge at the oceanic ridges where new sea floor forms. Abyssal sediments are generally a mixture of three grain types: carbonate muds and siliceous muds of biogenic (organic) origin, and red clays of terrigenous origin. Carbonate-rich muds generally accumulate in water depths of less than 2 to 2.5 mi (3-4 km); at deeper depths, colder water and higher pressures combine to dissolve the carbonate. Siliceous muds occur where abundant nutrients in surface waters support high rates of biogenic silica (SiO2) production. Red clays, transported from the land by winds and stream flow, predominate where quantities of carbonate and siliceous mud are insufficient to dilute these fine grained terrigenous deposits.

3.4 MARINE SEDIMENTS

Any deposit of insoluble material, primarily rock and soil particles, transported from land areas to the ocean by wind, ice, and rivers, as well as the remains of marine organisms, products of submarine volcanism, chemical precipitates from seawater, and materials from outer space (e.g., meteorites) that accumulate on the seafloor is called as marine sediment.

sediments deposited in the ocean are an archive of historical information about the Earth and, specifically, they provide information about global biogeochemical cycles.

The distribution of sediments in the ocean is determined by biological and chemical Processes. The first detailed study of marine sediments was done in the 1870's. An expedition called the "Challenger expedition" led by Sir Murray and Renard dredged the bottom of the ocean systematically and described the sediments. They classified their findings into 5 major groups: red clays, carbonate ooze, silicic ooze, nodules and volcanic materials.

Marine sediments deposited near continents cover approximately 25 percent of the seafloor, but they probably account for roughly 90 percent by volume of all sediment deposits. Submarine canyons constitute the main route for sediment movement from continental shelves and slopes onto the deep seafloor.

Deposits produced by turbidity currents are called turbidites. Most of them consist of sands and silts, but a few are composed of gravels. Turbidites tend to have distinct boundaries between adjacent units. Each of these units is formed by a separate flow and often exhibits a systematic change in grain size from coarsest at the bottom to finest at the top.

Roughly 75 percent of the deep seafloor is covered by slowly accumulating deposits known as pelagic sediments. Because of its great distance from the continents, the abyssal plain does not receive turbidity currents and their associated coarse-grained sediments. Moreover, since relatively little land-derived sediment consisting of silicate mineral and rock fragments reach the ocean bottom, deposits there show a predominance of biogenic constituents (i.e., the skeletal remains of marine organisms). In areas where surface waters are fertile, opal from diatoms (algae) and radiolarians (protozoans) and calcium carbonate from such organisms as foraminifera's, coccolithophorids, and pteropods are supplied to the sediment.

3.4.1 SEDIMENT TYPES

The sediments in the ocean consist of 3 major components: detrital, biogenic and authigenic based on their origin. They are classified using the 30% rule, if there is more than 30% of any type of component in the sediment it will be classified as such.

Detrital sediments are brought into the ocean from outside consists of terrigenous, volcanic, and cosmogenic material.

- Terrigenous sediments are those where the ultimate source is weathering and erosion of rocks on land.
- Volcanic sediments are composed of minerals brought into the ocean mostly by wind, as dust and ash from volcanic eruptions. They are typically in the size range of 1 micrometer.
- Cosmogenic particles are those that arrive from outer space and survive the Earth's atmosphere to enter the sedimentary record.

Biogenic Sediments are one of the most important constituents of marine sediments. As the name implies, these form directly or indirectly through biological activity. They are made of a variety of delicate and intricate structures mostly of skeletal remains of marine phytoplankton and zooplankton.

1. Carbonate Sediments are composed principally of skeletal remains of calcite or aragonite secreting organisms.
   - Foraminifera
   - Pteropods
   - Corals
   - Ostracods
   - Coccolithophores
   - Gastropods

2. Silica Secreting Organisms includes
   - Sponges
   - Silicoflagellates
   - Diatoms
   - Radiolarians

Authigenic sedimentary minerals forms during sedimentation by precipitation or recrystallization.

- Calcium carbonate
- Apatite
- Glauconite
- Pyrite

3.4.2 SEDIMENTATION PATTERN

The patterns of sedimentation in the ocean basins have not been static over geologic time. The existing basins, no more than 200 million years old, contain a highly variable sedimentary record. The major factor behind the variations is plate movements and related changes in climate and ocean water circulation. Since about 200 million years ago, a single vast ocean basin has given way to five or six smaller ones. Changes in seafloor spreading rates and glaciations have caused sea levels to rise and fall, greatly altering the deep-sea sedimentation pattern of both terrigenous and biogenic sediments. The calcite compensation depth (CCD), or the depth at which the rate of carbonate accumulation equals the rate of carbonate dissolution, has fluctuated more than 2,000m (about 6,600 feet) in response to changes in carbonate supply and the corrosive nature of ocean bottom waters. Bottom currents have changed, becoming erosive or non-depositional in some regions to produce geological unconformities (that is, gaps in the geological record) and redistribute enormous volumes of sediment to other locations.

3.4.3 CHARACTERIZATION OF MARINE SEDIMENTS

Marine sediments deposited near continents cover approximately 25 percent of the seafloor, but they probably account for roughly 90 percent by volume of all sediment deposits. Submarine canyons constitute the main route for sediment movement from continental shelves and slopes onto the deep seafloor. In most cases, an earthquake triggers a massive slumping and stirring of sedimentary material at the canyon head. Mixed with seawater, a dense liquid mass forms, giving rise to a density current that flows down the canyon at speeds of several tens of kilometers per hour. After reaching the base of the continental slope, the sediment- laden mass moves out onto the continental rise at the base of the slope. Deposits from turbidity currents (i.e., short-lived density currents caused by suspended sediment concentrations) can build outward for hundreds and sometimes thousands of kilometers across the ocean bottom. Large sediment-built plains commonly occur in the Atlantic Ocean, where turbidity currents flow from the base of a continent to the Mid-Atlantic Ridge.

Deposits produced by turbidity currents are called turbidites. Most of them consist of sands and silts, but a few are composed of gravels. Turbidites characteristically contain the remains of shallow-water organisms mixed with deep-water varieties. The shallow-water organisms came from areas where the density current originated, whereas the deep-water forms existed in the area traversed by the current or where it finally deposited its load.

The sediments deposited on continental shelves and rises, frequently referred to as hemipelagic sediments, ordinarily accumulate too rapidly to react chemically with seawater. In most cases, individual grains thus retain characteristics imparted to them in the area where they formed. As a rule, sediments deposited near coral reefs in shallow tropical waters contain abundant carbonate material.

Roughly 75 percent of the deep seafloor is covered by slowly accumulating deposits known as pelagic sediments. Because of its great distance from the continents the abyssal plain does not receive turbidity currents and their associated coarse-grained sediments. Moreover, since relatively little land-derived sediment consisting of silicate mineral and rock fragments reach the ocean bottom, deposits there show a predominance of biogenic constituents. If the biological constituents exceed 30 percent by volume, then the deep-ocean sediments are usually classified on the basis of their biogenic components. For example, a mud containing 30 percent by volume of foraminiferal tests (external hard parts) is called a foraminiferal mud or ooze. When one genus dominates, it is frequently referred to by the generic name, such as Globigerina ooze. Where biogenic constituents compose less than 30 percent of the total, the deposit is called a deep-sea clay, brown mud, or red clay.

4. GRAIN SIZE ANALYSIS

4.1 INTRODUCTION

Grain size or particle size is the diameter of individual grains of sediment or the lithified particles in clastic rocks. The term may also be applied to other granular materials. Granular material can range from very small colloidal particles through clay, silt, sand, gravel, and cobbles to boulders.

Size of a clast depends upon the grain size of the parent rock distinctiveness of the transporting medium and distance of the transport. The size of sediment particles can be determined by direct measurement or by sieve analysis, particle size analyzer using laser beam, X-rays sedigraphs' and other methods. The size of particles is represented either using phi scale which is the negative logarithm to the base 2 of the particle diameter in millimeter or in metric units. Udden-Went Worth classes in metric and phi system is given below in table 4.1. Based on the size particles sediments present are classified as gravel, sand, silt and clay.

4.2 METHODS OF GRAIN SIZE DETERMINATION

Mechanical analysis is a quantitative determination of the size frequency distribution of particle in samples in to different grain size.

There are several methods for carrying out mechanical analysis leading directly or indirectly to particle size evaluation and dimension of the grain size. The most important as well as common methods employed are:

a. Direct measurement of particle which are sufficiently coarse.
b. By sieving.
c. Pipette analysis.

a) Direct measurement: Sedimentary particles larger than about 16mm diameter will be measured with Vernier calipers.

b) Sieve analysis: Sieve analysis is one of the commonly used tools in determining the grain size distribution of sand. Sieves are screens of standard size. In the sieving technique a known weight of dry sample is placed on top of a stack sieves in order of increasing sieve diameter with a pan at the bottom to catch any sediment that passes through the lowest and finest sieve. The theory of sieving assumes that the weight of material on each sieve is proportional to the weight of the original material of that particular size in the sample.

c) Pipette analysis: The standard sedimentation method for measuring the sizes of small particles is pipette analysis (Galehouse, 1971) Any sediment coarser than 62 micrometers is removed by sieving (wet sieving). The sample is then added to distilled water to produce dilute suspension of uniform concentration. A specified volume of suspension is then withdrawn from the prescribed depth on a time schedule determined by calculations based on Stoke's law. At this time all particles of a given size will have settled below the depth and only finer particles remain in the sample that is withdrawn. The dry weight of this sample is used to calculate the grain size distribution of the original sample.

