Chapter 6

GRAIN SIZE ANALYSIS AND TEXTURAL CLASSIFICATION

Sediment texture refers to the proportions of sand, silt and clay or the proportion of size fraction below 2000 micrometers (2mm) in a unit mass of sediment (Ivara, 1999). Texture also gives a clear picture of size, shape and mutual relationships existing among different particles of the sediments. Grain size distribution is considered as a potentially informative and fundamental property of the sediments. Knowledge of grain size is often essential to understanding the temporal and spatial changes of sediment and their bearing on depositional environments. Grain size studies on shallow marine sediments has clearly demonstrated that they are not only reliable indicators for their environment of formation but also provide in depth insight of the regional hydrodynamics which also includes patterns of transport and deposition of the sediment (Petschick et al., 1996; Preda and Cox, 2005).

The grain size distribution in sediments is controlled by factors that includes channel morphology, source materials, process of weathering, abrasion and corrosion of the grains and sorting processes during transport and deposition. The identification of the source and depositional areas of sediments is important in understanding the evolution and current behaviour of any sedimentary systems. Textural characteristics and compositional properties of sediments are important criteria in determining the sedimentary provenance.

The characteristics of texture size distribution of sediments are related to the source materials, processes of weathering, abrasion and corrosion of the grains and sorting processes during transport and deposition (Mishra, 1969; Patro et al., 1989; Williams et al., 1978; Forstner and Wittmann, 1983; Seralathan, 1979, 1988; Samsuddin, 1990; Padmalal and Seralathan, 1991; Padmalal, 1992; Joseph et al., 1997; Rajamanickam and Gujar, 1984, 1985, 1997; Rajaguru et al., 1995). The understanding on textural characteristics of sediment is relevant in sedimentological studies and it receives valuable attention in recent decades. Grain size analysis is also one of the most important natural properties of sediment and commonly used parameter for sedimentological studies (Riyaz, Ahmad mir and Jeelani, 2015). The fundamental property of sediments that affect the transportation, entrainment and the deposition is the is the grain size. Grain size distribution of the sediments are considered as the sub-populations which represents the transportation of sediments by the process of saltation, rolling, and suspension (Inaman, 1952). The textural attributes of sediments are strongly affected by considerable factors, which include the composition at the source area, length, climate and energy of the transporting medium and the redox condition at the environment of deposition (Fralick and Kronberg, 1997).

GRAIN SIZE PARAMETERS

The sediment textural attributes including the Mean (Mz), standard deviation (σ1), skewness (SK1), and kurtosis (KG) are widely used parameters in reconstructing the depositional environment of sediments and sedimentary rocks (Komar 1998; Poppe and Elison, 2007). The depositional mechanism/processes of transport and size parameters in sediments are related to each other. Several studies related to ancient and modern sedimentary environments is also established (Itam et al., 2018; Chinna Durai et al., 2017; Temitope, 2016; Ganesh et al., 2013; Babu et al., 2007; Angusamy and Rajamanickam 2006). The knowledge on textural parameters and the sediment size is assumed to be one of the better tools to differentiate the various environments of depositional in recent as well as the ancient sediments (Kumar et al., 2010; Nordstorn, 1977).

The paleoclimate can also be interpreted from the grain size analysis of sediments (Beal et al., 1956). Large attempts are carried out by several sedimentologists in differentiating the sediments of various environments such as fluvial, fluviatile, and estuarine and other coastal environments over the years (Karuna Karudu et al., 2018; Mohtar et al., 2017; Bhattacharya et al., 2016; Manivel et al., 2016, Ramesh et al., 2015; Karuna Karudu and Jagannadha Rao, 2013). There are few grain size derived parameters which further helps in evaluation the sediment nature are mentioned below.

Mean Size (Mz)

The graphic mean size will emulate the overall average size of the sediments in the grain size spectrum or the central tendency. They also reveal the index of impacted energy to the sediment as a result of current velocity and turbulence of the medium of transport and also the energy circumstances of the environment of deposition (Durai et al., 2017; Itam et al., 2017; Sahu, 1964).

