SPATIAL AND TEMPORAL VARIATION OF OSTRACODES IN THE WEST OF LAKSHADWEEP RIDGE, OFF COCHIN-THEIR SIGNIFICANCE IN THEPALAEOCLIMATIC RECONSTRUCTION

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CERTIFICATE

This is to certify that this thesis entitled "SPATIAL AND TEMPORAL VARIATION OF OSTRACODES IN THE WEST OFLAKSHADWEEP RIDGE, OFF COCHIN-THEIR SIGNIFICANCE IN THE PALAEOCLIMATIC RECONSTRUCTION" is an authentic work carried out by Shri. N. Mohamed Shareef in the Department of PG studies and Research in Geology, MES Ponnani College, Ponnani under my supervision.

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this thesis entitled" SPATIAL AND TEMPORAL VARIATION OF OSTRACODES IN THE WEST OF LAKSHADWEEP RIDGE, OFF COCHIN-THEIR SIGNIFICANCE IN THE PALAEOCLIMATIC RECONSTRUCTION" in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy and submitted in the University of Calicut is an authentic record of my own work carried out during the period 02^{nd} September 2010 to 31^{st} August, 2017 under the supervision of Dr. K. Gopalakrishna, Professor (Rtd.), Department of PG studies and research in Geology, MES Ponnani College, Ponnani and Dr. V.A. Ayisha, Professor, Department of PG studies and research in Geology, MES Ponnani College, Ponnani.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

(N. Mohamed Shareef)

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Any work is the result of many hands and most of them may not be visible. The emotional support I have received from my family is highly appreciated. I submit to the almighty for everything I am and I have.

Place: PONNANI N. M. SHAREEF

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Chapter 1

INTRODUCTION

Ostracods are found in most marine environments and are among the most important group of modern and ancient benthic communities (Zhao and Whatley, 1997; Fontanier et al., 2002; Martínez-García et al., 2013). These most successful crustaceans are represented by nearly 8000 living species. Though they are generally small, many ostracods range in length from 0.1 to 32 mm. The largest member of this group Gigantocypris, a planktonic ostracod is reaching up to a size of 32 mm. As it is adapting a pelagic life style and swims continuously in the open sea, *Gigantocypris* remains as distinct from many other ostracods as well. Majority of other ostracods are either crawling in the bottom sediments of Ocean or lakes or are seen burrowing into the sediments. A few species like *Mesocypris* sp., are also found crawling around in moist terrestrial habitats such as mosses. In these habitats, they feed on dead organic material, suspended organic particles, microscopic plants, as well as predating on other organisms.

Like other crustaceans, they periodically shed the hard exoskeleton surrounding the soft body of the creature in order to grow. In this process, ostracod valves get preserved as fossils in various aquatic sediments.

Ostracods live in various aquatic environments, including fresh and brackish water. Though they inhabit both the sea floor and the planktonic zones, most commonly they are found in the sea floor zone and are therefore generally benthic in nature. Depending on the species, surface ornamentation of ostracod valves varies in degrees.

Temporal and spatial distribution patterns of ostracods are understood by statistical methods. Their high sensitivity to environmental conditions made them an important tool in the paleo-climatic and environmental reconstructions. (Barut et al., 2015; Casier et al., 2015; Trabelsi et al., 2015). As ostracod shells contain biogenic carbonate, their chemical composition, including stable oxygen and carbon isotopes, are widely used as proxies for environmental reconstructions (Von Grafenstein et al., 2000; Alvarez Zarikian et al., 2005; Anadón et al., 2006; Medley et al., 2008; Wrozyna et al., 2010; Escobar et al., 2012; Marco-Barba et al., 2012; Pérez et al., 2013; Börner et al., 2013). Many studies of ostracods especially from the North Atlantic and other climate-sensitive areas have established the utility of ostracods in the paleo-oceanographic reconstructions. This is more so because the species distribution is directly linked to the nature of water particularly the deep-water masses (Dingle and Lord, 1990; Ayress et al., 1997; Cronin and Raymo, 1997; Didie and Bauch, 2000; Alvarez Zarikian, 2009; Yasuhara et al., 2009, 2012). These factors driven many researchers to study these benthic microfossils largely across the world (Zhao and Whatley, 1997; Triantaphyllou et al., 2005; Nachite et al., 2010; Martínez-García et al., 2013).

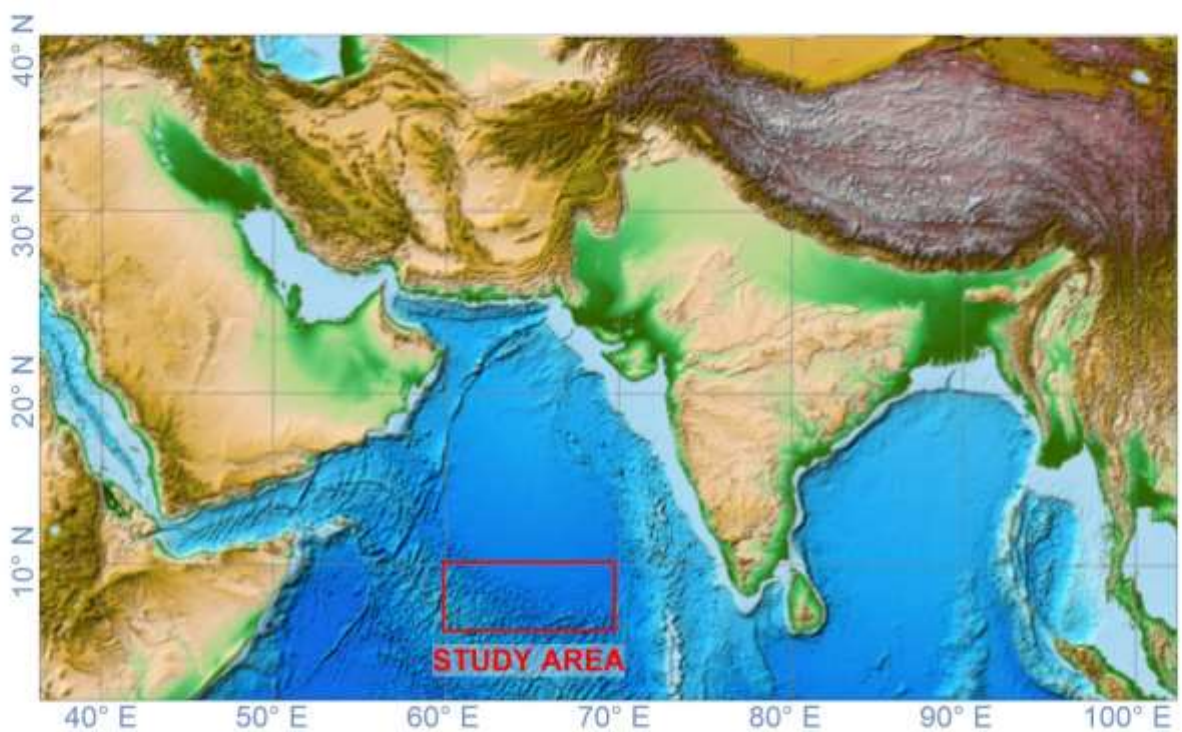


Fig.1.1 Study area on a lager perspective

The lower diversity of ostracods in the Indian Ocean compared to the Pacific may possibly be due to difference in sampling frequency as well as water depth. The studies also reveal that the distinct variation in diversity from the Atlantic to the Indian Ocean as well as from the Indian to the Pacific Ocean are due to the variation in the environmental parameters prevalent in different sea conditions. Furthermore, the study of deep-water ostracod faunas in the Indian Continental Margin still lags behind studies of shallow water faunas. Though India has a wide west coast, most of the research on bathyal ostracods is still concentrated in the shallow margin areas. In the slope, the assemblages are usually composed of mixed autochthonous and allochthonous species, transported by sedimentary processes, such as turbidity currents, slumps and reworking linked to sea level changes. Therefore, the analysis of the assemblages from the adjacent continental shelf is necessary and critical for the spatial and temporal variation of ostracods off west coast of India. In these limited studies on ostracods along West coast of India, studies on variation and distribution of benthic ostracod assemblages off Lakshadweep are very rare. With these gap in understanding of the ostracods in off Lakshadweep area (Fig.1.1), the present study has taken up.

1.1. Objectives

Ostracods are significant in the study of taxonomy, ecology, palaeoecology, palaeo oceanography etc. In the isotopic studies they are better suited due to various reasons like i) they can be easily separated from the surrounding sediments, ii) Well preserved low Mg-calcite carapaces are abundantly available, iii) ubiquitous presence of all sediments of various environments, and iv) the characteristics of the water in which they live are reflected in the shell morphology as wee as composition.

Most of the studies across the world have been carried out on the fossil ostracods from the morphological as well as application point of view. In Indian sub-continent also, studies have been made on fossil ostracods. However, most of these studies are confined to fresh water or near shore ostracods. No detailed study on distributional aspects, especially in the deep sea set up has been documented. Therefore, an attempt has been made in the present study to understand Taxonomical variations of ostracods temporally in the Deep sea conditions.

Following are the major objectives of the present work:

1. Identification and documentation of the composition of ostracod genera and species in the study area and generating data about the general bathymetric distribution of those in this area.

2. Evaluating the assemblages, distribution, abundance and diversity patterns of the ostracods.

3. Study the environmental relations of the ostracods.

Therefore, the research methodologies adopted to understand the spatial and temporal variations of ostracods off Lakshadweep during the present study area are

1) Granulometric studies, clay mineralogy and geochemical studies of selected cores to understand the variation in the cores

2) Identification of ostracod species and their distribution and density down the core

3) Exploring the correlation between the distribution pattern of ostracods and establishing the relationship if any.

The ostracods from the deep marine environment of the Arabian Sea are incompletely known because of a lack of sampling and study. This study is the first to report species from a wide depth range of material, often well preserved, in the Arabian Sea. Changes seen in the ostracod assemblages with bathymetry and their relationship to environmental parameters are the focus of this contribution.

Chapter 2

MATERIALS AND METHODS

2.1. The Study Area

The study area is off Lakshadweep in the Indian Exclusive Economic Zone (EEZ) in the Arabian Sea (AS) (Fig. 2.1). The hydrographic and biological characteristics of Arabian Sea is strongly influenced by the Asian land mass which is the northern limit. The basin experiences annually reversing monsoon currents, which are induced by the Southwest (SM) and Northeast (WM) monsoons. Between these monsoons are inter monsoonal transition periods in spring (SIM) and in the Fall (FIM). Only two main rivers - the Tapti and Narmada discharge in to the AS. The freshwater inputs into the AS have been estimated to be $0.3x10^{12}$ m^3 yr^{-1} into the AS (UNESCO, 1988). In addition, the negative water balance, resulting from the excess of evaporation over precipitation and the intrusion of Persian Gulf and the Red Sea generates warm and high saline water masses, modify the AS hydrography with high salinity water (ASHSW ca. 36). This leads to convective mixing and brings nutrients to photic zone, which support high biological production. During summer monsoon, the strong and steady southwesterly wind (Findlater, 1969) blowing over the northern Indian Ocean cools the surface waters and deepens the MLD in the open ocean. On the northern side of the Findlater jet upward Ekman pumping is induced, which advects the upwelled waters from the Arabian coast offshore, which makes the northern AS highly productive (Prasanna Kumar et al., 2001).

During the NEM, dry cool continental air (Northeasterly) from Tibetan plateau flows over both seas imparting momentum and heat flux and cools the ocean and causes evaporation making the surface waters high saline and dense (ASHSW), and these sink to deeper depths by buoyancy. As a result, nutrient rich subsurface water reaches to the surface layer, creating eutrophic conditions in the northern AS.

In the AS, the studied cores collected from two physiographic domains; Arabian basin abutting the lower Indus Fan (IF) and the Carlsberg Ridge (CR). The IF, an important physical feature of the Arabian Sea, covers an area of about 1.25 million sq. km roughly constituting one third of the Arabian Sea floor and which forms the northwestern arm of Indian Ocean. It is the second largest submarine Fan in the world, next only to the Bengal Fan located east of the Indian Peninsula. This cone shaped sediment deposit is bounded by the continental margin of India-Pakistan and Chagos-Lakshadweep Ridge in the east, the Owen-Murray Ridge and Fracture Zone in the west and the Carlsberg Ridge system in the south. The Indus Fan has a relatively plain surface, although many turbidity current channels dissect it. The maximum sediment thickness within the Indus Fan is not fully known though as per available information it exceeds seven kilometers (Naini and Talwani,1982).

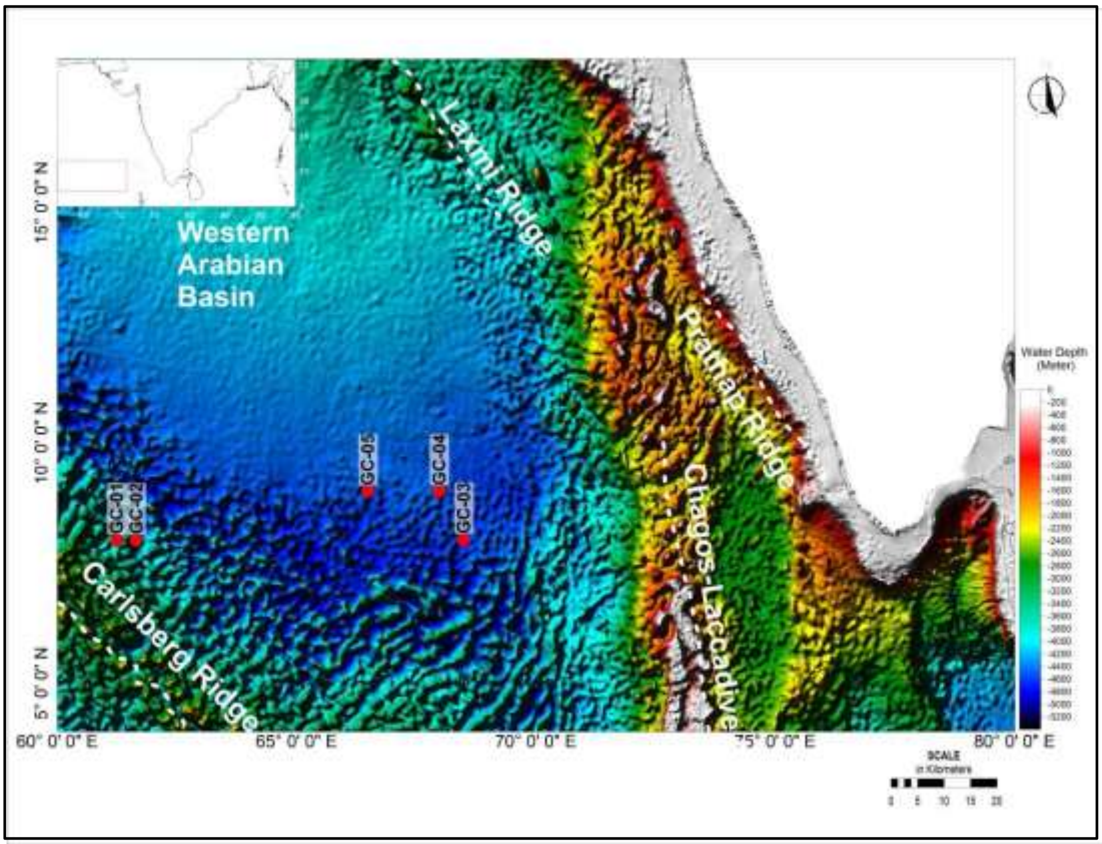


Fig. 2.1 Study area with sample location

Table 2.1 Sample details

Sample No	Lattitude	Longitude	Water Depth	Core Length
GC-01	7.988917 °N	61.2428 °E	3468 m	2.07m
GC-02	7.984217 °N	61.65055 °E	4200m	1.73m
GC-03	7.995433 °N	68.49322 °E	4668 m	1.84m
GC-04	9.007367 °N	67.9817 °E	4699m	2.78m
GC-05	9.003166 °N	66.48975 °E	4518m	2.47m

The second morphological domain between longitudes 62°30'E and 60°E is conspicuous by a craggy surface typical of a ridge system identified as the Carlsberg Ridge (CR) which extends from 2°S to 10°N. This forms a NW–SE trending slow accreting plate boundary between the African and Indian Plates and continues to the Gulf of Aden and to Red Sea as highly segmented Sheba Ridge. In the region north of 10°N on the CR, the Arabia–India–Somalia triple junction has been evolving since last 16 m.y. as Ridge–Ridge–Ridge triple junction. One arm of this ridge trends N80°E, which is the ultra-slow divergent boundary between Arabian and Indian Plate. The modern phase of Carlsberg Ridge is characterized by its slow spreading and is segmented by a few transforming and non-transforming discontinuities.

2.2. Methodology

The selected samples were collected during the cruise SM-153 of Geological survey of India on board RVS during the annual field programme in the Arabian Sea. In total, 5 gravity cores (GC-01 to GC-05) were collected from water depth ranging from 3468 to 4699 m in the south-eastern part of Indus Fan and from the Carlsberg Ridge. The details of the samples collected along with other related information are tabulated and given in Table. 2.2.1 The gravity cores collected were split, logged and sub sampled. The details of the core logs are given in Table-2.2.2 to 2.2.6 and diagrammatically represented in Fig 2.2.1 to Fig.2.2.5. The cores were logged based on different sediment types/units, its colour and description based on visual observations.

2.2.1. Granulometric Studies

Core sub-samples were subjected to the conventional analysis outlined by Folk (1974). About 15 to 20 gm of sediment from each sample was first treated with hydrogen peroxide (15 %) and then washed with distilled water to remove organic matter and dissolved salts respectively. Size analysis is carried out by dry sieving at ½ phi interval for sand and other large grains and by pipetting for silt and clay. The sediment fraction coarser than 0.0625 mm diameter was separated by wet sieving (using ASTM sieve of 230), dried and then subjected to standard dry sieving techniques through a set of sieves with mesh sizes ranging from 4 to 0.0625 mm. The fraction finer than 0.0625 mm was subjected to pipette analysis following the standard procedure (Folk, 1974), and the weight percentage of the different size fractions in the sample is calculated. Nomenclature of the sediment type was established after Shepard (1954), based on the relative proportion of the three major size fractions in the sediment, viz., sand (grain size between 2 mm and 0.0625 mm), silt (grain size between 0.0625 mm and 0.0039 mm), and clay (material finer than 0.0039 mm). The sedimentological parameters such as Mean, Standard deviation, Kurtosis and Skewness were determined and the results of the analyses are provided in Table form.

2.2.2 Clay Mineralogy

Subsamples selected from five cores were prepared and studied under XRD to understand the nature of the fine grained particles in the sediment, both in surface and subsurfaceata, to understand the dominant mineral phases in clay fraction. The samples run on an X'pert Pro XRD™(PANalytical make) in the laboratory, CHQ, Kolkata, Geological Survey of India. This is a computer controlled X-ray Powder Diffractometer. It mainly consists of X-ray tube, incident and diffracted beam optical components, the Goniometer consisting of the platform that holds and moves the sample and the detector.

X’Pert Pro uses the Bragg-Brentano parafocussing geometry with vertical θ-θ geometry. With the help of operating software “X’Pert Data Collector” the system generates a diffraction pattern of the sample loaded in the sample stage of the machine.

2.2.3. Geochemistry

Five gravity cores retrieved during the present cruise were analysed for major and trace elements. From the subsamples, 20gm of subsamples were air dried and crushed by hand in an agate mortar to avoid contamination until entire quantity passed through -120 +100 ASTM mesh size. All samples were washed with distilled water prior to the analysis. An aliquot of 0.25gm were taken from each subsample and treated with aquaregia to dissolve the iron in the sediments. Thereafter the dried residues were treated with HF to remove the silicon. Perchloric acid was used later on to remove the organic content in the sediments and then the dried samples were brought to a 100ml solution using the dilute nitric acid. Thereafter the samples in nitric medium fed to a Varian 720-ES Inductively Coupled Plasma Optical Emission Spectrometer for major oxide and trace element analysis (ICP-OES) at Chemical laboratory of Marine & Coastal Survey Division, GSI, Kolkata. These analyses gave 8 major elements (Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2 and P_2O_5) and 10 trace elements (Cu, Pb, Zn, Ni, Co, Cd, Mn, Ba, Sr and Cr). Analytical precision was checked by of international reference material and in-house standards. Major element data are considered accurate between 1% and 5%, whereas trace element accuracy varies from 2% to 10%. Loss on ignition is determined by igniting 1 gm sample in muffle furnace at 1,0000C. P_2O_5 is determined by colour development with Ammonium Molybdate & Ammonium-Meta-Vanadate solutions & subsequently measured directly by Spectrophotometer at 465 nm. Contents of major oxides and trace elements are reported as analysed, not on a carbonate free basis. Analytical precision, as checked by parallel analysis of international reference material and in-house standards, is better than 5% for major oxides and better than 10% for the trace elements.

2.2.4. Isotopic Study

Sediments were ground by mortar and pestle, weighed, acidified in 10% HCl, and sonicated for 1 h. Carbonate-free residue was filtered through a Whatman quartz microfibre filter with a 0.6 mm pore size. Filters were dried and combusted under vacuum with CuO at 850^{o}C for 12 h. Following combustion, samples were purified and expanded into a known volume and pressure was recorded, providing calculation of the percent of total organic carbon (%TOC). %TOC are reported based on total sediment weight. Sample weights were not corrected for potential salt residues. Prior to acidification ground samples were split and entire analysis was performed in duplicate, though limited sample size for many allowed for only a single analysis. Duplicate analyses of %TOC provided an average precision of 0.004%. It should be noted that acidification and filtering will result in the loss of some dissolved organic matter. This loss was not quantified for this study. The sediments were freeze-dried, homogenized and ground in an agate mortar prior to elemental and isotopic analysis. The carbonate free sediments were analyzed for C and N by a Finnigan DELTA plus XL isotope ratio mass spectrometer, and the results were expressed in d notation as the deviation from standard reference material in parts per mil (‰).

2.2.5. Ostracod Study

About 10 gms of dried +230 fraction of every sample was separately taken after washing off all the impurities and salts. The samples were studied under binocular microscope to visually estimate the biogenous and terrigenous components of the entire sample. Entire samples were scanned under binocular microscope and ostracod valves were picked up using hand brush from every sample. The number of valves of each in every sample was counted and tabulated. Ostracod valves were photographed using scanning electron microscope and identified based on valve morphology.

Table 2.2.2 Core details of GC-01

Core No. GC-01				Core length: 2.07m
Location: Lat: 7.988917: Long: 61.2428				Water depth: 3468m
Core Depth (cm)		Thickness (cm)	Colour	Description
From	To			
0	4.5	4.5	10YR 6/2 Light brownish grey	Slightly compact sticky clay with robust tests.
4.5	5.5	1	10YR 6/2 to 6/3 Light brownish grey to pale brown	Slightly compact, silty clay with more tests.
5.5	12.5	7	10YR 6/3 pale brown.	Slightly compact silty clay with more tests.
12.5	17	4.5	10YR 6/2 to 6/3 Light brownish grey	Slightly compact silty clay with considerable number of tests.
17	27	10	10YR 7/2 Light grey	Loose to slightly compact clayey silt (ooze) with grey sediment intercalations.
27	29	2	10YR 6/4 Light yellowish brown,	Slightly compact silty clay with considerable amount of robust tests.
29	32	3	2.5 Y 5/2 to 4/2 Greyish brown	Slightly compact silty clay with large number of robust tests.
32	42	10	2.5 Y 6/4 to 5/4 Light yellowish brown	Light olive brown loose to slightly compact silty clay with robust tests and grey clay intercalation.
42	56	14	2.5Y 7/4 Pale yellow	Slightly to moderately compact silty clay with a few tests and intercalation.
56	57.5	1.5	2.5 Y 7/2 Light grey	Slightly compact, silty clay with a few tests.
57.5	71	13.5	2.5 Y 7/2 Light grey	Moderately compact silty clay with a few tests and grey intercalations
71	73.5	2.5	2.5Y 7/2 Light grey	Slightly compact silty clay with robust tests & grey green band.
73.5	77.5	4	2.5Y 7/2 to 6/2 Light grey to light brownish grey	Slightly compact silty clay with tests.
77.5	79	1.5	2.5 Y 7/2 Light grey	Slightly compact silty clay with grey green band
79	81	2	2.5 Y 7/2 Light grey	Slightly compact silty clay with a few tests.
81	82.5	1.5	2.5 Y 7/w to 6/2 Light grey to brownish grey	Slightly compact silty clay with a few tests.
82.5	95.5	13	10YR 7/2 Light grey	Loose to slightly compact silty clay with tests.
95.5	98	3.5	5Y 5/2 Olive grey,	Slightly compact silty clay with robust tests.
98	111	13	5Y 7/1 Light grey	Slightly compact silty clay with robust tests.
111	116	4.5	5Y 7/1 Light grey	Slightly compact silty clay with a few tests.
115.5	118	2.5	5Y 7/1 grey	Slightly compact silty clay with a few tests.
118	139	20.5	5Y 7/1 to 6/1 Light grey to grey	Moderately compact silty clay with a few tests.
138.5	148	9	5Y 7/1 Light grey	Slightly compact sticky silty clay with very few tests.
147.5	189	41.5	5Y 7/1 Light grey	Moderately compact sticky silty clay with very few tests and a few grey intercalations
188.5	194	5	5Y 8/1 to 7/1 White to light grey	Slightly compact, sticky silty clay with a few tests.
193.5	196	2.5	5Y 6/1 grey,	Moderately compact, sticky silty clay with tests.
196	199	3	5Y 7/1 Light grey,	Slightly compact sticky silty clay with a few tests.
199	207	8	5Y 7/2 Light grey,	Moderately compact slightly sticky, silty clay with robust tests.

Table 2.2.3 Core details of GC-02

Core No. GC-02				**Core length: 1.73m**
Location: Lat: 7.984217: Long: 61.65055				**Water depth: 4200m**
Core Depth (cm)		**Thickness (cm)**	**Colour**	**Description**
From	**To**			
0	10	10	2.5 Y 5/4 Light olive brown	Slightly compact sticky clay with a few tests.
10	15	5	2.5 Y 5/4 Light olive brown	Slightly compact sticky clay with olive brown clay bands & a few tests.
15	53	38	2.5 Y 54 Light olive brown	Slightly to moderately compact sticky clay with alternate laminations of very dark greyish brown clay. A few tests are present.
53	83	30	2.5 Y 5/4 Light yellowish brown,	Slightly to moderately compact sticky clay with laminations of olive brown clay and a few tests.
83	120	37	2.5 Y 6/4 Light yellowish brown	Moderately compact sticky clay with laminations. A few tests are present.
120	136	16	2.5 Y 5/4 Light olive brown	Moderately compact sticky clay with a no test.
136	145	9	2.5 Y 7/1 Pale yellow.	Moderately compact sticky clay with interlaminations of light olive brown clay.
145	152	6.5	2.5 Y 6/4 Light yellowish brown	Moderately compact sticky clay with few tests.
151.5	165	3.5	2.5Y 7/4 Pale yellow	Moderately compact sticky clay with feeble interlaminations of light olive brown clay with a few tests.
165	173	8	2.5 Y 5/4, Light olive brown	Moderately compact sticky clay with no test.

Table 2.2.4 Core details of GC-03

Core No. GC-03				Core length: 1.84m
Location: Lat: 7.995433: Long: 68.49322				Water depth: 4668m
Core Depth (cm)		Thickness (cm)	Colour	Description
From	To			
0	3.5	3.5	5Y 6/2Light olive grey	Slightly compact clay with a few test.
3.5	10	6.5	5Y 6/1 grey,	Moderately compact clay with a few tests and feeble interlaminations of dark olive grey clay.
10	14	4	5Y 5/2 Olive grey	Moderately compact clay with packets & interlaminations of dark grey clay.
14	24.5	10.5	5Y 5/1 Grey	Moderately compact clay with dark grey interlaminations with a few test.
24.5	26.5	2	5Y 6/1 Grey,	Slightly compact clay.
26.5	41.5	15	5Y 5/1 to 5/2 Grey to olive grey	Slightly compact clay silty clay.
41.5	45	3.5	5Y 5/1 Grey to 5Y 5/2 Olive grey	Silty clay without tests.
45	53	8	5Y 5/1 Grey	Slightly compact clay with very few tests.
53	69	16	5Y 5/1 to 5/2 Grey to Olive grey	Clay without tests.
69	74	5	5Y 5/1 Grey	Slightly compact clay with very few tests.
74	79	5	5Y 6/1 to 6/2 Light grey to light olive grey	Clay with dark grey clay laminations with a few tests.
79	86	7	5Y 5/1 to 5/2 Grey to Olive grey	Moderately compact clay with a few tests.
86	114	27.5	5Y 6/1 to 6/2 Light grey to light olive grey	Slightly compact clay
113.5	119	5	5Y 4/1 Dark grey	Moderately compact clay with a few tests.
118.5	124	5	5Y 5/2 Olive grey	Moderately compact clay no tests.
123.5	130	6.5	5Y 6/1 to 5/1 Grey	Moderately compact clay with intercalation of dark grey sediment and good amount of shell fragments.
130	151	20.5	5Y 5/2 Olive grey	Moderately compact clay no tests.
150.5	156	5.5	5Y 5/1 to 4/1 Grey to dark grey	Slightly compact clay with good amount of shell fragments.
156	159	3	5Y 6/1 to 5/1 Grey	Moderately compact clay with shell fragments.
159	173	12	5Y 5/2 Olive grey	Moderately compact clay no tests.
173	177	3.5	5Y 5/1 to 5/2 Grey to olive grey	Clay with tests.
176.5	181	4.5	5Y 7/1 Light grey	Loose to slightly compact clay with dark grey clay intercalations
181	184	3	5Y 5/2 Olive grey	Moderately compact clay.

Table 2.2.5 Core details of GC-04

Core No. GC-04				Core length: 2.78m
Location:	Lat: 9.007367: Long: 67.9817			Water depth: 4699m
Core Depth (cm)		Thickness (cm)	Colour	Description
From	To			
0	12	12	10YR 5/3 Brown	Loose slightly sticky without test clay.
12	17	5	10YR 5/4 to 10YR 4/3	Yellowish brown with occasion lists with dark brown patches of clay
17	20.5	3.5	10YR 5/4 Yellowish brown	Slightly compact slightly sticky clay with no test
20.5	30	9.5	10YR 4/4 dark yellowish brown	Slightly compact, slightly sticky clay with no test.
30	54	24	10YR 5/4 yellowish brown	Slightly compact slightly sticky clay with few tests.
54	64	10	10YR 5/3 brown,	Slightly compact slightly sticky clay with dark grey intercalations in the upper of the unit.
64	74.5	10.5	10YR 5.4 Yellowish brown	Slightly sticky clay no test.
74.5	81	6.5	10YR 5/3 brown,	Moderately compact sticky clay with no test
81	87	6	2.5Y 4/4 Olive brown	Slightly compact & slightly sticky clay no test
87	90	3	10YR 5/3 Brown	Moderately compact slightly sticky clay no test.
90	106	16	2.5Y 4/4 Olive brown	Moderately compact slightly sticky clay, no test.
106	110	3.5	10YR 5/3	Loose slightly sticky clay with no tests.
109.5	122	12.5	2.5Y 5/9 Light olive brown	Moderately compact, slightly sticky clay with no test.
122	127	6.5	2.5 Y 5/4 Light Olive brown	Slightly compact and slightly sticky clay with no test with very dark greyish brown patches.
126.5	138	11	2.5 Y 5/4 Light olive brown	Slightly compact and slightly sticky clay with no test.
137.5	142	4	2.5 Y 5/4 Light olive brown	Slightly compact and slightly sticky clay with no test.
141.5	170	28	2.5 Y 6/4 Light yellowish brown	Moderately compact slightly sticky clay with few intercalation of dark sediments toward top, no test.
169.5	180	10.5	2.5 Y 5/4 Light olive brown	Slightly compact clay with inter laminations of dark greyish brown sediments, no test.
180	188	7.5	2.5 Y 5/4 Light olive brown	Slightly to moderately compact slightly sticky clay with no test.
187.5	193	5.5	2.5 Y 5/4 Light yellowish brown	Moderately compact slightly sticky clay with few intercalation of dark greyish brown sediments, no test.

193	205	12	2.5 Y 5/4 Light olive brown	Slightly to moderately compact sticky clay with no test.
205	209	3.5	2.5 Y 6/4 Light yellowish brown	Slightly compact and slightly sticky slightly compact and slightly sticky clay with few intercalations of dark grey sediments.
208.5	214	5	2.5Y 5/4 Light Olive brown	Slightly compact & sticky clay with intercalations of dark greyish brown sediments. No tests.
213.5	218	4.5	5Y 5/3 Olive	Moderately compact slightly sticky clay with intercalation of dark grey sediments, no test.
218	224	5.5	2.5 Y 6/4 to 5/4 Light yellowish brown to light olive brown	Moderately compact slightly sticky clay with few intercalations of dark sediments
223.5	226	2.5	2.5Y 5/4 to 4/4 Light olive brown to olive brown	Slightly to moderately compact clay with intercalations of dark grey sediments. No tests.
226	23.5	7.5	2.5 Y 5/4 Light olive brown	Moderately compact slightly sticky clay no test with alternating dark & light bench.
233.5	236	2.5	2.5 Y 6/4 Light yellowish brown	Moderately compact slightly sticky clay with no test.
236	238	2	2.5 Y 5/4 Light olive brown.	Slightly compact slightly sticky clay with no test.
238	241	2.5	2.5 Y 6/4 Light yellowish brown	Moderately compact slightly sticky clay with no test.
240.5	248	7	2.5 Y 7/2 Light grey	Moderately compact silty clay with few test.
247.5	261	13.5	2.5 Y 5/4 Light olive brown	Moderately compact slightly sticky clay with few tests and three bench of greyish brown sediments.
261	272	10.5	2.5 Y 5/4 Light olive brown	Slightly to moderately compact, slightly sticky clay with no test.
271.5	274	2	2.5 Y 6/4 Light yellowish brown	Moderately compact clay with intercalation of light grey clay with few tests.
273.5	278	6.5	2.5 Y 4/4 Olive brown	Slightly compact & sticky clay with no test.