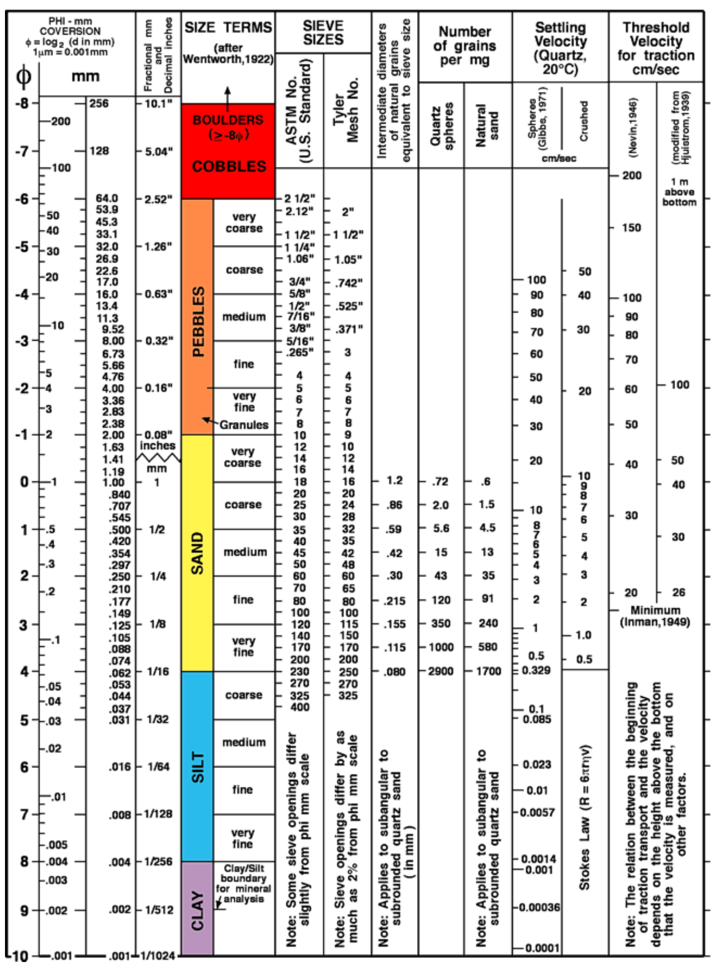


Fig.4.1 Wodden Went Worth classification of sediments

4.3 STOKES LAW

Stokes's law is a mathematical equation that expresses the settling velocities of small spherical particles in a fluid medium. "An expression describing the resisting force on a particle moving through a viscous fluid and showing that a maximum velocity is reached in such cases, e.g. for an object falling under gravity through a fluid." The law, first set forth by the British scientist Sir George G. Stokes in 1851, is derived by consideration of the forces acting on a particular particle as it sinks through a liquid column under the influence of gravity. The force acting in resistance to the fall is given by

$$F_d = 6\pi\eta\nu$$

r is the radius of the sphere, η is the viscosity of the liquid, and v is the velocity of fall
The force acting downward is equal to

$$4/3\pi r3\ (d1\text{-}d2)g$$

dl is the density of the sphere, d2 is the density of the liquid and g is the gravitational constant.

At a constant velocity of fall the upward and downward forces are in balance. Equating the two expressions given above and solving for v therefore yields the required velocity, expressed by Stokes's law as

$$v=2/9(d1 - d2)gr2/\eta$$

Sedimentation analysis based upon Stokes' Law provides a convenient method for determining particle size distribution (PSD). A single solid (or nonporous) sphere settling in a fluid has a terminal settling velocity which is uniquely related to its diameter. The SediGraph determines particle size distributions using the sedimentation method. By measuring the gravity- induced settling velocities of different size particles in a liquid with known properties, the particle sizes are determined.

Stokes's law finds application in several areas, particularly with regard to the settling of sediment in fresh water and in measurements of the viscosity of fluids. Because its validity is limited to conditions in which the motion of the particle does not produce turbulence in the fluid, however, various modifications have been set forth.

4.4 GRAPHICAL REPRESENTATION OF GRAIN SIZE ANALYSIS DATA

The purpose of this graphic presentation is to introduce the techniques in:

i. Graphically plotting size analysis data

ii. Computation of many statistical parameters of size distribution.

These parameters are useful in description of texture and give information about the method of formation and origin of rocks or environment of deposition.

4.4.1 DATA ANALYSIS AND PRESENTATION:

The mass retained on each sieve is recorded and converted to mass percent of the original dry mass.

$$M\% = (m/M_o) *100$$

where m is the mass retained on each sieve and Mo is the original dry mass of the sample. The cumulative mass percent retained on each sieve or cumulative % coarser, is found by adding the mass percent of material on all coarser sieves.

The particle size distribution may be displayed graphically as histograms, frequency curves or cumulative frequency curves or may be expressed as numerical moments of the distribution. The cumulative frequency curve is plotted using cumulative mass % coarser on a probability-scale ordinate and particle size in o units on the abscissa Folk and Ward (1957) devised graphical moments of the distribution based upon o values obtained graphically from the cumulative frequency curve at specific percentile levels.

4.5 STATISTICAL PARAMETERS OF GRAIN SIZE

The mean, mode and median collectively referred as the central tendency help in interpreting the grain size parameters.

4.5.1 MEAN

The mean is another word for average and is defined as the sum of all the observations divided by the total number of observations. The sum of negative deviations from the mean exactly equals the sum of positive deviations from the mean. Mean is very useful when making inferences from a sample to a population. Mean is influenced by extreme scores and skewed distributions.

$$\textbf{Mean size} = \frac{16Ø+50\ Ø+84\ Ø}{3}$$

16Ø-average size of grains at the 16th percentile,

50Ø-average size of grains at the 50thpercentile,

84Ø-average size of grains at the 84th percentile.

4.5.2 MEDIAN

The median is the size for which half of the particles (Ø 50) by weight or coarser and half finer or in other word sit is value midway in the frequency distribution. It is not sensitive to the exact location of every score in the distribution, but is used as the measure of central tendency when the mean is very much skewed. Median is not influenced by extreme scores or skewed distributions.

4.5.3 MODE

The value that occurs with the greatest frequency is called the mode. Mode is good for nominal data and when there are two "typical" scores. It is easy to compute and understand. The score comes from the data set. But it ignores most of the information in a distribution and is not suitable for a few numbers of samples. -average size of grains at the 54th percentile. The median is the size for which half of the particles by weight are coarser.

4.5.4 STANDARD DEVIATION

Standard deviation is a more of the degree of sting or the uniformity of the particle size distribution. It is a much m enure of the average amount by which observations deviate on either side of the meas. Sorting is calculated by subtracting the overall mean of the entire data used from the mean of the individual data set. After calculating the square of these of these differences, these values have to be added together and divided by the total number of data. The square root of this will give the standard deviation values. It lends itself to computation of other stable measures and is a prerequisite for calculating many of them. It helps in understanding the average of deviations around the mean Standard deviation will be influenced by extreme scores. Fig.4.2 and Fig 4.3 shows the changes in the curves for well sorted and poorly sorted sediments.

$$\textbf{Standard deviation} = \frac{84Ø\text{-}16Ø}{4} + \frac{95Ø\text{-}5Ø}{6.6}$$

STANDARD DEVIATION	
DESCRIPTION	**Ø RANGE**
Very Well Sorted	<0.35
Well Sorted	0.35 -0.50
Moderately Well Sorted	0.50-0.70
Moderately Sorted	0.70-1.00
Poorly Sorted	1.00-2.00
Very Poorly Sorted	2.00-4.00
Extremely Poorly Sorted	>4.00

Table 1. Standard Deviation

4.5.5 SKEWNESS

Skewness the asymmetry of a distribution. If there is more material in the courser or finer tail of the distribution it is called a skewed (negatively skewed) or fine skewed (positively skewed) respectively and half finer

$$\textbf{Skewness} = \frac{84\,Ø+16Ø-(2\times 50Ø)}{2(84Ø-16Ø)} + \frac{95\,Ø+5Ø-(2\times 50Ø)}{2(95Ø-50\,Ø)}$$

4.5.6 KURTOSIS

Kurtosis measures the ratio between the sorting in the tails of the distribution and the sorting in the central portion of the distribution (Fig 4.5). If the central portion is better sorted than the tails, the frequency curve is said to be excessively peaked orlepto-kurtic. If the tails are better sorted than the central portion, the curve is said to be flatpeaked or plati-kurtic. Strongly platy-kurtic curves are often bimodal with sub equal amounts of the two models.

$$\textbf{Kurtosis} = \frac{\text{Ø}95 - \text{Ø}5}{2.44(\text{Ø}75 - \text{Ø}25)}$$

KURTOSIS	
DESCRIPTION	**Ø RANGE**
Very Platykurtic	<0.67
Platykurtic	0.67-0.90
Mesokurtic	0.90-1.11
Leptokurtic	1.50-3.00
Extremely Leptokurtic	>3.00

Table 2. Kurtosis

4.5.7 CUMULATIVE FREQUENCY CURVES:

WEIGHT PERCENTAGE:

WEIGHT %						
SCALE	**SAMPLE NO**	SR 083 VC 30/1	SR 083 VC 30/2	SR 083 VC 30	SR 083 GC 10	SR 083 GC 34
%	**-2**	0.423398575	1.024489678	0	0	4.481993535
	-1.5	0.605249921	1.261982827	0.354584046	0.128346327	1.110609816
	-1	0.331643792	0.509600685	0.063003016	0.156964089	1.677966416
	-0.5	0.834636878	1.892253108	0.334991644	0.499510029	5.032663177
	0	0.305665029	1.274001711	0.041873956	0.270567932	1.617398936
	0.5	1.019251922	1.645625607	0.355352375	0.598371389	3.98694709
	1	3.00469276	4.19987885	2.557768771	0.97994155	3.326885163
	1.5	7.371336027	6.074344009	14.30245289	1.799450192	4.866411624
	2	54.10271008	50.38845033	40.17325829	12.1824946	43.2927696
	2.5	9.871377482	9.257425267	5.118995025	7.091134564	5.638956014
	3	13.55925645	11.94917454	15.37004668	20.66115702	12.79209903
	3.5	4.193083016	4.399873081	10.40126006	15.91754616	6.534489472
	4	3.744811156	4.593617492	7.850022089	20.60478871	5.417699301
	4.5	0.632886904	1.529282809	3.076391157	19.10972744	0.22311082
TOTAL		100	100	100	100	100