Standard Deviation (σI)

The graphic standard deviation in sediments will indicate the degree of sorting or the uniformity of particle size distribution. The parameter also describes the fluctuation in the aggressive energy, pontin towards the acceleration conditions of the depositing agent and also about its average velocity (Manivel et al., 2016). Spencer (1963) states that the standard deviation will reflect the energy condition of the depositional environment, without gauging the severity to which the sediment has been mixed. The higher value of standard deviation exhibits the selection of grains during the process of depositional as well as the transportation process. On the other hand, good sorting will represent the lower standard deviation values formed by the transport and deposits range of grain size due to the selective action of energy (Kamaruzzaman, 2002).

Skewness (SkI)

The skewness in sediments measures the asymmetric degree of the frequency distribution either predominant coarse or fine sediments in respect to the median (Xu et al, 2009). The variation pertaining to the energy conditions of the sedimentary process is reflected by the skewness (J. Siyi et al., 2014) and the skewness represents inversely proportional relation to the standard deviation (Cadigan, 1961).

Kurtosis (KG)

The graphic kurtosis is the measure used to describe the departure from the normal distribution. The kurtosis is a measure of broadness or peakedness of the curve and it would be afflicted due to the irregularities near the distribution at the center (Cadigan, 1961). Kurtosis is inversely proportional as well as an important function of the standard deviation (Riyaz et al., 2015). The kurtosis values are a consensus for normal distribution and the greater kurtosis values will point out that 50 percent of the average velocity within the centre is controlled by the fluctuation in the velocity.

GRAIN SIZE ANALYSIS IN GREAT RANN OF KACHCHH (GRK)

The present chapter deals with the subsurface sediment characteristics, wide scale palaeoevironmental conditions and development of lithostratigraphic framework of the Great Rann of Kachchh basin based on the two sediment cores (Dhordo and Berada). Two continuous cores, one from the central part of the basin (~60m depth) and the other from the marginal part of the basin. Banni plain (~51m) was raised. The cores were drilled by considering that, the central and marginal parts of the Great Rann basin would provide a basin wide record to reconstruct palaeoenvironmental conditions, provenance of the Rann sediments and its geological evolution throughout Holocene times. South marginal core in Banni plain can be assessed to estimate the role of the southern hillocks in the sediment budget of the Rann basin. A detail account on the regional geomorphic set-up is given in Chapter 2. A brief description of subsurface sediment characteristic with palaeoenvironmental conditions which existed in the Rann basin is given below.

DHORDO CORE

Particle size analysis on the selected 92 samples on regular interval of ~60 cm was carried out using Laser Diffraction Particle Size Analyser (Beckman Coulter). The samples were measured from the range of coarse sand to clay. All the samples were air dried and mildly crushed before treating them for carbonate and organic matter removal using mild 30% concentration of HCL (Hydrochloric Acid) and Hydrogen Peroxide following standard procedure (Folk, 1966). After removal of organics and carbonates, samples were treated with Sodium hexametaphosphate $(NaPO_3)6$ for dispersion before measurements and mixed well using shaker/sonicator. All the processed samples were then run on the particle size analyser and the data was processed and compiled using Gradistat program in Microsoft Excel (Blott and Pye, 2001).

Dhordo core show significant variations in its grain size variability; there appears cyclic sedimentation pattern of fining upward sequences with at least three cycles (Figure 6.1). The sand, silt sized particle abundance varies between 0.2 to 35 % and 60 to 85 % whereas; clay abundance ranges from 4.7 to 18 % (Table. 6.1). This points towards the mud dominated settings with variations in the energy of depositional environments. The calculation for all the parameters like mean grain size, kurtosis, mode, standard deviations and skewness are included and taken into consideration for better analysis of palaeoenvironmental and depositional conditions. Depositional conditions inferred from grain size variations in Dhordo core are as follows.