Table 2.2.6 Core details of GC-05

Core No. GC-05				Core length: 2.47m
Location:	Lat: 9.003166: Long: 66.48975			Water depth: 4519m
Core Depth (cm)		Thickness (cm)	Colour	Description
From	To			
0	7	7	2.5Y 5/4 Light olive brown	Slightly compact slightly sticky clay with a few tests.
7	10.5	3.5	2.5 Y 6/4 Light yellowish brown	Slightly compact & sticky clay with intercalations of dark greyish brown clay. A few tests present.
10.5	18.5	8	2.5 Y 5/4 Light Olive brown	Moderately compact slightly sticky clay with intercalations of dark greyish brown clay.
18.5	43.5	25	10YR 5/3 Brown,	Slightly compact clay with dark laminations. No tests.
43.5	63	19.5	10YR 4/3 Dark brown	Slightly to moderately compact clay with thin dark laminations.
63	67	4	10YR 4/2 to 4/3 Dark greyish brown to dark brown	Moderately compact clay with dark admixture bands. No tests.
67	80	13	10YR 5/3 Brown	Moderately compact clay.
80	82.5	2.5	2.5Y 4/2 Dark greyish brown	Lose admixture clay, silt and very fine sand.
82.5	85	2.5	2.5 Y 6/2 Light brownish grey	Moderately compact sticky clay.
85	88	3	2.5 Y 6/4 Light yellowish brown	Soft clay with pockets of hard, compact clay.
88	90	2	5Y 5/2 Olive grey,	Slightly compact sticky clay. No tests.
90	94.5	4.5	5Y 5/2 Olive grey	Slightly compact clay with patch of hard & compact clay.
94.5	124	29.5	5Y 5/1 Grey	Moderately compact sticky clay with patches of dark grey hard & compact clay.
124	132	8	5Y 4/1 Dark grey	Clayey silt with patches compact & hard clay & very fine sand and silt.
132	143	10.5	2.5 Y 5/4 Light olive brown	Loose to slightly compact clay with intercalations & grey clay.
142.5	158	15	2.5Y 5/4 Light olive brown	Slightly compact clay. Dark grey brown clay ball at bottom.
157.5	162	4	2.5Y 5/2 Greyish brown	Clay with dark greyish brown silt patches with miraculous minerals.
161.5	189	27	2.5Y 5/4 Light olive brown	Moderately compact sticky clay with interlaminations of light grey clay.
188.5	208	19.5	2.5Y 6/4 Light yellowish brown	Moderately compact, sticky clay with intercalations.
208	215	6.5	2.5Y 6/4 Light yellowish brown	Moderately compact sticky clay with patch of hard silt.
214.5	236	21.5	2.5Y 5/4 Light olive brown	Moderately compact slightly sticky clay with irregular laminations of grey clay. No tests.
236	247	11	2.5 Y 5/4 Light olive brown,	Slightly compact clay with irregular laminations of grey clay. Very fine sand at bottom.

Chapter-3

LITERATURE REVIEW

3.1. Work on Marine Ostracods: World Scenario.

There are many studies and publications on recent ostracods, their morphology, taxonomy and ecology from localities of the world. A brief account of the same is presented under the following headings.

1. Recent ostracoda from the marginal environs of Atlantic Ocean including Mediterranean and Baltic sea.
2. Recent ostracoda from Indian ocean and Pacific regions.
3. Recent ostracoda from Arabian sea region

3.1.1. Recent ostracoda from the marginal environs of Atlantic Ocean

The studies on ostarcoda by Remane (1933) and Elofson (1941) are considered as the most significant one during the 20th century. They have reported systematic and ecology of ostracods, inhabiting the shallow marine waters of North Sea and Baltic Sea.

Thus Elofson's work on ostracods is presently regarded as one of the significant ecological works. It is to his credit that the systematic ecological studies on recent ostracods took a serious dimension with his pioneering work. Swain (1955) dealt in detail the ostracoda distribution in San Antonio Bay; Wagner (1957) highlighted importance of ostracoda as environmental indicators in recent and sub-recent estuarine marine deposits of Netherlands

Puri (1960) studied the recent ostarcoda and recorded 70 species including many new taxa from west coast of Florida, Further, his work (1966) on the ecology of recent marine ostracoda forms one of the best monographic works and is widely used by the ostracodologists even today. Kornicker (1961,1969) presented the taxonomy and ecology of *Bairdia* sp .and *Cytherelloidea* sp. from Bimilli Islands of Bahaman region and reported a few new species in these genera.

Puri et al., (1964) while dealing with the ecology of ostracoda from the Gulf of Napes demonstrated that among the various environmental parameters, depth, substrate and salinity appears to influence the distribution of ostracods. According to them, no single factor seems to be the controlling factor in the distributions of the ostracods. Kornicker (1964) made a seasonal study of the recent ostracoda from Redfish Bay, Texas. Engel and Swain (1967) discussed the environmental relationship of ostracods from the Mesquite, Arkansas and Capano Bays. Krutak (1975) found that the living populations of ostracoda decrease from the estuarine areas to the gulf in coastal Mississippi area.

3.1.2. Recent Ostracoda from the Indian Ocean and Pacific regions.

Kingma (1984) is credited for his work on Cenozoic ostracoda from Malay region and he recorded 47 new species and 6 new genera. Sohn (1958) discussed the chemical constituents of ostracoda and their application to the palaeontology and palaeoecology.

Bensen’s (1959) paper on ostracoda from the Todos Santos Bay region, Baja, California, is one of the significant contributions on ostarcoda ecology. Hartman (1964) contributed an excellent taxonomic and ecological account on recent ostracods from the Red Sea. Besides, his work on ostracods from tropical and subtropical waters of Australia is indispensable. Keij (1964) reported thirteen species of *Cytherelloidea* from the North Western Borneo of which eight are new.

Benson is regarded as one of the pioneering workers in the ostracoda field. In his paper (1986) on r ecent podocopid ostracods, the last hundred years of study on this group has been discussed. His other papers (1972, 1982, and 1983) explain the measurements of morphology, their changes, evolution and biochemical stability of deep water ostracods. Hazel and Valentine (1969) recorded three new species of Cytheracean family from North and Northeast of America.

Maddocks (1966) presented the distribution pattern of Podocopid ostracods recorded from Nosy Be' area of Madgaskar. He also (1969b) revised large number of species referred earlier to Bairdiidae and proposed two new genera Neonesidea and Paranesidea together with Bairdoppilata and Triebelina to accommodate many taxa which represent Bairdian family. Mckenzie (1967a) studied recent ostracods from Philip Bay, Victoria followed by Mckenzie and Swain (1967) who studied on the recent ostracoda from Scammon Lagoon, Baja California. Later Mckenzie (1988) described a genus Jankeijcythere.

Omatosa (1970a,b) studied Podocopid ostracods from lagoons of Nigeria who also discussed the structure and morphological variation of normal system in recent Cytherid and suggested that different types of normal pore canals indicate their immediate environment. Swain and Gilby (1974) described and illustrated 80 species of ostracoda including 4 new genera and 16 new species of ostracoda from near shore localities in the Pacific coast of North and central America. Bonaduce et al., (1977,1980) described and illustrated many species of ostracoda including a new genus from the gulf of Aquaba, Red Sea. Hartmann have contributed many papers on the recent ostracoda and it is worth mentioning here the one on zoogeography of littoral ostracoda from S. Africa, Angola and Mozambique, wherein they have discussed briefly the faunal affinity and their ecological studies.

Similarly, several Japanese workers, such as Hanai (1957), Hiruta (1975), Okubo (1975, 1977), Ishizaki & Kato (1976) and Yajima (1978) have described ostracods from the seas of Japan. Okada (1983) considered that muscle scar and its structure of muscle attachment is an important factor as noticed in *Bicornucythere bisanensis.* Akira Tsukagoshi (1990) explained the ontogenic changes and distributional patterns of pore systems in *Cythere* sp and its phylogenetic significance. Akira Tsukagoshi et al.,(1996) discussed the ostracod hingement and its significance for taxonomy. Yashura and Toshiaki (2001) studied the relationships between environmental factors and recent ostracod species distribution from the Northeastern part of Osaka Bay, Southwestern Japan.

Whatley and Quanhong (1987a, 1988) have done comprehensive work in the Indo-West Pacific region and recorded 129 taxa from the Malacca straits, of which 22 species and 2 genera are mentioned as new. Besides, they (1987) have revised some of the earlier works of Brady (1869) and Kingma (1984). Zhao and Whatley (1988) studied 14 species of *Neomonoceratina* from the west Pacific region. In a monographic work 'Bairdian dynasty', Malz (1988) discussed in detail the historical development of Bairdian group since Carboniferous period. Kaesler and Foster (1988) gave the shape analysis of *Bradleya normani* using graphical method that how the change in ostracoda growth takes place.

Titterton and Whatley (1988a, b) described 21 taxa belonging to Bairdiidae from the Solomon Islands of which 13 were new. They have also discussed the origin, migration, history and distribution of the indo-Pacific shallow water ostracoda fauna ever since the closure of the Tethys. Zhao and Whatley (1989) reported 101 taxa of Podocopid ostracoda in the Sedii River and Jason Bay, southeastern Malay Peninsula. Howe and Mckenzie (1989) recorded 130 species from Darwin and Northwestern Australia.

Whatley and Keeler (1989), Whatley and Watson (1988) and Whatley and Ayress (1988) have reported recent ostracoda from Reunion Islands, recent reef of Java sea and Southwest Indian and North Atlantic Oceans respectively. White (1993) studied the taxonomy and origin of modern West African shallow marine ostracoda. Yassini and Jones (1995) reported 241 ostracoda from the estuaries and continental shelf of New South Wales, South Eastern Australia.

3.1.3. Recent ostracoda from the Arabian Sea.

Bate (1970) recognized an ostracod assemblage from Abudhabi Lagoon, Persian Gulf. Paik (1977) reported 52 species from the Gulf of Persia and Oman. As Abdul Razzak et al., (1983) presented the distribution and ecology of ostracods from Sulaibi Kahat Bay, a shallow, warm, tide dominated embayment off Southwest Kuwait Bay.

3.2. Previous Research Work on Marine ostracoda from the Indian Sub-Continent.

Previous work pertaining to the study of recent ostracoda from the Indian sub continent may be dealt under two headings.

1. Recent ostracoda from the East Coast of India.
2. Recent ostracoda from the West Coast of India.

3.2.1. Recent ostracoda from the East Coast of India:

The earliest noteworthy contribution to our knowledge of ostracoda study from the Indian subcontinent is that of Brady (1886), who studied dredged samples from calpentyn, Gulf of Mannar and reported 35 species. Scott (1903) reported 76 species from the Gulf of Mannar. However, the taxa reported by these authors need a revision, though a few of them were revised. Rathnam and Rao (1965) recorded three genera from the Chilka Lake of Orissa.

Maddocks (1969 a, b) gave a detailed report on the ostracoda from the Bengal coast, Andaman Island and Gulf of Mannar, during the Indian Ocean expedition. She recorded a new species called *Propontocypris (Schedopontocypris) bengalensis* and observed that it occurs very widely along the coasts of Bay of Bengal and Arabian Sea.

Gramman (1975) made a casual reference to some Indian ostracod taxa. Jain (1976) gave an account of six species from the Chilka lake, Orissa which included four new species and also it is observed that *Phlyctenophora bhatiai* has close resemblance to *P.orientalis*. Misra and Shrivastava (1979) recorded 25 species of ostarcods from the bottom sediments collected from six stations off the east of Tuticorin, Gulf of Mannar. Of these *Ornatoleberis morkhoveni Keij*,which was earlier reported as *Cythere bimmailata* by Brady (1886),appears endemic to east coast of India and Malayan region.

Taxonomic and ecological studies of brackish water ostracods were first initiated by Annapurna and Rama Sharma (1979 and 1981) and Annapurna (1981) from the Bimili Baracheruvu tidal stream. Annapurna and Rama Sharma (1982) reviewed the distribution of ostracods in relation to sedimentological characteristics such as sand –silt-clay percentage, organic matter content and bottom water parameters like temperature, dissolved oxygen and salinity in the Balacheruvu tidal stream and Bimili back waters. From these areas, Annapurna and Rama Sharma (1986) described 3 new species. Subsequently, Verma et al., (1993) revised the above species and opined that these species are considered to *Hemicytheridea andraensis* and *Tanella gracilis* respectively. Annapurna and Rama Sarma (1987) further identified 40 species of ostracods belonging to 27 genera from those marginal marine environments.

Sreenivas et al., (1991) reported 13 taxa from the Pulicat lake estuary. Subsequently, Bhatia (1985) pointed out many inconsistencies and commented on taxonomic interpretations made in their paper. Later, Hussain (1998) gave a detailed systematic description of 52 ostracod species belonging to 41 genera from the Gulf of Mannar off Tuticorin. He (after making a study of several different environmental parameters and ostracod population size) has analyzed the distribution of the fauna in relation to various ecological factors. Hussain while reporting *Quasibradleya plicocarinata* from off Tuticorin observed that its geographic distribution extends from the west coast of Australia to the east coast of India.

Varma et al., (1993) recorded 25 ostracods from the Tekkali Creek on the east coast of India. Shyam Sundar et al., (1995) identified and described 33 species from the Gonguleru creek. Sridhar (1996) gave a detailed systematic of 48 ostracods from the inner shelf in Park Bay, off Rameshwaram . Hussain et al., (1996) discussed the species diversity of recent benthic ostracods of the Gulf of Mannar and found that the higher diversity value (benthic life conditions) is during south west monsoon months. They also recorded 7 species for the first time from Indian waters. Husain and Rajeshwar Rao (1996) gave a detailed review of the recent ostracod fauna recorded from the marginal and marine water bodies along the east and west coast of India and commented on the faunal affinities and zoogeographic distribution of ostracod fauna of both these coasts. Hussain et al., (1996) explained the distributions of ostracoda in waters off Tuticorin. Kumar and. Hussain (1997) reported on recent ostracods from Pitchavaram mangroves, Tamil Nadu. Hussain (1998) explained 43 species of recent benthonic ostracoda from the Gulf off Mannar, Tuticorin. Hussain et al., (1998) reported recent Cytherellides, Bairdids and Cytherids from the Gulf of Mannar, off Tuticorin. Hussain and Mohan (2000) recorded 26 species of recent ostracod fauna from the brackish waters of Adayar river estuary. Shyam Sundar et al., (2000) reported about the salinity control on the distribution of recent ostracoda from the Goguleru Creek east coast of India. Varma et al., (2000) described the biotope analysis of ostracoda and characterization of environment in the Bavanapadu fishing harbor, Tekkali Creek, Andhra Pradesh. Mohan et al., (2002) gave an account of recent ostracoda from the Bay of Bengal, off Karikkattukuppam, near Chennai, Tamilnadu. Hussain and Mohan (2000) gave distribution of recent benthic ostracoda in Adayar river estuary, east coast of India.

3.2.2. Recent ostracods from the West Coast of India

Maddocks (1969a,b) during the Indian ocean expedition, dealt with a few ostracod taxa from the recent sediments of Cochin and Mangalore coasts. James (1973a) recorded the occurrence of four species of pelagic ostracods from off Kerala coast, Arabian Sea. Honnappa and Pathi (1975) presented the morphology, taxonomy and statistical interpretation of *Actinocythereis tumefacentis (*Lubimova and Guha), recorded from the Mangalore harbor area. This species appears conspecific with *Henryhowella (Neohenryhowella) hartmanni.* Jain (1978) gave a comprehensive account of 56 species from the beach sands of Mandvi, which included one new genus *Vijaiella,* one subgenus and sixteen new species. Bhatia (1984) noted that *Carinocythereis (Tandonella) Indica and Vijaiella mandviensis* described by Jain (1978) shows close resemblance to and affinities with *Hiltermannicythere bassiouni* and *Australimoosella leibaui,* respectively described by Hartmann (1978) from west coast of Australia. Jain (1981) documented 34 ostracod taxa from the beach sands of Cochin, Quilon and Trivandrum, south Kerala coast which included four new species: *Pajenborchellina indoarabica, Kaijella whatleyi, Ruggieria indoiranica and Moosalle cochinesis.* Bhatia (1984) opined that the lineages of *Alocopocythere reticulata indoaustralica, Actinocythereis scutigera, Henryhowella (Neohenryhowella) hartmanni, callistocythere flavidofusca intricatoides* and *Cyprideis mandviensis* can be traced to many Palaeogene and Neogene Tethyan taxa which evolved and diversified in the Tethyan corridor and subsequently migrated east and southeastwards during Quaternary period. Bhatia and Kumar (1979) recorded 13 species of ostracods in the vicinity of Karwar, Anjidiv island (These include one new genus *Jainella* and one subgenus *Neohenryhowella).* They have also established a new genus *Lankacythere* on the basis of Homeotype *Cythere coralloides* Brady. Whatley and Quanhong (1988) shifted *Jainella karwarensis* (Bhatia and Kumar, 1979) to *Keijella karwarensis*.

Guha (1980) recorded 18 species from Bombay and Ratnagiri coasts. Khosla et al., (1982) recorded 58 species from the Miani lagoon, Saurastra, most of which are left under open nomenclature. Honnappa and Abrar (1983) reported *Biardoppilata carinata, Neonisidea cracenticlavula, N.schulzi* and *Paranesidea fracticorallicola* form the coastal sediments of Bhatkal area. Honnappa et al., (1984) described a new genus *Neomangaloria* from Mangalore-Karwar Coatsal sediments. Later on it has been considered to be a junior synonym of *Phlyctenophora.* Khosla et al.,(1982) established a new species *Miocypredeis* while dealing Tertiary and Recent species of *Miocypredeis* from India.

Khosla and Nagori (1989) reported several species of ostracods from Quilon beds of Kerala. Vaidya and Mannikeri (1994) recorded 80 species of recent ostracoda around Karwar, west Coast of India. They recorded 12 species for the first time from Indian waters. Vaidya et al., (1995) reported some relationship between the bottom sediments and recent ostracoda from the Karwar beaches. Rajesh Raghunathan et al., (1999) reported about the distribution of ostracods in the inner shelf sediments off Kasaragod, south west coast of India. Mannikeri (2000) explained the role of ostracods in micropalaeontological research. Vaidya and Mannikeri (2000) reported about the recent ostracods from beach sands along Goa coast, India. They attempted to review in brief the ecology and distribution of recent ostracods from West coast of India. Gopalakrishna et al., (2007) reported the distribution of ostracods in the coastal and inner shelf sediments off Kannur.

Chapter 4

SEDIMENT ANALYSIS

All the core samples were studied in detail for various parameters like granulometric study, geochemistry, clay mineral analysis, Total organic carbon etc, besides the detailed ostracoda study. This was done to understand the controlling factors for ostracod distribution and diversity.

In GC-01, major sediment type is silt with almost equal amount of clay with varying amounts of sand also. Chemical analysis of the core samples clearly indicates the dominance of CaO. Coarse fraction studies indicate a biogenous material constituting 90% of the total material. All the planktonic forams listed earlier are well represented throughout the core with less abundance of benthic forms. Ostracods constitute less than 1 % of the total biogenous material and is confined to few valves of *Propontocypris*, *Phlyctenophora*, *Bytheoceratina*, *Krithe*, *Neocytheromorpha* etc. Analysis of ostracodes down the core clearly indicate that throughout the core, though the number is very less, distribution of ostracods are controlled by depth and there is some substratum relationship also.

Similar trend is observed in all the other core samples also except the occurrence of shallow water forms like Keijella, Xestoleberis, Hemicytheridae etc in GC-03, GC-04 & GC-05 indicating a possible mix up of shallow water sediments, probably by the Indus supply. This view is corroborated by the distinct geomorphic features of the sample locations.

4.1. Grain size Analysis

Grain size analysis of GC-01 indicate that sand varies between 4.24 and 45.04 %, silt between 0.47 and 82.53% and clay between 4.14 and 64.91%. The major sediment type is silt (Table 4.1.1). In GC-02, sand is between 5.24 and 45.41 %, silt between 0.64 and

78.99% and clay between 5.42 and 64.91%. This core is also silt dominant (Table 4.1.2). In GC-03, sand is as low as 6%, whereas silt is as high as 98% and clay ranges upto 76% at places. The core is a mixture of silt and clay (Table 4.1.3). In GC-04, sand is less than 55, silt upto 98% and clay below 30% except at two places where it goes up to 55%. Here also the dominant sediment is silt (Table 4.1.4). In GC-05, sand is as low as 2%, silt is 30-40% and clay is 40-70%. The dominant sediment here is clay (Table 4.1.5).

4.1.2. Sediment down core variation

4.1.2.1. GC-01

This core is retrieved from a water depth of 3468m and is having a core length of 2.07m. Down core variation studies of Core GC-01 indicate that sand content varies between 4.24 and 45.04%. The lowest sand percentage is recorded at the top of the core and the maximum is recorded at a depth of 42.5cm. Sand content is gradually increasing from the top of the core and peaking at 42.5 cm and further below it is falling down to less than 20%.

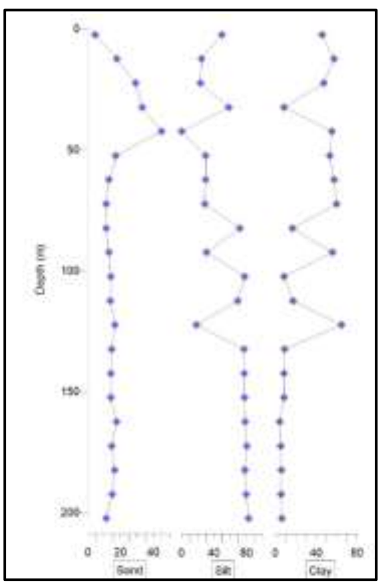


Fig 4.1.1 Sediment Downcore Variation GC-01

Similarly, silt content is varying between 0.47 and 82.53%. The minimum recorded is at 42.5 cm and the maximum is recorded at 202.5 cm. Silt content is more than 65 % below the core length of 92. 5 cm except at 122.5 cm where silt content comes down to 18.60.

Top 32.5 cm of the core has a clay content ranging between 45 and 55 % and at 32.5 cm clay content comes down to 8.56%. Down below up to 72.5 cm, clay content is between 50 and 60%. At 82.5 cm, clay is 16.78%, increases to 56.125, further reduces to 8.36 %, further increasing to 64.91%. Below 122.50 cm, clay content is well below 9% till the bottom of the core (Fig 4.1.1). Available data clearly show that sediment type in the core sample is changing between clay and silt with a major portion of the core dominated by silty material.

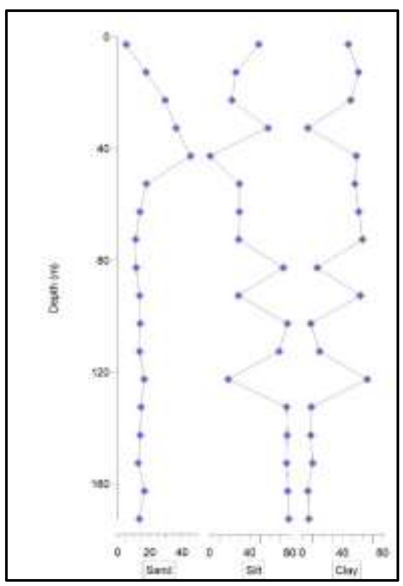


Fig 4.1.2 Sediment Downcore Variation GC-02

4.1.2.2. GC-02

This core is collected from a water depth of 4200m and is having a core length of1.73m. Down core variation studies of this core reveals that sand percentage is varying between 5.24 and 45.41 %. The minimum percentage is recorded at the top of the corer and the maximum is recorded at 42.5 cm depth. After reaching the maximum sand percentage at 42.5 cm, sand content is showing a declining trend with an average value of 15%. Silt content in the core is in a wide range with as low as 0.64% at 42.5 cm and a maximum of 78.99% recorded at the bottom of the core. Silt content remains at a range of 70-80% below 82.5 cm till the bottom of the core except at 92.5 cm where silt content is 28.6% and at 122.5 cm where is 18.6%.

Clay content is ranging between 5.42 and 64.91% with the minimum recorded at a depth of 162.5 cm and the maximum at 122.5 cm. Up to a core depth of 92.5 cm, clay content is around 50% and below this depth, clay content is drastically reduced and remains around 10%. The maximum clay content recorded is a sudden spiking of clay content otherwise in a zone of low clay content (Fig 4.1.2).

Sediment analysis of the core indicate that the dominant sediment type of the core is silt and silty clay with sand patches between 22.5 and 42.5 cm core depth.

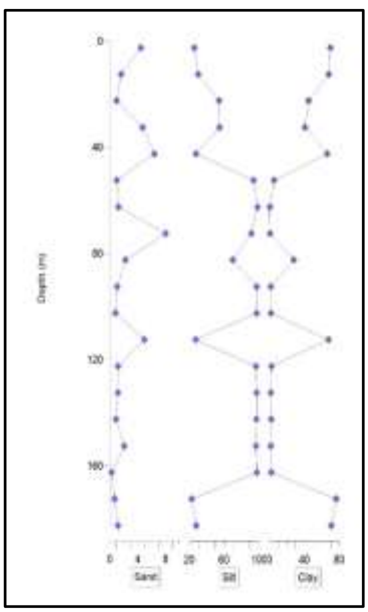


Fig 4.1.3 Sediment Downcore Variation GC-03

4.1.2.3. GC-03

This core is retrieved from a water depth of 4668m having a core length of 1,84m. Sand content is generally less than 2% with occasional increase upto 8 % at depths like 77.5 cm. The core is dominantly silty with admixture of clay at places. Silt is ranging between 22.75 and 98.52% with maximum at 62.5 cm and minimum at 172.5 cm. Clay also shows variations down the core with a maximum of 76% at 172.5 cm and as low as 0.27 at 62.5 cm (Fig 4.1.3).

4.1.2.4. GC-04

This core is retrieved from a water depth of 4699 m having a core length of 2.78m. Sand content is very low in the core with a maximum of 4.97% at a depth of 242.5 cm. Rest of the places, sand content is very low. Silt is the dominant sediment type of the core with as high as 97.63% at the bottom of the core though at 212.5 cm silt is nil. There are pockets where silt percentage ranges around 40% also. Clay also shows wide variations down the core with a maximum of 99.31% clay at 212.5 cm. Other than this high value, clay maintains a low value of less than 10 % with occasional increase in the clay content to the tune of a maximum of 50% (Fig 4.1.4).

4.1.2.5. GC-05

This core is retrieved from a water depth of 4518m having a core length of 2.47m. Sand content is very low with a maximum of 2.46% at the bottom of the core. Silt and clay shows sizeable percentage throughout the core with silt percentage ranging between 23.19 and 74. 64%. The maximum recorded silt percentage is at a core depth of 152.5 cm. Silt is content in the core on an average is almost 30-40 %. Clay is present in the core in a 50-70 % range throughout except at depth like 152.5 cm where it is as low as 24.23% (Fig 4.1.5). The sediment type of the core is mainly clay with admixture of silt at places with varying amounts.

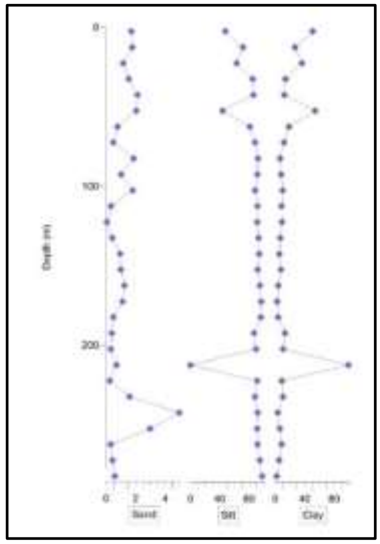


Fig 4.1.4 Sediment Downcore Variation GC-04

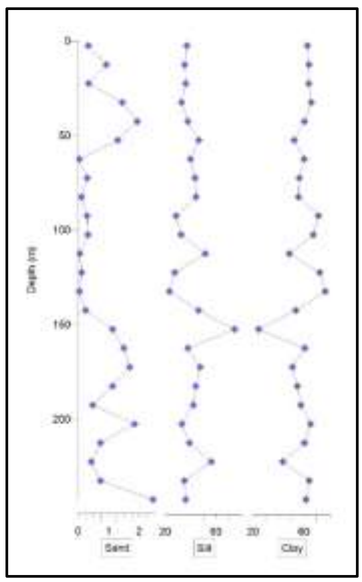


Fig 4.1.5 Sediment Downcore Variation GC-05

4.2. Geochemistry

Chemical analysis of core samples indicates that in GC-01, SiO_2 is up to 14% and CaO is upto 75% (Table 4.2.1). In GC-02, SiO_2 is upto 20% and CaO is upto 85% (Table 4.2.3). However, in GC-03 SiO_2 is 60-70% and CaO less than 20-25% (Table 4.2.5). Similarly, in GC-04, SiO_2 is between 60-70% and CaO is as low as 10% (Table 4.2.7). This trend is followed in GC-05 also where SiO_2 is 50-60% and CaO is 15-25% (Table 4.2.9).

Analysis of major oxides and traces of the core GC-01 shows that major oxide present in the core is Cao followed by SiO_2. All other oxides are less than 10%. Ni and Zn are the major traces of the core followed by other traces like Cr, Co & Cu containing less than 60 ppb (Table 4.2.2). While CaO percentage is ranging between 64 and 80%, SiO_2 is ranging between 9 and 14%. Oxides are uniformly present down the core without showing any variations at varying depths. All Other oxides are in negligible amount and $Al_2 O_3$ at places shows a slight increase up to 10 % (Fig 4.2.1).

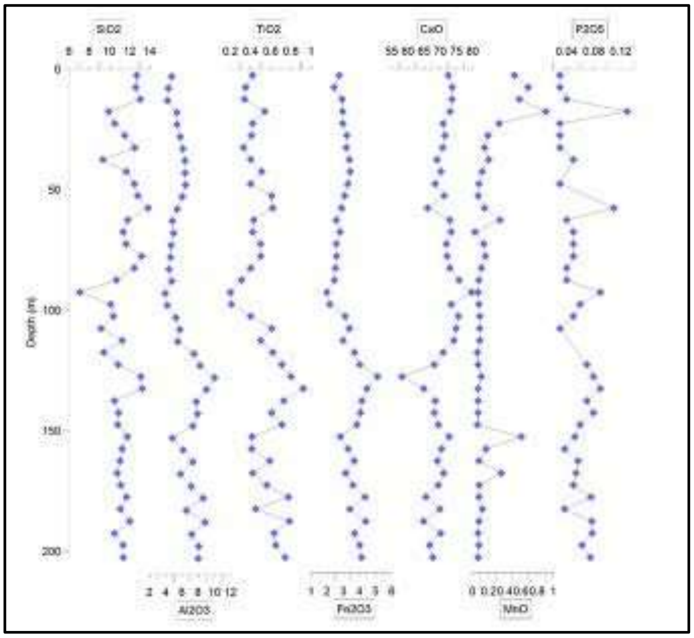


Fig 4.2.1 Down core variation of major oxides GC-01

Geochemical analyses of the samples core GC-02 were carried for major oxides and traces. Results indicate that Cao is the dominant one followed by SiO_2.cao values are ranging between 60 to 86% throughout the core. Highest value of 85.20% is recorded at 12.5 cm core depth and the lowest value is 60.88 recorded at 142.5 cm core depth. SiO_2 is ranging between 7.3% and 19.3 % with the minimum recorded at a core depth of 117.5 cm and the maximum recorded at 62.5 cm. Other oxides like TiO_2, Fe_2O_3, MnO, MgO, Na_2O, K_2O, P_2O_5, are well below 4%. Al_2O_3 at places is reaching up to 7% (Fig 4.2.2). Trace element analyses indicate that Zn and Ni are the dominant traces varying between 61-107 ppm and 22-179 ppm respectively. While Cu is ranging between 19-68 ppm, cobalt ranges between 7-24 and Cr ranges between 17-51 ppm (Table 4.2.4).

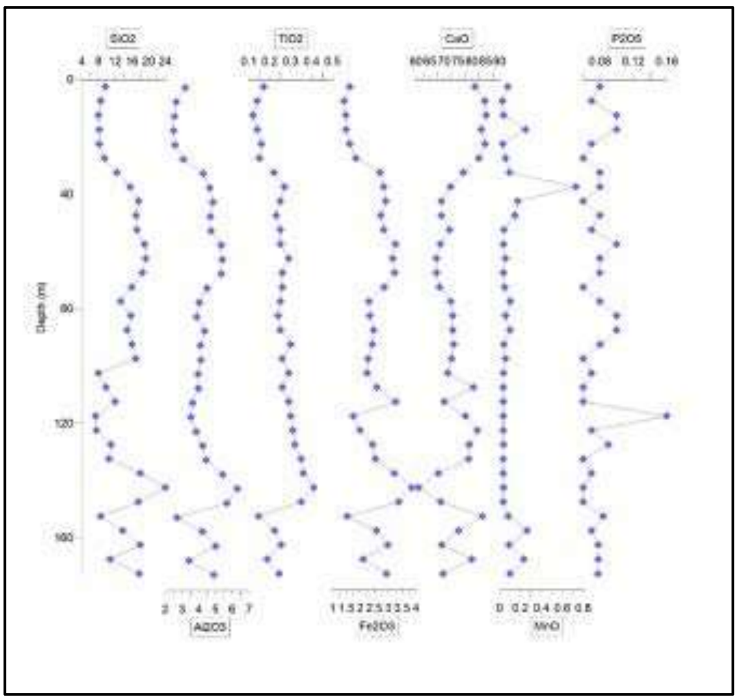


Fig 4.2.2 Down core variation of major oxides GC-02

Geochemical analyses of samples of core GC-03 for major oxides and trace elements indicate that SiO_2 is the dominant oxide ranging between 50-70%. CaO is ranging between 8 to 27% and Al_2O_3 goes up to 14%. While Fe_2O_3 is consistent with a low percentage of 4-6 throughout, other oxides like TiO_2, MnO, Na_2O, K_2O and P_2O_5 are less than 2%. MgO is varying between 1 to 9% in the core (Fig 4.2.3). Among the trace elements, Zn is the dominant one ranging between 82 to 135 ppm up to a core depth of 142.5 cm and below that it is gradually decreasing. Other trace elements are also recorded from the core with Cu ranging between 55-120 ppm, Pb from 20-55 ppm, Ni from 20-50 ppm, Co from 10-50 ppm and Cr from 40-115 ppm (Table 4.2.6).