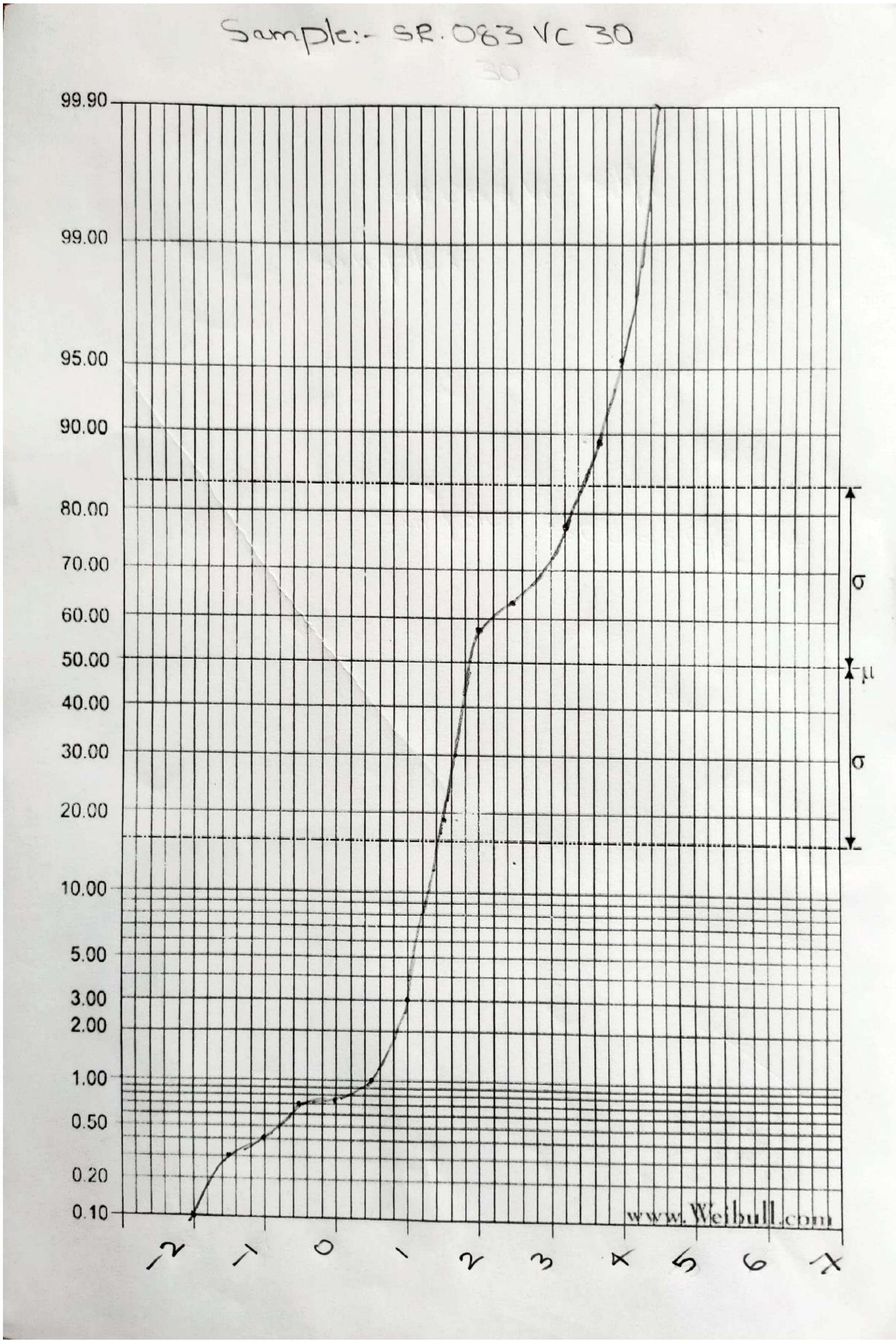
Table 3. Sample weight percentage

CUMULATIVE WEIGHT PERCENTAGE:

CUMULATIVE WEIGHT %						
SCALE	**SAMPLE NO**	SR 083 VC 30/1	SR 083 VC 30/2	SR 083 VC 30	SR 083 GC 10	SR 083 GC 34
Φ	**-2**	0.423398575	1.024489678	0	0	4.481993535
	-1.5	1.028648496	2.286472506	0.354584046	0.128346327	5.592603351
	-1	1.360292289	2.79607319	0.417587061	0.285310416	7.270569767
	-0.5	2.194929166	4.688326298	0.752578706	0.784820445	12.30323294
	0	2.500594195	5.96232801	0.794452661	1.055388378	13.92063188
	0.5	3.519846117	7.607953617	1.149805036	1.653759767	17.90757897
	1	6.524538877	11.80783247	3.707573808	2.633701317	21.23446413
	1.5	13.8958749	17.88217648	18.0100267	4.433151509	26.10087576
	2	67.99858499	68.27062681	58.18328499	16.61564611	69.39364536
	2.5	77.86996247	77.52805208	63.30228002	23.70678068	75.03260137
	3	91.42921892	89.47722662	78.67232669	44.3679377	87.82470041
	3.5	95.62230194	93.8770997	89.07358675	60.28548386	94.35918988
	4	99.3671131	98.47071719	96.92360884	80.89027256	99.77688918
	4.5	100	100	100	100	100

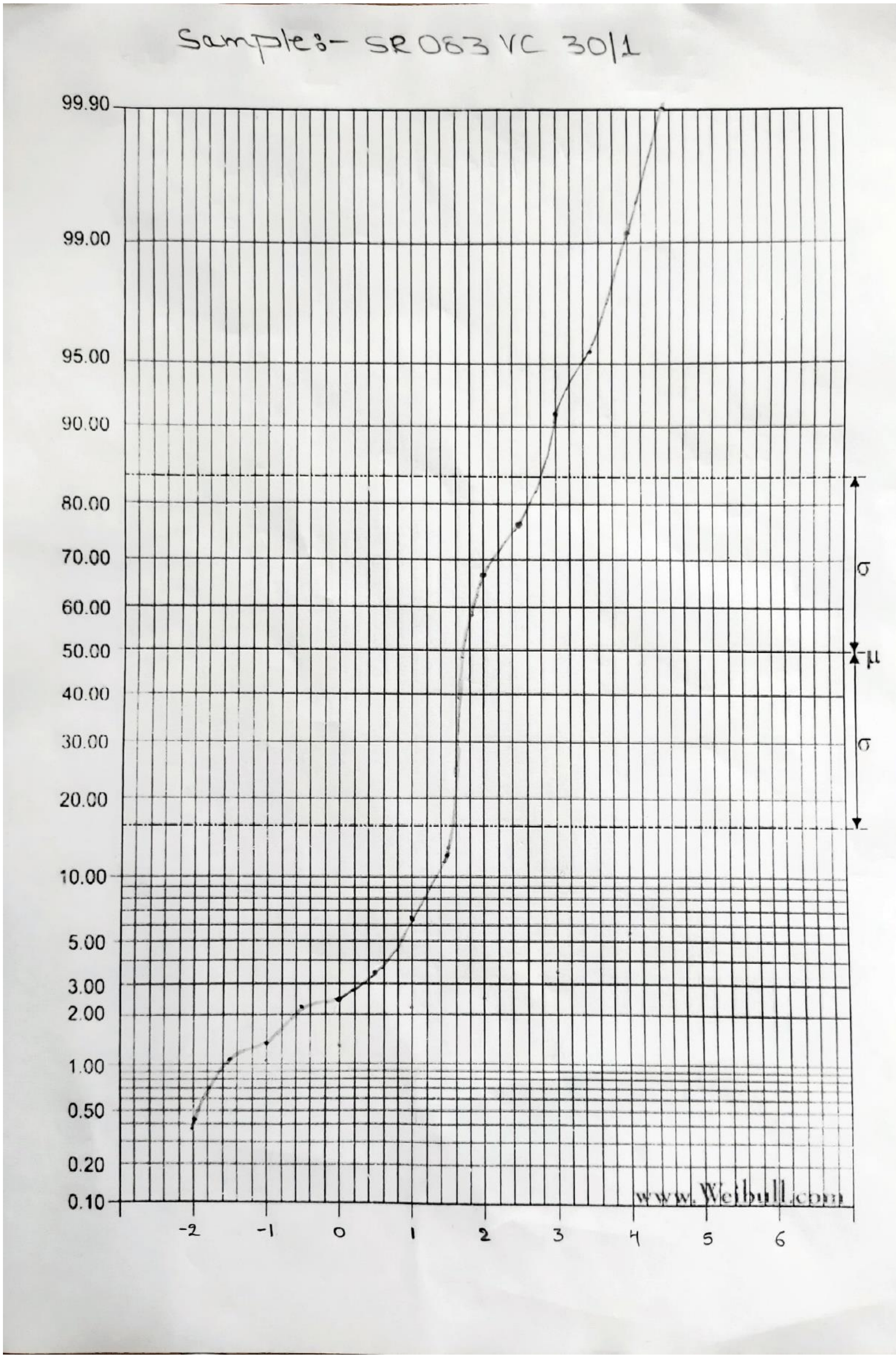
Table 4. Cumulative weight percentage

SR O83 VC-30:



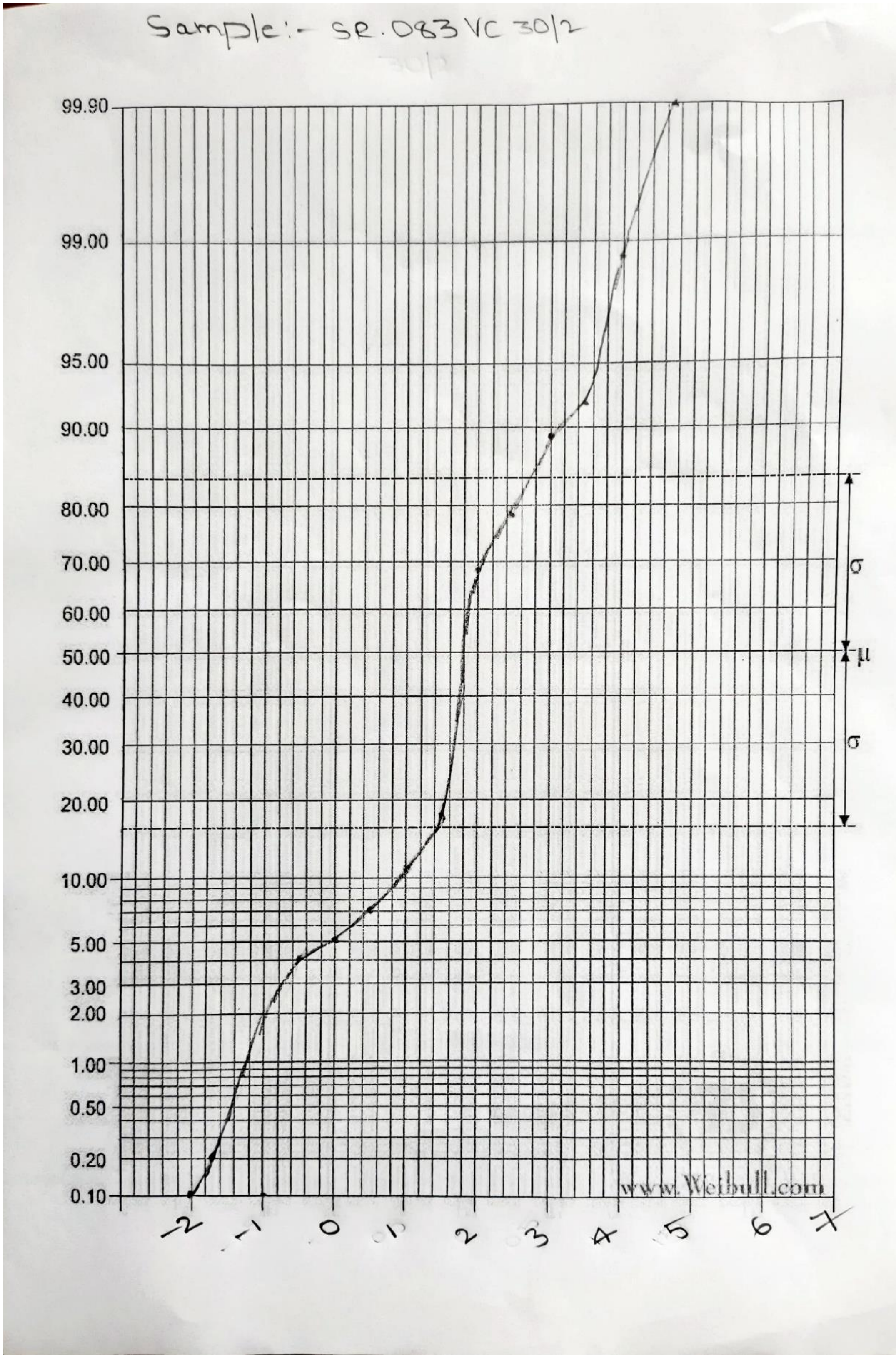
Sample:- SR.O83 VC 30
99.90
99.00
95.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
5.00
3.00
2.00
1.00
0.50
0.20
0.10
σ
μ
σ
www.Weibull.com
-2
-1
0
1
2
3
4
5
6
7