Grain size variations

Greenlandian Stage (10.6 -6.5 kyr BP) (60 m – 22 m)

During this stage, the sediment grain size shows fining upward sequence between 10.6 to 6.5 kyr BP with higher sand content (8-20 % rapidly fluctuating) specifically between ~10.6 to 9.3 kyr BP thereafter it decreases from ~9.3 toward 6.5 kyr BP (Figure 6.1 and Table 6.1). In contrast to sand, the clay sized particles clearly show inverse trend that is characterised by lower to higher abundance from bottom towards upward section of the core record during this stage. The grain size analysis shows increase in the sand and silt percentage till 50 m particularly at 53 m depth (Figure 6.1 and Table 6.1), however increment in clay percentage can be seen towards the bottom of the stage. The clay percentage dips to its minimum value at 41m depth (5%) which marks its lowest peak from this stage. The consistency from the clay data is noted from 41m depth upto 22 m. In fact, constant increase in the clay percentage is noted throughout this stage. The silt is marked with little variation from 60 m to 35 m depths ranging from 85 to 75 percent. However, the consistency in the silt is noted from 35 m up till 22 m around ~82 percent on an average. The silt percentage on an average through this stage marks > 85 %, whereas the clay remains on the lower side with an average percentage of <10 through this stage. Overall sand is noted to remain less than 10 percent from 60 – 45 m depth, although it yet again reaches to ~10 percent from 43 m depth till the depth of 35 m. From 35 m sand tends to mark less than 1 percent continuing till 22 m. It can be concluded that this stage marks the dominance of silt with occasionally presence of clay and fine sand.

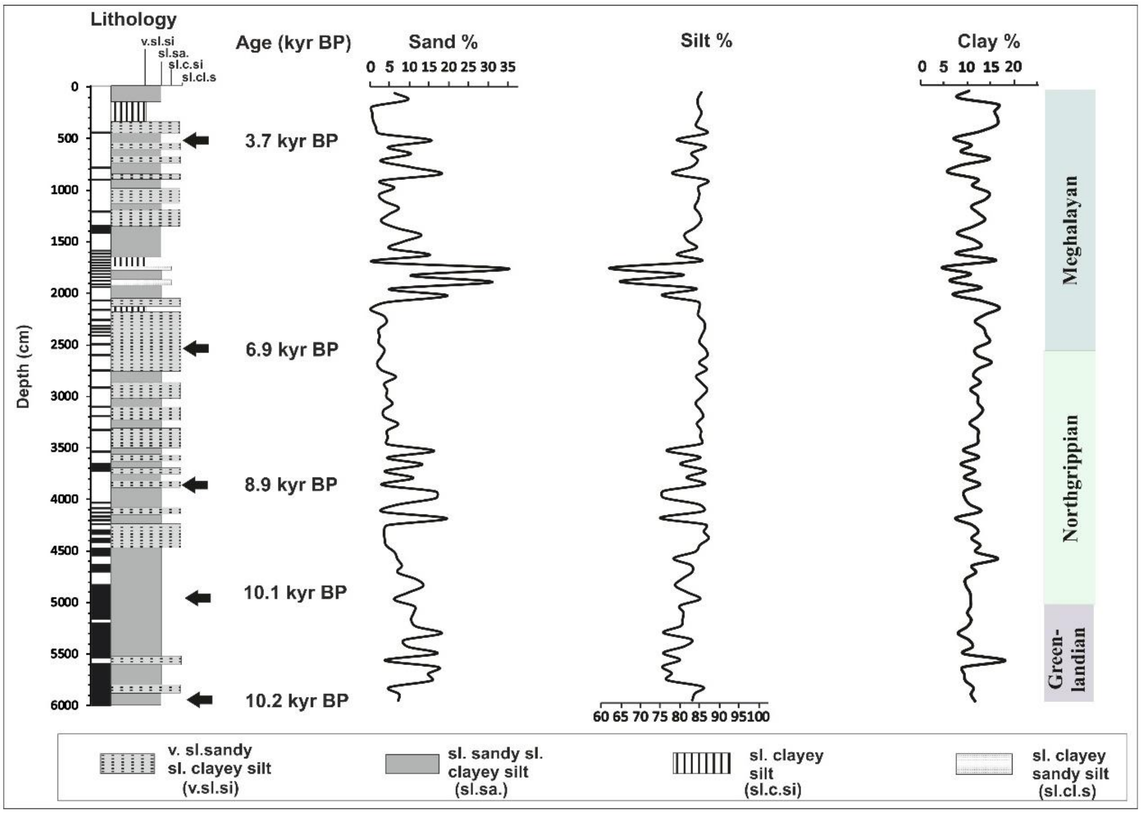


Figure 6.1. Grain size variation of sand silt clay along with lithological variation of the Dhordo core from GRK basin.