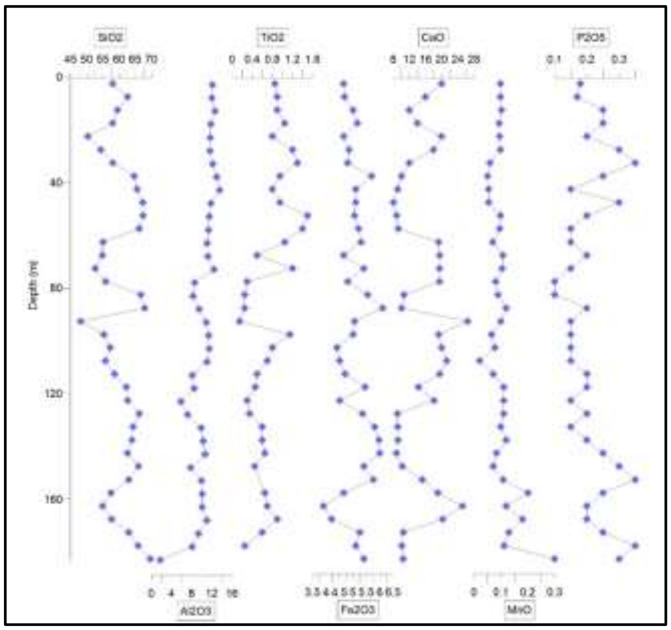


Fig 4.2.3 Down core variation of major oxides GC-03

Geochemical analyses of samples of core GC-04 for major oxides and trace elements indicate that SiO_2 is the dominant oxide ranging between 50-65%. CaO is showing a low percentage ranging between 3 to 18% and Al_2O_3 ranges between 7-16%. While Fe_2O_3 is consistent with a low percentage of 2-8 throughout, other oxides like TiO_2, Na_2O, K_2O and P_2O_5 are less than 2%. MgO is varying between 2 and 6% in the core (Fig 4.2.4). Among the trace elements, Zn, Ni and Cu gives values more than 150 ppm at places. Zn varies between 40 and 170 ppm. The lowest Ni value recorded is 75 ppm and the highest value recorded is 235 ppm. Similarly, Cu value ranges between 25-150 ppm. Cobalt is also recorded from the core with values ranging between 5-50 ppm. Cr at places goes upto 90 ppm at places and is generally recorded lower than 10 ppm throughout. Pb is also recorded in the core with values ranging between 5-45 ppm (Table 4.2.8).

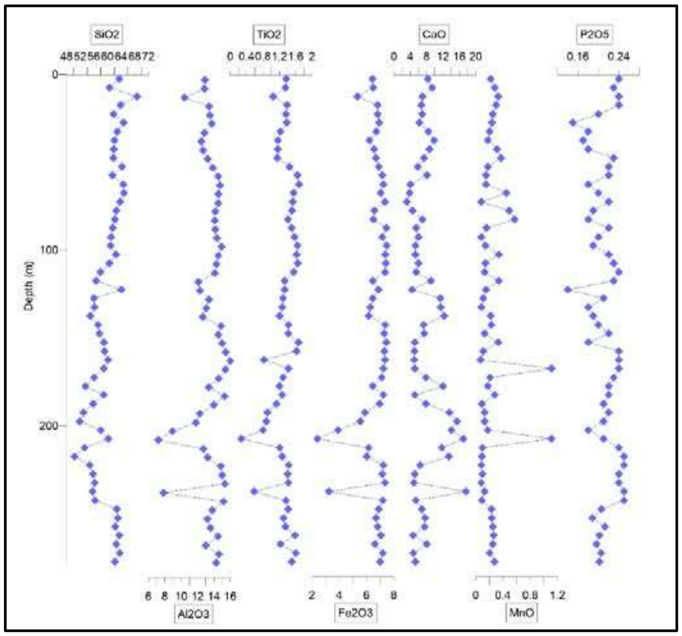


Fig 4.2.4 Down core variation of major oxides GC-04

Geochemical analyses of samples of core GC-05 for major oxides and trace elements indicate that SiO_2 is the dominant oxide ranging between 40-63%. All other oxides are less than 26 % with CaO ranging between 1 to 26% and Al_2O_3 ranging between 10-19%. Upto a depth of 32.5 cm, CaO is ranging between 16-26% and below that it is decreasing drastically and maintains well below 10%. While Fe_2O_3 is consistent with a low percentage of 6-12% throughout, other oxides like Na_2O, K_2O and MgO are less than 3%. In this core, P_2O_5 and TiO_2 is almost nil with less than 1% (Fig 4.2.5). Among the trace elements, Zn, Ni and Cr gives values more than 120 ppm at places. Zn values are relatively high upto 77.5cm of the core depth and is falling down below upto 95.7 cm and has a maximum value of 521 ppm at 112.5 cm and is maintaining a minimum value of 50 ppm throughout the core. Cr ranges between 20-128 ppm, Ni ranges between 20-120 ppm, Cu varies between 20 and 85. Pb is very low with less than 10 ppm(Table 4.2.10).

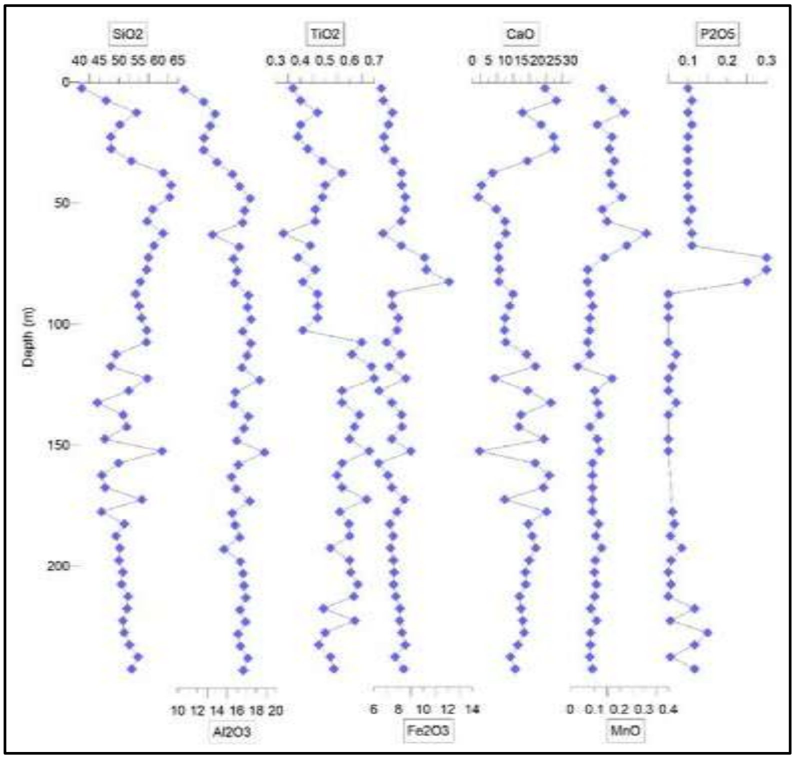


Fig 4.2.5 Down core variation of major oxides GC-05

4.3. Granulometric Studies:

Granulometric studies were carried out on 4 core samples, GC-01, 02, 03 & 05 with a view to understand the down core grain size variation.

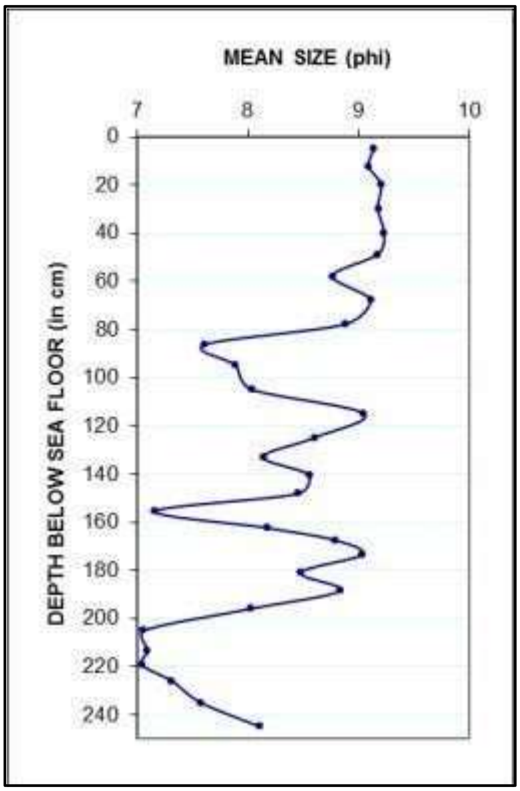
Gravity core sub-samples were subjected to the conventional techniques of gradational analysis outlined by Folk (1974). Size analysis is carried out by dry sieving at

½ phi interval for sand and other large grains and by pipetting for silt and clay. About 15 to 20g of sediment from each sample was first treated with hydrogen peroxide (15 %) and then washed with distilled water to remove organic matter and dissolved salts respectively.

The sediment fraction coarser than 0.0625 mm diameter was separated by wet sieving using ASTM sieve No: 230, dried and then subjected to standard dry sieving techniques through a nest of sieves with mesh sizes ranging from 4mm to 0.0625 mm. The fraction finer than 0.0625 mm was subjected to pipette analysis following the standard procedure (Folk, 1974), and the weight percentage of the different size fractions in the sample is calculated. Nomenclature of the sediment type was established after Shepard (1954), based on the relative proportion of the three major size fractions in the sediment, viz., sand (material having a grain size between 2 mm and 0.0625 mm), silt (material having a grain size between 0.0625 mm and 0.0039 mm), and clay (material finer than 0.0039mm). The sedimentological parameters such as Mean, Standard deviation, Kurtosis and Skewness were determined and the results of the analyses are provided in (Table 4.3.1 to 4.3.5).

Analytical results of GC-01 indicate majority are silt (mean size value ranging from 7.04 to 7.89 phi) and remaining are clay having mean size value ranging from 8.03 to 9.24 phi and the rest are. Standard deviation values indicate very poor sorting (2.03 to 3.35 phi) and poor sorting (1.31 to 1.95 phi) and a lone sample is moderately sorted (0.95 phi). Kurtosis values show mainly very leptokurtic nature (1.50 to 2.47), followed by mesokurtic (0.93 to1.11), leptokurtic (1.12 to 1.47) and platykurtic (0.71 and 0.87) behaviour. Skewness values indicate near symmetrical (-0.06 to 0.08) and fine skewed (0.10 to 0.24) followed by a few with strongly fine skewed (0.32 to 0.42) nature (Fig 4.3.1a, b, c, d).

In GC-02, the result indicates that majority of them (18) are silt (mean size value ranging from 5.34 to 7.65 phi) followed by clay (8.12 to 9.96 phi). Standard deviation values show wide range of sorting from very poor (2.31 to 3.04 phi), very well (0.19 to 0.26 phi), poor (1.60 to 1.86 phi), moderate (0.59 to 0.87 phi) and well sorting (0.40 and 0.50 phi). The kurtosis values indicate leptokurtic (1.16 to 1.47), mesokurtic (0.96 to 1.11), platykurtic (0.75 to 0.88), very leptokurtic (1.51 to 2.27) and extremely leptokurtic (4.19) nature. Skewness values vary between near symmetrical (-0.08 to 0.09), coarse skewed (-0.27 to –0.11), fine skewed (0.18 to 0.28), strongly fine skewed (0.41 to 0.67) and one sub-sample with strongly coarse skewed (-0.42) nature (Fig 4.3.2a, b, c, d).



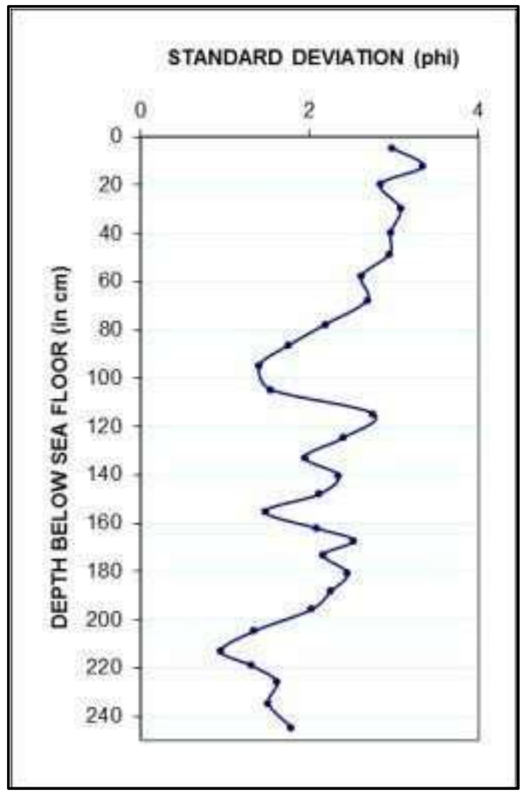


Fig 4.3.1a Variation in GC-01 **Fig 4.3.1b Variation in GC-01**

In gravity core GC-03, results of sub-samples analyzed indicates that majority are silt (7.20 phi) and remaining are clay with mean size value ranging from 8.38 to 9.86 phi. The clay samples are very poorly sorted (standard deviation values ranging from 2.14 to 2.84 phi). Two samples are poorly sorted (1.21 and 1.88 phi). Kurtosis values indicate that majority of the sub-samples are platykurtic (0.72 to 0.90), followed by mesokurtic

(0.92 to 1.02), leptokurtic (1.11 to 1.48) and very leptokurtic nature (1.62 and 2.11). The skewness values show dominance of fine skewed nature (0.11 to 0.29), followed by strongly fine skewed (0.30 to 0.36) and a lone sub-sample with near symmetrical (0.02) behavior (Fig 4.3.3a, b, c, d).

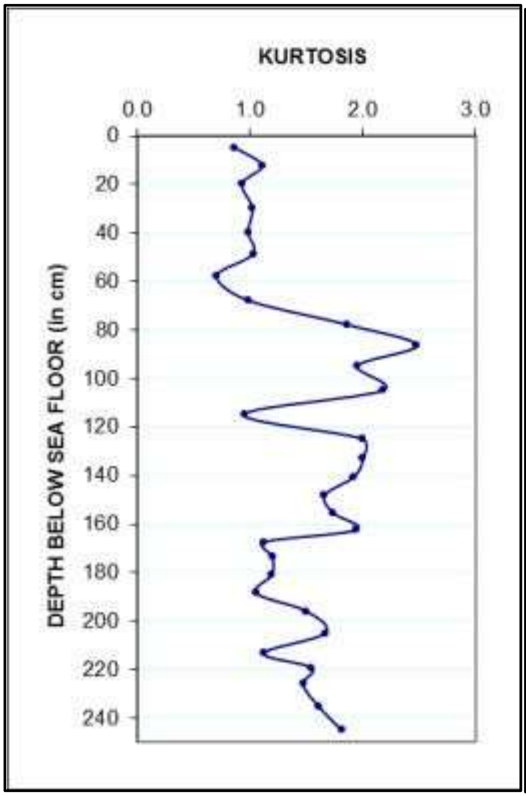


Fig 4.3.1c Variation in GC-01

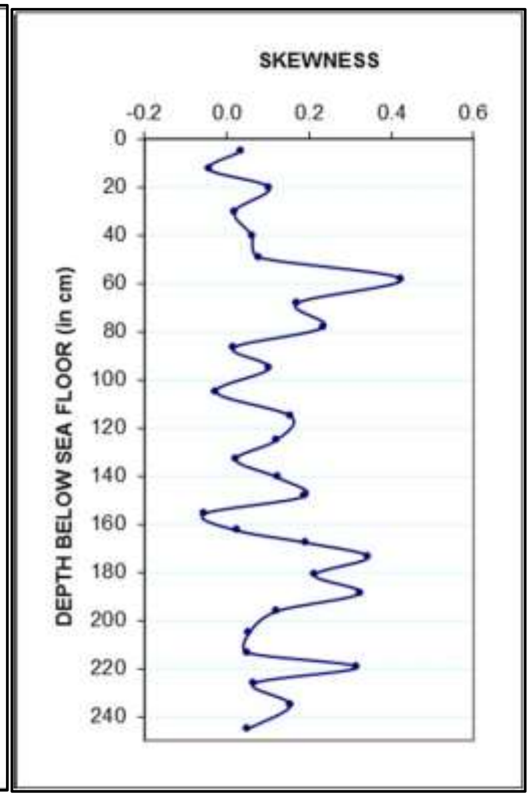


Fig 4.3.1d Variation in GC-01

In gravity core GC-05, 27 sub-samples have been analysed. The result indicates that majority of the sub-samples (26 out of 27) are clay with mean size values ranging from 8.08 to 9.89 phi. One sub-sample (GC-05/ 22) is silt with mean size of 7.08 phi. Standard deviation values indicate that almost all sub-samples except one are very poorly sorted with values ranging from 2.06 to 3.26 phi. Sub-sample GC-05/11 is poorly sorted (1.52 phi). In case of kurtosis, 20 out of 27 belong to platykurtic group with values ranging from 0.69 to 0.90. Two each sub-samples are very platykurtic (0.66 and 0.67), mesokurtic (0.93) and leptokurtic (1.12 to 1.36). One sub-sample (GC-05/ 11) is very leptokurtic (2.55). 19 out of 27 samples are fine skewed with skewness values ranging from 0.11 to 0.28. Four each sub-samples are strongly fine skewed (0.31 to 0.43) and near symmetrical (0.03 to 0.07) (Fig.4.3.4a, b, c, d).

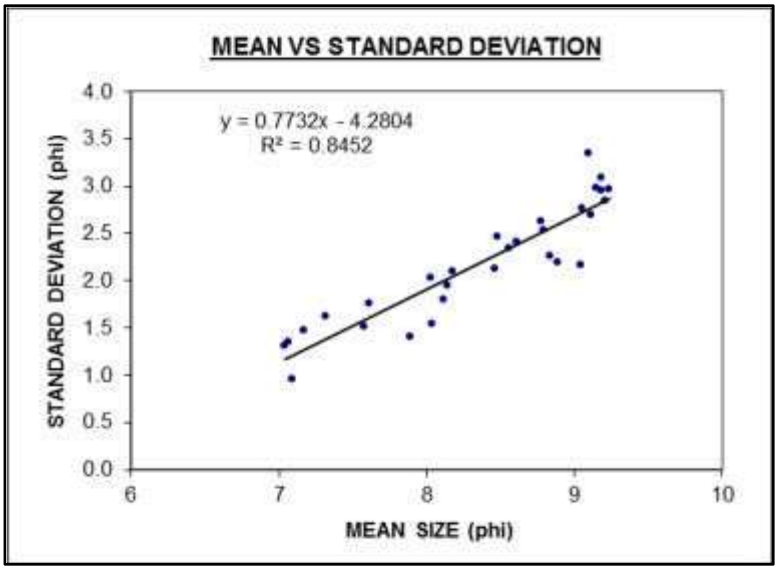


Fig 4.3.5 Bivarient plot of GC-01

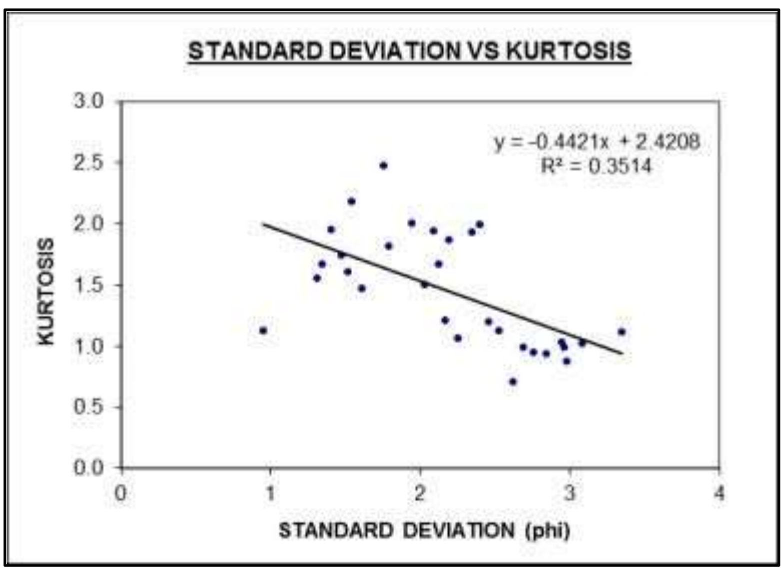


Fig 4.3.6 Bivarient plot of GC-01

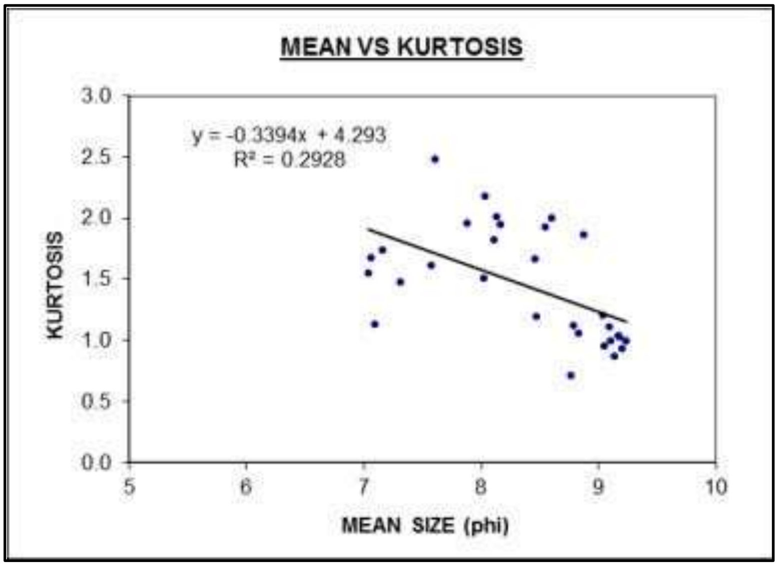


Fig 4.3.7 Bivarient plot in GC-01

Bivariant plots of Mean size (phi), Standard deviation (phi), Kurtosis and Skewness are prepared, taking two variables at a time (Figures 4.3.5 to 4.3.14). Salient features of the plots are discussed core wise below:

In GC-02 the relationship between mean and standard deviation shows strong positive correlation with regression coefficient R^2 value being 0.85. With increase in mean size, standard deviation value also increases, affecting the sorting of the sediment package.

The plot between standard deviation and kurtosis indicates moderate negative relationship with R^2 value of 0.35 and that of mean and kurtosis is also moderate negatively correlated with R^2 value of 0.29.

In GC-03 the relationship between mean and standard deviation is strong positively correlated with R^2 value of 0.91. The plots between standard deviation and skewness indicates moderate positive correlation with R^2 value of 0.27.

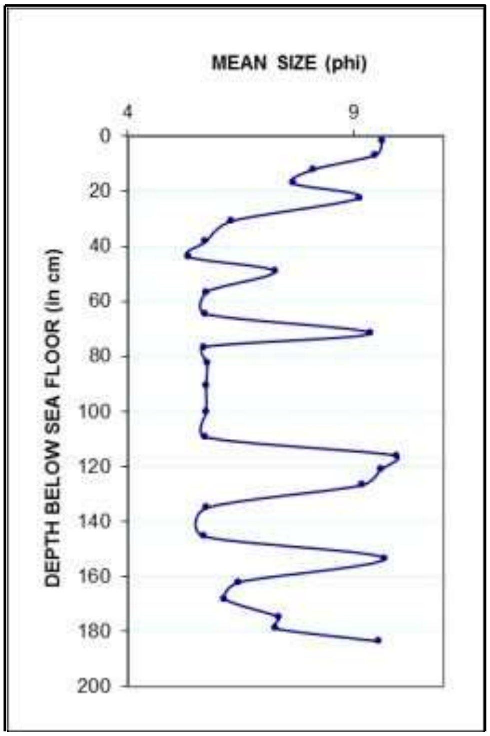


Fig 4.3.2a variation in GC-02

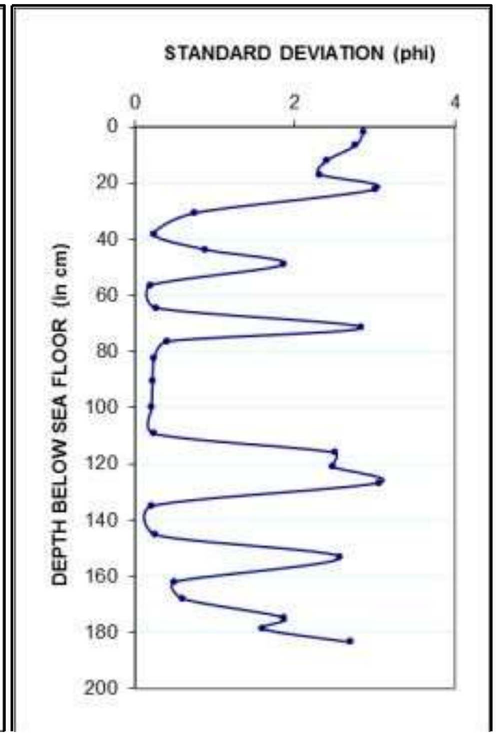


Fig 4.3.2b variation in GC-02

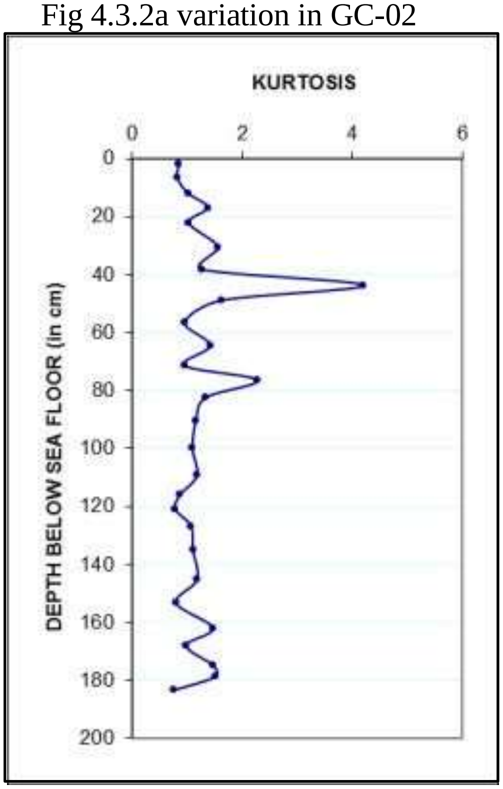


Fig 4.3.2c Variation in GC-02

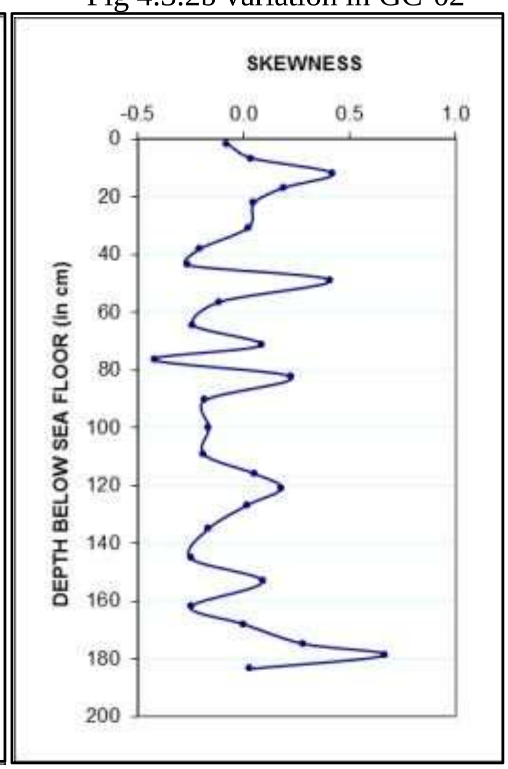


Fig 4.3.2d Variation in GC-02

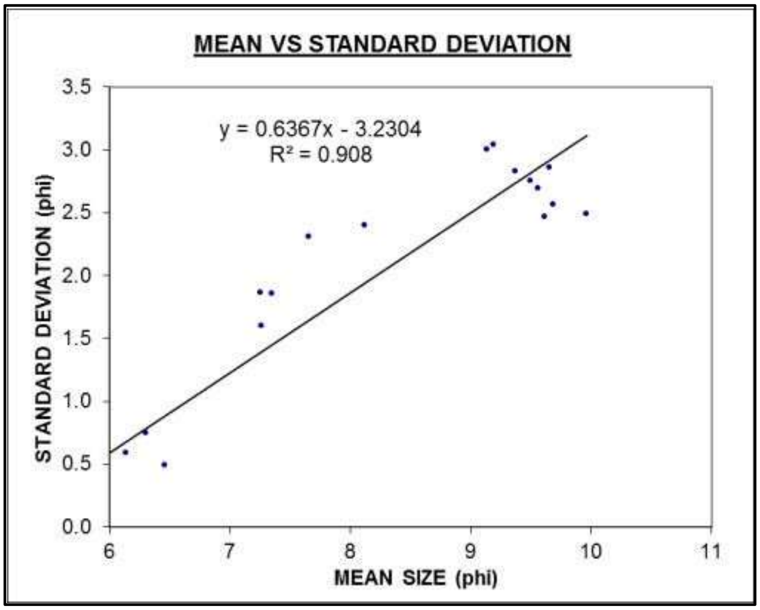


Fig 4.3.8 Bivariant plot of GC-02

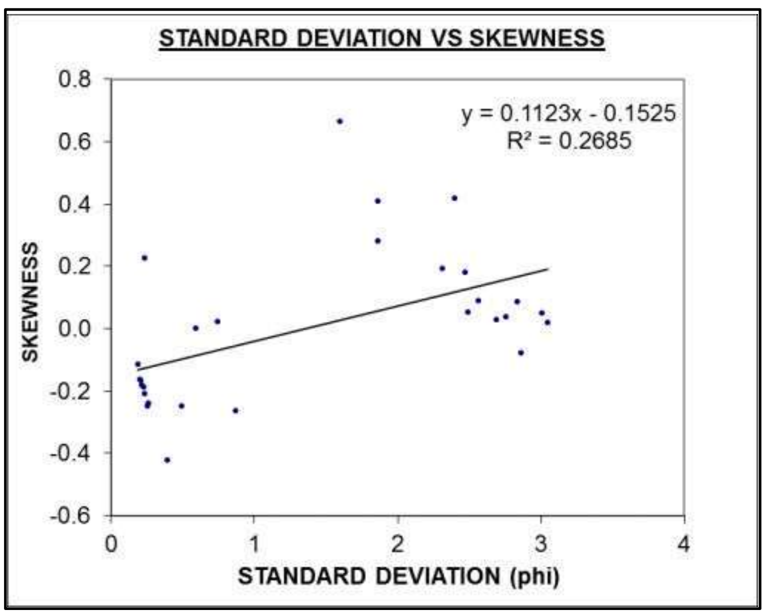


Fig 4.3.9 Bivariant plot of GC-02

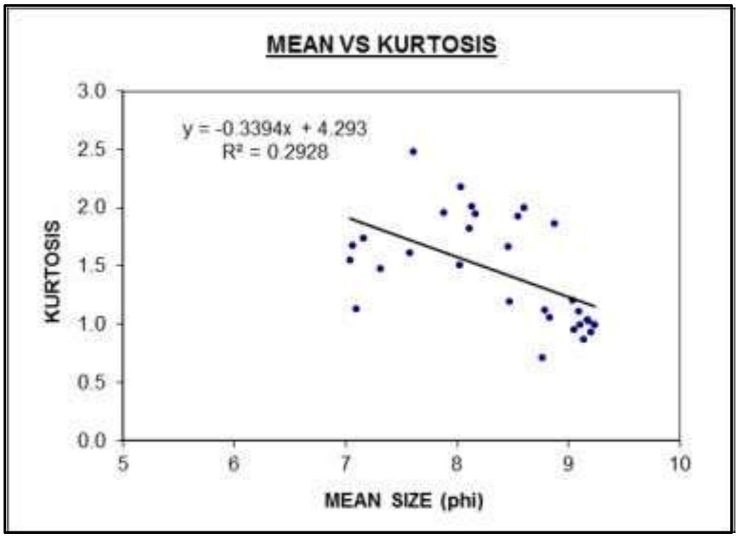
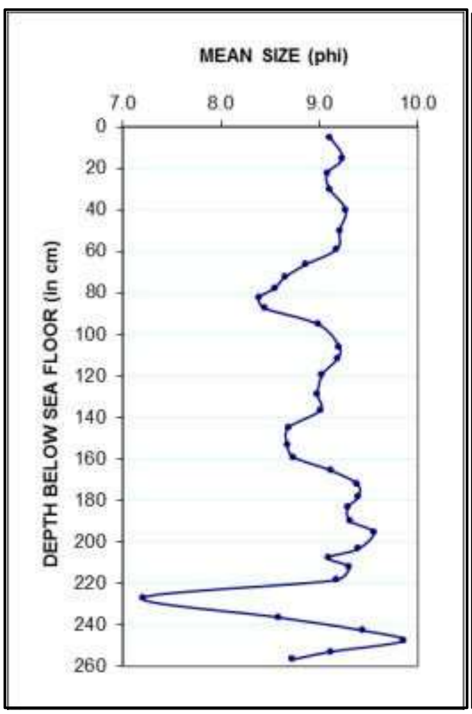


Fig 4.3.10 Bivarient plot of GC-02

In GC-05 the plots between standard deviation and kurtosis; and mean and kurtosis are moderate, negatively correlated with R^2 value of 0.45 and 0.29. The one between mean and standard deviation is moderate, positively correlated with R^2 value of 0.26