SR O83 VC-30\1:



Sample:- SR O83 VC 30/1
99.90
99.00
95.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
5.00
3.00
2.00
1.00
0.50
0.20
0.10
σ
μ
σ
-2
-1
0
1
2
3
4
5
6
www.Weibull.com

SR O83 VC-30\2: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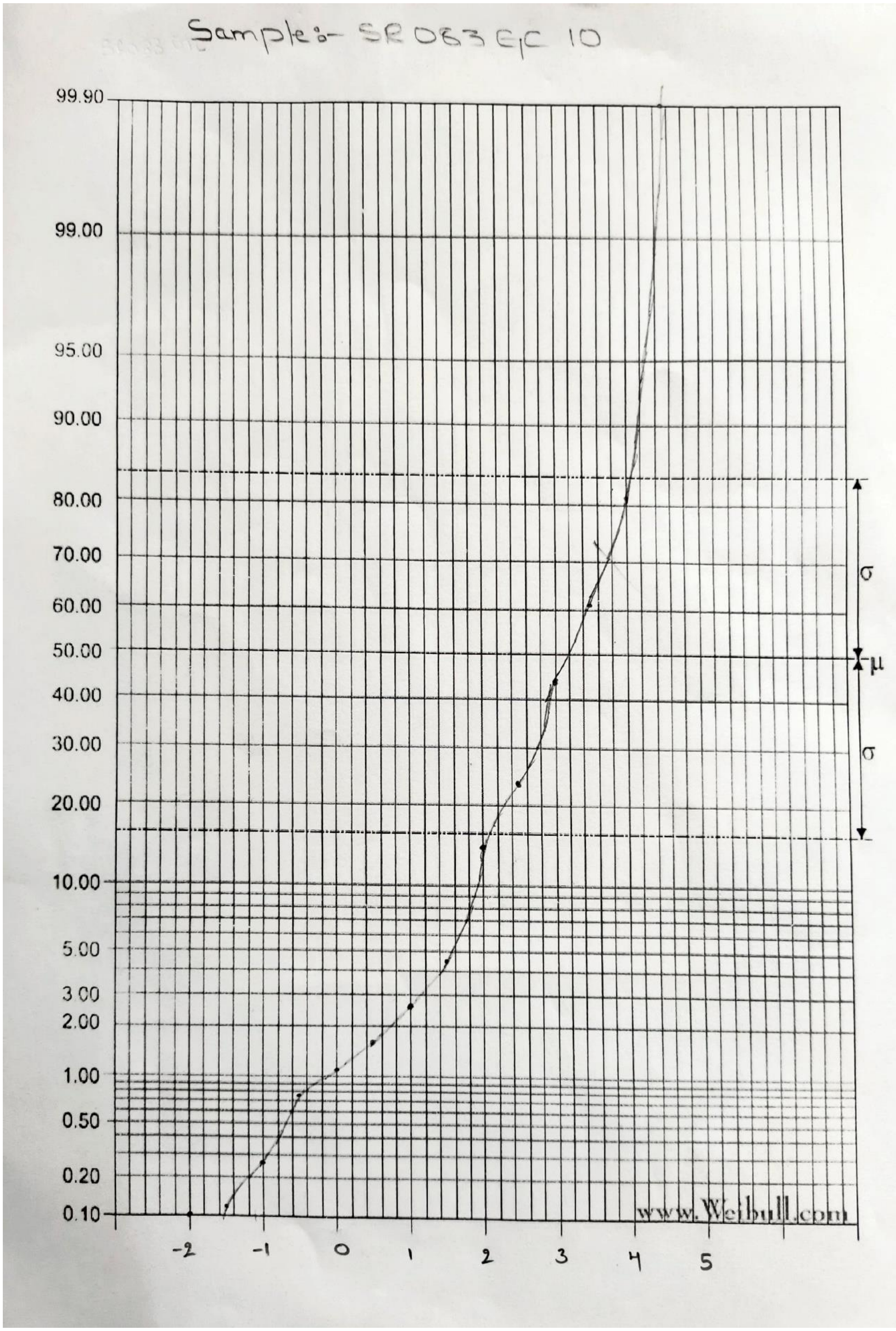
99.00
95.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
5.00
3.00
2.00
1.00
0.50
0.20
0.10
σ
μ
σ
www.Weibull.com
-2
-1
0
1
2
3
4
5
6
7

SR O83 GC-10:



Sample:- SR O83 GC 10
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99.00
95.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
5.00
3.00
2.00
1.00
0.50
0.20
0.10
-2
-1
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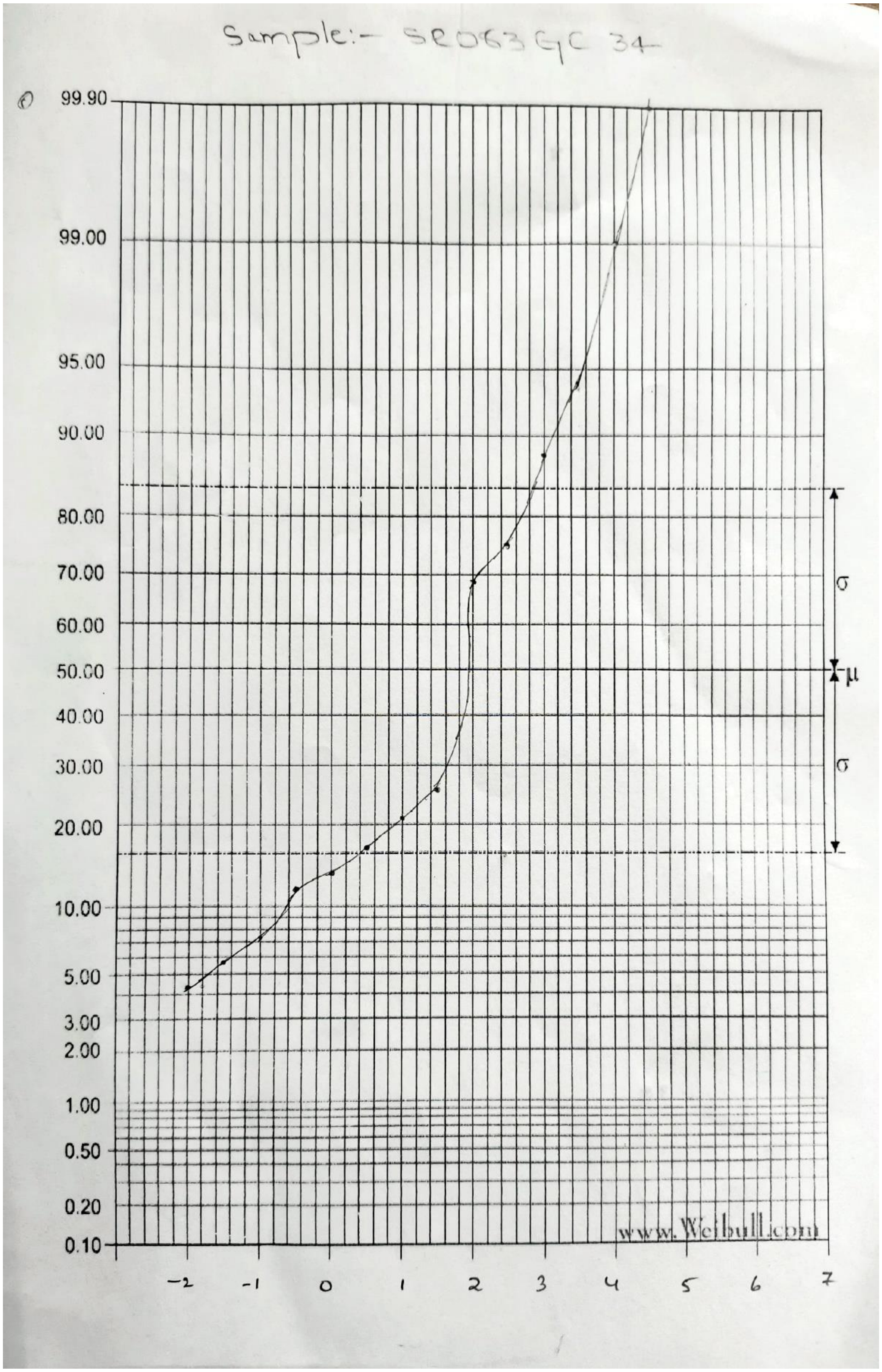
www.Weibull.com

SR O83 GC-34:



Sample:- SR083GC 34
99.90
99.00
95.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
5.00
3.00
2.00
1.00
0.50
0.20
0.10
σ
μ
σ
www.Weibull.com
-2
-1
0
1
2
3
4
5
6
7

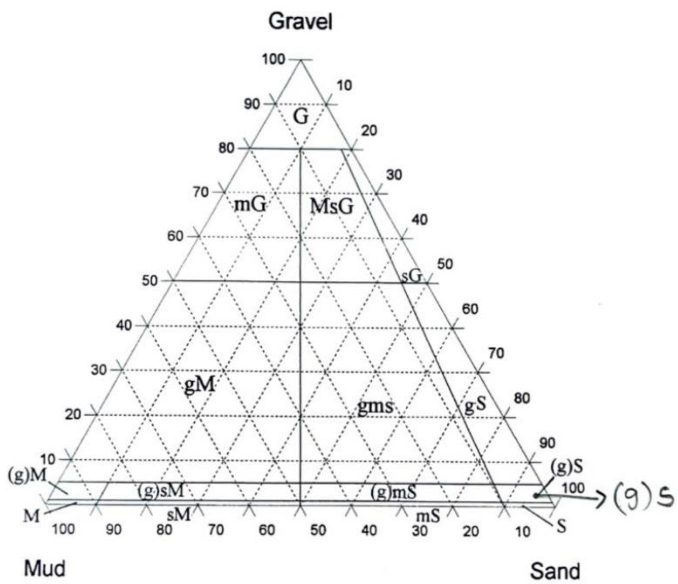
4.5.8 TRIANGULAR DIAGRAM BY folks (1954;1980)

Triangular diagram of Folk gives the idea of sedimentary grain size classes in which the samples belongs to. The arca inside the triangle is divided into 10 categories in SSC. Those are sand, silty sand, muddy sand, clayey sand, sandy silt, sandy mud, sandy slay, wilt, mud and clay. The samples are plotted manually.