The texture noted from this stage varies between two textural classes which are very slightly sandy slightly clayey silt and slightly sandy slightly clayey silt. The percentage dominance of very slightly sandy slightly clayey silt from this stage is marked at 65 percent and the rest 35 percent is contributed by slightly sandy slightly clayey silt. The distribution of mode is dominated by unimodal followed by bimodal, trimodal and polymodal. The unimodal distribution of sediments is uniformly present throughout this stage which marks 52 percent of its presence whereas the stage is secondly dominated by bimodal which marks 35 percent of the total modal distributions. The polymodal mode distribution is poorly present in this stage confirming its least presence from the core. Trimodal mode of distribution shares 11 percent in this stage.

Northgrippian Stage (6.5-4.2 kyr BP) (22 m – 7 m)

The sand content in the sediments increases to its maximum ~35 % (sl. clayey sandy silt) at 5.9 kyr BP and decreased upward to the lowest value of ~1% (sl. sandy sl. clayey silt) in the Dhordo core (Figure 6.1 and Table 6.1). The sand remains consistently on the lower side from 18 m to 11 m which contributes an average of ~4 percent. The silt from this stage ranges between 60 to 85 percent whereas the lowest peak in the silt percentage is noted at 18 m. The contribution of clay is constant which translate between 5 to 15 percent with an average of 8 percent. The clay shows its lowest percentage at 18 m depth which marks the lowest point of clay distribution from the entire Dhordo core. This change in grain size is abrupt and characterised by large scale fluctuations in all grain size denoting parameter (sand, silt and clay). The sediment characteristic in this stage shows three component system of unimodal, bimodal and trimodal sedimentation from the lower half of the stage where maximum sand content increases. From the upper half sand remains mostly bimodal and unimodal dominant (3.5 kyr BP) (~4.7 m) (Table. 6.1). The sediment sorting in this stage therefore suggests mixed and course sediment input to the basin.

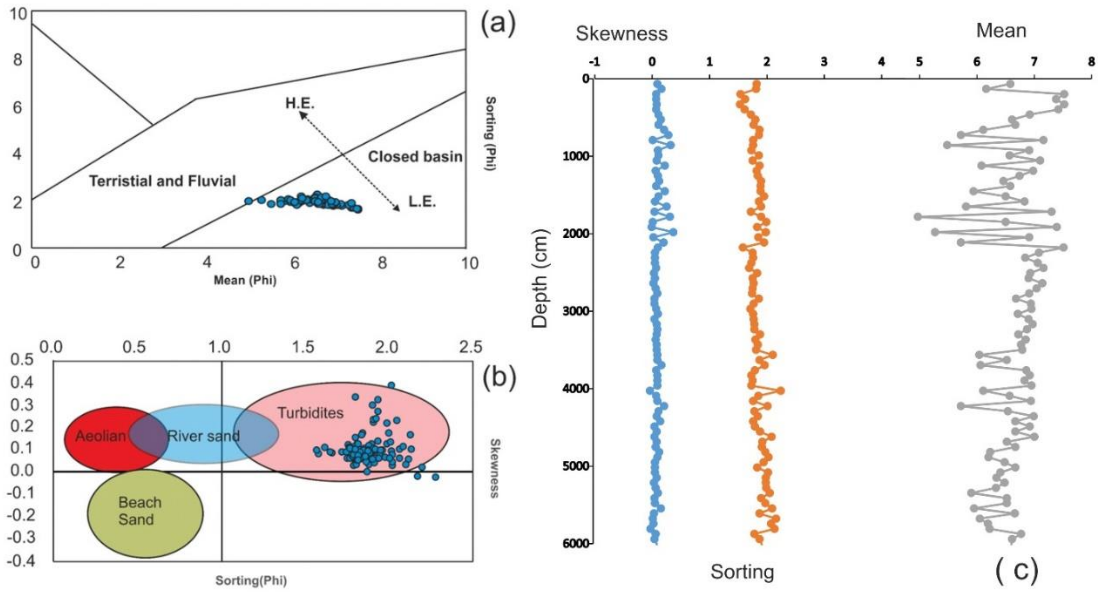


Figure 6.2. a) Diagram of mean grain size versus sorting of sediments from Dhordo core showing different energy and depositional environmental conditions (modified after Tanner (1991). b) Bivariate plot of grain-size distribution parameters of sorting and skewness showing energy of depositional environment. (after Bjørlykke, 2010). c) Line graphical presentation of mean, sorting and skewness along with the depths.