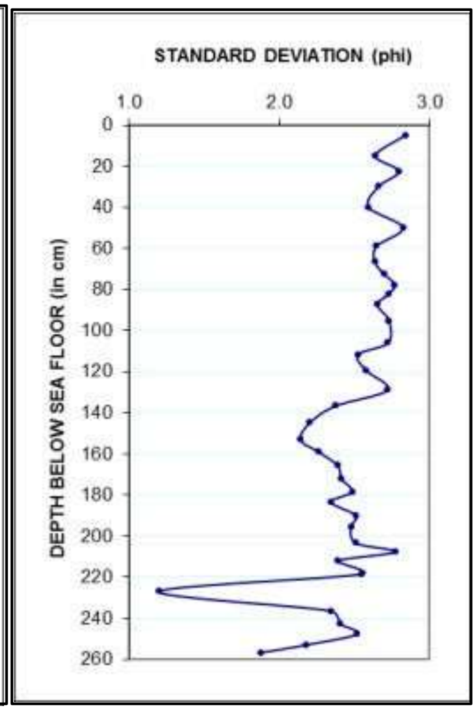


Fig 4.3.3a variation in GC-03 **Fig 4.3.b variation in GC-03**

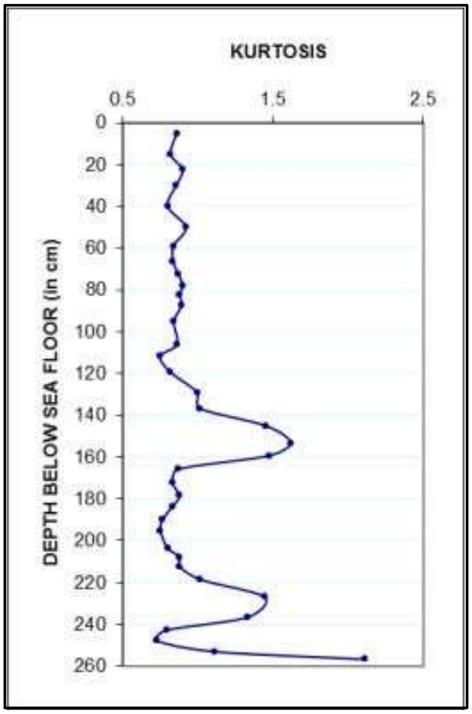


Fig 4.3.3c variation in GC-03

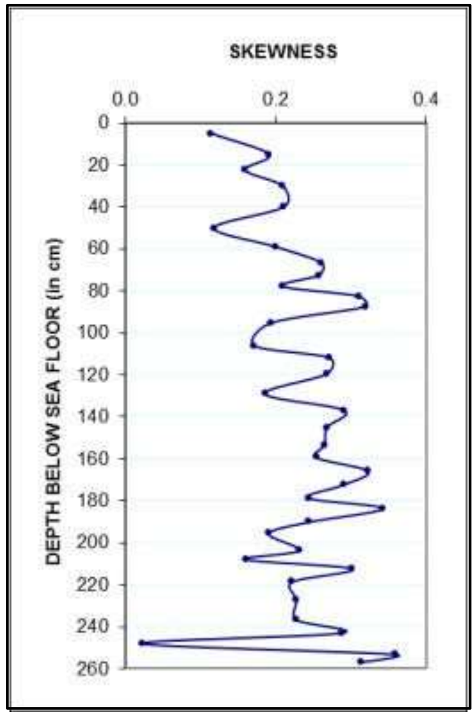


Fig 4.3.3d variation in GC-03

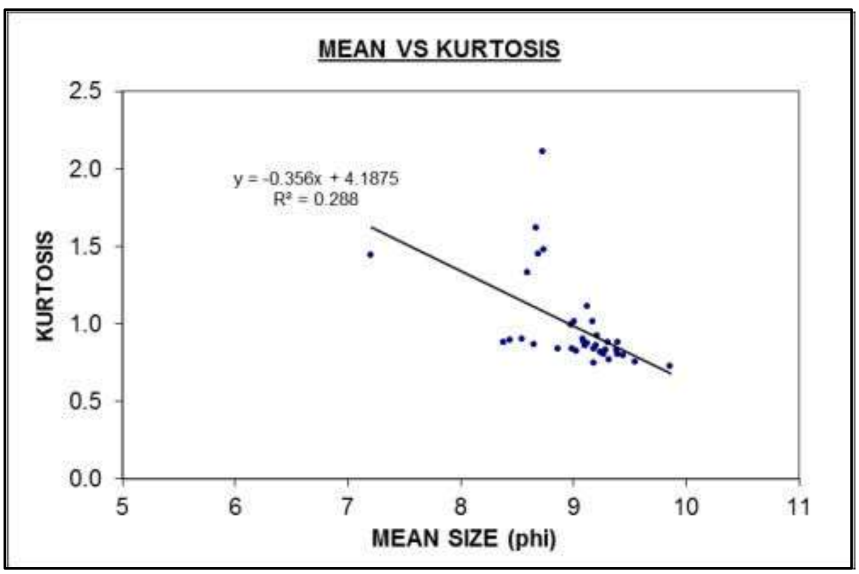


Fig 4.3.11 Bivarient plot of GC-03

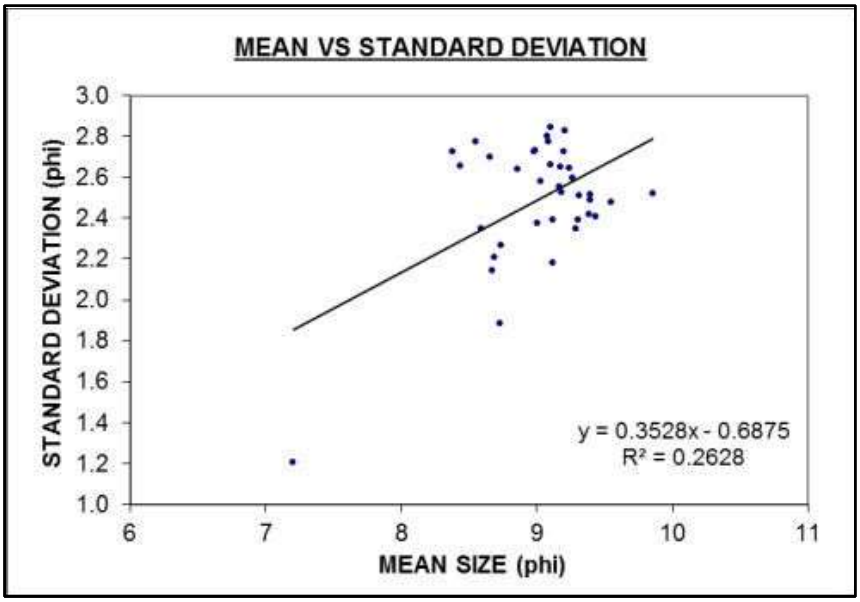


Fig 4.3.12 Bivarient plot of GC-03

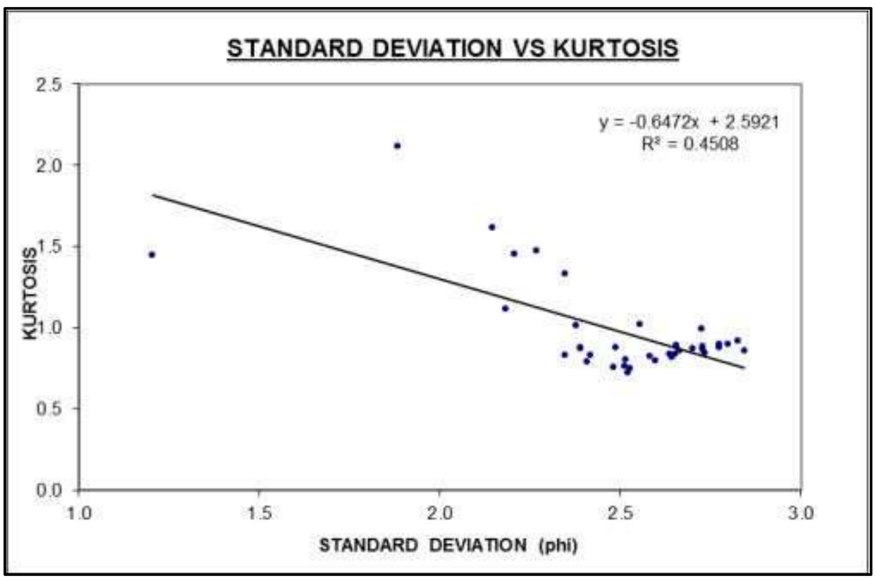


Fig 4.3.13 Bivarient plot of GC-03

While drawing the down core variation of sediment parameters such as mean, standard deviation, kurtosis and skewness with respect to depth below sea floor, the average depth of the sample interval is taken into consideration. The plots are described below core wise:

In GC-03 the variation of mean and standard deviation are uniform in their behavior with depth. Others do not show significant noticeable changes.

In GC-03 the plots of mean and standard deviation show almost similar distribution. Where as in case of kurtosis and skewness distribution curves are not uniform.

In GC-05 the down core plots of mean and standard deviation are uniform from the bottom (256.75 cm) to 95.25 cm (with minor variation) and later on standard deviation curve becomes sinuous.

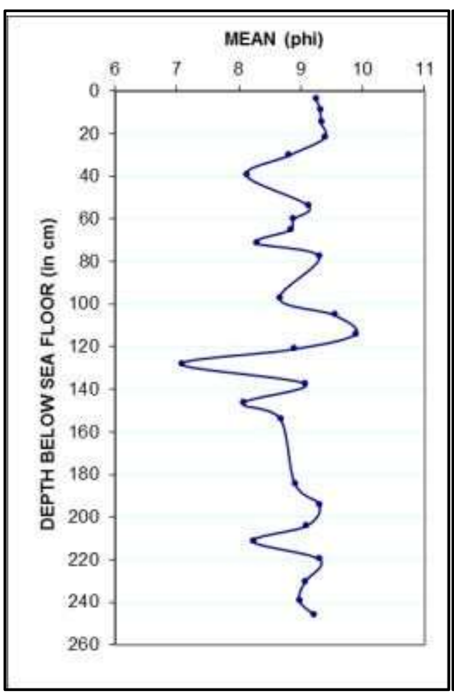


Fig 4.3.4a variation in GC-05

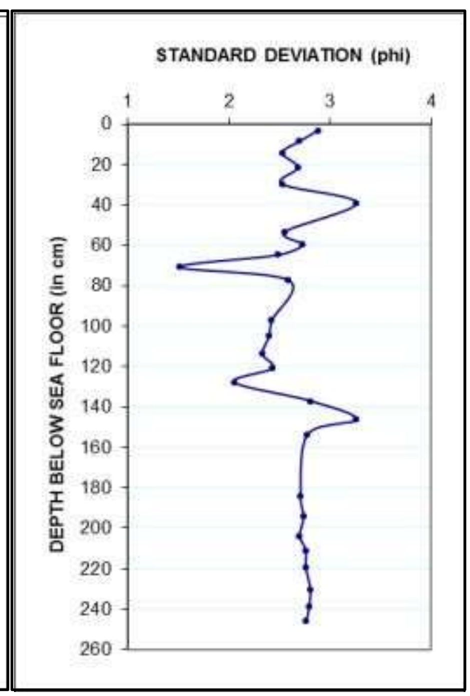
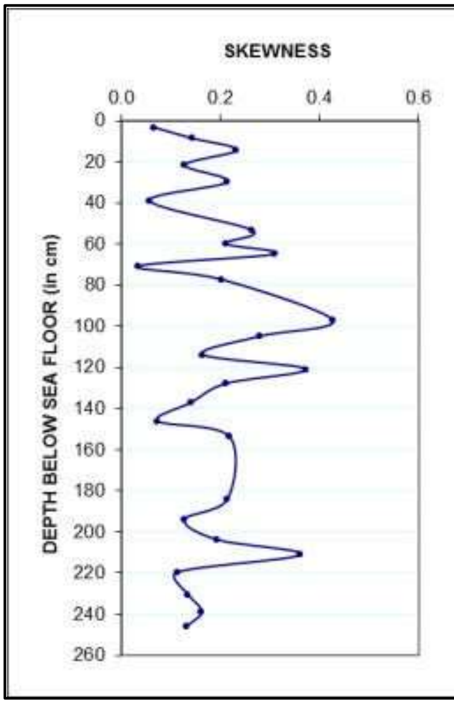


Fig 4.3.4b variation in GC-05



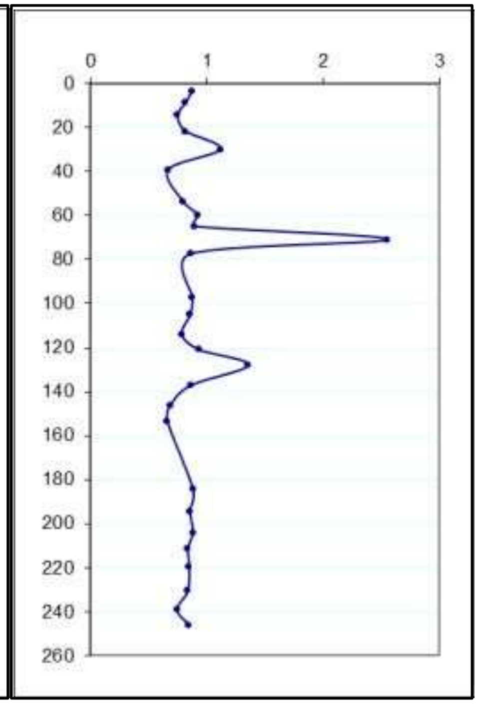


Fig 4.3.4c variation in GC-05 **Fig 4.3.4d variation in GC-05**

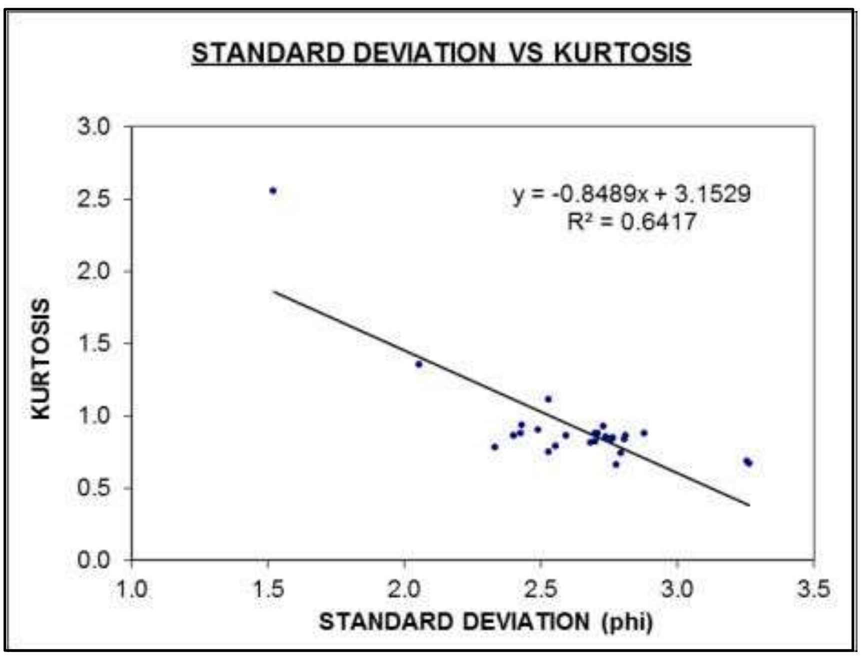


Fig 4.3.14 Bivarient plot of GC-05

4.4. Clay Mineralogy:

A total of 118 sub samples of 5 cores were studied under XRD to know the mineral phases in clay fraction which is the dominant in most of the samples. Fourteen sub samples of GC-01 were analysed (Table-4.4.1). In all the samples, calcite dominates in clay fraction with good amount of dolomite, plagioclase feldspar & quartz. Other minerals in minor quantities include chlorite, ilite, kaolinite, phlogopite & montmorillonite. The sub-samples do not show any variation in the type of mineral or dominations of mineral with depth. Ten sub-samples of GC-02 were analysed (Table-4.4.2) and also found that calcite dominates in all the samples with minor amounts of plagioclase feldspar, dolomite, chlorite, illite, kaolinite, phlogopite and quartz. Out of 30 sub-samples of GC-03 analysed, (Table-4.4.3) calcite is present as major mineral in 19, others do not show any domination. One sub-sample at a depth of 4503 has quartz as major mineral and followed by montmorillonite, calcite, plagioclase feldspar & chlorite, Mg-calcite, illite and hematite are in small amount or traces. In the top 6 sub samples that comprise a thickness of 53cm, quartz and montmorillonite are in significant amount after calcite. chlorite, illite & Plagioclase are in good amount. From 120 to bottom of the core illite and chlorite are either dominating or in considerable amount. The occurrence of illite along with chlorite suggests they were carried all the way from Himalayas to the farthest point of Indus Fan and moreover the deposition of this sediment may be connected with upliftment of Himalayas. Out of 31 sub-samples of GC-04, 15 were analysed (Table-4.4.4), all show calcite as major mineral. Interestingly, aragonite is present in significant amount in few of the sub-samples. illite, chlorite & montmorillonite are in considerable amount in few sub-samples. Thirty-seven sub-samples were analysed out of 39 of GC-05 (Table-4.4.5). Half of them show calcite as dominating mineral phase, the other half has quartz or montmorillonite as major mineral phase. Other mineral phases in minor quantities include plagioclase feldspar, illite, chlorite etc.

4.5 Stable isotope analysis:

The TOC profile content in the core shows prominent variation in trend down the core. These values are not linearly related to depth in the sediment column. Upto about 60 cm down the core TOC values range from 1 to 1.6 wt% with its peak 42 cm down the depth. After this depth range, values reduced to 0.6 to 0.8 wt%. Hence, the TOC content is slightly higher in the uppermost portion of the core. Further, the TOC values decrease with depth in the sediment.

In consistent with this variation, Total Nitrogen (TN) concentration ranges from 8 to 9.8 % at the top and reduces to 6.2 to 7.9 % towards bottom parts of the core. Hence, the TN concentration in superficial sediments displays a polynomial pattern with increasing sediment column depth (Figure 4.5.1& 4.5.2, Table 4.5). TOC shows a direct relation with TN in the superficial sediments in the study area.

The Carbon/Nitrogen (C/N) ratio ranges from 9.2 to 11.3 at the surface and reduces even upto 4.6 towards the bottom part of the core. The C/N ratio also depicts the same picture in tandem with the variation in TOC and TN content down the core.

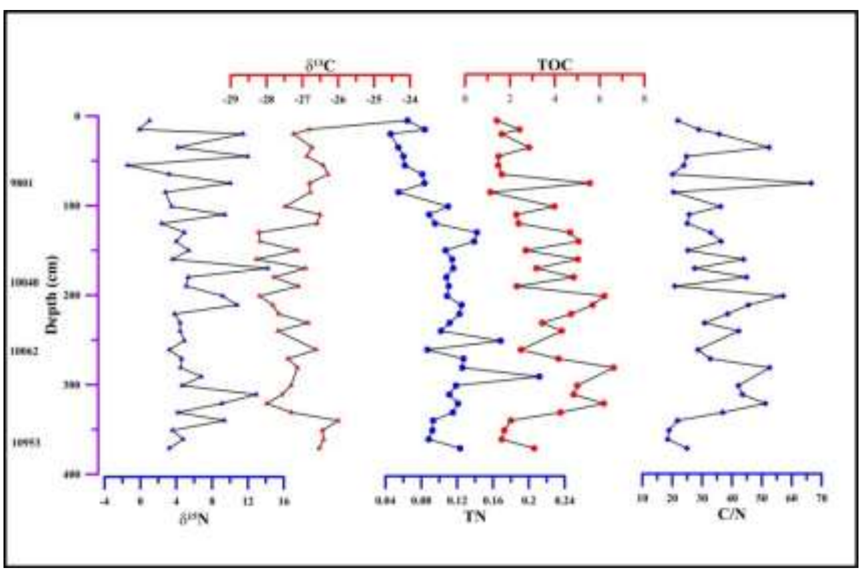


Fig.4.5.1 Down core variation of the δ ^{15}N, TN and C/N

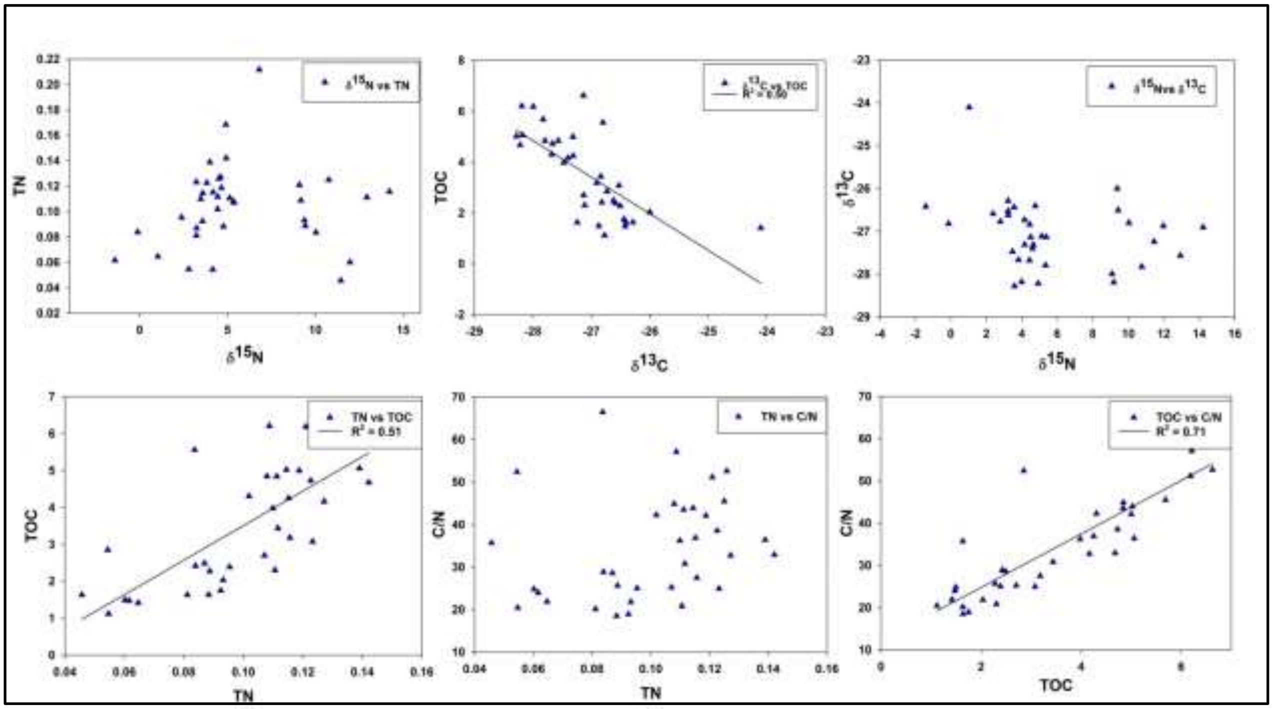


Fig.4.5.2 Different cross plots of TOC-TN-C/N

Table 4.1.1 Grain size of GC-01					
Sample No.	**Depth**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Sediment type**
GC- 01/1	**2.5**	4.24	49.96	45.73	Clayey silt
GC- 01/3	**12.5**	17.63	24.84	57.53	Silty clay
GC- 01/5	**22.5**	29.12	23.49	47.39	Sandy clay
GC- 01/7	**32.5**	33.21	58.22	8.56	Sandy Silt
GC- 01/9	**42.5**	45.04	0.47	55.43	Clay
GC- 01/11	**52.5**	16.98	29.68	53.33	Silty clay
GC- 01/13	**62.5**	12.88	29.69	57.44	Silty clay
GC- 01/15	**72.5**	11.22	28.89	59.89	Silty clay
GC- 01/17	**82.5**	11.15	72.07	16.78	Silt
GC- 01/19	**92.5**	12.85	31.03	56.12	Clay
GC- 01/21	**102.5**	13.95	77.69	8.36	Silt
GC- 01/23	**112.5**	13.63	69.18	17.19	Silt
GC- 01/25	**122.5**	16.49	18.6	64.91	Clay
GC- 01/27	**132.5**	14.43	76.73	8.84	Silt
GC- 01/29	**142.5**	14.06	77.34	8.6	Silt
GC- 01/31	**152.5**	13.95	77.69	8.36	Silt
GC- 01/33	**162.5**	17.57	78.29	4.14	Silt
GC- 01/35	**172.5**	14.52	80.22	5.26	Silt
GC- 01/37	**182.5**	16.25	77.97	5.77	Silt
GC- 01/39	**192.5**	14.91	79.56	5.53	Silt
GC- 01/41	**202.5**	11.2	82.53	6.26	Silt

Table 4.1.2 Grain size of GC-02					
Sample No.	**Depth**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Sediment type**
GC- 02/1	**2.5**	5.24	49.03	45.73	Clayey silt
GC- 02/3	**12.5**	17.63	26.39	55.98	Silty clay
GC- 02/5	**22.5**	29.54	22.22	48.24	Sandy clay
GC- 02/7	**32.5**	36.32	58.22	5.46	Sandy Silt
GC- 02/9	**42.5**	45.41	0.64	53.95	Sandy Clay
GC- 02/11	**52.5**	17.89	29.68	52.42	Silty clay
GC- 02/13	**62.5**	13.79	29.86	56.35	Silty clay
GC- 02/15	**72.5**	11.22	28.89	59.89	Silty clay
GC- 02/17	**82.5**	11.51	73.6	14.88	Silt
GC- 02/19	**92.5**	13.58	28.6	57.81	Clay
GC- 02/21	**102.5**	13.95	77.69	8.36	Silt
GC- 02/23	**112.5**	13.63	69.18	17.19	Silt
GC- 02/25	**122.5**	16.49	18.6	64.91	Clay
GC- 02/27	**132.5**	14.43	76.73	8.84	Silt
GC- 02/29	**142.5**	14.06	77.34	8.6	Silt
GC- 02/31	**152.5**	12.85	76.86	10.29	Silt
GC- 02/33	**162.5**	16.66	77.93	5.42	Silt
GC- 02/35	**172.5**	13.47	78.99	6.54	Silt

Table 4.1.3 Grain size of GC-03					
Sample No.	Depth	Sand (%)	Silt (%)	Clay (%)	Sediment type
GC- 03/1	2.5	4.45	25.53	70.02	Silty Clay
GC- 03/3	12.5	1.61	30.24	68.15	Silty Clay
GC- 03/5	22.5	0.96	54.28	44.76	Clayey Silt
GC- 03/7	32.5	4.7	54.69	40.62	Clayey Silt
GC- 03/9	42.5	6.38	27.47	66.15	Silty Clay
GC- 03/11	52.5	0.98	93.89	5.14	Silt
GC- 03/13	62.5	1.21	98.52	0.27	Silt
GC- 03/15	72.5	8.01	91.24	0.75	Silt
GC- 03/17	82.5	2.24	69.88	27.88	Clayey Silt
GC- 03/19	92.5	1.05	97.57	1.38	Silt
GC- 03/21	102.5	0.78	97.63	1.59	Silt
GC- 03/23	112.5	4.96	27.17	67.86	Silty Clay
GC- 03/25	122.5	1.16	96.53	2.31	Silt
GC- 03/27	132.5	1.17	97.47	1.35	Silt
GC- 03/29	142.5	0.88	97.27	1.85	Silt
GC- 03/31	152.5	2.07	96.6	1.33	Silt
GC- 03/33	162.5	0.26	97.79	1.95	Silt
GC- 03/35	172.5	0.65	22.75	76.6	Clay
GC- 03/37	182.5	1.17	27.82	71	Silty Clay

Table 4.1.4 Grain size of GC-04					
Sample No.	Depth	Sand (%)	Silt (%)	Clay (%)	Sediment type
GC- 04/1	2.5	1.72	47.5	50.78	Clayey silt
GC- 04/3	12.5	1.77	71.41	26.82	Clayey silt
GC- 04/5	22.5	1.14	62.87	35.98	Clayey silt
GC- 04/7	32.5	1.53	84.74	13.73	Silt
GC- 04/9	42.5	2.13	85.65	12.22	Silt
GC- 04/11	52.5	2.05	43.65	54.3	Silty clay
GC- 04/13	62.5	0.77	80.87	18.37	Clayey silt
GC- 04/15	72.5	0.48	87.79	11.73	Silt
GC- 04/17	82.5	1.86	91.79	6.35	Silt
GC- 04/19	92.5	1.01	91.06	7.93	Silt
GC- 04/21	102.5	1.79	88.01	10.2	Silt
GC- 04/23	112.5	0.33	91.07	8.6	Silt
GC- 04/25	122.5	0.05	90.87	9.08	Silt
GC- 04/27	132.5	0.41	92.85	6.74	Silt
GC- 04/29	142.5	0.95	93.64	5.41	Silt
GC- 04/31	152.5	1	91.15	7.85	Silt
GC- 04/33	162.5	1.22	94.58	4.2	Silt
GC- 04/35	172.5	1.11	96.3	2.6	Silt
GC- 04/37	182.5	0.48	95.66	3.86	Silt
GC- 04/39	192.5	0.38	86.44	13.19	Silt
GC- 04/41	202.5	0.31	89.06	10.64	Silt
GC- 04/43	212.5	0.69	0	99.31	Clay
GC- 04/45	222.5	0.24	90.99	8.76	Silt
GC- 04/47	232.5	1.57	87.95	10.48	Silt
GC- 04/49	242.5	4.97	91.59	3.44	Silt
GC- 04/51	252.5	2.98	90.79	6.23	Silt
GC- 04/53	262.5	0.29	91.27	8.44	Silt
GC- 04/55	272.5	0.43	94.45	5.12	Silt
GC- 04/57	282.5	0.57	97.63	1.81	Silt

Table 4.1.5 Grain size of GC-05					
Sample No.	Depth	Sand (%)	Silt (%)	Clay (%)	Sediment type
GC- 05/1	2.5	0.33	37.07	62.6	Silty Clay
GC- 05/3	12.5	0.92	35.23	63.85	Silty Clay
GC- 05/5	22.5	0.34	36.01	63.66	Silty Clay
GC- 05/7	32.5	1.45	32.87	65.68	Silty Clay
GC- 05/9	42.5	1.94	37.86	60.2	Silty Clay
GC- 05/11	52.5	1.29	46.5	52.21	Silty Clay
GC- 05/13	62.5	0.04	39.86	60.11	Silty Clay
GC- 05/15	72.5	0.3	43.41	56.29	Silty Clay
GC- 05/17	82.5	0.11	44.26	55.63	Silty Clay
GC- 05/19	92.5	0.29	28.48	71.23	Silty Clay
GC- 05/21	102.5	0.32	32.38	67.3	Silty Clay
GC- 05/23	112.5	0.05	51.44	48.5	Clayey Silt
GC- 05/25	122.5	0.12	27.48	72.4	Silty Clay
GC- 05/27	132.5	0.04	23.19	76.76	Clay
GC- 05/29	142.5	0.25	46.29	53.47	Silty Clay
GC- 05/31	152.5	1.13	74.64	24.23	Clayey Silt
GC- 05/33	162.5	1.5	37.91	60.59	Silty Clay
GC- 05/35	172.5	1.69	47.45	50.86	Silty Clay
GC- 05/37	182.5	1.13	44.1	54.76	Silty Clay
GC- 05/39	192.5	0.48	42.02	57.5	Silty Clay
GC- 05/41	202.5	1.85	33.17	64.98	Silty Clay
GC- 05/43	212.5	0.73	39.08	60.19	Silty Clay
GC- 05/45	222.5	0.43	56.33	43.23	Clayey Silt
GC- 05/47	232.5	0.73	35.14	64.13	Silty Clay
GC- 05/49	242.5	2.46	36.02	61.52	Silty Clay