SR O83 VC-30:

Sample : SR083-VC-30

Grain Size Ternary Plot 3
Gravel-Sand-Mud (Folk, 1954;1980)



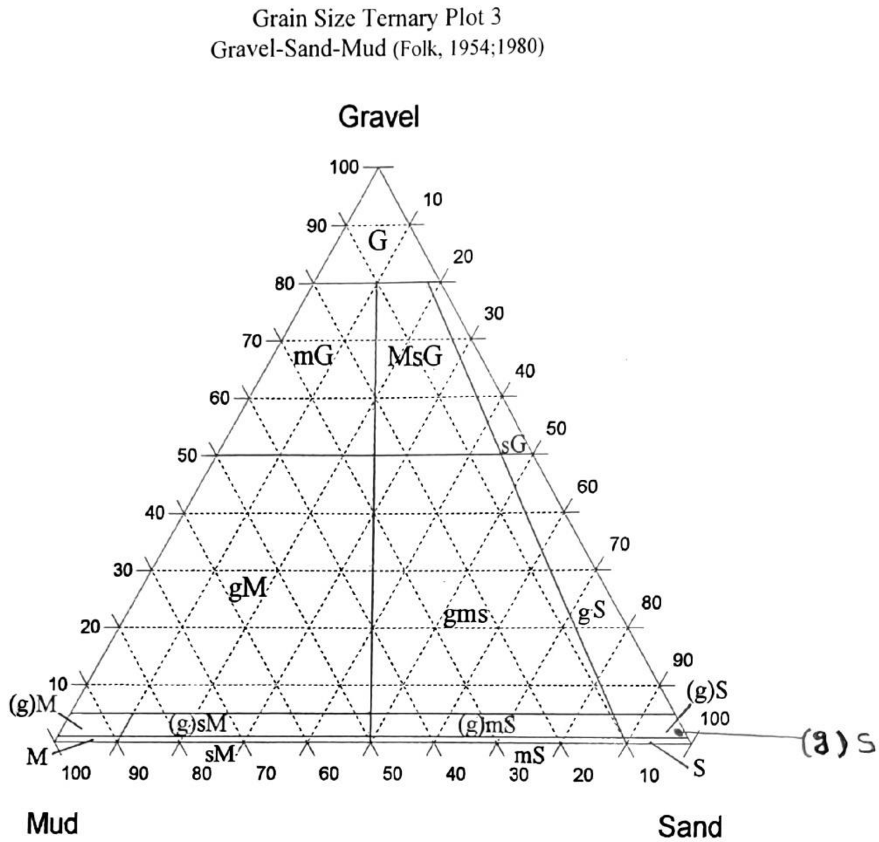
Symbol Index
M-mud; G-gravel; S-sand; sM –sandy mud; mS-muddy sand;
(g)M-slightly gravelly mud; (g)S-slightly gravelly sand;
(g)sM-slightly gravelly sandy mud; (g)mS-slightly gravelly muddy sand;
gM-gravelly mud; gms-gravelly muddy sand; gS-gravelly sand;
mG-muddy gravel; MsG-muddy sandy gravel; sG sandy gravel

Folk, R.L., 1954. The distinction between grain size and mineral composition in sedimentary rocks. *Journal of Geology*, **62**, 344-359.

Folk, R.L., 1980. Petrology of Sedimentary Rocks. Hemphill Publishing, Austin, TX, 184p.

SR O83 VC-30\1:

Sample : SR 083 -VC · 30/1



Symbol Index

M-mud; G-gravel; S-sand; sM –sandy mud; mS-muddy sand;
(g)M-slightly gravelly mud; (g)S-slightly gravelly sand;
(g)sM-slightly gravelly sandy mud; (g)mS-slightly gravelly muddy sand;
gM-gravelly mud; gms-gravelly muddy sand; gS-gravelly sand;
mG-muddy gravel; MsG-muddy sandy gravel; sG sandy gravel

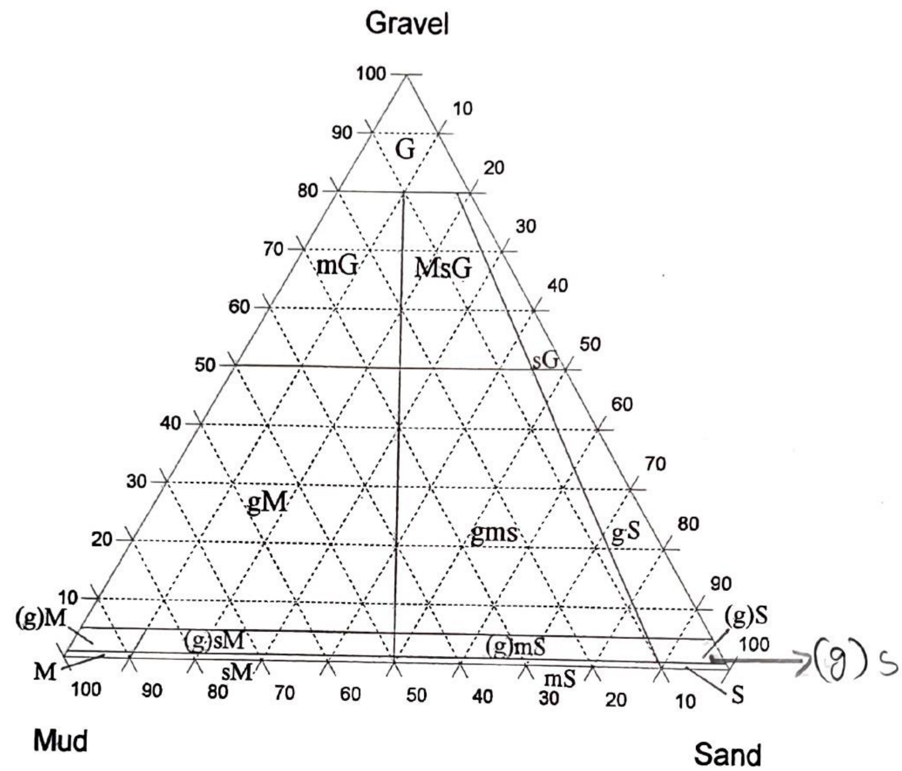
Folk, R.L., 1954. The distinction between grain size and mineral composition in sedimentary rocks. *Journal of Geology*, **62**, 344-359.

Folk, R.L., 1980. Petrology of Sedimentary Rocks. Hemphill Publishing, Austin, TX, 184p.

SR O83 VC-30\2:

Sample : SR083-VC-30/2

Grain Size Ternary Plot 3
Gravel-Sand-Mud (Folk, 1954;1980)



Symbol Index
M-mud; G-gravel; S-sand; sM –sandy mud; mS-muddy sand;
(g)M-slightly gravelly mud; (g)S-slightly gravelly sand;
(g)sM-slightly gravelly sandy mud; (g)mS-slightly gravelly muddy sand;
gM-gravelly mud; gms-gravelly muddy sand; gS-gravelly sand;
mG-muddy gravel; MsG-muddy sandy gravel; sG sandy gravel

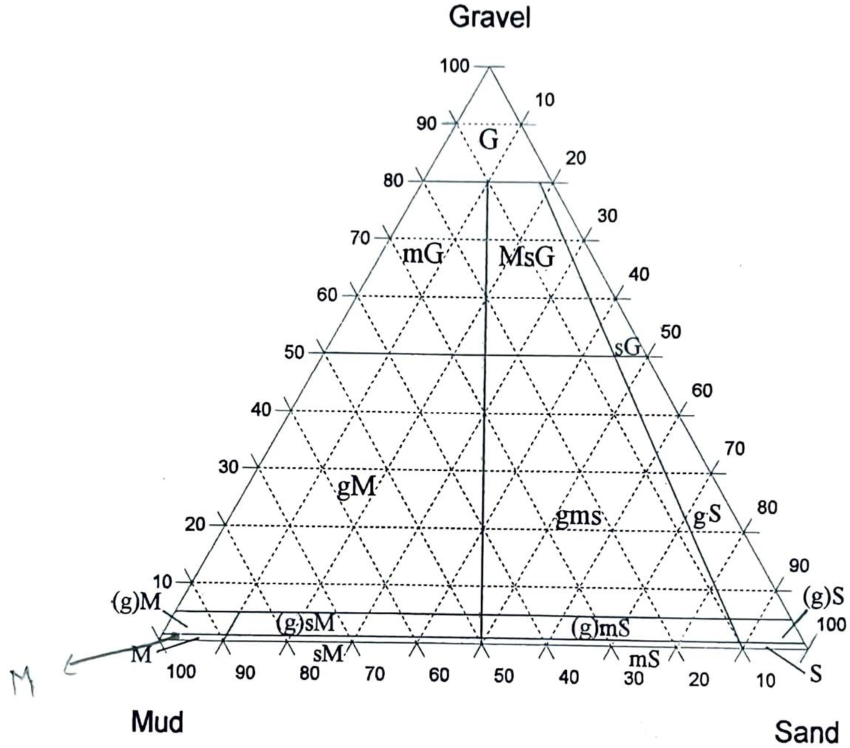
Folk, R.L., 1954. The distinction between grain size and mineral composition in sedimentary rocks. *Journal of Geology*, **62**, 344-359.

Folk, R.L., 1980. Petrology of Sedimentary Rocks. Hemphill Publishing, Austin, TX, 184p.

SR O83 GC-10:

Sample : SR083-GC-10

Grain Size Ternary Plot 3
Gravel-Sand-Mud (Folk, 1954;1980)



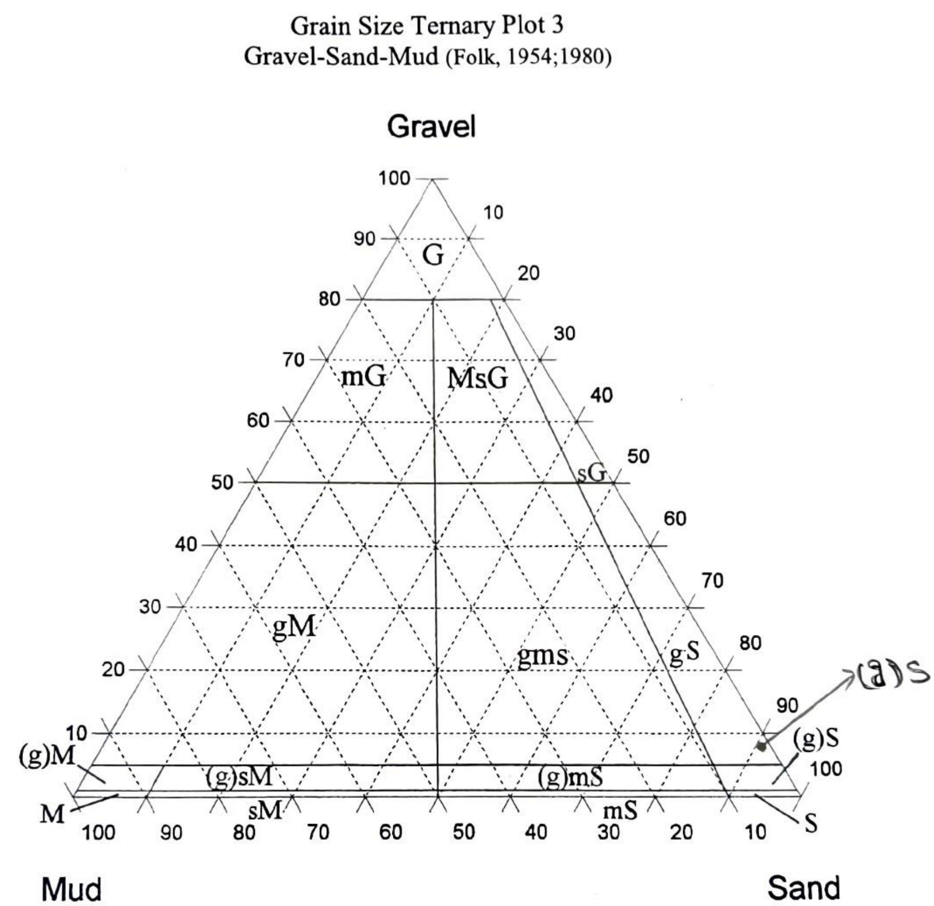
Symbol Index
M-mud; G-gravel; S-sand; sM –sandy mud; mS-muddy sand;
(g)M-slightly gravelly mud; (g)S-slightly gravelly sand;
(g)sM-slightly gravelly sandy mud; (g)mS-slightly gravelly muddy sand;
gM-gravelly mud; gms-gravelly muddy sand; gS-gravelly sand;
mG-muddy gravel; MsG-muddy sandy gravel; sG sandy gravel

Folk, R.L., 1954. The distinction between grain size and mineral composition in sedimentary rocks. *Journal of Geology*, **62**, 344-359.

Folk, R.L., 1980. Petrology of Sedimentary Rocks. Hemphill Publishing, Austin, TX, 184p.

SR O83 GC-34:

Sample : SR 083 - GC - 34



Symbol Index

M-mud; G-gravel; S-sand; sM –sandy mud; mS-muddy sand;
(g)M-slightly gravelly mud; (g)S-slightly gravelly sand;
(g)sM-slightly gravelly sandy mud; (g)mS-slightly gravelly muddy sand;
gM-gravelly mud; gms-gravelly muddy sand; gS-gravelly sand;
mG-muddy gravel; MsG-muddy sandy gravel; sG sandy gravel

Folk, R.L., 1954. The distinction between grain size and mineral composition in sedimentary rocks. *Journal of Geology*, **62**, 344-359.

Folk, R.L., 1980. Petrology of Sedimentary Rocks. Hemphill Publishing, Austin, TX, 184p.

4.6 METHODOLOGY

SAMPLE COLLECTION

The sediment samples for the present study were collected by using R.V. Sumudra Ratnakar during the cruise SR-083 from the Continental shelf and Continental slope of - Nagapattinam, by using corers of Gravity and Vibro cores of five samples i.e GC-34, GC-10, VC-30/1, VC-30/2, VC-30/. Each core was sub-sampled according to colou, texture, presence of shells.

SAMPLE PROCESSING:

Since sediment is a mixture of grains varying size, organic matter, chemical precipitates, dissolved salts etc.; it is necessary to treat the samples to remove all the impurities. The following are the processes for removing impurities from sample.

Removal of organic matter by H_2O_2:

About 15 – 20 grams homogenized sediment was taken from each sub-sampled and transferred to a 1000ml beaker for grain size analysis. The samples were treated with H_2O_2 (15% Hydrogen peroxide) for removal of organic matter. The mixture was kept overnight and the next day it was heated to remove excess H_2O_2.

Removal of Chlorides and Salts:

Salt content in the sample are removed by washing the samples with distilled water until all the salts are removed. After H_2O_2 treatment Distilled water added to all samples and kept aside for the settledown of the sediments. After the complete settlement of the sediments, decanted for the removal of salts. This processes repeated for three times.

Dispersal of particles:

Each sample is then treated with ammonia (NH3) and kept overnight for the deflocculation of clay particles. Then the samples were stirred for about 3 minutes using a magnetic stirrer for complete dispersion.

Wet Sieving:

Wet sieving is done to remove the mud fraction (-63 microns) from the coarse (+63 micrones) fraction of the sediment sample. The silt and clay fractions are separated by adding distilled water and agitating the samples in 230 ASTM mesh (63 microns) manually. The -230 fraction (caly and silt) was collected in a 1000 ml cylindrical jar and +230 fraction collected in sieve was oven-dried and weighted. The -230 fraction collected in 1000 ml cylindrical jar is kept a side for pipette analysis.

Dry Sieving:

The weighted +230 fractions were sieved using ASTM Sieves at half phi intervals (+5,+7,+10,+14,+18,+25,+35,+45,+60,+80,+120,+170,+230,-230). In the sieving techinique a known weight of dry sample is poured in to the top sieve which has the largest sieve opening. Each lower sieve in the column has smaller openings then the one above. At the bottom a pan is placed to collect any sediment that passes through the lowest sieve. The coloumn is palced in a sieve shaker. The shaker shakes the coloumn for about 15 minutes. After the shaking is complete the material on each sieve is weighed. The weight of the sample of each sieve is then divided by the total weight to give a percentage retained on each sieve.

Pipette Analysis:

Pipette analysis is a standard method for measuring the finer particles (Galehouse, 1971). The -230 fraction obtained by wet sieving was collected in a 1000 ml pipette jar and made it into exactly 1000 ml solution by adding distilled water. Each sample was stirred for 3 minutes and after 20 sec 20 ml of the sample was pipitted out from a depth of 20 cm and transferred to pre-weighed 50 ml beaker and dried to get the weight of mud fraction. Another 20 ml of the sample was pipitted out immediately after collecting the first one, i.e. within another 20 sec, and used for grain size analysis on Particle size analyser.

Laser Particle Analyzer (PSA):

Lasser diffraction particle size analyzers are used to measure the particles in a material. It is a well-established techinique of grain size analysis of particles ranking in size from sub-microns to millimeters. It is a reliable and rapid method of volumetric analysisof grain size of particles in a range of 0.1 to 2000 microns particle size is calculated by measuring the angle of light scattered by the particles as they pass through a laser beam.

Laser particle size analyzer works on the basic principle of laser diffraction. A laser diffraction particle size analyzer uses multiple light detectors, with more detector elements estending sensitivity and size limits. The angle of light scattering is inversely proportional to particle size. It is a convenient method of grain size analysis which gives instant feedback.

The system consists of a source of laser which emits a coherent intense light of fixed wavelength, series of detectors measure the intensity of the incident laser beams and a display system. The light source used by a laser particle size analyzer also affects particle size measuring limits; shoter wave length violet and UV lasers are better suited to measure submicron-sized particles than red lasers.

Large particles scatter light at small angles relative to a laser beam and small particles scatter light at large angles. The angular scattering intensity data is then analyzed to calculate the size of the particles responsible for creating the scattering pattern. The particle size is reported as a volume equivalent sphere diameter.

Microtrac S3500 PSA instrument was used during the present work for the analysis of the pipetted samples.

4.7 COMPUTATION OF GRAIN SIZE PARAMETERS:

The data obtained from mechanical sieving and PSA were used for determining various textural parameters like weight, percentage of granule, sand, silt and clay & various statistical parameters such as mean, standard deviation, skewness, & kurtosis with the help of “GRAIN SIZE” Application software. For calculating the textural and statistical parameters the results of dry sieved data and pipette data are combined into a particular format which is compatible with Grain Size Application software and then the data is processed in the software for grain size parameters.

4.8 DATA

4.8.1 SIEVE DATA

S.NO	1	2	3	4	5
SAMPLE	SR 083 VC 30	SR 083 VC 30/1	SR 083 VC 30/2	SR 083 GC 10	SR 083 GC 34
WEIGHT AFTER WET SIEVING	26.0335	18.5526	20.8029	11.7693	17.8041
5	0	0.0766	0.2131	0	0.7252
7	0.0923	0.1095	0.2625	0.0148	0.1797
10	0.0164	0.06	0.106	0.0181	0.2715
14	0.0872	0.151	0.3936	0.0576	0.8143
18	0.0109	0.0553	0.265	0.0312	0.2617
25	0.0925	0.1844	0.3423	0.069	0.6451
35	0.6658	0.5436	0.8736	0.113	0.5383
45	3.723	1.3336	1.2635	0.2075	0.7874
60	10.4573	9.7881	10.4811	1.4048	7.0049
80	1.3325	1.7859	1.9256	0.8177	0.9124
120	4.0009	2.4531	2.4855	2.3825	2.0698
170	2.7075	0.7586	0.9152	1.8355	1.0573
230	2.0434	0.6775	0.9555	2.376	0.8766
-230	0.8008	0.1145	0.3181	2.2036	0.0361
TOTAL SIEVE WEIGHT	26.0305	18.0917	20.8006	11.5313	16.1803

Table 5. Sieve analysis data

4.8.2 PIPETTE DATA

SR 083 VC 30/1				
Sample & Beaker No	Wt of beaker	wt of beaker + sample	wt of sample	wt of sample * 50
1	28.56	28.6851	0.1251	6.255
2	30.3115	30.4336	0.1221	6.105
3	36.463	36.5787	0.1157	5.785
4	31.3905	31.5458	0.1553	7.765
5	29.3011	29.4172	0.1161	5.805
6	26.2878	26.3814	0.0936	4.68
7	29.6402	29.7408	0.1006	5.03
8	29.0289	29.1219	0.093	4.65

Table 6.1. VC 30/1

SR 083 VC 30/2				
Sample & Beaker No	Wt of beaker	wt of beaker + sample	wt of sample	wt of sample * 50
9	27.7614	27.8418	0.0804	4.02
10	29.5029	29.5768	0.0739	3.695
11	28.0539	28.1236	0.0697	3.485
12	28.2579	28.3225	0.0646	3.23
13	28.1722	28.2316	0.0594	2.97
14	25.4182	25.4856	0.0674	3.37
15	30.965	31.0157	0.0507	2.535
16	29.3057	29.35	0.0443	2.215