Table.4.2.1. Major oxides of GC-01.												
Sl.No.	Sample No.	Depth	SiO2	TiO2	Al2O3	Fe2O3	CaO	MnO	MgO	Na2O	K2O	P2O5
			%	%	%	%	%	%	%	%	%	%
1	GC- 01/1	2.5	12.72	0.42	4.76	2.74	72.5	0.52	2.11	0.87	1.49	0.03
2	GC- 01/2	7.5	12.61	0.35	4.31	2.43	73.75	0.69	1.97	0.94	1.45	0.03
3	GC- 01/3	12.5	13.09	0.34	4.21	2.93	73.6	0.58	1.97	0.66	1.32	0.04
4	GC- 01/4	17.5	9.94	0.54	5.37	2.96	73.05	0.91	2.47	0.67	1.57	0.13
5	GC- 01/5	22.5	10.55	0.42	5.39	2.96	70.9	0.33	2.41	1.02	1.72	0.03
6	GC- 01/6	27.5	11.54	0.41	5.78	3.2	71.45	0.19	2.57	0.76	1.67	0.03
7	GC- 01/7	32.5	12.5	0.33	6.1	3.18	70.75	0.15	2.61	1.04	1.83	0.03
8	GC- 01/8	37.5	9.36	0.4	6.37	3.37	69	0.2	2.74	1.42	2.08	0.05
9	GC- 01/9	42.5	11.7	0.51	6.37	3.42	70.25	0.12	2.79	0.97	1.88	<0.02
10	GC- 01/10	47.5	12.5	0.4	6.44	3.27	68.35	0.08	2.84	1.31	2.07	0.03
11	GC- 01/11	52.5	12.83	0.61	6.05	3.07	71.2	0.07	2.65	0.59	1.62	<0.02
12	GC- 01/12	57.5	13.85	0.62	5.4	2.89	66.05	0.15	2.37	0.64	1.5	0.11
13	GC- 01/13	62.5	11.81	0.43	4.8	2.56	73	0.34	2.14	0.83	1.49	0.04
14	GC- 01/14	67.5	11.36	0.42	4.97	2.79	73.35	0.03	2.22	1.12	1.67	0.05
15	GC- 01/15	72.5	11.65	0.5	4.63	2.56	71.9	0.14	2.07	0.57	1.32	0.05
16	GC- 01/16	77.5	13.22	0.5	4.57	2.57	72.15	0.16	2.06	1.04	1.55	0.05
17	GC- 01/17	82.5	12.46	0.4	4.42	2.51	73	0.11	2.05	0.27	1.16	0.04
18	GC- 01/18	87.5	10.7	0.31	4.74	2.44	75.8	0.08	2.07	1.35	1.71	0.04
19	GC- 01/19	92.5	7.07	0.2	3.91	1.97	79.75	0.07	1.71	1.11	1.41	0.09
20	GC- 01/20	97.5	10.14	0.21	4.17	2.16	73.35	0.08	1.81	0.73	1.27	0.06
21	GC- 01/21	102.5	10.41	0.4	5.25	3.11	75.6	0.09	2.21	0.52	1.36	0.05
22	GC- 01/22	107.5	9.18	0.61	5.76	3.37	74.9	0.09	2.42	0.69	1.55	0.03
23	GC- 01/23	112.5	11.28	0.5	5.48	2.97	74.2	0.09	2.31	0.75	1.53	<0.02
24	GC- 01/24	117.5	9.46	0.62	7.48	3.69	70.85	0.06	3.05	0.82	1.93	<0.02
25	GC- 01/25	122.5	10.87	0.71	8.24	4	68.15	0.07	3.33	1.09	2.21	0.07
26	GC- 01/26	127.5	13.12	0.8	10.03	5.1	58.15	0.11	4.03	0.6	2.31	0.08
27	GC- 01/27	132.5	13.27	0.92	9.01	4.46	64.85	0.07	3.65	0.3	1.98	0.09
28	GC- 01/28	137.5	10.52	0.73	7.79	4.14	68.5	0.07	3.05	1.27	2.16	0.07
29	GC- 01/29	142.5	10.91	0.61	7.95	4.06	68.1	0.07	3.07	1.18	2.12	0.08
30	GC- 01/30	147.5	10.84	0.71	7.33	3.82	69.35	0.06	2.87	1.29	2.08	0.06
31	GC- 01/31	152.5	11.78	0.41	4.81	2.8	72.76	0.61	2.19	0.83	1.51	0.05
32	GC- 01/32	157.5	11.27	0.41	6.16	3.29	70.36	0.17	2.68	1.05	1.86	0.04
33	GC- 01/33	162.5	11.08	0.59	7.35	3.68	69.15	0.08	3.07	1.05	2.06	0.06
34	GC- 01/34	167.5	10.78	0.42	5.8	3.13	71.03	0.36	2.56	0.98	1.77	0.05
35	GC- 01/35	172.5	11.13	0.56	7.13	3.6	69.4	0.08	3	1.04	2.02	0.05
36	GC- 01/36	177.5	11.73	0.77	8.66	4.34	65.56	0.08	3.48	0.87	2.17	0.08
37	GC- 01/37	182.5	11.1	0.45	6.55	3.39	69.84	0.12	2.81	1.11	1.96	0.04
38	GC- 01/38	187.5	12.03	0.79	8.88	4.39	64.83	0.08	3.59	0.77	2.18	0.08
39	GC- 01/39	192.5	10.52	0.63	7.2	3.69	70.11	0.07	2.87	1.03	1.95	0.08
40	GC- 01/40	197.5	11.36	0.65	8.09	4.01	66.73	0.08	3.32	0.98	2.15	0.06
41	GC- 01/41	202.5	11.39	0.74	8.02	4.12	67.7	0.07	3.16	1.01	2.09	0.08

Table 4.2.2. Trace elements of GC-01								
Sl.No.	Sample No.	Depth	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Cr ppm
				ppm	ppm	ppm	ppm	ppm
1	GC- 01/1	2.5	90	15	110	120	15	25
2	GC- 01/2	7.5	90	5	115	155	15	20
3	GC- 01/3	12.5	65	15	105	85	10	20
4	GC- 01/4	17.5	75	10	125	125	10	5
5	GC- 01/5	22.5	70	15	125	200	20	30
6	GC- 01/6	27.5	70	10	115	100	20	5
7	GC- 01/7	32.5	60	15	110	90	15	30
8	GC- 01/8	37.5	65	5	125	105	20	15
9	GC- 01/9	42.5	65	20	125	95	15	35
10	GC- 01/10	47.5	70	10	115	85	10	50
11	GC- 01/11	52.5	70	15	110	75	10	20
12	GC- 01/12	57.5	65	10	115	75	20	30
13	GC- 01/13	62.5	70	10	100	100	25	40
14	GC- 01/14	67.5	80	30	110	105	30	5
15	GC- 01/15	72.5	75	20	95	85	15	105
16	GC- 01/16	77.5	70	20	100	90	25	40
17	GC- 01/17	82.5	80	10	105	80	<5	125
18	GC- 01/18	87.5	65	20	105	75	15	25
19	GC- 01/19	92.5	50	10	90	65	<5	25
20	GC- 01/20	97.5	60	10	95	70	10	60
21	GC- 01/21	102.5	65	10	105	85	15	70
22	GC- 01/22	107.5	60	10	105	85	10	30
23	GC- 01/23	112.5	65	15	100	105	10	45
24	GC- 01/24	117.5	100	45	100	140	20	55
25	GC- 01/25	122.5	100	20	100	145	20	30
26	GC- 01/26	127.5	130	20	130	185	35	45
27	GC- 01/27	132.5	35	35	130	170	25	35
28	GC- 01/28	137.5	120	20	115	150	25	50
29	GC- 01/29	142.5	140	20	120	145	25	55
30	GC- 01/30	147.5	165	25	115	135	25	30
31	GC- 01/31	152.5	78	12	116	137	14	20
32	GC- 01/32	157.5	65	13	119	98	18	21
33	GC- 01/33	162.5	68	13	113	86	16	35
34	GC- 01/34	167.5	68	11	120	124	17	17
35	GC- 01/35	172.5	68	14	116	83	14	34
36	GC- 01/36	177.5	72	18	104	91	23	44
37	GC- 01/37	182.5	66	13	117	90	14	30
38	GC- 01/38	187.5	73	18	105	91	23	45
39	GC- 01/39	192.5	68	16	99	79	18	64
40	GC- 01/40	197.5	71	15	110	88	19	29
41	GC- 01/41	202.5	73	18	101	83	18	74

Table 4.2.3. Major Oxides of GC-02													
Sl.No.	**Sample No.**	**Depth**	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MnO**	**MgO**	**Na_2O**	**K_2O**	**P_2O_5**
			%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
1	GC- 02/1	2.5	9.62	0.17	3.19	1.62	81.2	0.08	0.75	0.63	0.47	0.08
2	GC- 02/2	7.5	8.5	0.14	2.65	1.42	84.67	0.02	0.57	0.47	0.67	0.07
3	GC- 02/3	12.5	7.97	0.12	2.54	1.48	85.2	0.04	0.56	0.8	0.6	0.1
4	GC- 02/4	17.5	8.17	0.14	2.49	1.49	83.33	0.25	0.57	0.79	0.59	0.1
5	GC- 02/5	22.5	8.21	0.16	2.58	1.62	84.77	0.03	0.58	0.64	0.48	0.07
6	GC- 02/6	27.5	9.46	0.15	3.07	1.84	82.58	0.06	0.74	0.67	0.5	0.06
7	GC- 02/7	32.5	12.4	0.22	4.26	2.71	77.01	0.09	0.95	0.68	0.51	0.08
8	GC- 02/8	37.5	15.6	0.27	4.66	2.84	72.36	0.73	1.11	0.51	0.38	0.08
9	GC- 02/9	42.5	17.6	0.25	4.84	2.91	69.06	0.17	1.16	0.83	0.62	0.06
10	GC- 02/10	47.5	17	0.23	4.7	2.74	69.06	0.15	1.09	0.71	0.53	0.08
11	GC- 02/11	52.5	17.14	0.25	4.73	2.84	71.93	0.04	1.12	0.35	0.56	0.07
12	GC- 02/12	57.5	19	0.25	5.34	3.26	68.77	0.04	1.13	0.78	0.58	0.1
13	GC- 02/13	62.5	19.3	0.29	5.41	3.16	67.29	0.06	1.19	0.85	0.64	0.08
14	GC- 02/14	67.5	18.5	0.26	5.34	3.23	67.23	0.04	1.17	0.88	0.66	0.08
15	GC- 02/15	72.5	16	0.26	4.49	2.86	68.47	0.05	0.93	0.5	0.37	0.06
16	GC- 02/16	77.5	13.32	0.25	4.02	2.31	72.47	0.1	0.89	0.54	0.41	0.08
17	GC- 02/17	82.5	15.8	0.24	3.88	2.34	73.16	0.05	0.85	0.14	0.19	0.1
18	GC- 02/18	87.5	14.86	0.25	4.34	2.48	73.2	0.1	0.88	0.99	0.74	0.1
19	GC- 02/19	92.5	16.04	0.3	4.1	2.43	73.45	0.04	0.86	0.7	0.52	0.08
20	GC- 02/20	97.5	16.88	0.26	4.13	2.28	72.74	0.06	0.77	0.72	0.54	0.06
21	GC- 02/21	102.5	8	0.29	3.96	2.24	71.41	0.04	0.78	0.74	0.56	0.07
22	GC- 02/22	107.5	9.8	0.26	3.97	2.59	80.58	0.03	0.77	0.82	0.62	0.06
23	GC- 02/23	112.5	12	0.29	3.62	3.27	70.12	0.04	0.81	0.77	0.58	0.06
24	GC- 02/24	117.5	7.3	0.3	3.52	1.75	77.69	0.03	0.76	0.54	0.4	0.16
25	GC- 02/25	122.5	7.5	0.31	3.84	1.99	82.03	0.03	0.68	0.83	0.62	0.07
26	GC- 02/26	127.5	11	0.32	4.22	2.44	79.06	0.04	0.75	0.78	0.59	0.09
27	GC- 02/27	132.5	10.5	0.35	4.44	2.54	78.85	0.03	0.83	0.57	0.42	0.06
28	GC- 02/28	137.5	18	0.36	5.43	3.22	67.94	0.03	0.98	0.59	0.44	0.07
29	GC- 02/29	142.5	24	0.41	6.31	3.85	60.88	0.04	0.98	0.64	0.48	0.06
30	GC- 02/30	147.5	17.5	0.35	5.68	3.38	68.84	0.03	0.91	0.68	0.51	0.06
31	GC- 02/31	152.5	8.49	0.15	2.69	1.53	83.83	0.08	0.61	0.67	0.56	0.08
32	GC- 02/32	157.5	13.77	0.22	4.21	2.58	75.25	0.26	0.99	0.67	0.5	0.07
33	GC- 02/33	162.5	18.01	0.25	5	2.98	69.22	0.09	1.14	0.7	0.59	0.08
34	GC- 02/34	167.5	10.77	0.19	3.41	2.1	80.01	0.23	0.79	0.66	0.49	0.08
35	GC- 02/35	172.5	17.69	0.25	4.9	2.94	69.71	0.1	1.13	0.67	0.57	0.08

Table 4.2.4 Trace elements of GC-02								
Sl.No.	**Sample No.**	**Depth**	**Cu ppm**	**Pb ppm**	**Zn ppm**	**Ni ppm**	**Co ppm**	**Cr ppm**
				ppm	ppm	ppm	ppm	ppm
1	GC- 02/1	2.5	35	10	74	50	7	27
2	GC- 02/2	7.5	45	<10	68	59	9	23
3	GC- 02/3	12.5	40	<10	61	26	6	21
4	GC- 02/4	17.5	50	<10	71	75	10	17
5	GC- 02/5	22.5	37	<10	77	22	6	21
6	GC- 02/6	27.5	40	<10	76	40	8	24
7	GC- 02/7	32.5	39	<10	84	53	8	38
8	GC- 02/8	37.5	60	<10	107	179	17	41
9	GC- 02/9	42.5	36	<10	76	71	17	40
10	GC- 02/10	47.5	32	<10	84	66	24	41
11	GC- 02/11	52.5	39	<10	79	59	12	46
12	GC- 02/12	57.5	36	<10	82	56	10	47
13	GC- 02/13	62.5	38	<10	87	61	19	46
14	GC- 02/14	67.5	38	<10	91	53	15	45
15	GC- 02/15	72.5	37	<10	80	49	11	38
16	GC- 02/16	77.5	41	<10	78	61	21	34
17	GC- 02/17	82.5	47	<10	71	47	15	36
18	GC- 02/18	87.5	53	<10	65	58	20	38
19	GC- 02/19	92.5	55	<10	62	44	12	38
20	GC- 02/20	97.5	58	<10	69	41	16	35
21	GC- 02/21	102.5	68	<10	69	41	10	33
22	GC- 02/22	107.5	34	<10	65	45	13	34
23	GC- 02/23	112.5	81	<10	72	52	16	33
24	GC- 02/24	117.5	67	<10	65	51	13	32
25	GC- 02/25	122.5	32	<10	81	41	12	34
26	GC- 02/26	127.5	19	<10	77	46	13	41
27	GC- 02/27	132.5	25	<10	66	45	15	40
28	GC- 02/28	137.5	26	<10	74	62	16	51
29	GC- 02/29	142.5	28	<10	83	65	14	53
30	GC- 02/30	147.5	27	<10	77	61	17	46
31	GC- 02/31	152.5	41	<10	70	46	8	22
32	GC- 02/32	157.5	32	<10	71	44	8	21
33	GC- 02/33	162.5	41	<10	74	43	8	24
34	GC- 02/34	167.5	25	<10	83	74	10	28
35	GC- 02/35	172.5	31	<10	84	73	11	33

Table 4.2.5 Major oxides of GC-03												
Sl.No.	**Sample No.**	**Depth**	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MnO**	**MgO**	**Na_2O**	**K_2O**	**P_2O_5**
			%	%	%	%	%	%	%	%	%	%
1	GC - 03/1	2.5	57.98	0.85	12.1	4.65	19.95	0.1	1.65	0.69	0.23	0.18
2	GC - 03/2	7.5	62.68	0.9	12	4.68	15.95	0.1	1.65	0.88	0.07	0.17
3	GC - 03/3	12.5	59.56	0.9	12.65	5	11.95	0.1	8.4	0.33	0.17	0.25
4	GC - 03/4	17.5	58.06	1.05	11.8	5.16	13.95	0.09	5.04	0.34	0.77	0.25
5	GC - 03/5	22.5	50.33	0.8	11.7	4.65	19.95	0.1	9.25	0.88	0.19	0.2
6	GC - 03/6	27.5	54.38	1.2	11.65	4.85	17.95	0.1	6.72	0.54	0.46	0.3
7	GC - 03/7	32.5	58.07	1.3	12.2	4.8	11.95	0.06	6.85	0.88	0.4	0.35
8	GC - 03/8	37.5	64.69	0.95	13	5.7	10	0.05	3.35	1.45	0.29	0.25
9	GC - 03/9	42.5	65.57	0.8	13.55	5.1	9.1	0.06	2.5	0.69	0.88	0.15
10	GC - 03/10	47.5	67.32	0.95	11.8	5.1	8	0.06	2	1.19	0.84	0.3
11	GC - 03/11	52.5	67.42	1.5	11.5	5.05	8.8	0.1	1.5	0.51	0.72	0.2
12	GC - 03/12	57.5	66.3	1.4	11.4	5.2	9.25	0.1	1.65	0.31	0.63	0.15
13	GC - 03/13	62.5	54.98	1.05	11.05	5.3	19.25	0.07	4.5	0.51	1.05	0.15
14	GC - 03/14	67.5	54.87	0.5	11.2	4.65	19.5	0.11	5	0.85	1.1	0.2
15	GC - 03/15	72.5	52.6	1.2	12.45	5.4	19.4	0.11	4.6	0.4	1.85	0.15
16	GC - 03/16	77.5	55.84	0.3	8.6	4.8	19.45	0.08	4.6	0.96	1.6	0.1
17	GC - 03/17	82.5	66.79	0.25	8.3	5.55	10.65	0.09	5.1	0.25	1.02	0.1
18	GC - 03/18	87.5	67.9	0.25	9.5	6.1	10	0.12	3.4	1.07	1.2	0.2
19	GC - 03/19	92.5	48.12	0.15	10.9	5.05	26.45	0.1	6.25	0.96	1.13	0.15
20	GC - 03/20	97.5	55.36	1.15	11.4	5	19.25	0.07	5.05	0.46	1.46	0.15
21	GC - 03/21	102.5	57.31	0.8	11.5	4.4	19.95	0.08	3.4	0.18	0.19	0.15
22	GC - 03/22	107.5	55.79	0.7	11.05	4.5	21.2	0.02	3.6	0.34	1.46	0.15
23	GC - 03/23	112.5	58.62	0.5	8.1	4.7	19.5	0.07	3.4	0.46	2.73	0.2
24	GC - 03/24	117.5	62.27	0.46	8.5	5.46	14.25	0.11	5.05	0.69	2.43	0.2
25	GC - 03/25	122.5	62.68	0.3	5.9	4.5	18.1	0.11	3.65	0.84	1.39	0.15
26	GC - 03/26	127.5	66.25	0.35	7.2	5.35	9	0.11	6.75	0.26	1.82	0.2
27	GC - 03/27	132.5	64.35	0.6	9.85	5.8	9.1	0.1	6.84	0.03	2.05	0.15
28	GC - 03/28	137.5	64.04	0.6	10.3	5.96	9.15	0.12	6.25	1.22	1.77	0.2
29	GC - 03/29	142.5	62.61	0.65	10.7	6	8.75	0.08	7.75	1.07	1.83	0.25
30	GC - 03/30	147.5	66.05	0.45	7.8	5.4	10.2	0.07	5.4	1.19	1.81	0.3
31	GC - 03/31	152.5	63	N.D	10	5.75	15.15	0.11	1.8	0.13	2.39	0.35
32	GC - 03/32	157.5	57.53	0.65	10.1	4.65	19	0.2	3.35	0.71	2.09	0.25
33	GC - 03/33	162.5	54.89	0.7	10.1	3.9	25.15	0.12	1.5	0.62	2.19	0.2
34	GC - 03/34	167.5	57.7	0.9	11.05	4.2	20.2	0.18	1.8	0.69	2.28	0.2
35	GC - 03/35	172.5	62.98	0.6	9.35	5.25	10.5	0.13	4.45	0.4	2.5	0.25
36	GC - 03/36	177.5	65.89	0.25	8.1	5.1	10.1	0.11	5.65	0.19	2.64	0.35
37	GC - 03/37	182.5	69.7	N.D	1.75	5.4	10.4	0.3	5.2	0.51	2.64	0.3

Table 4.2.6 Trace elements of GC-03								
Sl.No.	**Sample No.**	**Depth**	**Cu ppm**	**Pb ppm**	**Zn ppm**	**Ni ppm**	**Co ppm**	**Cr ppm**
			ppm	ppm	ppm	ppm	ppm	ppm
1	GC - 03/1	2.5	90	25	90	35	45	90
2	GC - 03/2	7.5	60	20	90	30	30	85
3	GC - 03/3	12.5	65	20	95	25	40	90
4	GC - 03/4	17.5	60	20	85	35	30	40
5	GC - 03/5	22.5	55	30	85	40	55	85
6	GC - 03/6	27.5	60	35	90	20	10	75
7	GC - 03/7	32.5	60	40	100	45	25	80
8	GC - 03/8	37.5	65	45	125	50	30	90
9	GC - 03/9	42.5	70	40	120	50	30	85
10	GC - 03/10	47.5	70	35	110	40	50	60
11	GC - 03/11	52.5	120	35	145	40	40	55
12	GC - 03/12	57.5	75	25	130	40	20	60
13	GC - 03/13	62.5	100	20	125	35	35	110
14	GC - 03/14	67.5	85	20	110	30	35	100
15	GC - 03/15	72.5	85	25	110	30	40	115
16	GC - 03/16	77.5	110	30	105	25	15	110
17	GC - 03/17	82.5	125	35	120	45	40	116
18	GC - 03/18	87.5	130	40	135	40	45	110
19	GC - 03/19	92.5	85	50	130	20	40	70
20	GC - 03/20	97.5	65	20	115	35	50	80
21	GC - 03/21	102.5	65	40	135	25	25	80
22	GC - 03/22	107.5	70	30	105	25	35	90
23	GC - 03/23	112.5	70	25	120	30	15	100
24	GC - 03/24	117.5	80	25	125	25	10	85
25	GC - 03/25	122.5	85	30	110	20	20	85
26	GC - 03/26	127.5	60	20	110	40	35	70
27	GC - 03/27	132.5	55	20	120	35	25	55
28	GC - 03/28	137.5	70	25	115	35	35	60
29	GC - 03/29	142.5	70	30	80	30	20	115
30	GC - 03/30	147.5	60	25	55	25	30	80
31	GC - 03/31	152.5	60	45	45	30	30	80
32	GC - 03/32	157.5	75	50	30	25	20	75
33	GC - 03/33	162.5	110	40	20	25	35	55
34	GC - 03/34	167.5	90	30	20	40	30	85
35	GC - 03/35	172.5	60	20	30	45	40	110
36	GC - 03/36	177.5	65	20	20	35	35	105
37	GC - 03/37	182.5	65	25	10	35	40	75

Table 4.2.7 Major Oxides of GC-04												
Sl.No.	**Sample No.**	**Depth**	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MnO**	**MgO**	**Na_2O**	**K_2O**	**P_2O_5**
			%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
1	GC-04/1	2.5	63.47	1.37	12.9	6.43	8.3	0.22	5.11	1.1	0.37	0.24
2	GC-04/2	7.5	60.55	1.35	12.85	6.48	9.37	0.28	5.18	1.41	0.11	0.23
3	GC-04/3	12.5	68.62	1.05	10.4	5.33	6.97	0.33	4.13	0.53	0.27	0.24
4	GC-04/4	17.5	63.82	1.39	13.42	6.82	6.7	0.3	4.26	0.55	1.23	0.24
5	GC-04/5	22.5	61.77	1.36	13.51	6.81	6.89	0.25	4.21	1.41	0.3	0.2
6	GC-04/6	27.5	64.7	1.38	13.75	6.94	6.22	0.24	4.31	0.86	0.73	0.15
7	GC-04/7	32.5	62.94	1.23	12.85	6.71	8.46	0.2	4.75	1.41	0.63	0.18
8	GC-04/8	37.5	62.03	1.16	12.47	6.21	9.81	0.18	4.71	2.33	0.46	0.17
9	GC-04/9	42.5	61.83	1.16	12.66	6.54	8.72	0.31	4.75	1.1	1.4	0.18
10	GC-04/10	47.5	61.68	1.15	13.23	6.69	7.36	0.37	4.81	1.9	1.35	0.23
11	GC-04/11	52.5	64.24	1.45	13.89	6.89	5.87	0.18	3.98	0.82	1.15	0.22
12	GC-04/12	57.5	61.41	1.64	14.55	7.15	8.08	0.15	4.18	0.5	1	0.22
13	GC-04/13	62.5	64.65	1.68	14.75	7.22	4.07	0.15	2.91	0.82	1.69	0.18
14	GC-04/14	67.5	64.85	1.55	14.55	7.02	3.81	0.45	2.83	1.35	1.76	0.2
15	GC-04/15	72.5	63.71	1.53	14.55	7.34	3.15	0.08	2.74	0.64	2.97	0.22
16	GC-04/16	77.5	62.6	1.51	14.16	6.56	4.54	0.49	3.61	1.53	2.56	0.19
17	GC-04/17	82.5	62.14	1.41	14.1	6.49	6.96	0.57	4.71	0.39	1.63	0.18
18	GC-04/18	87.5	61.51	1.5	14.18	7.45	5.4	0.16	3.9	1.71	1.91	0.22
19	GC-04/19	92.5	61.03	1.57	14.39	7.15	6.06	0.08	4.13	1.53	1.81	0.2
20	GC-04/20	97.5	60.92	1.64	14.95	7.47	5.28	0.14	3.81	0.73	2.33	0.19
21	GC-04/21	102.5	62.52	1.62	14.55	7.37	5.2	0.34	4.4	0.29	0.31	0.22
22	GC-04/22	107.5	60.58	1.65	14.32	7.42	6.04	0.14	4.08	0.55	2.34	0.23
23	GC-04/23	112.5	57.95	1.55	14.1	7.35	5.44	0.13	3.56	0.73	4.36	0.24
24	GC-04/24	117.5	56.64	1.33	12.1	6.44	9	0.34	4.9	1.1	3.89	0.23
25	GC-04/25	122.5	64.06	1.33	12.32	6.88	4.4	0.15	4.78	1.35	2.23	0.14
26	GC-04/26	127.5	55.99	1.29	13.4	6.46	11.34	0.11	4.75	0.41	2.91	0.21
27	GC-04/27	132.5	56.2	1.27	13.06	6.26	11.44	0.08	4.68	0.04	3.28	0.18
28	GC-04/28	137.5	55	1.21	12.63	6.14	12.32	0.22	4.61	1.96	2.83	0.19
29	GC-04/29	142.5	57.22	1.42	14.86	7.37	7.22	0.23	3.86	1.71	2.93	0.2
30	GC-04/30	147.5	57.64	1.42	14.53	7.29	7.4	0.13	3.56	1.9	2.89	0.22
31	GC-04/31	152.5	59	1.67	15	7.45	5.13	0.33	3.45	0.21	3.82	0.18
32	GC-04/32	157.5	59.17	1.62	15.44	7.29	5.04	0.11	3.14	1.14	3.35	0.24
33	GC-04/33	162.5	60.14	0.82	16	7.35	4.95	0.07	2.18	1	3.5	0.24
34	GC-04/34	167.5	58.91	1.42	15.4	7.24	5.12	1.11	3.02	1.1	3.65	0.24
35	GC-04/35	172.5	56.11	1.29	14.57	7.11	7.83	0.21	4.05	0.64	3.99	0.23
36	GC-04/36	177.5	53.53	1.2	13.36	6.46	12.04	0.18	4.08	0.3	4.22	0.22
37	GC-04/37	182.5	58.88	1.27	15.3	7.22	5.11	0.28	2.66	0.82	4.22	0.22
38	GC-04/38	187.5	55.77	1.13	14	6.95	7.8	0.09	4.73	0.64	4.31	0.21
39	GC-04/39	192.5	52.98	0.91	12.28	5.86	13.58	0.13	4.65	1.07	4.16	0.22
40	GC-04/40	197.5	51.89	0.88	11.81	5.52	15.4	0.13	4.52	1.07	4.29	0.21
41	GC-04/41	202.5	57.98	0.8	8.95	3.9	14.03	0.18	3.8	1.14	4.54	0.18

42	GC-04/42	207.5	60.21	0.27	7.2	2.39	16.98	1.11	2.21	1	4.7	0.21
43	GC-04/43	212.5	53.27	1.21	12.7	6.16	11.7	0.1	4.36	1.46	4.34	0.24
44	GC-04/44	217.5	50.35	1.27	13.23	6	13.46	0.09	4.57	1.82	4.93	0.25
45	GC-04/45	222.5	54.82	1.43	14.84	7.24	6.46	0.08	4.08	1	4.86	0.25
46	GC-04/46	227.5	55.8	1.4	15.02	7.15	5.1	0.1	3.9	1.82	5.22	0.24
47	GC-04/47	232.5	56.27	1.42	15.35	7.35	4.9	0.08	2.88	1.82	5.34	0.24
48	GC-04/48	237.5	55.62	0.58	7.85	3.23	17.63	0.13	3.04	1.64	5.5	0.25
49	GC-04/49	242.5	56.36	1.36	15.18	7.19	5.35	0.09	2.96	1.82	5.2	0.25
50	GC-04/50	247.5	62.76	1.42	13.82	6.9	6.82	0.23	4.13	1.03	1.32	0.21
51	GC-04/51	252.5	63.05	1.3	13.2	6.7	7.62	0.23	4.45	1.31	0.67	0.19
52	GC-04/52	257.5	62.29	1.35	13.58	6.82	7.51	0.25	4.43	1.08	1.23	0.21
53	GC-04/53	262.5	63.44	1.58	14.51	7.06	4.73	0.26	3.25	0.97	1.99	0.2
54	GC-04/54	267.5	62.54	1.23	13.02	6.61	8.04	0.25	4.6	1.51	1	0.2
55	GC-04/55	272.5	63.65	1.6	14.6	7.18	4.78	0.21	3.17	0.83	1.85	0.21
56	GC-04/56	277.5	62.2	1.5	14.28	7	5.22	0.28	3.82	1.16	2.18	0.2

Table 4.2.8 Trace elements of GC-04

Sl.No.	**Sample No.**	**Depth**	**Cu ppm**	**Pb ppm**	**Zn ppm**	**Ni ppm**	**Co ppm**	**Cr ppm**
			ppm	ppm	ppm	ppm	ppm	ppm
1	GC-04/1	2.5	50	15	60	75	30	40
2	GC-04/2	7.5	120	20	70	180	30	75
3	GC-04/3	12.5	95	10	125	160	25	55
4	GC-04/4	17.5	80	10	125	150	30	55
5	GC-04/5	22.5	80	5	120	140	25	65
6	GC-04/6	27.5	80	5	65	130	20	90
7	GC-04/7	32.5	80	10	115	130	25	95
8	GC-04/8	37.5	75	10	110	125	25	50
9	GC-04/9	42.5	85	10	125	155	25	40
10	GC-04/10	47.5	75	10	120	140	30	35
11	GC-04/11	52.5	75	10	115	125	30	45
12	GC-04/12	57.5	80	10	135	135	30	30
13	GC-04/13	62.5	75	5	125	135	30	35
14	GC-04/14	67.5	95	10	120	195	45	20
15	GC-04/15	72.5	85	10	130	140	25	25
16	GC-04/16	77.5	145	5	135	150	25	25
17	GC-04/17	82.5	135	5	135	165	20	40
18	GC-04/18	87.5	105	10	130	160	30	65
19	GC-04/19	92.5	105	45	120	135	25	40
20	GC-04/20	97.5	120	10	140	160	35	35
21	GC-04/21	102.5	150	10	145	200	50	50
22	GC-04/22	107.5	120	10	160	155	30	35

23	GC-04/23	112.5	110	10	140	145	25	30
24	GC-04/24	117.5	105	15	145	170	45	40
25	GC-04/25	122.5	85	10	130	145	25	40
26	GC-04/26	127.5	75	10	125	125	20	30
27	GC-04/27	132.5	70	10	110	130	20	<10
28	GC-04/28	137.5	75	10	115	150	30	25
29	GC-04/29	142.5	85	10	130	165	35	<10
30	GC-04/30	147.5	95	10	130	150	25	20
31	GC-04/31	152.5	105	10	130	195	45	20
32	GC-04/32	157.5	110	15	145	160	25	50
33	GC-04/33	162.5	130	10	145	160	25	65
34	GC-04/34	167.5	110	15	130	135	25	30
35	GC-04/35	172.5	105	10	115	145	30	20
36	GC-04/36	177.5	85	15	110	120	35	15
37	GC-04/37	182.5	105	10	140	115	25	<10
38	GC-04/38	187.5	135	15	165	235	45	65
39	GC-04/39	192.5	100	10	135	150	25	30
40	GC-04/40	197.5	85	10	110	125	20	<10
41	GC-04/41	202.5	90	10	115	125	20	15
42	GC-04/42	207.5	60	10	80	85	15	<10
43	GC-04/43	212.5	25	5	40	30	5	35
44	GC-04/44	217.5	65	5	70	130	20	20
45	GC-04/45	222.5	75	10	115	105	25	75
46	GC-04/46	227.5	85	10	120	150	25	20
47	GC-04/47	232.5	110	10	120	155	25	50
48	GC-04/48	237.5	50	10	70	80	10	60
49	GC-04/49	242.5	110	15	145	200	30	55
50	GC-04/50	247.5	83	8	110	142	25	72
51	GC-04/51	252.5	79	8	107	135	25	71
52	GC-04/52	257.5	80	8	107	136	24	68
53	GC-04/53	262.5	79	9	107	136	25	62
54	GC-04/54	267.5	78	10	117	135	27	53
55	GC-04/55	272.5	78	10	121	136	28	40
56	GC-04/56	277.5	78	9	124	138	29	37

Table 4.2.9 Major Oxides of GC-05												
Sl. No.	**Sample No.**	**Depth**	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MnO**	**MgO**	**Na_2O**	**K_2O**	**P_2O_5**
			%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
1	GC- 05/1	2.5	40.5	0.37	10.63	6.59	22.24	0.13	2	1.97	1.83	0.1
2	GC- 05/2	7.5	46.8	0.4	12.65	6.77	25.76	0.17	2.01	1.41	2.68	0.11
3	GC- 05/3	12.5	54.5	0.47	13.81	7.51	15.32	0.22	2.11	1	2.55	0.1
4	GC- 05/4	17.5	50.3	0.4	13.31	7.18	21.05	0.11	1.97	1.22	2.32	0.11
5	GC- 05/5	22.5	47.9	0.39	12.66	6.81	24.91	0.17	1.81	2.25	1.96	0.1
6	GC- 05/6	27.5	48.05	0.43	12.65	6.88	25.31	0.16	1.71	1.48	1.82	0.1
7	GC- 05/7	32.5	53.2	0.49	14.01	7.62	16.83	0.18	1.88	2.2	1.93	0.1
8	GC- 05/8	37.5	61.35	0.57	15.58	8.24	6.2	0.16	2.01	3.43	1.29	0.1
9	GC- 05/9	42.5	63.3	0.5	16.31	8.25	2.84	0.17	1.93	1.84	2.66	0.1
10	GC- 05/10	47.5	62.95	0.49	17.37	8.54	1.89	0.21	1.73	2.92	2.16	0.1
11	GC- 05/11	52.5	58.6	0.46	16.8	8.55	7.31	0.13	1.4	1.58	2.18	0.11
12	GC- 05/12	57.5	57.2	0.46	16.6	8.22	10.07	0.15	1.49	1.05	2.3	0.1
13	GC- 05/13	62.5	61.3	0.33	13.54	6.74	10.26	0.31	1.34	1.59	2.62	0.11
14	GC- 05/14	67.5	58.9	0.44	16.27	8.22	8.01	0.23	1.37	2.29	2.72	0.11
15	GC- 05/15	72.5	57.5	0.39	15.67	10.12	8.04	0.14	1.36	1.13	1.54	0.3
16	GC- 05/16	77.5	57.08	0.46	16.06	10.26	8.35	0.07	1.38	2.33	1.67	0.3
17	GC- 05/17	82.5	55.45	0.41	15.78	12.13	8.18	0.07	1.46	1.02	1.36	0.25
18	GC- 05/18	87.5	54.3	0.47	17.2	7.44	12.47	0.08	1.55	1.75	3.04	0.05
19	GC- 05/19	92.5	55.2	0.47	17.1	7.51	11.49	0.09	1.52	2.5	2.15	0.05
20	GC- 05/20	97.5	55.8	0.47	17.49	7.98	10.06	0.08	1.49	1.46	2.05	0.05
21	GC- 05/21	102.5	57.1	0.41	16.61	7.87	9.84	0.08	1.41	1.26	2.26	<0.05
22	GC- 05/22	107.5	57	0.65	17.44	7.03	10.21	0.07	1.2	1.36	2.81	0.05
23	GC- 05/23	112.5	49.3	0.61	17.06	8.2	16.68	0.08	1.86	1.49	2.56	0.07
24	GC- 05/24	117.5	47.9	0.69	16.55	7.25	19.31	0.03	1.79	2.14	1.57	0.06
25	GC- 05/25	122.5	57.3	0.7	18.33	8.59	6.83	0.17	1.68	2.21	2.92	0.05
26	GC- 05/26	127.5	52.5	0.57	15.87	6.41	16.92	0.1	1.75	1.01	2.33	0.05
27	GC- 05/27	132.5	44.5	0.57	15.7	7.45	24.01	0.11	2.15	0.48	1.61	0.07
28	GC- 05/28	137.5	51.08	0.64	17.2	8.24	14.82	0.12	1.94	3.04	1.8	0.05
29	GC- 05/29	142.5	52	0.62	16.75	8.27	14.26	0.08	2.12	2.71	2.08	<0.05
30	GC- 05/30	147.5	46.45	0.6	16.02	7.46	21.96	0.11	1.91	1.93	1.82	0.05
31	GC- 05/31	152.5	61	0.68	18.83	8.99	2.21	0.12	2	0.66	1.96	0.05
32	GC- 05/32	157.5	49.9	0.57	16.18	6.39	19.21	0.09	1.82	1.86	2.15	<0.05
33	GC- 05/33	162.5	45.65	0.55	15.46	7.14	23.53	0.09	1.92	1.79	2.79	<0.05
34	GC- 05/34	167.5	46.5	0.57	15.96	7.46	21.71	0.09	1.66	1.85	2.84	<0.05
35	GC- 05/35	172.5	55.85	0.67	17.34	8.47	9.92	0.09	1.64	1.12	2.59	<0.05
36	GC- 05/36	177.5	45.6	0.56	15.53	7.87	22.75	0.09	1.91	0.92	2.48	0.06
37	GC- 05/37	182.5	51.44	0.6	15.85	7.28	17.09	0.12	1.73	1.71	2.16	0.07
38	GC- 05/38	187.5	49.31	0.6	16.31	7.57	18.39	0.1	1.97	1.83	1.93	0.06
39	GC- 05/39	192.5	50.29	0.52	14.7	7.34	19.48	0.13	1.79	1.86	2.12	0.08
40	GC- 05/40	197.5	50.02	0.6	16.38	7.59	17.5	0.1	1.99	1.81	1.96	0.06

41	GC- 05/41	202.5	51	0.6	16.65	7.65	16.23	0.1	1.95	1.79	2.16	0.05
42	GC- 05/42	207.5	50.66	0.63	16.73	7.59	16.38	0.11	1.86	1.78	2.05	0.06
43	GC- 05/43	212.5	52.34	0.62	16.95	7.78	14.41	0.1	1.96	1.79	2	0.05
44	GC- 05/44	217.5	52.1	0.49	16.34	8.12	14.98	0.08	1.65	1.78	2.3	0.12
45	GC- 05/45	222.5	51.01	0.62	16.9	8.08	15.45	0.11	2.02	1.76	1.86	0.06
46	GC- 05/46	227.5	51.33	0.5	16.16	8.28	15.85	0.08	1.69	1.6	2.33	0.15
47	GC- 05/47	232.5	52.65	0.48	16.39	8.56	13.92	0.08	1.61	1.77	2.33	0.12
48	GC- 05/48	237.5	54.88	0.52	17.14	7.72	11.66	0.08	1.5	1.62	2.37	0.06
49	GC- 05/49	242.5	53.26	0.54	16.69	8.42	13.12	0.09	1.75	1.42	2.26	0.12

Table 4.2.10 Trace Elements of GC-05

Sl.No.	**Sample No.**	**Depth**	**Cu ppm**	**Pb ppm**	**Zn ppm**	**Ni ppm**	**Co ppm**	**Cr ppm**
			ppm	ppm	ppm	ppm	ppm	ppm
1	GC- 05/1	2.5	80	<10	120	105	108	20
2	GC- 05/2	7.5	70	<10	120	106	20	110
3	GC- 05/3	12.5	75	<10	140	118	21	120
4	GC- 05/4	17.5	67	<10	100	89	19	109
5	GC- 05/5	22.5	69	<10	125	87	24	104
6	GC- 05/6	27.5	68	<10	125	91	21	110
7	GC- 05/7	32.5	71	<10	125	105	23	117
8	GC- 05/8	37.5	76	<10	150	110	25	126
9	GC- 05/9	42.5	78	<10	132	105	29	129
10	GC- 05/10	47.5	79	<10	150	107	28	127
11	GC- 05/11	52.5	54	<10	155	74	21	122
12	GC- 05/12	57.5	49	<10	140	64	22	117
13	GC- 05/13	62.5	32	<10	149	45	18	83
14	GC- 05/14	67.5	40	<10	118	59	22	116
15	GC- 05/15	72.5	40	<10	89	55	19	116
16	GC- 05/16	77.5	35	<10	126	55	18	120
17	GC- 05/17	82.5	30	<10	57	55	17	114
18	GC- 05/18	87.5	47	<10	50	55	19	120
19	GC- 05/19	92.5	50	<10	55	60	20	120
20	GC- 05/20	97.5	78	<10	60	55	18	115
21	GC- 05/21	102.5	45	<10	99	50	17	118
22	GC- 05/22	107.5	39	<10	118	42	11	79
23	GC- 05/23	112.5	77	<10	521	87	13	97
24	GC- 05/24	117.5	71	<10	336	88	13	91
25	GC- 05/25	122.5	22	<10	109	20	<10	36
26	GC- 05/26	127.5	63	<10	100	77	10	84
27	GC- 05/27	132.5	82	<10	113	109	15	92
28	GC- 05/28	137.5	76	<10	118	105	10	100

29	GC- 05/29	142.5	84	<10	135	115	15	97
30	GC- 05/30	147.5	74	<10	116	86	12	105
31	GC- 05/31	152.5	81	<10	131	87	16	90
32	GC- 05/32	157.5	78	<10	120	90	18	90
33	GC- 05/33	162.5	84	<10	128	100	12	90
34	GC- 05/34	167.5	78	<10	115	100	13	100
35	GC- 05/35	172.5	84	<10	131	95	13	90
36	GC- 05/36	177.5	78	<10	120	95	12	95
37	GC- 05/37	182.5	70	<10	122	98	21	111
38	GC- 05/38	187.5	70	<10	165	95	20	107
39	GC- 05/39	192.5	59	<10	159	75	19	90
40	GC- 05/40	197.5	59	<10	159	73	17	85
41	GC- 05/41	202.5	61	<10	157	77	15	83
42	GC- 05/42	207.5	63	<10	155	80	12	81
43	GC- 05/43	212.5	65	<10	115	85	13	82
44	GC- 05/44	217.5	76	<10	116	98	12	96
45	GC- 05/45	222.5	79	<10	123	100	14	97
46	GC- 05/46	227.5	79	<10	124	97	14	96
47	GC- 05/47	232.5	53	<10	73	68	17	111
48	GC- 05/48	237.5	58	<10	171	59	16	106
49	GC- 05/49	242.5	64	<10	97	77	16	101

Table 4.3.1 Granulometric data of GC-01					
SAMPLE No.	**DEPTH (cm)**	**MEAN (phi)**	**Standard dev.**	**KURTOSIS**	**SKEWNESS**
GC-01/1	0-10	9.14	2.99	0.87	0.03
GC-01/2	Oct-15	9.1	3.35	1.11	-0.04
GC-01/3	15-25	9.21	2.85	0.93	0.1
GC-01/4	25-35	9.18	3.08	1.02	0.02
GC-01/5	35-45	9.24	2.97	0.99	0.06
GC-01/6	45-53	9.18	2.95	1.03	0.08
GC-01/7	53-63	8.77	2.62	0.71	0.42
GC-01/8	63-73	9.11	2.69	0.99	0.17
GC-01/9	73-83	8.88	2.19	1.86	0.24
GC-01/10	83-90	7.61	1.76	2.47	0.02
GC-01/11	90-100	7.89	1.41	1.95	0.1
GC-01/12	100-110	8.03	1.55	2.18	-0.03
GC-01/13	110-120	9.05	2.76	0.95	0.15
GC-01/14	120-130	8.61	2.4	1.99	0.12
GC-01/15	130-136	8.14	1.95	2	0.02
GC-01/16	136-145	8.56	2.35	1.92	0.12
GC-01/17	145-151.5	8.46	2.12	1.66	0.19
GC-01/18	151-160	7.17	1.48	1.74	-0.06
GC-01/19	160-165	8.17	2.1	1.94	0.02
GC-01/20	165-170	8.79	2.53	1.12	0.19
GC-01/21	170-177	9.04	2.17	1.2	0.34
GC-01/22	177-185	8.48	2.46	1.2	0.21
GC-01/23	185-192	8.84	2.26	1.06	0.32
GC-01/24	192-200	8.03	2.03	1.5	0.12

Table 4.3.2 Granulometric data of GC-02					
SAMPLE No.	**DEPTH (cm)**	**MEAN (phi)**	**Standard dev.**	**KURTOSIS**	**SKEWNESS**
GC-02/1	0-3.5	9.65	2.86	0.86	-0.08
GC-02/2	3.5-10	9.49	2.76	0.83	0.04
GC-02/3	Oct-14	8.12	2.4	1.02	0.42
GC-02/4	14-20	7.65	2.31	1.37	0.19
GC-02/5	20-24.5	9.13	3.01	1.04	0.05
GC-02/6	26.5-35	6.3	0.75	1.57	0.02
GC-02/7	35-41.5	5.72	0.24	1.27	-0.21
GC-02/8	41.5-45	5.34	0.87	4.19	-0.27
GC-02/9	45-53	7.25	1.86	1.62	0.41
GC-02/10	53-60	5.74	0.19	0.96	-0.11
GC-02/11	60-69	5.72	0.26	1.42	-0.24
GC-02/12	69-74	9.37	2.83	0.96	0.08
GC-02/13	74-79	5.68	0.4	2.27	-0.42
GC-02/14	79-86	5.76	0.24	1.34	0.22
GC-02/15	86-95	5.73	0.22	1.16	-0.18
GC-02/16	95-105	5.74	0.21	1.1	-0.16
GC-02/17	105-113.5	5.72	0.23	1.18	-0.19
GC-02/18	113.5-118.5	9.96	2.49	0.88	0.05
GC-02/19	118.5-123.5	9.61	2.47	0.79	0.18
GC-02/20	123.5-130	9.19	3.04	1.07	0.02
GC-02/21	130-140	5.73	0.21	1.11	-0.17
GC-02/22	140-150.5	5.68	0.26	1.18	-0.25
GC-02/23	150.5-156	9.68	2.57	0.8	0.09
GC-02/24	159-165	6.46	0.5	1.47	-0.25
GC-02/25	165-171	6.14	0.59	0.99	0

Table 4.3.3 Granulometric data of GC-03					
SAMPLE No.	**DEPTH (cm)**	**MEAN (phi)**	**Standard dev.**	**KURTOSIS**	**SKEWNESS**
GC-03/1	0-10	9.11	2.84	0.86	0.11
GC-03/2	Oct-20	9.24	2.64	0.82	0.19
GC-03/3	20-25	9.08	2.8	0.9	0.16
GC-03/4	25-35	9.1	2.66	0.86	0.21
GC-03/5	35-45	9.27	2.6	0.8	0.21
GC-03/6	45-55	9.21	2.83	0.92	0.12
GC-03/7	55-63	9.18	2.65	0.84	0.2
GC-03/8	63-70	8.86	2.64	0.84	0.26
GC-03/9	70-75	8.65	2.7	0.87	0.26
GC-03/10	75-80.5	8.55	2.77	0.9	0.21
GC-03/11	80.5-84.5	8.38	2.73	0.88	0.31
GC-03/12	84.5-90.5	8.44	2.66	0.89	0.32
GC-03/13	90.5-100	8.99	2.73	0.84	0.19
GC-03/14	103-109	9.2	2.73	0.86	0.17
GC-03/15	109-114.5	9.18	2.53	0.75	0.27
GC-03/16	114.5-124.5	9.03	2.58	0.82	0.27
GC-03/17	124.5-133.5	8.98	2.72	1	0.19
GC-03/18	133.5-140	9.01	2.38	1.02	0.29
GC-03/19	140-150	8.68	2.21	1.45	0.27
GC-03/20	150-156.5	8.67	2.14	1.62	0.27
GC-03/21	156.5-162	8.74	2.27	1.48	0.25
GC-03/22	162-169.5	9.12	2.39	0.87	0.32
GC-03/23	169.5-175	9.39	2.42	0.83	0.29
GC-03/24	175-182	9.39	2.49	0.88	0.24
GC-03/25	182-184	9.29	2.35	0.83	0.34

Table 4.3.4 Granulometric data of GC-05					
SAMPLE No.	**DEPTH (cm)**	**MEAN (phi)**	**Standard dev.**	**KURTOSIS**	**SKEWNESS**
GC-05/1	0-7	9.25	2.88	0.88	0.07
GC-05/2	7-10.5	9.32	2.7	0.82	0.14
GC-05/3	10.5-18.5	9.33	2.53	0.75	0.23
GC-05/4	18.5-25	9.39	2.68	0.82	0.13
GC-05/5	25-35	8.81	2.53	1.12	0.21
GC-05/6	35-43.5	8.13	3.26	0.67	0.06
GC-05/7	50-57	9.13	2.56	0.79	0.26
GC-05/8	57-63	8.89	2.73	0.93	0.21
GC-05/9	63-67	8.84	2.49	0.9	0.31
GC-05/10	67-75	8.28	1.52	2.55	0.03
GC-05/11	75-80	9.3	2.59	0.86	0.2
GC-05/12	94.5-100	8.66	2.43	0.88	0.43
GC-05/13	100-110	9.55	2.4	0.86	0.28
GC-05/14	110-118	9.89	2.33	0.78	0.16
GC-05/15	118-124	8.9	2.43	0.93	0.37
GC-05/16	124-132	7.08	2.06	1.36	0.21
GC-05/17	132-142.5	9.08	2.81	0.86	0.14
GC-05/18	142.5-150	8.08	3.26	0.69	0.07
GC-05/19	150-157.5	8.68	2.78	0.66	0.22
GC-05/20	180-188.5	8.91	2.71	0.88	0.21
GC-05/21	188.5-200	9.31	2.74	0.86	0.13
GC-05/22	200-208	9.1	2.7	0.88	0.19
GC-05/23	208-214.5	8.23	2.76	0.84	0.36
GC-05/24	214.5-225	9.31	2.76	0.85	0.11
GC-05/25	225-236	9.07	2.81	0.84	0.13
GC-05/26	236-242	8.98	2.79	0.74	0.16
GC-05/27	242-250	9.23	2.77	0.84	0.13

Table 4.4.1. Clay mineral data of GC-01

Sl. No.	Sample No.	CONSTITUTENTS DETECTED					
		Major	Minor	Good Amount	Considerable amount	Small Amount	Trace Amount
1	GC-01/4	Calcite	-	-	Pl. Feldspar Dolomite	Mica	Gypsum Hematite
2	GC-01/9	Calcite	-	-	Pl. Feldspar Dolomite	Chlorite Illite Phlogopite	Amphibole
3	GC-01/14	Calcite	-	Pl. Feldspar	Dolomite Chlorite Illite	Phlogopite Quartz	Hematite
4	GC-01/22	Calcite	-	Pl. Feldspar Dolomite	Chlorite	Quartz	Phlogopite
5	GC-01/29	Calcite	-	Pl. Feldspar Dolomite	Chlorite Illite	Quartz	Phlogopite Hematite
6	GC-01/33	Calcite	-	Pl. Feldspar Dolomite	Chlorite Illite	Phlogopite Quartz Dolomite	
7	GC-01/36	Calcite	-	Pl. Feldspar	Dolomite	Chlorite& Illite	Phlogopite Hematite
8	GC-01/40	Calcite	-	Pl. Feldspar	Dolomite Chlorite Illite	Phlogopite Quartz	

Table 4.4.2 Clay mineral data of GC-02

Sl. No.	Sample No.	CONSTITUTENTS DETECTED					
		Major	Minor	Good Amount	Considerable amount	Small Amount	Trace Amount
1	GC-02/1	Calcite	Quartz	Montmorillonite	Chlorite Illite Plagioclase Feldspar	Mg-Calcite	
2	GC-02/2	Calcite	Quartz	Montmorillonite	Chlorite Illite Pl. Feldspar	Mg-Calcite	Hematite
3	GC-02/3	Calcite	Quartz	Montmorillonite	Chlorite Illite Pl. Feldspar	Mg-Calcite Hematite	
4	GC-02/4	Calcite	Quartz	Montmorillonite	Chlorite Illite Pl. Feldspar	Mg-Calcite	Hematite
5	GC-02/5	Calcite	Quartz	Montmorillonite	Chlorite Illite Pl. Feldspar	Mg-Calcite	
6	GC-02/6	Calcite	Quartz	Montmorillonite	Chlorite Illite Pl. Feldspar	Mg-Calcite	
7	GC-02/7	Quartz	Montmorillonite	Calcite Pl. Feldspar	Chlorite Pl. Feldspar	Mg-Calcite Illite	Hematite
8	GC-02/8	Calcite	Quartz	Montmorillonite	Chlorite Illite Pl. Feldspar	Mg-Calcite	
9	GC-02/9	Calcite	Quartz	Montmorillonite	Chlorite Illite Pl. Feldspar	Mg-Calcite	
10	GC-02/10	Calcite	Montmorillonite	Quartz	Chlorite Pl. Feldspar	Mg-Calcite	Hematite
11	GC-02/11	Calcite	Montmorillonite	Quartz	Chlorite Pl. Feldspar	Mg-Calcite Kaolinite	Hematite
12	GC-02/12	Calcite	Montmorillonite	Quartz	Chlorite Pl. Feldspar	Mg-Calcite	Hematite
13	GC-02/13	Calcite	Quartz	Pl. Feldspar Montmorillonite	Kaolinite Illite	Chlorite Mg-Calcite Aragonite	Hematite
14	GC-02/14	Calcite	Montmorillonite	Quartz Chlorite Illite	Kaolinite Illite Pl. Feldspar	Mg-Calcite	Aragonite
15	GC-02/15	Calcite	Quartz	Montmorillonite	Chlorite Illite Pl. Feldspar	Mg-Calcite Aragonite	Hematite
16	GC-02/16	Calcite	Quartz	Montmorillonite	Chlorite Kaolinite Pl. Feldspar	Illite	Hematite Mg-Calcite
17	GC-02/17	Calcite	Quartz	Montmorillonite	Kaolinite Illite Pl. Feldspar	Mg-Calcite Hematite	
18	GC-02/18	Calcite	Quartz	Chlorite Illite	Montmorillonite Pl. Feldspar	Mg-Calcite	Hematite
19	GC-02/19	Calcite	Montmorillonite	Quartz	Chlorite Illite Pl. Felspar	Mg-Calcite	
20	GC-02/20	Calcite	Quartz	Montmorillonite	Chlorite Illite Pl. Felspar	Mg-Calcite	Halite
21	GC-02/21			Illite Chlorite	Quartz Calcite	Feldspar	
22	GC-02/22			Chlorite Illite	Quartz		Feldspar Calcite
23	GC-02/23			Illite Chlorite	Quartz	Calcite	Feldspar
24	GC-02/24			Illite	Chlorite	Calcite Quartz	Feldspar
25	GC-02/25		Illite		Chlorite Calcite	Quartz	Feldspar
26	GC-02/26			Illite Chlorite	Calcite	Quartz	Feldspar
27	GC-02/27			Illite	Chlorite Calcite	Quartz	Feldspar
28	GC-02/28		Illite	Chlorite		Quartz	Calcite Dolomite
29	GC-02/29		Illite	Chlorite		Calcite	Quartz
30	GC-02/30			Illite Chlorite	Quartz	-	Feldspar

Table 4.4.3 Clay mineral data of GC-03

Sl. No.	Sample No.	CONSTITUTENTS DETECTED					
		Major	Minor	Good Amount	Considerable amount	Small Amount	Trace Amount
1	GC-03/1	Calcite	-	Aragonite		Quartz Chlorite Kaolinite Mont.	Mixed layer clay Feldspar
2	GC-03/2	Calcite	Aragonite	-	-	Quartz Kaolinite Mont.	Mica
3	GC-03/3	-	-	Calcite Aragonite	-	Mont chlorite Mica Kaolinite Quartz	Mixed layer clay
4	GC-03/4	Calcite	-	AragoniteMont. Chlorite	Illite Quartz	Mixed layer clay	-
5	GC-03/5	Calcite	Aragonite	Mont. Illite chlorite	-	Mixed layer clay Quartz Feldspar Goethite	-
6	GC-03/6	Calcite	-	Aragonite Illite	Quartz Chlorite	Mixed clay	
7	GC-03/10	Calcite	Quartz	Chlorite Aragonite	Mica (Illite mainly)	Feldspar Mixed layer clay FeldsparMont.	Kaolinite
8	GC-03/13	Calcite	Aragonite	Chlorite	Illite	Mixed layer clay FeldsparMont.	Kaolinite
9	GC-03/19	Calcite	Quartz	Chlorite Mica (Illite mainly)	Mixed layer clay Mont.	Feldspar	
10	GC-03/20	Calcite	-	Aragonite Chlorite	Mica (Illite mainly) Mixed layer clay	Kaolinite Mont.	Feldspar
11	GC-03/21	Calcite	-	Aragonite Chlorite	Mica (Illite mainly) Mixed layer clay Mont.	Kaolinite Feldspar Qurartz	Feldspar
12	GC-03/24	Calcite	-	Aragonite	ChloriteMont. Mica (Illite mainly)	Feldspar Mixed layer clay	-
13	GC-03/29	Calcite	Aragonite	Chlorite Mica (Illite)	Mixed layer clay	Feldspar	
14	GC-03/30	Calcite	-	QuartzMont. Illite Chlorite	-	Mixed layer clay	Amphibole Kaolinite
15	GC-03/31	Calcite	-	QuartzMont. Illite Chlorite	Mixed layer clay	Kaolinite	Feldspar

Table 4.4.4 Clay mineral data of GC-04							
Sl. No.	Sample No.	CONSTITUTENTS DETECTED					
		Major	Minor	Good Amount	Considerable amount	Small Amount	Trace Amount
1	GC-04/1	Calcite	Montomorillonite	Quartz Chlorite	Illite Plagioclase Feldspar	-	-
2	GC-04/2	Quartz	Montomorillonite	Kaolinite Plagioclase Feldspar Calcite	Illite	-	Hematite
3	GC-04/3	Quartz	Montomorillonite	Calcite Plagioclase Feldspar Kaolinite	Illite	Chlorite	Hematite
4	GC-04/4	Quartz	Montomorillonite	Calcite	Illite Plagioclase Feldspar Chlorite	-	Hematite
5	GC-04/5	Calcite	Montomorillonite	Quartz Plagioclase Feldspar	Chlorite Illite	-	-
6	GC-04/6	Calcite	Montomorillonite	Quartz	Kaolinite Illite Plagioclase Feldspar	Chlorite	-
7	GC-04/7	Calcite	Montomorillonite	Chlorite Illite Plagioclase Feldspar	Kaolinite	-	Hematite & Amphibole
8	GC-04/8	Montomorillonite	Calcite & Quartz	Chlorite	Illite Plagioclase Feldspar	-	Hematite & Amphibole
9	GC-04/9	Quartz	Montomorillonite	Plagioclase Feldspar Chlorite	Illite Mg-calcite	Calcite Hematite	Amphibole
10	GC-04/10	Montomorillonite	Quartz	Plagioclase Feldspar Chlorite	Illite	Mg-calcite	Hematite
11	GC-04/11	Montomorillonite	Quartz	Chlorite Plagioclase Feldspar	Illite	Kaolinite Mg-calcite	Amphibole
12	GC-04/12	Montomorillonite	Quartz	Chlorite Plagioclase Feldspar	Illite	Calcite	Amphibole & Hematite
13	GC-04/13	Montomorillonite	Quartz	Chlorite Illite Plagioclase Feldspar	-	Mg-calcite	Hematite
14	GC-04/16	Quartz	Calcite Montomorillonite	Pl. Feldspar	Chlorite	Illite	-
15	GC-04/17	Quartz	Montomorillonite	Pl. Feldspar	Calcite Chlorite	Illite	-
16	GC-04/18	Quartz	Montomorillonite	Pl. Feldspar	Chlorite	Calcite	Illite Halite
17	GC-04/19	Quartz	Calcite	Mont. Pl. Feldspar	Chlorite	-	Illite
18	GC-04/20	Calcite	Quartz	Montomorillonite	-	Pl. Feldspar	Illite
19	GC-04/21	Calcite	Quartz	Mont.	Chlorite	Pl. Feldspar	Illite
20	GC-04/22	Calcite	Quartz	Mont.	Chlorite	Pl. Feldspar	Illite
21	GC-04/23	Calcite	Quartz	Mont.	Chlorite	Pl. Feldspar	Illite
22	GC-04/24	Calcite	Quartz	Mont.	Chlorite, Pl.Fe	-	Illite
23	GC-0425	Calcite	Quartz	Mont.	Chlorite Pl. Feldspar	-	Illite
24	GC-04/26	Quartz	Calcite	Mont.	Chlorite Pl. Feldspar	-	Illite
25	GC-04/27	Quartz	Pl.Feldspar Chlorite	Mont.	Calcite	Illite	Hematite

26	GC-04/28	Quartz	Mont.	Pl.Feldspar Chlorite	-	Calcite	Illite Halite
27	GC-04/29	Mont.	Quartz	Chlorite Illite Pl. Feldspar	-	Calcite Mg-Calcite	Hematite
28	GC-04/30	Calcite	Quartz	Mont.	Chlorite Illite Pl. Feldspar	Mg- Calcite	
29	GC-04/31	Calcite	Quartz	Mont.	Chlorite Illite Pl. Feldspar	Mg- Calcite	
30	GC-04/32	Calcite	Mont.	Quartz	Chlorite Illite Pl. Feldspar	Mg- Calcite	
31	GC-04/33	Calcite	Mont.	Quartz	Chlorite Illite Pl. Feldspar	Mg- Calcite	
32	GC-04/34	Calcite	Mont.	Quartz	Chlorite Illite Pl. Feldspar	Mg- Calcite	
33	GC-04/35	Calcite	Quartz	Mont.	Chlorite Illite Pl. Feldspar	Mg- Calcite Hematite	
34	GC-04/36	Quartz	Mont.	Plagioclasse	Chlorite Illite	Calcite	
35	GC-04/37	Quartz	Mont.	Plagioclasse	Chlorite Illite	Calcite	
36	GC-04/38	Calcite	Quartz	Mont.	Chlorite Illite	Mg-Calcite	
37	GC-04/39	Calcite	Mont.	Quartz	Chlorite Illite Pl.Feldspar	Mg-Calcite Kaolinite	

Table 4.4.5 Clay mineral data of GC-05

Sl. No.	Sample No.	CONSTITUTENTS DETECTED					
		Major	Minor	Good Amount	Considerable amount	Small Amount	Trace Amount
1	GC-05/3	Pl. Feldspar	Calcite	Chlorite Illite	Dolomite Quartz	-	Hematite
2	GC-05/7	Pl. Feldspar	Calcite	Chlorite Illite	Phlogopite Quartz	-	Hematite Amphibole Gypsum
3	GC-05/11	Pl. Feldspar	-	Calcite	Quartz Illite Dolomite Chlorite	Phlogopite	Hematite Gypsum
4	GC-05/15	Pl. Feldspar	-	Chlorite Illite	Phlogopite Calcite	Dolomite Quartz	Gypsum Amphibole
5	GC-05/19	Pl. Feldspar	-	Calcite	Quartz chlorite Illite Mg-calcite	Dolomite Phlogopite	Amphibole Gypsum
6	GC-05/22	Pl. Feldspar	-	Chlorite Illite	Dolomite	Calcite Phlogopite	Amphibole
7	GC-05/26	Pl. Feldspar	-	Chlorite & dolomite	Chlorite Illite quartz	-	Hematite
8	GC-05/30	Calcite	Pl. Feldspar	Chlorite Illite	Dolomite Quartz	-	Hematite
9	GC-05/33	Pl. Feldspar	-	Chlorite Illite	Quartz Dolomite	-	Hematite
10	GC-05/37	Pl. Feldspar	Calcite	Chlorite Illite	Quartz	Dolomite Kaolinite	Phlogopite Hematite
11	GC-05/43	Calcite	-	Pl. Feldspar Dolomite		-	Mica Amphibole Chlorite
12	GC-05/47	Pl. Feldspar	-	Dolomite Chlorite	Chlorite Illite	Phlogopite	Hematite

Table. 4.5 Representative stable isotope analytical results Nitrogen (N), Carbon (C) and TOC						
Sample	Avg Depth (cm)	$\delta^{15}N$	TN	$\delta^{13}C$	TOC	C/N
1	7.5	9.8	0.16	-18.5	1.5	9.4
2	12.5	8.2	0.13	-22.6	1.2	9.2
3	22.5	8.4	0.15	-23.6	1.5	10.3
4	27.5	8.2	0.12	-22.65	1.35	11.3
5	32.5	7.8	0.15	-22	1.3	8.7
6	42.5	9.2	0.15	-24.4	1.6	10.7
7	47.5	8.4	0.14	-21.2	1.1	7.9
8	52.5	8.2	0.15	-18.9	1	6.7
9	62.5	7.6	0.13	-24.3	1.3	10.0
10	72.5	7.0	0.13	-21	0.85	6.5
11	82.5	7.1	0.12	-20.6	0.7	5.8
12	87.5	7.9	0.13	-20.5	0.6	4.6
13	97.5	7.5	0.13	-20.5	0.7	5.4
14	107.5	7.7	0.14	-21.8	1	7.4
15	117.5	7.3	0.12	-20.2	0.7	5.8
16	127.5	7.3	0.11	-19.8	0.6	5.5
17	137.5	7.3	0.13	-19.1	0.7	5.4
18	157.5	7.7	0.14	-21.4	0.8	5.7
19	167.5	7.4	0.13	-20.1	0.8	6.2
20	177.5	7.9	0.13	-18.2	0.8	6.2
21	187.5	7.1	0.12	-19.6	0.6	5.0
22	203.5	6.2	0.13	-20.3	0.8	6.2

Chapter -5

OSTRACODS

Ostracods from the deep marine environments of the Arabian Sea especially off Lakshadweep area are scantily known and no systematic study has been carried out till date. This study is aimed at bringing out the relationship of ostracod assemblage with depth and their relationship with other environmental parameters as well as substratum sediments. The variation in ostracod diversity from different Oceans of the world is well established. Environmental parameters like temperature, food availability, carbon flux etc. changes with water depth as well as co-ordinates of the area. Polar marine benthic communities are directly influenced by the Sea Ice, but its impact on species diversity is not well established (Gradinger, 1996; Gutt,2001; Piepenburg,2005; Tamelander et al., 2006; Hoste et al., 2007; Soltwedel, 1997). Abundance and distribution of deep sea ostracods are controlled by sediment characteristics (eg., temperature, oxygen, sediment flux) and food supply (Cronin et al., 2000; Didie et al., 2002). Arabian Sea is considered to have higher biological productivity as compared to its eastern counterpart, the Bay of Bengal.

5.1 Coarse fraction study of the core samples

In order to understand the percentage of biogenous and terrigenous material, their nature and their relationship in the distribution of ostracods down the core, all the subsamples were studies in detail under the binocular microscope and quantified by visual estimation. Out of the total coarser fractions in GC-01, 95% of the material is biogenous with only 05% being the terrigenous material. Biogenpous is mainly composed of Planktonic foraminifera constituting 99 %. Less than 1% is composed of benthic foraminifera and ostracods. Planktonic foraminifera include *Globorotalia menardi, Globorotalia tumida, Globorotalia truncatulinoides, Neogloboquadrina dutertreii, Globigerinoides sacculifer, Globigerinoides ruber*, *globigerinoids conglobatus, Globigerina bulloides, Pullaniatina obliquilateralis, Candeina nitida, Orbulina universa,* *Boliella adamsi, Boliella digitata, Hastigerina aequilateralis, Spheroidinella dehiscensis* etc.

The benthic foraminifera identified are *Pyrgo, Uvigerina, Quinquiloculina, Melonis, Textularia, Chellestominella, Casidulna, Spiroloculina, Rusella, Fontbotia, Lagina, Fissurina, Lenticulina, Dentalina, Virgulina* etc. However, a detailed study of foraminifera was not attempted in this study as it is not falling within the objective.

The trend is almost similar in all the cores except in slight increase in the terrigenous percentage and the corresponding decrease in the biogenous content.

5.2 Introduction to ostracods

5.2.1 Overview of ostracods

Ostracods are small bivalve crustaceans, commonly seen in most of the aquatic environments across the globe. They are so and are represented by nearly 33000 extant and fossil species of 4500 genera and subgenera (Horne et al., 2011). Ostracods are present in marine and non-marine environments, shallow as well as deep ocean, fresh water lakes and even some semi-terrestrial habitats. The calcitic valves of ostracods preserve the signatures of ambient water conditions prevalent at the time of shell formation.