Table 6.2. VC 30/2

SR 083 VC 30				
Sample & Beaker No	Wt of beaker	wt of beaker + sample	wt of sample	wt of sample * 50
17	31.3909	31.553	0.1621	8.105
18	26.3715	26.5278	0.1563	7.815
19	26.6551	26.8008	0.1457	7.285
20	28.8213	28.9584	0.1371	6.855
21	28.0099	28.1324	0.1225	6.125
22	27.4375	27.4514	0.0139	0.695
23	28.2012	28.2139	0.0127	0.635
24	26.0155	26.0254	0.0099	0.495

Table 6.3 VC 30

SR 083 GC 10				
Sample & Beaker No	Wt of beaker	wt of beaker + sample	wt of sample	wt of sample * 50
25	28.7112	28.9066	0.1954	9.77
26	30.5613	30.7391	0.1778	8.89
27	29.7651	29.9235	0.1584	7.92
28	29.1405	29.2864	0.1459	7.295
29	31.306	31.4415	0.1355	6.775
30	30.0034	30.1248	0.1214	6.07
31	29.6345	29.7438	0.1093	5.465
32	30.2767	30.3427	0.066	3.3

Table 6.4 GC 10

SR 083 GC 34				
Sample & Beaker No	Wt of beaker	wt of beaker + sample	wt of sample	wt of sample * 50
33	27.2612	27.3858	0.1246	6.23
34	30.0618	30.2326	0.1708	8.54
35	29.9318	30.0494	0.1176	5.88
36	29.483	29.5878	0.1048	5.24
37	29.874	29.9751	0.1011	5.055
38	29.4951	29.6046	0.1095	5.475
39	29.7452	29.7915	0.0463	2.315
40	28.9668	28.9783	0.0115	0.575

Table 6.4 GC 34

4.9 RESULTS

4.9.1 GRAINSIZE SOFTWARE DATA

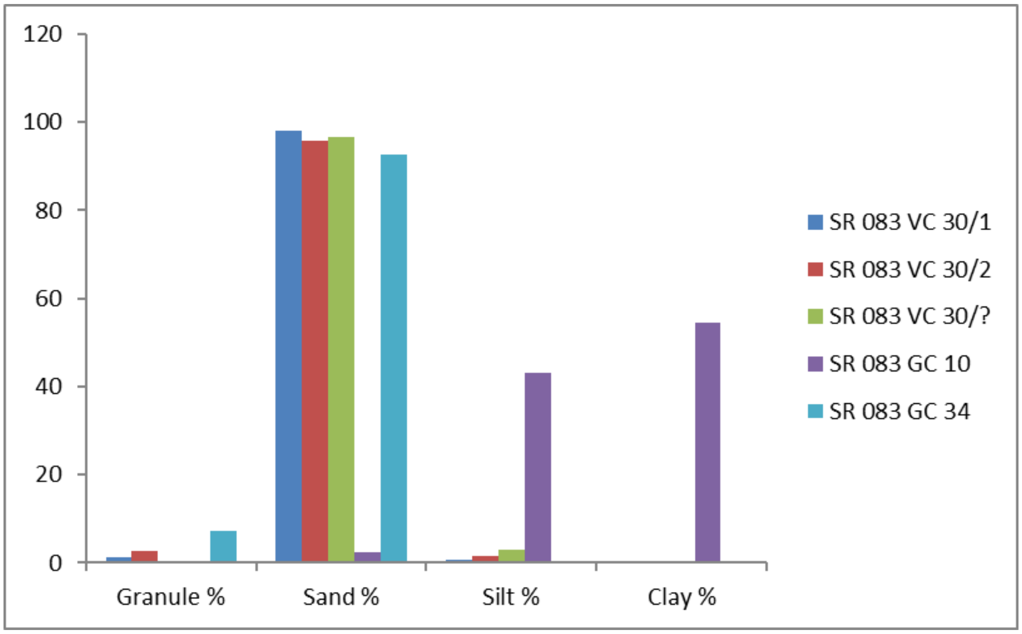
Sample No.	Median (Phi)	Mean (Phi)	Std.Dev.(Phi)	Skewness	Kurtosis	Sediment Type (Folk)
SR 083/ VC-30	1.8982	2.1947	0.8857	0.4424	0.8974	Slightly Gravelly Sand
SR 083/VC-30/1	1.8337	2.0264	0.7076	0.3338	1.4603	Slightly Gravelly Sand
SR 083/ VC-30/2	1.8187	1.9782	0.9625	0.1187	2.0677	Slightly Gravelly Sand
SR 083 GC-10	8.2135	8.1794	3.0836	0.0456	0.764	Mud
SR 083/ GC-34	1.776	1.6291	1.4544	-0.2503	1.9661	Gravelly Sand

Table 7 Grain Size Software data

Sample No	Granule %	Sand %	Silt %	Clay %	Sediment Type (Folk)
SR 083 VC 30/1	1.36	98.01	0.63	0	Slightly Gravelly Sand
SR 083 VC 30/2	2.8	95.67	1.53	0	Slightly Gravelly Sand
SR 083 VC 30	0.42	96.51	3.08	0	Slightly Gravelly Sand
SR 083 GC 10	0.01	2.34	43.03	54.62	Mud
SR 083 GC 34	7.27	92.51	0.22	0	Gravelly Sand

Table 7.1 Percentages

GRAPHICAL REPRESENTATION OF PERCENTAGES



Sample No	Mean	Standard Deviation	Sorting Type	Skewness	Skewness Type	Kurtosis	Kurtosis Type	Median
SR 083 VC 30/1	2.026	0.7076	Moderately Well Sorted	0.3338	Strongly Fine Skewed	1.4603	Leptokurtic	1.8337
SR 083 VC 30/2	1.978	0.9625	Moderately Sorted	0.1187	Fine Skewed	2.0677	Very Leptokurtic	1.8187
SR 083 VC 30	2.195	0.8857	Moderately Sorted	0.4424	Strongly Fine Skewed	0.8974	Platykurtic	1.8982
SR 083 GC 10	8.179	3.0836	Very Poorly Sorted	0.0456	Near Symmetrical	0.764	Platykurtic	8.2135
SR 083 GC 34	1.291	1.4544	Poorly Sorted	-0.2503	Coarse Skewed	1.9661	Very Leptokurtic	1.776

Table 7.2 Grain size parameters intrepretation

4.9.2 LINEAR DISCRIMINANT ANALYSIS (LDA)

The linear Discriminant function of Sahu (1964) has been used for multivariate analysis of beach sediments. According to Sahu, the statistical method of analysis of the sediments to interpret variations in the energy and fluidity factors seems to have excellent correlation with different processes and environment of deposition. The following formulae and their limitation to a particular environment were utilised to interpret the environment of deposition of sediments.

To distinguish environment of deposition between aeolian and beach, the following equation has been applied: $\mathbf{Y1}_{\mathbf{Aeol: Beach}} = -3.5688M + 3.7016r^2 - 2.0766SK + 3.1135KG$

Where if Y is ≥ -2.7411, environment of deposition is beach, and if Y is ≤ -2.7411, environment of deposition is aeolian.

To delineate and to confirm the environment of deposition between beach and shallow marine, the following equation has been applied:

$\mathbf{Y2}_{\mathbf{Beach: Shallow\ marine}} = 15.6534M + 65.7091r^2 + 18.1071SK + 18.5043KG$

Where if Y is ≥ 63.3650, environment of deposition is shallow marine, and if Y is ≤63.3650, environment of deposition is beach.

To distinguish environment of deposition between shallow marine and fluvial, the following equation has been applied:

$\mathbf{Y3\ Shallow}_{\mathbf{marine: Fluvial}} = 0.2852M - 8.7604r^2 - 4.8932SK + 0.0428KG$ (3)

Where if Y is ≥-7.4190, environment of deposition is shallow marine, and if Y is ≤-7.4190, environment of deposition is fluvial.

(M= mean, r = standard deviation, SK= skewness and KG= kurtosis)

SAMPLE NO	Y1	Y2	Y3	INTERPRETATION
SR 083 VC 30/1	-1.523531002	97.68016685	-3.931161977	Environment of deposition is shallow marine
SR 083 VC 30/2	2.561390505	132.2464	-6.630014593	Environment of deposition is shallow marine
SR 083 VC 30	-3.054375184	110.5220085	-6.803565678	Environment of deposition is aeolian
SR 083 GC 10	8.291798734	767.7929504	-75.31047345	Environment of deposition is fluvial
SR 083 GC 34	9.863822609	191.0507395	-15.93077627	Environment of deposition is fluvial

Table 8 Linear discriminant analysis

4.10 CONCLUSIONS:

SR 083 VC-30:

Abundance of particles in sample VC-30 is in the order of Sand>Gravel>Silt>Clay. Grain size parameters of the VC-30 shows that sand is 98.01%, Gravel is 1.36%, Silt is 0.63%, Clay is 0%. The sediment type is slightly gravelly sand which indicates the medium energy conditions are prevailed at the time of deposition. Moderately well sorting indicates that the sediment is far from the source and from linear discriminant analysis (LDA) the environment of deposition is aeolian.

SR 083 VC-30\1:

Abundance of particles in sample VC-30\1 is in the order of Sand>Gravel>Silt>Clay. Grain size parameters of the VC-30\1 shows that sand is 95.67%, Gravel is 2.8%, Silt is 1.53%, Clay is 0%. The sediment type is slightly gravelly sand which indicates the medium energy conditions are prevailed at the time of deposition. Moderate sorting indicates that the sediment is far from the source and from linear discriminant analysis (LDA) the environment of deposition is shallow marine.

SR 083 VC-30\2:

Abundance of particles in sample VC-30\2 is in the order of Sand>Silt>Gravel>Clay. Grain size parameters of the VC-30\2 shows that sand is 96.51%, Gravel 0.42%, Silt is 3.08%, Clay is 0%. The sediment type is slightly gravelly sand which indicates the medium energy conditions are prevailed at the time of deposition. Moderate sorting indicates that the sediment is far from the source and from linear discriminant analysis (LDA) the environment of deposition is shallow marine.

SR 083 GC-10:

Abundance of particles in sample GC-10 is in the order of Clay>Silt>Sand>Gravel. Grain size parameters of the GC-10 shows that sand is 2.34%. Gravel 0.01%, Silt is 43.03%, Clay is 54.62%. The sediment type is Mud which indicates the low energy conditions are prevailed at the time of deposition. Very poorly sorting indicates that the sediment near to the source and from linear discriminant analysis (LDA) the environment of deposition is fluvial.

SR 083 GC-34:

Abundance of particles in sample GC- 34 is in the order of Sand>Gravel>Silt>Clay. Grain size parameters of the GC-34 shows that sand is 92.51%, Gravel 7.27%, Silt is 0.22%, Clay is 0%. The sediment type is Gravelly sand which indicates medium to high energy conditions are prevailed at the time of deposition. poorly sorting indicates fluctuations in the energy levels and from linear discriminant analysis (LDA) the environment of deposition is fluvial.