Ostracods are very sensitive to wide range of ecological variables, and are well represented in the various aquatic habitats. Since their shells and valves are well preserved in the fossil record, they are considered as one of the most important proxies for the study of palaeo-environments. Adult ostracods are usually less than 3mm in length with a bivalve carapace hinged along the dorsal margin. These two valves are composed of low-magnesium calcite (Kesling, 1951), formed from components directly taken from the host water (Turpen and Angell, 1971). The majority of ostracods reproduce sexually, although parthenogenesis occurs in some non-marine species (Horne, 1983; Horne et al., 1998). The Life span of ostracods varies from few months to few years. Some cold water forms live upto four years. Most ostracods are benthic living on the surface and within the sediment.

5.2.2 Valve structure and taxonomy

The class ostracoda (Bowmann and Abele, 1982) is divided into two subclasses, Myodocopa and Podocopa. All of the myodocopans are marine taxa; however, as many have poorly calcified valves, they are rarely represented in the fossil record. The podocopans comprise the three orders, Platycopida (marine), Podocopina (ubiquitous) and Palaeocopida.

After the death of the ostracod, its soft parts get decomposed leaving only the calcareous carapace. As the valves are the only part identified in the present study, taxonomic classification in this thesis is done on the basis of the structure and morphology of the valves.

5.2.3 Ostracods as palaeo-environmental indicators

The distribution of ostracods depends on many physical and chemical parameters. This include water depth, temperature turbidity, substratum sediment, salinity, alkalinity dissolved oxygen content of water etc. Diversity of ostracods is much greater in stable environments, such as open sea, whereas more marginal environments are often characterised by a great abundance of one or two species (Neale, 1988). The deep water forms are occurring on finer sediments where as some shallow water species have been found to live in coarser sediments (Smith and Horne, 2002).

The vast majority of ostracod taxa in marine environments today are of the superfamily Cytheroidea. All representatives are benthic crawlers or burrowers and are unable to swim. Whatley (1988), in his review of coastline and continental shelf ostracods assigned familial association to these settings. The shelf fauna is diverse in nature and typically include *Trachyleberidae, Pectocytheridae, Leptocytheridae, Hemicytheridae,* *Cytherideidae* and *Cytheruridae. Loxoconchidae* are predominant in the inner shelf while the outer shelf is dominated by *Krithidae*.

Distribution of ostracods in the marine environment is related to water depth, type and nature of substrate as well as the dynamism of the environment in which they live. Since the above characters determine the nature of marine sediment, the forms associated with these sediments are distinctive as the ostracods live on them. The littoral and shallow water ostracods are unique due to the heavy ornamentation, complex hinge structures, eye spots and branching marginal pore canals (van Morkhoven, 1972). Ostracods found in the deeper ocean are smooth shelled. Those living interstitially within sandy sediment, particularly those with tapering carapaces are also smooth shelled. Benthic forms are commonly oblong or elongate, whilst free swimming forms are rounded. (Horne et al., 2007).

5.2.4 Depositional environment

Palaeoecological information regarding the conditions at the time of valve formation and effects after the deposition can be extracted from ostracod valves. In an ideal situation there will be a fixed ratio of deposition of valves for every individual adult ostracod. But in reality this may not be the case. A low –energy environment may be indicated by a broad distribution of instars being preserved, whereas higher energy is indicated by the dominance of adult valves (e.g. Brouwers, 1988). In addition, the absence of adult valves may represent a change in conditions during the life cycle of the ostracod, such as a decrease in temperature or dissolved oxygen concentration (De Deckker, 2002). Dynamic environments may also be indicated by allochthonous elements within the assemblage, transported by water, wind or with the aid of agents such as waterfowl (Boomer and Eisenhauer, 2002). As such, population age structure may be indicative of palaeo-environments (Whatley, 1988; Ruiz and Romeo, 2003). Careful approach is required, especially in fossil samples of mixed assemblages. This may reflect mixed provenance, reworking of the sediment or a change in environment in the time represented by the sediment interval being examined (De Deckker, 2002).

Valve preservation gives some indication about the post depositional conditions. Living forms have a chitinous sheath which protects the ostracod carapace. Immediately after death, this sheath is consumed by microbes leading to the separation of vales. Normally, whole carapaces are rarely preserved in the fossils record. The presence of carapace indicates that either the deposition has been rapid or burrowing of the ostracod in the sediment prior to death (De Deckker, 1988). The microbial activity leaves signatures of on the calcitic shell. The trails represent areas of weakness in the valve and leave it susceptible to breakage. Hence, the presence of broken shells within an assemblage may be indicative of a higher-energy environment or bacterial activity in a low-energy environment (De Deckker, 1988).

5.3 Ostracod fauna present in core samples

5.3.1 Ostracod variation in GC-01

Almost 10gms of dry samples sub-sampled at 5 cm interval of the entire core were scanned under binocular microscope. All the ostracods were picked up from the subsamples to understand the total assemblage in every samples and also to establish the temporal variation of ostracods in the study area by drawing the down core variation diagram. Valves were imaged using Scanning Electron Microscope. A total of 340 valves have been picked up from the entire core (Table 5.3.1). As such ostracod valves are insignificant in number compared to planktonic foraminifera. Two species are found in almost all the subsamples where as other species are found in some samples. Occurrence of valves in the samples is irregular indicating different depositional environments. Ostracods are represented by 7 species and the species diversity very less. Species variation down the core is plotted (Fig 5.3.1). The species recorded are *Bythoceratina reticulate, Alocopocytherere reticulate indoaustralica, Bradleya plicocarinata, Propontocypris bengalensis, Phlyctenophora orientalis, Bairdopilata alcyonicola and*

Krithe sp. Out of the 7 species recorded in this core, Kirthe sp-1 is one of the most prominent ostracod which is well preserved as valves. Nearly 101 valves have been picked up from the entire core and is appearing and disappearing at different depths. From the top of the core up to 27.5 cm below, it is nearly 3 to 6 valves are recorded in every sample. At 32.5 cm, it is suddenly disappearing and further down again present. Between 37.5 to 92.5 cm it is persistently appearing in every sample ranging from 2-6 valves. Further down the core till the bottom it is generally following a reduced trend maintaining 1 or 2 valves or at places almost absent except at certain depths like 123-128 cm where 9 valves are recorded.

Another prominent species recorded is *Phlyctenophora orientalis* which is nearly 203 valves throughout the core. This also shows a definite trend down the core and is more in number from certain depth. Below 133 cm till the bottom of the core, every sample has almost 7-10 valves. From the top of the core to the depth of 27.5 cm, number of valves are below 4 in every sample and between 32.5 and 42.5, valves are not recovered. Again between 42.5 and 77.5 cm valve recovery is 4-6 in each sample and between 77.5 to 87.5 cm valves are not recorded. Though between 92.5 and 97.5 valves are slightly increasing, further below, number of valves are very low till 133 cm depth.

Other species like *Bythoceratina reticulate*, *Alocopocytherere reticulate indoaustralica*, *Bradleya plicocarinata*, *Propontocypris bengalensis*, *Bairdopilata alcyonicola* are though recorded at different depth are not in sizeable number and is not following any trend. Due importance was given to these species also to unravel the environmental significance if any for their appearance and disappearance. In general, an observable trend in the variation of ostracod species down the core is recorded only in the case of the two species namely *Phlyctenophora orientalis and Krithe* sp-1.

5.3.2 Ostracod assemblage in core GC-02

A total of 8 species have been identified from the entire core (Table 5.3.2). Species identified are *Bythoceratina reticulate*, *Alocopocytherere reticulate* *indoaustralica, Bradleya plicocarinata, Propontocypris bengalensis, Phlyctenophora orientalis, Bairdopilata alcyonicola, Xestoleberis sp and Krithe* sp-1. Out of the 293 valves recovered from the entire core, 123 valves belong to *Phlyctenophora orientalis* and 119 are *Krithe* sp-1. Species variation down the core is plotted in (Fig 5.4.2).

Krithe sp-1 is valves are encountered up to a core depth of 38 cm in all the samples and the number of valves varies between 1-5. However, no valves are recovered from the samples between the depth of 38-48 cms. Further down, number of valves are gradually increasing and a maximum of 7 valves are recorded between 83 and 88 cms. Down below upto 128 cms, number of valves recorded are fluctuating between 1-5 in different samples. Again after 153 cm, number of valves recorded are relatively high.

Phlyctenophora orientalis is recorded from most of the samples in varying numbers. Up to 38 cm, 1-4 valves are recorded from every samples. Further down till the depth of 138 cm number of valves varies between 1 to 6 with most of the samples having 3 valves. Below 133 cm up to the core bottom, 6 -10 valves are recorded in every sample.

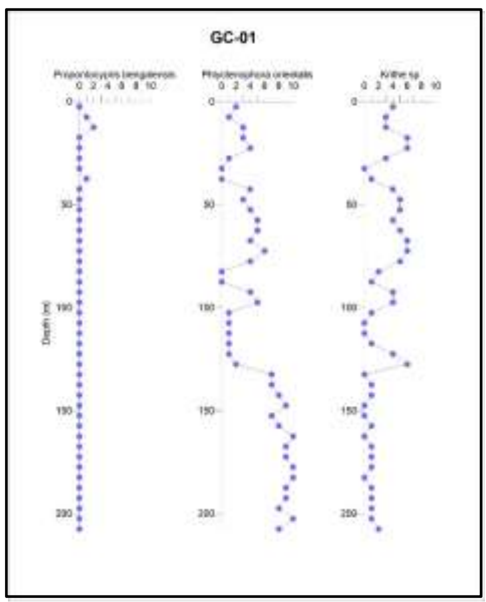


Fig 5.3.1 Down core variation in ostracods GC-01

Other species like *Bythoceratina reticulate, Bairdopilata alcyonicola and Xestoleberis* are found in all samples up to a core depth of 23 cm though in a very less number. Between 48 and 78 cms this species is recorded continuously.

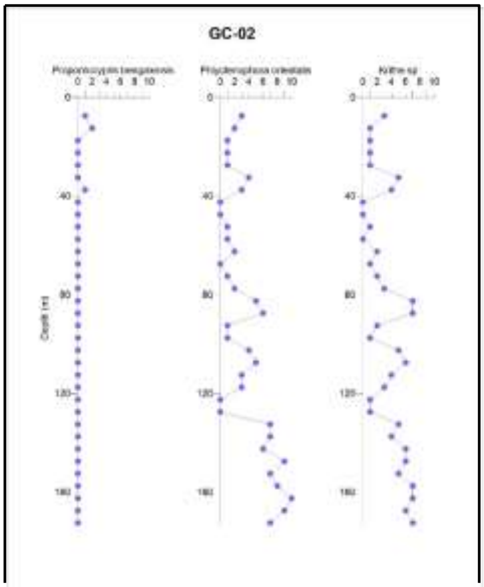


Fig 5.3.2Down core variation in ostracods GC-02

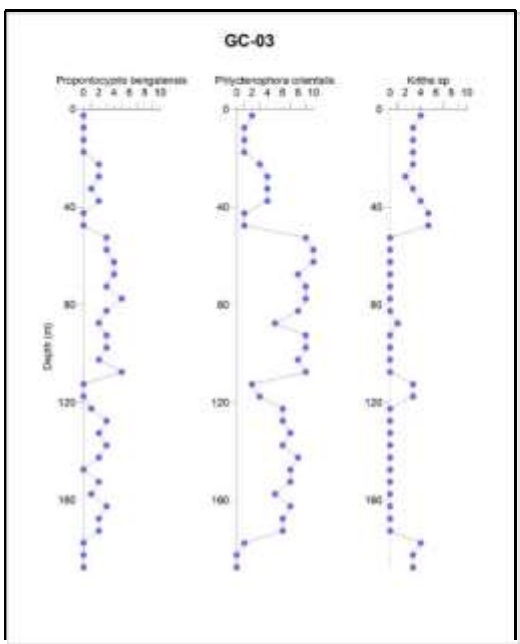


Fig 5.3.3. Down core variation in ostracods GC-03

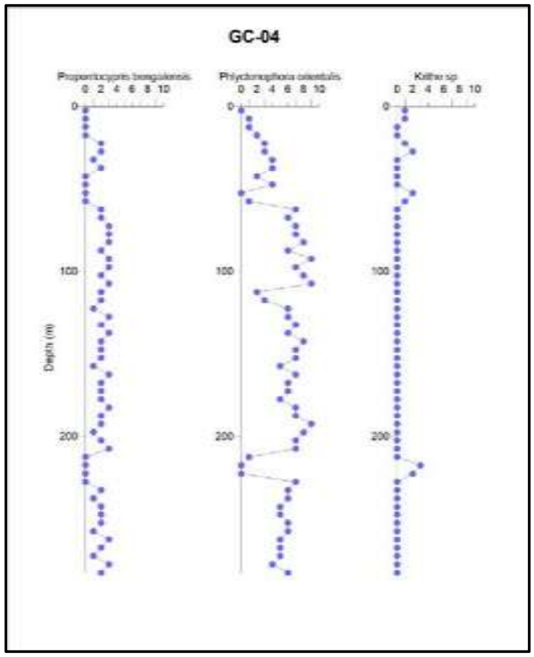


Fig 5.3.4. Down core variation of ostracods GC-04

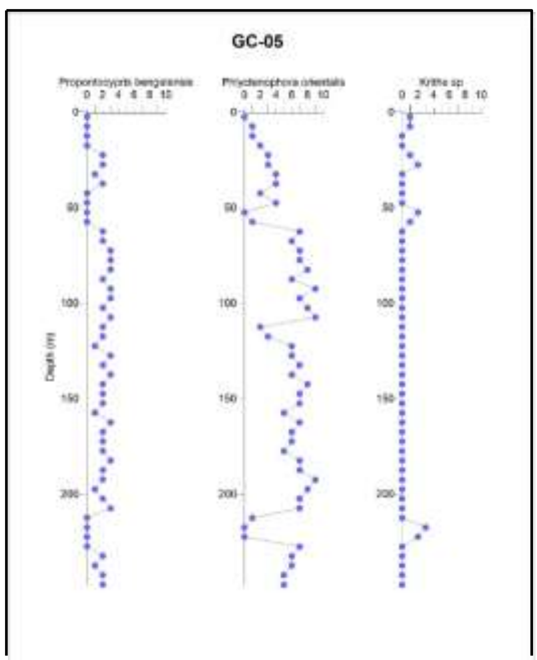


Fig 5.3.5 Down core variation of ostracods GC-05

5.3.3 Ostracods of GC-03

In this core, a total of 223 valves of ostracods belonging to 20 species have been recovered (Table 5.3.3). Maximum valves are from three species namely, *Krithe*, *Phlyctenophora orientalis* and *Propontocypris bengalensis*. A total of 90 valves are of *Phlyctenophora orientalis* whereas *Krithe* have 52 valves and 34 valves are of *Propontocypris bengalensis*. Species variation down the core is plotted in (Fig 5.3.3)

Phlyctenophora orientalis valves are recovered from every sample up to a core depth of 48 cms with number of valves ranging between 1-4 in various samples. Further down, number of valves increases steadily, reaching the maximum number of valves of 10 at the core depth of 58-63 cms. In the zone of 58- 173 cm, number of valves range between 5 to 10. No valves are recorded from the bottom of the core.

Krithe in the core is represented by three species and dominated by sp-1. A total of 52 species have been recovered from the core at different depths. Till the core depth of 53 cms, every sample contains nearly 5 valves. In many samples below, valves are nearly absent except at depths like 113-118 and 178-188, where 3-4 valves are recorded.

Propontocypris bengalensis is identified in the core at various levels. A total of 34 valves recovered from different samples of the core. No valves are recovered from the top 18 cm, between 43-48 cms, 113-118 cms and below 178 cms till the core bottom. Nearly 3-5 valves are recorded in the zones of 23-38, 53-108.

Valves of all other species are sparsely occurring in different samples at various depths without any pattern except *Bairdopilata alcyonicola* which is consistently recorded up to a depth of 58 cms though not in a sizeable number.

5.3.4 Ostracods of GC-04

From this core, 324 valves of ostracods belonging to 20 species have been recorded (Table 5.3.4). The species identified are *Hemicytheridea paiki*, *Neomonoceratina*

Iniqua, Bythoceratina reticulate, Keijella sp., *Alocopocythere reticulata indoaustralica, Bradleya (Quasibradleya) plicocarinata, Propontocypris bengalensis, Phlyctenophora orientalis, Paijenborchellina indoarabica, Miocyprideis spinulosa, Keijella reticulate, Bairdopillata alcyonicola, Krithe* sp., *Pterygocythereis* sp. *Chennaiensis, Xestoleberis* sp., *Arculocuthereis, Neocytheromorpha, Keijella karwarensis, Actinocythereis scutigera, Bythoceratina*.

Of the total valves identified,194 valves are of *Phlyctenophora orientalis* which is occurring throughout the core in varying numbers. In the zone of 0-57. 5 cm, number of valves range between 2 to 4. Below this depth, number of valves are relatively more and is ranging between 5-9 valves in various samples. However, at the depth of 218-223, no valves of this species could be recovered.

Another relatively dominant species is *Propontocypris bengalensis* which is also occurring throughout the core in varying numbers. A total of 67 valves have been recovered from various depths. In general, number of valves range between 1-3 wherever valves have been recovered though there are zones like 0-17.5 cms, 42.5-57.5 cms and 213-228 where no valves could be recovered.

In this core, Krithe is represented by three species and total Krithe is 21 valves. Other species like *Bairdopilata alcyonicola* continue to appear upto a depth of 57.5 cm though in limited numbers. Similarly, *Xestoleberis* is also appearing in the top 17.5 cm thickness of the core in a regular fashion (Fig 5.3.5).

5.3.5 Ostracods of GC-05

A total of 194 valves belonging to 19 species have been picked up from the entire core (Table 5.3.5). Maximum number of valves recovered from this core belong to the species *Propontocypris bengalensis* followed by *Phlyctenophora orientalis* and *Krithe sp*. All these three species are almost consistently appearing in every sample though not in good numbers. They are represented by one or two valves in most of the samples and at places no valves could be retrieved. In the case of *Propontocypris bengalensis*, top 18 cm of the core is devoid of any valves. Similarly, two zones, one at 43-58 cm and the other at 213-222 cm are devoid of any valves.

From this core, 37 *Krithe* valves have been recovered which are distributed almost uniformly down the core ranging between 1-2 valves except at certain depth like 73cms and between 158-163 cm where no valve could be recovered. Similarly, 40 valves of *Phlyctenophora orientalis* have been recovered which is also distributed almost uniformly throughout the core with number of valves ranging between 1-3 in each samples. However, there are some sample from depths like at the top and bottom of the core, at depths like 53 cm, 98-103, 168 cm, 183 cm, 198 cm, 208 cm, 218-228 cm no valves are recovered. A total of 56 valves of *Propontocypris bengalensis* is distributed down the core with some depths from where no valves could be recovered. They are occurring at depth ranges of 23-28 cm, 63-208 cm, 238 to the core bottom with maximum number of valves in any sample reaching to 3 (Fig 4.3.5). Another species which is maintaining some uniformity in its distribution pattern is *Bairdopilata alcyonicola* which is continuously appearing in all the samples upto a depth of 58 cm. Besides, species like *Hemicytheridea paiki Neomonoceratina iniqua, Bythoceratina reticulata. Keijella* sp. *Alocopocythere reticulata indoaustralica, Bradleya (Quasibradleya) plicocarinata, Paijenborchellina indoarabica, Miocyprideis spinulosa, Keijella reticulate, Pterygocythereis,. chennaiensis, Xestoleberis* sp., *Arculocythereis* sp., *Neocytheromorpha* sp., *Keijella karwarensis, sio*

5.4 SYSTEMATIC DESCRIPTION

In the present study, classification followed in the "Treatise on Invertebrate Palaeontology, Part Q, Arthropoda 3" (R. C. Moore & C.W. Pirat, 1961) is followed. Specimens of all the species identified and illustrated are deposited in the Marine and coastal survey division of Geological Survey of India.

Subclass **OSTRACODA** Latreille, 1802
Order **PODOCOPIDA** Sars, 1865
Suborder **PODOCOPINA** Sars, 1865
Super-family **CYTHERACEA** Baird, 1850
Family **HEMICYTHERIDAE** Puri, 1953
Genus **HEMICYTHERRIDEA** Kingma,1948
H*emicytheridea paiki*

Material: 11 open valves
Dimension: Length 0.52 mm, height 0.23mm
Remarks: Elongate shape and reticulate ornamentation are characteristic features. Originally recorded by Kingma (1948) and subsequently by Paiki.

Subclass **OSTRACODA** Latreille, 1802
Order **PODOCOPIDA** Sars, 1865
Suborder **PODOCOPINA** Sars, 1865
Super-family **CYTHERACEA** Baird, 1850
Family **SCHIZOCYTHERIDAE,** Mandalstan, 1960
Genus **NEOMONOCERATINA** Kingma,1948
Neomonoceratina Iniqua (Brady 1868)

Material: 15 open valves
Dimension: Length 0.53 mm, height 0.29mm
Remarks: Surface ornamentation is irregular and reticulate, vertical sulcus with longitudinal rib extending from anterior margin.

Family **BYTHOCYTHERIDAE** Sars,1926
Genus **BYTHOCERATINA**, Hornibrook, 1952
Bythoceratina reticulata, Bonaduce, Ciampo & Masoli, 1976

Material:24 open valves
Dimension: Length 0.47mm, height 0.27mm
Remarks: Characteristic features are longitudinal and vertical ridges with depression in the central region. Surface has sub rounded punctae.

Suborder **PODOCOPINA** Sars, 1865
Super-family **BAIRDIACEA** Sars, 1866
Family **BARDIDAE,** Sars,1888
Genus **BAIRDOPPILATA** Coryell, Sample and Fields, 1935
Bairdopilata alcyonicola, Maddocks, 1969

Material: 13 open valves
Dimension: Length 0.52mm, Height 0.33mm
Remarks: Valves are elongate and fusiform, dorsal part broadly arched, smooth surface, punctate, muscle scars of discrete spots.

Suborder **PODOCOPINA** Sars, 1865
Super-family **CYTHERACEA** Baird, 1850
Family **SCHIZOCYTHERIDAE,** Mandalstan, 1960
Genus **PAIJENBORCHELLINA** Kuzentsova,1957
Paijenborchellina indoarabica, Jain 1981

Material: 12 valves
Dimension: Length 0.57mm, height 0.32mm
Remarks: Long caudal process near posterior margin is the characteristic feature, vertical sulcus at middle of the valve, originally reported by Jain 1981 from Indian waters.

Family **BYTHOCYTHERIDAE,** Sars,1866
Genus **BYTHOCERATINA**, Hornibrook, 1952
Bythoceratina sp.

Material: 17 valves
Dimension: Length 0.47mm, height 0.27mm
Remarks: Characteristic features are longitudinal and vertical ridges with depression in the central region. Surface has sub rounded punctae.

Family **TRACHYLEBERIDIDAE**, Sylvester-Brady, 1948
Sub family **TRACHYLEBERIDINAE**, Sylvester-Brady, 1948
Genus **ACTINICYTHEREIS**, Puri, 1953
Actinocythereis scutigera (Brady,1868)

Material: 11 open valves
Dimension: Length 0.83mm, height 0.51mm
Remarks: Reported from many regions across the world. Spinose and strong surface ornamentation is the characteristic feature of the species.

Sub family **PTERIGOCYTHERINAE**, Puri, 1957
Genus **KEIJELLA,** Rugieri, 1967
Keijella karwarensis Bhatia and Kumar, 1979

Material: 06 open valves
Dimension: Length 0.55 mm, height 0.29mm
Remarks: Characterized by its smooth surface, vestibulum in the anterior and posterior regions.

Family **XESTOLEBERIDIDAE** Sars,1928
Genus **XESTOLEBERIS** Sars,1866
Xestoleberis sp.

Material:24 open valves
Dimension: Length 0.47mm, height 0.32mm
Remarks: Smooth surface and ovate valves are the distinguishing feature, reported from various locations in the globe.

Super family **CYPRIDACEA** Baird,1845F
Family **PORTOCYPRIDAE**, Muller,1894
Genus **PROPNTOCYPRIS** Sylvester-Bradley, 1947
Propontocypris bengalensis, Maddocks, 1969

Material: 225 open valves
Dimension: Length 0.56mm, height 0.28mm
Remarks: Smooth elongate surface, with near absence of any ornamentations.

Super family **CYPRIDACEA** Baird,1845
Family **PARACYPRIDIDAE**, Sars,1923
Genus **PHLYCTENOPHORA** Brady, 1880

Material: 488 open valves
Dimension: Length 0.88 mm, height 0.44mm
Remarks: Elongate valves with smooth surfaces, muscle scars slightly visible on the surface, dorsal margin convex.

Super family **CYTHERACEA** Baird,1850
Family **CYTHERIDAEIDAE**, Sars,1925
Genus **Krithe** Brady, 1874
Krithe Sp-1

Material: 117 open valves.
Dimension: Length 0. 77mm, height 0.44mm
Remarks: Elongate valves with smooth shell surface, Muscle scar visible in the outer valve, elongate posterior margin.

Krithe Sp-2

Material: 47 open valves.

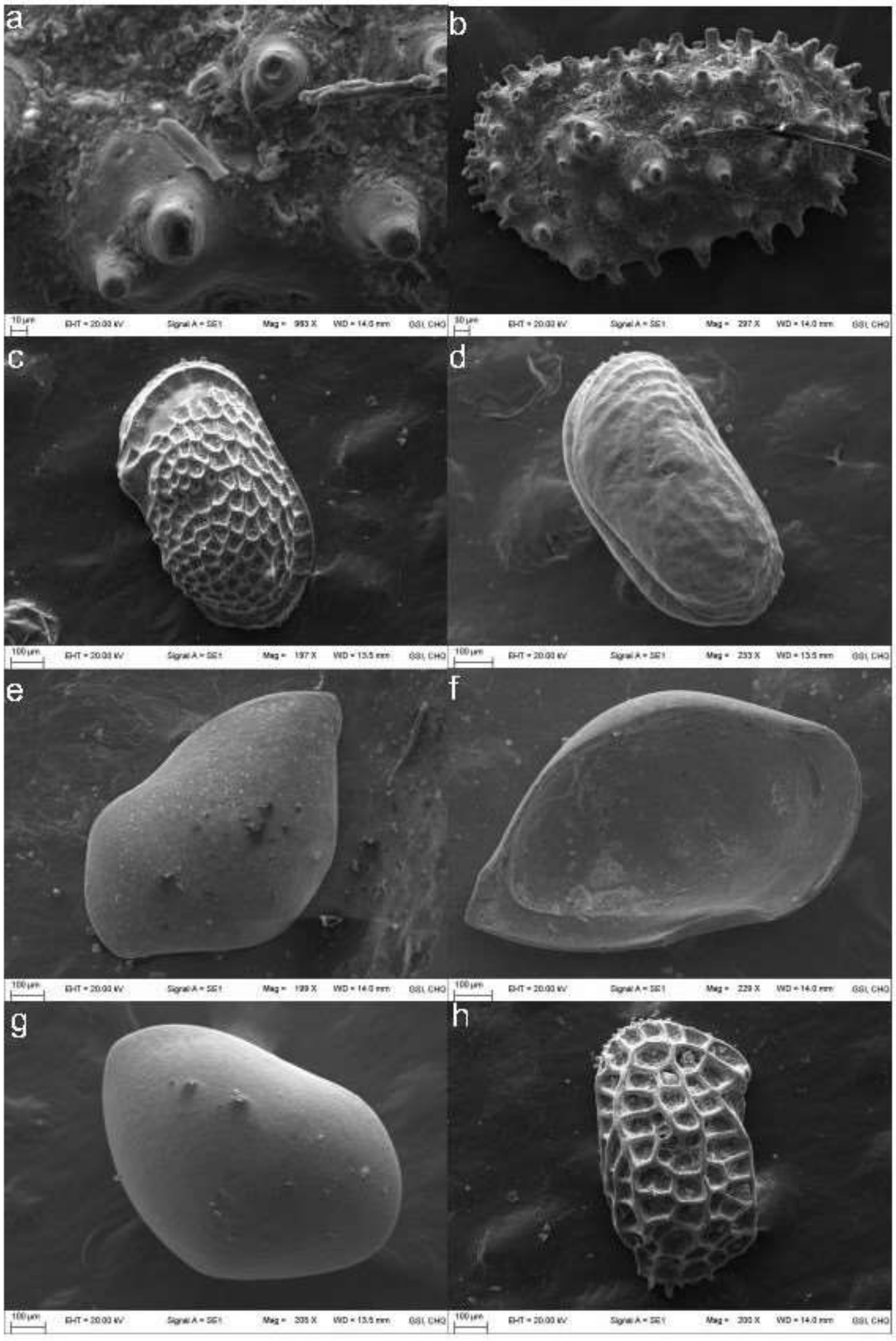


Plate 5.1.: a) *Actinocytheris scutigera* Spike, b) *Actinocytheris scutigera* c) *Alocopocythere reticulata indoaustralica*, d) *Arculacythereis, Neocytheromorpha sp.* e) *Bairdoppilata alcyonicola (E.View),* f) *Bairdoppilata alcyonicola (I.View)* g) *Bairdoppilata alcyonicola*, h) *Bradleya (Quasibradleya) plicocarinata*

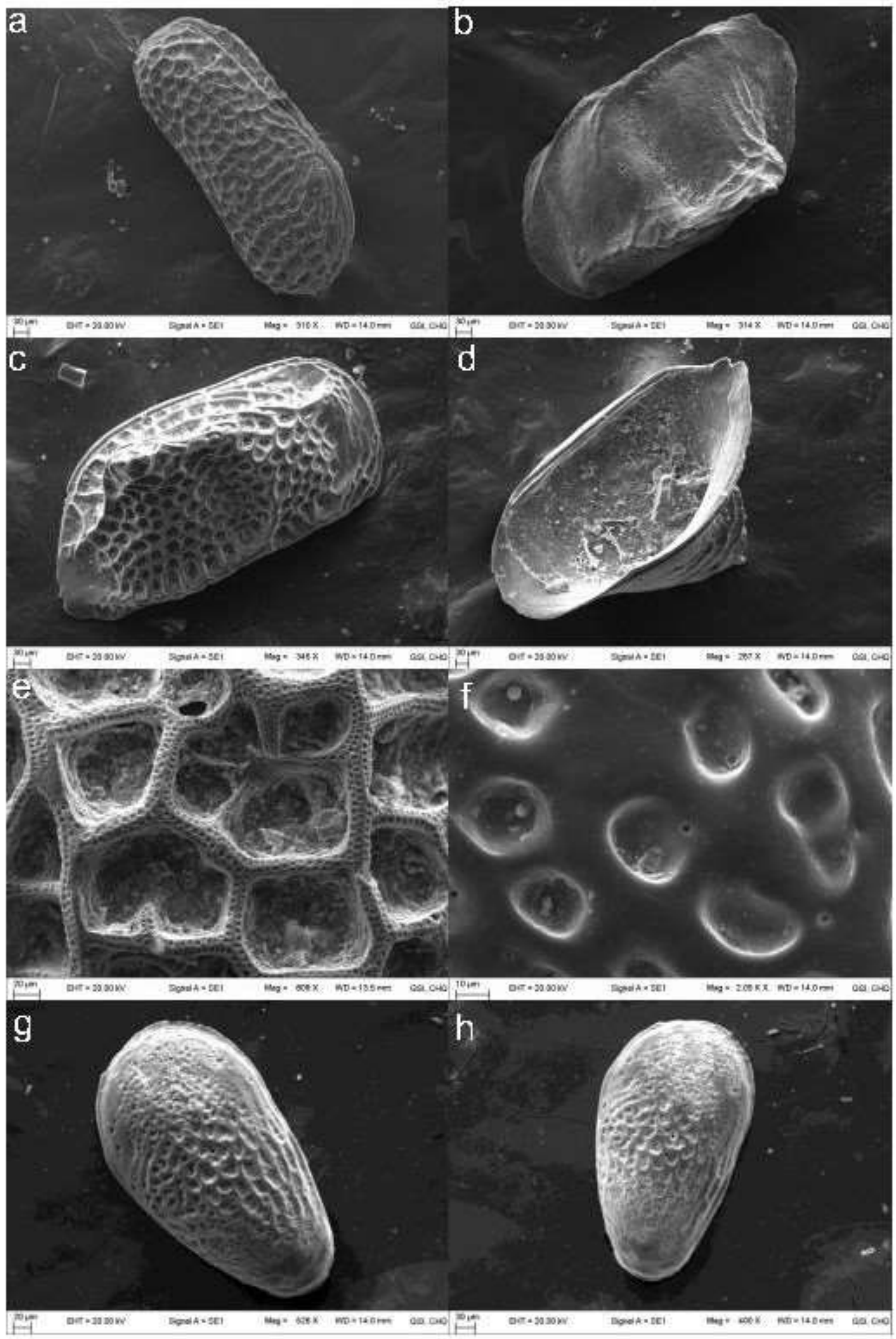


Plate 5.2.: a) *Hemicytheridea* sp, b) *Bythoceratina mandviensis* c) *Bythoceratina reticulata (E View)* d) *Bythoceratina reticulata(I.view)* e) enlargement of reticulation , f) enlargement of reticulation g) *Hemicytheridea paiki*, h) *Hemicytheridea paiki*

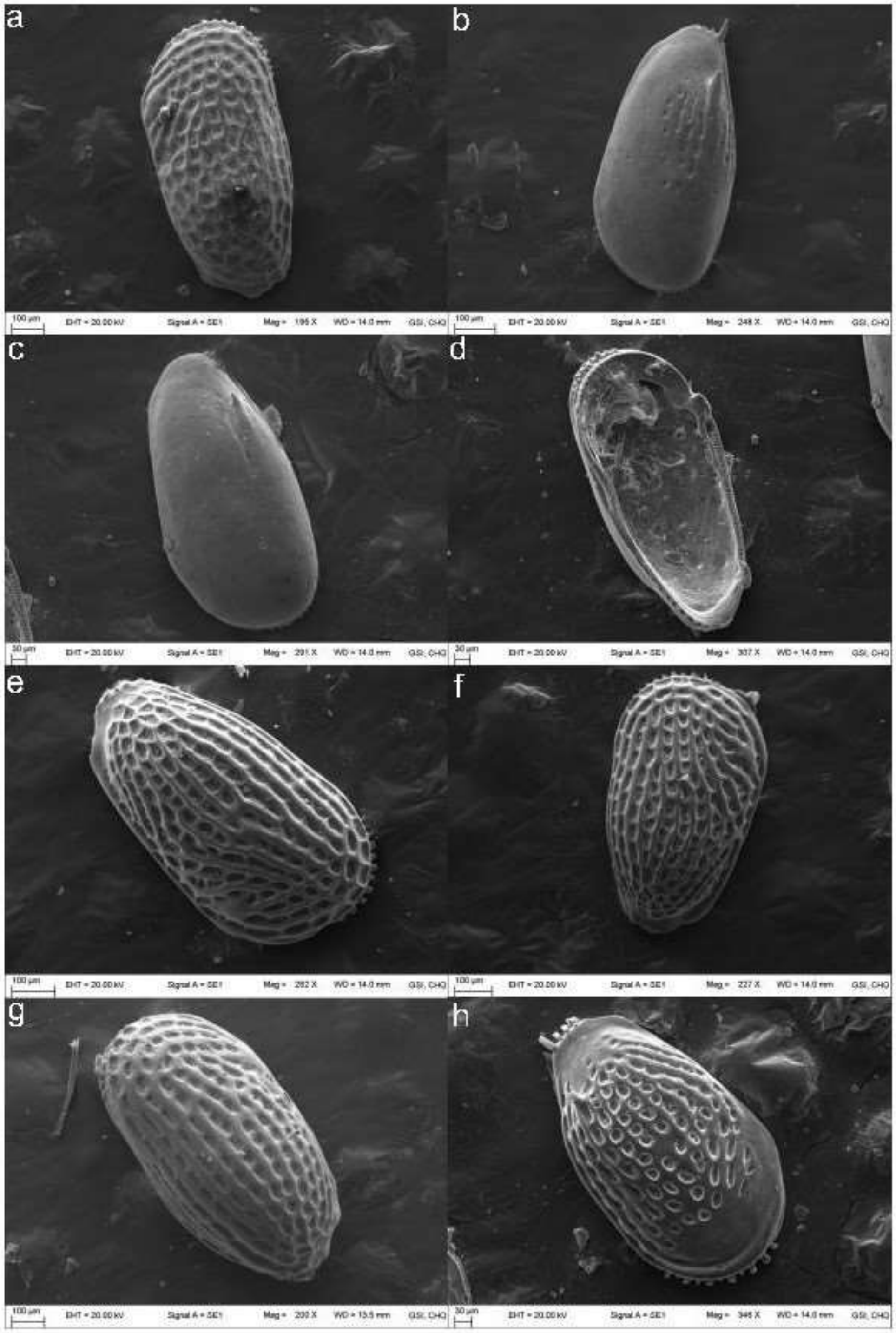


Plate 5.3.: a) *Keilella* sp(Juvenile), b) *Keijella karwarensis(E.View)* c) *Keijella karwarensis(E.View)* d) *Keijella karwarensis(I.view)* e) *Keijella reticulata,* f) *Keijella reticulata* g) *Keijella reticulata,* h) *Keijella* sp.