5. COARSE FRACTION STUDIES

5.1 INTRODUCTION:

It is the process of studying the coarse grain (i.e +230) to know the environmental conditions, type of deposit, provenance and energy conditions prevailed for the sediment deposition. Coarse fraction study is aim to understand the major terrigenous, biogenous, Authigenous components in the sediments. Individual components were estimated by calculating their relative abundance in the sediment.

There are three types of materials namely

1) Biogenous sediments
2) Terrigenous sediments
3) Authigenous sediments

1) **BIOGENOUS SEDIMENTS:** Biogenous sediments are composed of the remains of living organisms, including microscopic phytoplankton (Plants) and microscopic zooplanktons (animals), terrestrial and aquatic plants, shells of invertebrates, and vertebrate material (Teeth, bone), and associated organic residue. Biogenous sediments come from organisms like plankton when their exoskeletons break down.

They can be grouped in three major categories they are

Calcareous biogenous sediments – The sediments made up of calcareous material

Siliceous biogenous sediments - The sediments made up of siliceous material

Phosphatic biogenous sediments - The sediments made up of phosphatic material

E.g.: Planktonic, Benthic, Ostracods, Shell fragments, Corals, Pteropods, Bryozoa, Gastropods, Bivalves etc.

2) **TERRIGENOUS SEDIMENTS:** Terrigenous sediments are deposits of mud, sand, gravel, and volcanic materials derived from the denudation of continental rocks. The main sources of terrigenous deposits are terrestrial sediments. They are mainly found on near land covering the sea shore, continental shelf and upper parts of the continental slope.

E.g.: Brown clays are a variety of pelagic sediment, mostly of terrigenous origin, which are composed largely of four different clay minerals; chlorite, illite, kaolinite, and montmorillonite
On the basis of size of particles, the terrigenous deposits may be categorized into three classes
Mud

1. Sand - > mm
2. Gravel - > 2mm

E.g.: Quartz, Feldspar, Pyroboles(Pyroxene+Amphibole), Heavy minerals and mica etc.

3) **AUTHIGENOUS SEDIMENTS**: Authigenous sediments arethose that originate in place where they are found typically forming directly within a sedimentary environment through chemical, physical, or biological processes as opposed to being transported from elsewhere. These sediments include minerals and particles that have precipitated or ground in their current location, often providing insights into the geological history and environmental conditions of the area.

E.g.: Phosphatic grains, Phosphatic infillings, Glauconitic minerals, Chloritic minerals.

5.2 METHODOLOGY:

About 50 grams of homogenized sediment was taken from each sub-sample and transferred to pre-label 1000ml beaker for coarse fraction study. The sample were treated with H_2O_2 (15% hydrogen peroxide) for removal of organic matter. This mixture was kept overnight and the next day it was heated to remove excess H_2O_2. After the removal of organic matter Ammonia is added for the dispersion of clay particles and kept overnight. Then the sample was subjected to wet sieving using 230 ASTM mesh until the clay was removed completely washing was done carefully without causing any physical damage to the micro-faunal content. The washed samples were transferred to a porcelain dish and oven dried at $50^{O}C$ - 90 ^{O}C. The processed samples were examined under binocular microscope by taking suitable aliquot of sample by coning and quartering. Each fraction was studied to understand the mineralogical content and micro-faunal content.

Size analyses were carried out by the standard sieve and pipette techniques. Individual size fractions were reconstituted for the coarse-fraction studies. Sub-samples were taken after coning and quartering and spread over a gridded tray. In each case small fractions from each sieve were taken and the number percentage of the following components were determined: foraminifers, gastropods, pteropods, others (including bryozoans, ostracods, sponge spicules, algal fragments, etc.), rock fragments, light minerals and dark minerals.

5.3 RESULT:

1) **<u>COARSE FRACTION STUDY OF SR083 VC-30/1 (0-0.13m):</u>**

The sample includes Biogenous, Terrigenous and Authigenous forms

BIOGENOUS FORMS: Benthic, Planktonic, Pteropods and shell fragments

Benthic Forms: The main Benthic forms are Bolivina, Uvigerina, Trochammaina Inflata. The overall forms are about 30%.

Planktonic Forms: The main Planktonic forms are Globigerina, Bluloids, Globigerena Dubia. The overall forms are about 50%.

Pteropods: The overall pteropods are about 5%.

Shell fragments: The overall shell fragments are about 15%.

TERRIGENOUS FORMS: The terrigenous materials observed are transparent quartz with sub angular to angular shape. The overall terrigenous forms are about 10-12%.

AUTHIGENOUS FORMS: The Authigenous forms observed are Phosphatic infillings in shell fragments and broken Phosphatic material is observed. The overall Authigenous materials are about 8-10%.

2) **<u>COARSE FRACTION STUDY OF SR083 VC-30/2 (0.43-0.77m):</u>**

The sample includes Biogenous, Terrigenous and Authigenous forms

BIOGENOUS FORMS: Benthic, Planktonic, Pteropods and shell fragments. The overall forms are about 70%.

Benthic Forms: The main Benthic forms are Bolivina, Trochammaina Inflata. The overall forms are about 20%.

Planktonic Forms: The main Planktonic forms are Globigerina, Uvigerena. The overall forms are about 30 %.

Pteropods: The overall pteropods are about 10%.

Shell fragments: The overall shell fragments are about 40%.

TERRIGENOUS FORMS: The terrigenous materials observed are transparent quartz with sub angular to sub rounded grains. The overall terrigenous forms are about 10%.

AUTHIGENOUS FORMS: The Authigenous forms observed arebroken Phosphatic grains few iron precipates which are oxidized in brown colour. The overall Authigenous materials are about 20%.

3) COARSE FRACTION STUDY OF SR083 VC-30 (2.35-2.67m):

The sample includes Biogenous, Terrigenous and Authigenous forms

BIOGENOUS FORMS: Benithic, Planktonic, Pteropods, shell fragments and aggregate with grey cementation material is observed. The overall forms are about 50%.

Benthic Forms: The main Benthic forms are Bolivina, Uvigerena. The overall forms are about 30%.

Planktonic Forms: The main Planktonic forms are Globigerina, Globigerena rutalia. The overall forms are about 50 %.

Pteropods: The overall pteropods are about 5%.

Shell fragments: The overall shell fragments are about 15%.

TERRIGENOUS FORMS: The terrigenous materials observed are transparent quartz which are sub angular to sub rounded. The overall terrigenous forms are about 30%.

AUTHIGENOUS FORMS: The Authigenous forms observed arebroken Phosphatic grains, few iron precipitates observed. The overall Authigenous materials are about 20%.

4) COARSE FRACTION STUDY OF SR083 GC-10 (0.5-0.85m):

The sample includes Biogenous, Terrigenous and Authigenous forms

BIOGENOUS FORMS: Benthic, Planktonic, Pteropods,shell fragments is observed. The overall forms are about 90%.

Benthic Forms: The main Benthic forms are Bolivina, Uvigerena. The overall forms are about 30%.

Planktonic Forms: The main Planktonic forms are Globigerina. The overall forms are about 50%.

Pteropods: The overall pteropods are about 1-2%

Shell fragments: The overall shell fragments are about 18%

TERRIGENOUS FORMS: The terrigenous materials observed are transparent quartz which are sub angular to rounded. The overall terrigenous forms are about 8%.

AUTHIGENOUS FORMS: The Authigenous forms are few iron precipitates which are oxidized in brownish colour were observed. The overall Authigenous materials are about 2%.

5) COARSE FRACTION STUDY OF SR083 GC-34 (0.63-0.80m):

The sample includes Biogenous, Terrigenous and Authigenous forms

BIOGENOUS FORMS: Benthic, Planktonic, Pteropods, shell fragments is observed. The overall forms are about 70%.

Benthic Forms: The main Benthic forms are Bolivina, Uvigerena, rotalia. The overall forms are about 10%.

Planktonic Forms: The main Planktonic forms are Globigerina. The overall forms are about70%.

Pteropods: The overall pteropods are spongers about 5%.

Shell fragments: The overall shell fragments are gastropods, bivalves about 15%.

TERRIGENOUS FORMS: The terrigenous materials observed are transparent quartz which are sub rounded to rounded. The overall terrigenous forms are about 20%.

AUTHIGENOUS FORMS: The Authigenous forms are phosphatic materials which are medium sized were observed. The overall Authigenous materials are about 10%.

6. OBSERVED COARSE FRACTION MATERIALS:

SPONGES

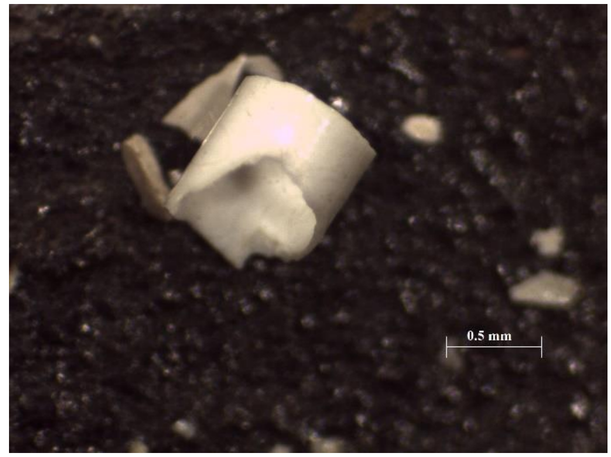
MICA FLAKE

BOLIVINA, GLOBIGERINA & CORAL

BENTHIC MATERIAL

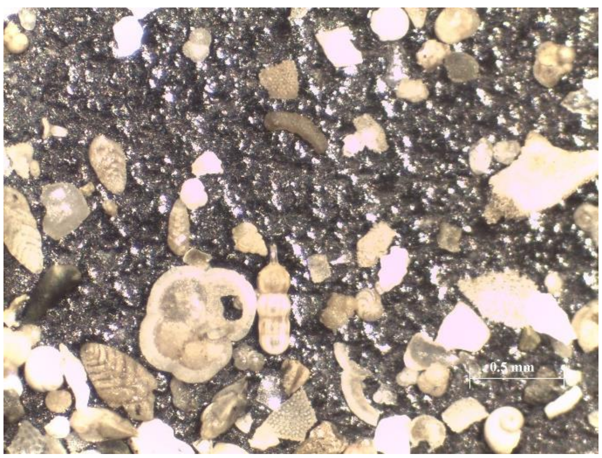
PHOSPHATIC MATERIAL

ROSE QUARTZ & TRANSPARENT QUARTZ



PHOSPHATIC MATERIAL

SHELL FRAGNMENT



MIXTURE OF MATERIALS

SPONGES

7. PROJECT PHOTOS

CORE STUDIES

WET SIEVING

MECHANICAL SIEVING

WEIGHING OF SAMPLES

PIPETTING

COARSE FRACTION STUDIES

8. REFERENCES:

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