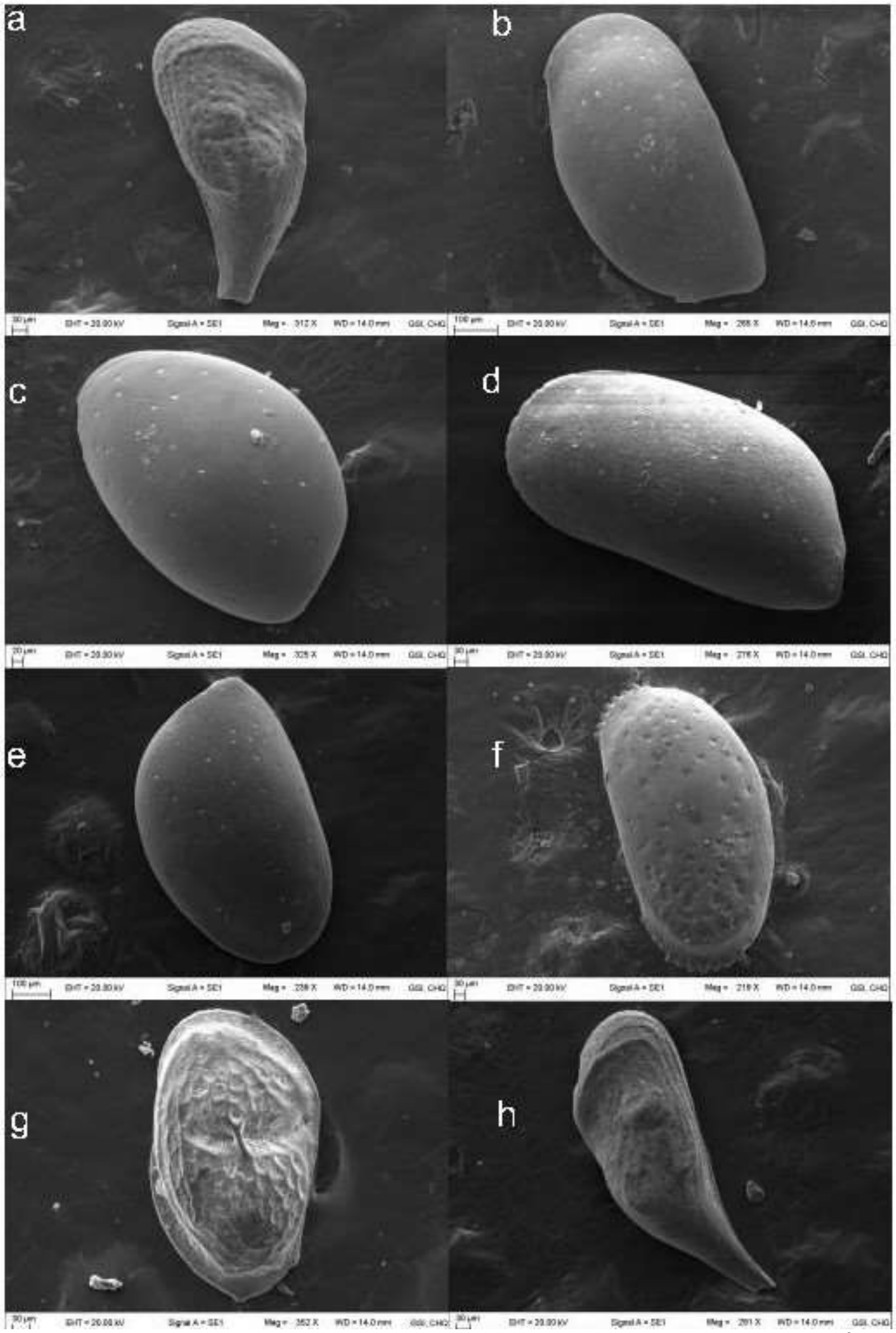


Plate 5.4.: a *Paijenborchellina indoarabica* , b) *Krithe sp* c) *Krithe sp* d) *Krithe sp* e Krithe sp, f) *Miocyprideis spinulosa* g) *Neomonoceratina iniqua*, h) *Paijenborchellina indoarabica*

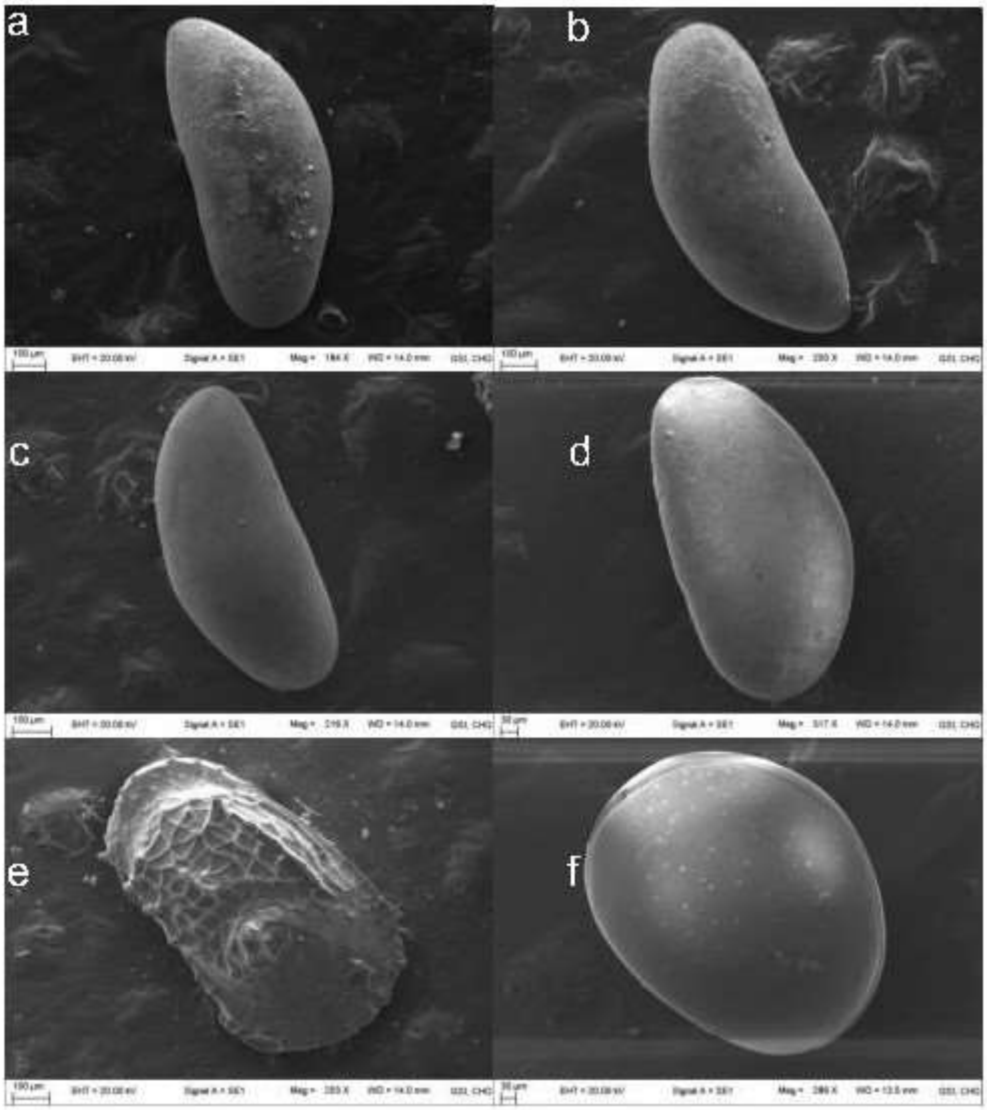


Plate 5.5.: a) *Phlyctenophora orientalis* , b) *Phlyctenophora orientalis* c) *Proponocypris* sp d) *Propontocypris bengalensis* e) *Pterygocythereis chennaiensis*, f) *Xestoleberis* sp.

Table 5.3.1 distribution of ostracods in CC-01									
Sample	**Depth (cm)**	***Bythoceratina reticulata***	***Alocopocythere reticulata***	***Bradleya (Quasibradleya)***	***Propontocypris bengalensis***	***Phlyctenophora orientalis***	***Miocyprideis spinulosa***	***Bairdoppilata alcyonicola***	***Krithe* sp**
GC-01/1	2.5	x		x	0	2		x	4
GC-01/2	7.5	x			1	1			3
GC-01/3	12.5	x	x		2	3			3
GC-01/4	17.5	x			0	3		x	6
GC-01/5	22.5	x			0	4			6
GC-01/6	27.5				0	1			3
GC-01/7	32.5		x		0	0		x	0
GC-01/8	37.5				1	0			1
GC-01/9	42.5		x		0	4		x	4
GC-01/10	47.5	x			0	3		x	5
GC-01/11	52.5	x			0	4		x	5
GC-01/12	57.5	x			0	5			4
GC-01/13	62.5	x			0	5		x	5
GC-01/14	67.5	x			0	4			6
GC-01/15	72.5	x			0	6			6
GC-01/16	77.5	x			0	4		x	5
GC-01/17	82.5				0	0			2
GC-01/18	87.5				0	0			1
GC-01/19	92.5				0	4		x	4
GC-01/20	97.5	x			0	5		x	4
GC-01/21	102.5				0	1			1
GC-01/22	107.5				0	1			0
GC-01/23	112.5				0	1		x	0
GC-01/24	117.5				0	1			1
GC-01/25	122.5				0	1		x	4
GC-01/26	127.5	x			0	2			6
GC-01/27	132.5				0	7			0
GC-01/28	137.5				0	7			1
GC-01/29	142.5				0	8			1

GC-01/30	147.5				0	9			0
GC-01/31	152.5				0	7			0
GC-01/32	157.5				0	8			1
GC-01/33	162.5				0	10		x	0
GC-01/34	167.5				0	9			1
GC-01/35	172.5				0	9			1
GC-01/36	177.5				0	10			1
GC-01/37	182.5				0	10			0
GC-01/38	187.5				0	9		x	1
GC-01/39	192.5				0	9			1
GC-01/40	197.5				0	8			1
GC-01/41	202.5				0	10			1
GC-01/42	207.5				0	8			2

Table 5.3.2 Distribution of ostracods in GC-02											
Sample	**Depth (cm)**	***Bythoceratina reticulata***	***Alocopocythere reticulata indoaustralica***	***Bradleya (Quasibradleya) plicocarinata***	***Propontocypris bengalensis***	***Phlyctenophora orientalis***	***Paijenborchellina indoarabica***	***Bairdoppilata alcyonicola***	***Krithe* sp**	***Pterygocythereis sp. chennaiensis***	***Xestoleberis* sp**
GC-02/19	92.5				0	1		x	2		x
GC-02/20	97.5	x			0	1			1		x
GC-02/21	103				0	4			5		
GC-02/22	108				0	5			6		
GC-02/23	113				0	3			4		
GC-02/24	118				0	3			3		
GC-02/25	123				0	0			1		x
GC-02/26	128	x			0	0			1		x
GC-02/27	133				0	7			5		
GC-02/28	138				0	7			4		
GC-02/29	143				0	6			6		
GC-02/30	148				0	9			6		
GC-02/31	153				0	7			5		
GC-02/32	158				0	8			7		
GC-02/33	163				0	10			7		
GC-02/34	168				0	9			6		
GC-02/35	173				0	7			7		

Table 5.3.3 Distribution of ostracods in GC-03

Sample	Depth (cm)	*Hemicytheridea paiki*	*Neomonoceratina iniqua*	*Bythoceratina reticulata*	*Keijella sp*	*Bradleya (Quasibradleya) plicocarinata*	*Propontocypris bengalensis*	*Phlyctenophora orientalis*	*Paijenborchellina indoarabica*	*Miocyprideis spinulosa*	*Keijella reticulata*	*Bairdoppilata alcyonicola*	*Krithe sp*	*Pterygocythereis sp. chennaiensis*	*Xestoleberis sp*	*Arculacythereis/?Neocytheromorpha sp*	*Actinocythereis scutigera*
GC-03/1	2.5						0	2				x	4		x		
GC-03/2	7.5						0	1	x			x	3		x		
GC-03/3	12.5						0	1			x	x	3		x		
GC-03/4	17.5				x	x	0	1				x	3		x		
GC-03/5	22.5						2	3				x	3				
GC-03/6	27.5						2	4		x		x	2				x
GC-03/7	32.5	x	x			x	1	4				x	3	x			
GC-03/8	37.5						2	4			x	x	4				
GC-03/9	42.5				x		0	1				x	5				
GC-03/10	47.5						0	1				x	5		x		
GC-03/11	52.5						3	9				x	0		x		
GC-03/12	57.5						3	10				x	0				
GC-03/13	62.5						4	10					0				
GC-03/14	67.5				x		4	8					0				
GC-03/15	72.5						3	9			x		0			x	
GC-03/16	77.5			x			5	9					0				
GC-03/17	82.5						3	8					0				
GC-03/18	87.5						2	5					1				
GC-03/19	92.5						3	9					0	x			
GC-03/20	97.5						3	9					0				
GC-03/21	103				x		2	8	x				0				
GC-03/22	108						5	9					0				
GC-03/23	113						0	2				x	3				
GC-03/24	118			x			0	3				x	3		x		
GC-03/25	123						1	6					0		x		
GC-03/26	128						3	6					0				

GC-03/27	133						2	7					0				
GC-03/28	138						3	6					0				
GC-03/29	143						2	8					0				
GC-03/30	148						0	7					0				
GC-03/31	153						2	7					0				
GC-03/32	158						1	5					0				
GC-03/33	163						3	7					0				
GC-03/34	168						2	6					0				
GC-03/35	173						2	6					0				
GC-03/36	178						0	1				x	4		x		
GC-03/37	183						0	0				x	3		x		
GC-03/38	188						0	0				x	3		x		

Table 5.3.4 Distribution of ostracods in GC-04																			
Sample	**Depth (cm)**	***Hemicytheridea paiki***	***Neomonoceratina iniqua***	***Bythoceratina reticulata***	***Keijella sp***	***Alocopocythere reticulata indoaustralica***	***Bradleya (Quasibradleya) plicocarinata***	***Propontocypris bengalensis***	***Phlyctenophora orientalis***	***Paijenborchellina indoarabica***	***Miocyprideis spinulosa***	***Keijella reticulata***	***Bairdoppilata alcyonicola***	***Krithe sp***	***Pterygocythereis sp. chennaiensis***	***Xestoleberis sp***	***Arculacythereis/?Neocytheromorpha sp***	***Actinocythereis scutigera***
GC-04/1	2.5							0	0				x	1		x		
GC-04/2	7.5							0	1	x			x	1		x		
GC-04/3	12.5							0	1			x	x	0		x		
GC-04/4	17.5				x		x	0	2				x	0		x		
GC-04/5	22.5							2	3				x	1				
GC-04/6	27.5							2	3		x		x	2				x
GC-04/7	32.5	x	x				x	1	4				x	0	x			
GC-04/8	37.5							2	4			x	x	0				
GC-04/9	42.5				x			0	2				x	0				
GC-04/10	47.5							0	4				x	0		x		
GC-04/11	52.5							0	0				x	2		x		
GC-04/12	57.5					x		0	1				x	1				
GC-04/13	62.5							2	7					0				
GC-04/14	67.5				x			2	6					0				
GC-04/15	72.5							3	7			x		0			x	
GC-04/16	77.5			x				3	7					0				
GC-04/17	82.5							3	8					0				
GC-04/18	87.5							2	6					0				
GC-04/19	92.5							3	9			x		0	x			
GC-04/20	97.5							3	7					0				
GC-04/21	102.5				x			2	8	x				0				
GC-04/22	107.5							3	9					0				
GC-04/23	112.5							2	2				x	0				
GC-04/24	117.5			x				2	3				x	0		x		
GC-04/25	122.5							1	6					0		x		

GC-04/26	127.5							3	6					0				
GC-04/27	132.5							2	7					0				
GC-04/28	137.5							3	6		x			0				
GC-04/29	142.5							2	8					0				
GC-04/30	147.5							2	7					0				x
GC-04/31	152.5		x					2	7					0				
GC-04/32	157.5							1	5					0				
GC-04/33	162.5							3	7					0				
GC-04/34	167.5					x		2	6					0				
GC-04/35	172.5							2	6					0				
GC-04/36	177.5							2	5				x	0				
GC-04/37	182.5							3	7				x	0				
GC-04/38	187.5							2	7				x	0				
GC-04/39	192.5							2	9					0				
GC-04/40	197.5							1	8					0				x
GC-04/41	202.5							2	7					0				
GC-04/42	207.5							3	7					0				
GC-04/43	212.5							0	1					0				
GC-04/44	217.5							0	0					3		x		
GC-04/45	222.5							0	0					2				
GC-04/46	227.5							0	7					0				
GC-04/47	232.5							2	6					0				
GC-04/48	237.5							1	6					0				
GC-04/49	242.5							2	5					0				
GC-04/50	247.5		x					2	5					0				
GC-04/51	252.5							2	6					0				
GC-04/52	257.5							1	6					0			x	
GC-04/53	262.5							3	5					0				
GC-04/54	267.5							2	5		x			0				
GC-04/55	272.5							1	5					0				
GC-04/56	277.5							3	4					0				
GC-04/57	282.5							2	6					0				

Table 5.3.5 Distribution of ostracods in GC-05																		
Sample	**Depth (cm)**	***Hemicytheridea paiki***	***Neomonoceratina iniqua***	***Bythoceratina reticulata***	***Keijella* sp**	***Alocopocythere reticulata indoaustralica***	***Bradleya (Quasibradleya) plicocarinata***	***Propontocypris bengalensis***	***Phlyctenophora orientalis***	***Paijenborchellina indoarabica***	***Miocyprideis spinulosa***	***Keijella reticulata***	***Bairdoppilata alcyonicola***	***Krithe* sp**	***Pterygocythereis* sp. *chennaiensis***	***Xestoleberis* sp**	***Arculacythereis/?Neocytheromorpha***	***Actinocythereis scutigera***
GC-05/1	2.5							0	0				x	1		x		
GC-05/2	7.5							0	1	x			x	1		x		
GC-05/3	12.5							0	1			x	x	2		x		
GC-05/4	17.5				x		x	0	2				x	1		x		
GC-05/5	22.5							2	1				x	1				
GC-05/6	27.5							2	2		x		x	2				x
GC-05/7	32.5	x	x				x	1	2				x	1	x			
GC-05/8	37.5							2	1			x	x	1				
GC-05/9	42.5				x			0	1				x	2				
GC-05/10	47.5							0	2				x	1		x		
GC-05/11	52.5			x				0	0				x	2		x		
GC-05/12	57.5					x		0	1				x	1				
GC-05/13	62.5							2	2					1				
GC-05/14	67.5				x			2	1					1				
GC-05/15	72.5							3	3			x		0			x	
GC-05/16	77.5			x				3	1					1				
GC-05/17	82.5							3	2					1				
GC-05/18	87.5							2	1					1				
GC-05/19	92.5							3	1			x		1	x			
GC-05/20	97.5							3	0					1				
GC-05/21	102.5				x			2	0	x				1				
GC-05/22	107.5							3	1					1				
GC-05/23	112.5							2	3				x	1				
GC-05/24	117.5			x				2	3				x	2		x		
GC-05/25	122.5							1	1					1		x		

GC-05/26	127.5							3	0					1				
GC-05/27	132.5							2	0					1				
GC-05/28	137.5							3	1		x			1				
GC-05/29	142.5							2	1					1				
GC-05/30	147.5							2	1					2				x
GC-05/31	152.5		x					2	2					2				
GC-05/32	157.5							1	1		x			0				
GC-05/33	162.5							3	1					0				
GC-05/34	167.5					x		2	0					2				
GC-05/35	172.5							2	1					1				
GC-05/36	177.5							2	1				x	1		x		
GC-05/37	182.5							3	0				x	1				
GC-05/38	187.5		x					2	1				x	2				
GC-05/39	192.5							2	1					2				
GC-05/40	197.5							1	0					1				x
GC-05/41	202.5							2	1					2				
GC-05/42	207.5				x			3	0					1				
GC-05/43	212.5							0	1					2				
GC-05/44	217.5							0	0					1		x		
GC-05/45	222.5							0	0		x			2				
GC-05/46	227.5							0	0					2				
GC-05/47	232.5					x		2	1					1				
GC-05/48	237.5							1	0					1				
GC-05/49	242.5							2	1					2				
GC-05/50	247.5		x					2	0					1				

Chapter-6

DISCUSSION AND CONCLUSION

6.1. Discussion

Grain size analysis is widely used as a sedimentological tool to understand the dynamic conditions of any aquatic environment. Grain size distribution and its properties are widely used to understand the aquatic settings and their ecosystems. The distribution of sediments with varying sizes throw light about the hydrodynamics as well as the depositional environment. In general, coarser sediments indicate a high energy condition whereas the finer sediments are normally deposited in a calmer environment. Size analyses of all the core s samples were carried out to understand the variation of sediment type down the core. In GC-01, the gradual increase of sand percentage up to 2.5 m indicate that sediments are deposited in a relatively higher energy conditions. Down below this depth, sand percentage is decreasing and maintaining a minimum percentage till the core bottom. This could possibly be due to the gradual deepening of the sea in that area. A close look at the variation diagram of silt and clay indicate that there is an inverse relationship between the sand and other finer materials. This clearly shows that distinct environments of deposition prevailed in the area during the geological past. The appearance of clay dominated pockets in between the otherwise silt dominated sequence of deposition may be an indication of the reduction in the energy of transporting medium or the deepening of the sea due to the local sea level changes. Geochemical analyses of marine sediments are an important tool in understanding the role of various environmental process in the control of sediment distribution (Sruthi et al., 2014). The information about the distribution of various proxies like clay minerals and elements are very useful in deciphering the environmental conditions. Sediments are a career as well as a source of different metals in the marine systems. Trace elements play a very crucial role in the oxygen minimum zones (OMZ). The correlation of geochemical data with grain size data indicate that distinct environmental events influenced the depositional history of sediments. Though the Carbonate Compensation Depth (CCD) of Arabian Sea is generally perceived as below 3500m, this sample shows that CCD is at a deeper depth. The higher rate of CaO than other oxides indicate that the area is biologically a high productive zone. The major oxides in the core are in the decreasing order of $CaO>SiO_2>Al_2O_3>Fe_2O_3>MgO>K_2O>TiO_2>MnO$. The trace elements are in the decreasing order of Zn>Ni>Cu>Cr>Co>Pb.

The ostracods in the core are mainly represented by three species namely *Krithe* sp-1, *Phlyctenophora orientalis and Propontocypris bengalensis.* These three species are consistently appearing down the core indicating that they can adapt to a deep sea environment and their tolerance to more than 3000m water depth. Down core variation also indicate that these species have some substratum affinity. While *Krthe* sp-1 and *Phlyctenophora orientalis* are having positive correlation with finer sediments like clay and silt, *Propontocypris bengalensis is showing the affinity to the coarser sediments.* This cannot be the only criteria for their presence in these sediments; the available data and their correlation indicate such an affinity. As the sediments in the core are mainly muddy with variation in the clay and sand content, it could be deduced that While *Krithe* Sp-1 is showing a positive affinity to finer clayey, the other two species *Phlyctenophora orientalis* and *Propontocypris bengalensis* have a positive affinity to silty substratum. This is more evident towards the bottom of the core where sediments are mainly silty in nature especially below the 135 cm. The down core variation curve below 135 cm clearly indicate that the increase in the number of valves of *Phlyctenophora orientalis* could be due to the predominance of silty substratum to which this species has some affinity. A review of other proxies like geochemistry and total organic carbon reveal that no marked correlation could be established with the occurrence and distribution of ostracods down the core.

In the core GC-02, various proxies down the core are showing similar trend like GC-01. The core is mainly composed of silty sediments with variations in clay content at places. Sand percentage is relatively less and is not showing any significant fluctuations indicating that the depositional environment was more or less calm. It also indicates that deepening of the sea floor was consistent throughout the depositional history of the sediment column. The dominance of clay over silt between 0-15 and 40-60 cms may be due to the sudden deepening of the sea floor. Geochemical data like major oxides and trace elements also do not show any significant trend different from GC-01. The major oxides are in the decreasing trend of $CaO>SiO_2>Al_2O_3>Fe_2O_3>MgO>K_2O>TiO_2>MnO$. The trace elements are in the decreasing order of Zn>Ni>Cu>Cr>Co>Pb.

Like in the earlier core GC-01, here also the relative abundance of ostracods is confined to three species namely *Krithe* sp-1, *Phlyctenophora orientalis and Propontocypris bengalensis.* These three species though not very abundant when compared to total biogenous constituent of the core clearly have some numerical dominance over other ostracod species and are maintaining some regularity in their occurrence down the core. Their regular appearance down the core indicate that the depositional environment including the bathymetry has some control over their distribution and down core variation. It is also an affirmation that they can adapt to a deep sea environment and tolerate more than 3000m water depth. Down core variation also indicate that these species have some substratum affinity. While *Krithe* sp-1 and *Phlyctenophora orientalis* are having positive correlation with finer sediments like clay and silt, *Propontocypris bengalensis* is showing the affinity to the coarser sediments. Though this cannot be the only criteria for their presence in these sediments, the available data and their correlation indicate such an affinity. As the sediments in the core are mainly muddy with variation in the clay and sand content, it could be deduced that while *Krithe* sp-1 is showing a positive affinity to finer clayey, the other two species *Phlyctenophora orientalis* and *Propontocypris bengalensis* have a positive affinity to silty substratum. The spike in the down core diagram of *Phlyctenophora orientalis* could be due to the predominance of silty substratum to which this species has some affinity. As such, other proxies like geochemistry and total organic carbon do not reveal any correlation pushing us to infer that controlling factors out of the studied proxies for the distribution of this species could be the bathymetry as well as type of substrate. As the other species *Propontocypris bengalensis* which was relatively more dominant in the earlier core is showing a declining g trend in this core, a generalization will be an unscientific approach. However, a comparison of these two cores indicates that both are deposited in an identical environment and the proxies are not showing much difference and there is a near similarity in the distribution of ostracods.

In GC-03, grain size analysis data show that sand content is very less compared to silt and clay. Though the percentage of sand in the core is very low, fluctuation observed in the core may be due to the occasional turbidity events. Sediment variation down the core indicates that upto 42.5 cm, Sediment type here is a mix up of clay and silt. Further down, Silt is the dominant sediment type with occasional clay pockets indicating that depositional environment in general is very calm favouring a deep sea condition. Geochemical data in this core however is drastically different from what has been observed in the earlier cores with respect to CaO and SiO_2. The entire core is having an SiO_2 domination over other oxides. Major oxides are in the decreasing trend of SiO_2> CaO> Al_2O_3> Fe_2O_3> MgO> K_2O> Na_2O> TiO_2> MnO. The trace elements are in the decreasing order of Zn> Cu >Cr> Ni> Pb> Co.

Relative abundance of ostracods in the core shows that three species are dominant over other species out of which valves *Phlyctenophora orientalis* is more than *Krithe* and *Proponocypris bengalensis.* The relative abundance of this species is increasing below 50 cms and is maintaining the trend till the bottom of the core with exceptions at around 115 cm and towards the bottom of the core. *Krithe* sp is more at top than bottom though number of valves are relatively lower than the other two species in each samples. Number of valves of *Propontocypris bengalensis* is fluctuating throughout the core without any trend. Correlation of grain size data with ostracod species abundance indicate that *Phlyctenophora orientalis* and *Krithe* are showing a positive correlation with sediments down the core. *Phlyctenophora orientalis* is showing strong positive correlation to the silty sediment indicating that this species has a strong affinity to silty substrate. The sharp reduction in the down core variation diagram corresponding to the down core variation diagram of silt percentage in the core throws light to this species versus substrate relationship. *Krithe* sp-1 though relatively less abundant than *Phlyctenophora orientalis* is also showing some substrate affinity by marginal increase in the number of valves wherever clay percentage in the sediment goes on the higher side. *Propontocypris bengalensis* is relatively less abundant than the other two species in this core. However, an affinity towards silty substratum is deducible from the data. In core GC-04 and GC-05 trend almost similar indicating that these three species have consistently appearing in deeper marine environments. The substratum affinity of the species listed are similar to the earlier core samples.

A comparative study of all the 5 cores indicate that same ostracod species are distributed in the deep marine environments wherever they have a favourable substrate. Location of core samples based on the bathymetry contour indicate that GC-01 &GC-02 belongs to a particular geomorphology whereas GC-03, 04 & 05 belong to another geomorphic set up. GC-01&02 appears to be on a ridge whereas 03, 04 & 05 are falling in a deeper basin like geomorphic unit. This difference is discernible in the chemical data also where CaO is dominant over the SiO_2 in GC-01 and GC-02. However, this trend is reversed in GC-03, 04 & 05 by increased SiO_2 content over CaO. In 03, 04 and 05 the SiO_2 increase may be due to the terrestrial supply of materials brought by the turbidity currents. The ridges might have prevented the sediments getting deposited in GC-01 &02. As Arabian Sea is known for the aerosols as well as the strong monsoon rainfall, SiO_2 in the deeper samples must have been due to the mixing up of sediments. The extension of lower Indus fan to almost near to these samples locations might also have contributed for the SiO_2 domination (Shareef et al., 2015). However, it is noteworthy that these changes in the chemical composition of the sediments have not affected the variations of the ostracods temporally as well as spatially. The inconsistent appearance of shallow water ostracods like *Keijella karwarensis, Neomonoceratina* sp., *Keijella reticulata, Hemicytheridae* sp. etc and the inner shelf forms like *Xestoleberis* sp. indicate that lot of sediment mix has happened in the sample locations especially in the near Indus fan samples. Besides, some of the clay mineralogy data suggest that the age of the sediments go beyond the Last Glacial

Maximum (Das et al., 2013).

6.2. Conclusion

Based on the detailed study of 5 core samples collected from more than 3500 m water depth off Lakshadweep, an attempt was made to find out the distribution pattern of ostracod in the deeper sediments. This was attempted as similar data from similar location was not available as on date. The study reveals the following:

Distribution of ostracods is very sparse in the study area. Twenty species of ostracods are recorded from core samples belonging to 17 genera. More than 90% of the biogenous material is composed of planktonic foraminifera and remaining are benthic foraminifera and ostracods.

Ostracod numbers are very marginal in all the depths of the core samples and are preserved as valves. Only three species *Phlyctenophora orientalis, Krithe* sp-1 and *Propontocyperis bengalensis* are showing the consistent distribution in all the cores.

Distribution of these species seems to be controlled by bathymetry as well as substrate. As the study area is a deep water environment, species diversity and density is very less. Only those species having tolerance to deep sea environment are occurring here. The correlation of species to different sediment indicate affinity of ostracod species to substrate.

Despite being a deep sea condition, the area appears to be a high productive zone, which has not favoured the diversity and density of ostracod species.

Changes in the chemical parameters has not affected the distribution of ostracods.

Turbidity and other ocean current circulation has brought many species from the inner-shore. However, at places especially in the non-disturbed areas, these indicate a possible sea level fluctuation indicating variation in the palaeo-climate.

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