Table 6.1. The grain size distribution of the Dhordo core.

Age (years)	Depth (cm)	Mean (φ)	Sorting (φ)	Skewness (φ)	Kurtosis (φ)	Mode	Sand %	Silt %	Clay %
494	66	6.58	1.82	0.09	1.00	Bimodal	6.32	83.27	10.40
976	132	6.16	1.81	0.16	1.02	Unimodal	9.63	82.36	8.01
1458	198	7.52	1.54	0.07	1.10	Bimodal	0.72	82.52	16.76
1940	264	7.38	1.62	0.07	1.08	Unimodal	0.73	83.32	15.95
2422	330	7.52	1.53	0.08	1.10	Unimodal	0.88	82.54	16.58
2904	396	7.42	1.61	0.07	1.11	Unimodal	1.59	82.00	16.41
3386	462	6.92	1.72	0.11	1.00	Unimodal	2.51	84.75	12.74
3867.5	528	6.61	1.80	0.15	1.01	Unimodal	15.69	77.12	7.19
4105	594	6.67	1.77	0.11	1.00	Bimodal	4.71	84.32	10.97
4207	660	6.11	1.87	0.21	1.01	Unimodal	10.43	80.81	8.76
4308	726	5.72	1.86	0.28	1.03	Unimodal	2.77	82.33	14.89
4411	792	7.16	1.76	0.01	1.03	Unimodal	10.70	80.80	8.50
4513	858	5.48	1.76	0.32	1.09	Unimodal	18.15	76.00	5.84
4616	924	6.91	1.73	0.10	1.04	Unimodal	2.85	84.84	12.31
4717.5	990	6.57	1.86	0.11	0.96	Bimodal	6.27	82.57	11.16
4821.5	1056	7.10	1.75	0.08	1.03	Unimodal	2.52	82.75	14.73
4924	1122	6.08	1.87	0.22	0.99	Unimodal	3.65	82.40	13.95
5026.5	1188	6.98	1.82	0.06	1.01	Bimodal	7.43	81.61	10.97
5129	1254	6.74	1.84	0.10	0.99	Bimodal	4.78	82.82	12.40
5232	1320	6.46	1.90	0.12	0.99	Unimodal	2.96	83.17	13.87
5335	1386	6.58	1.89	0.07	0.94	Bimodal	6.97	81.69	11.34
5439	1452	5.94	1.89	0.22	0.97	Unimodal	13.04	79.08	7.88
5536	1518	6.50	1.95	0.11	0.95	Bimodal	8.54	79.87	11.59
5638	1584	6.83	1.86	0.05	0.97	Bimodal	5.01	82.09	12.90
5741	1650	5.81	1.90	0.25	0.99	Unimodal	15.24	77.14	7.63
5843	1716	7.30	1.72	0.04	1.05	Bimodal	0.78	82.98	16.24
5944	1782	4.97	1.90	0.31	1.04	Bimodal	35.26	60.03	4.72
6045	1848	6.50	1.99	0.01	0.99	Trimodal	10.39	78.84	10.77
6148.5	1914	7.39	1.83	-0.01	1.14	Trimodal	31.03	62.68	6.28
6248	1980	5.27	1.98	0.37	0.92	Unimodal	5.06	81.87	13.08
6351	2046	6.91	1.85	0.02	1.01	Bimodal	19.72	73.32	6.96
6454	2112	5.72	1.95	0.20	0.90	Trimodal	4.18	82.48	13.34

6556	2178	7.51	1.58	0.10	1.10	Unimodal	0.26	82.71	17.03
6657	2244	7.08	1.75	0.05	1.08	Unimodal	3.59	82.49	13.92
6759	2310	6.84	1.76	0.05	1.04	Bimodal	4.26	83.99	11.74
6863	2376	7.06	1.73	0.05	1.07	Unimodal	2.30	84.12	13.59
6965	2442	7.16	1.69	0.07	1.10	Unimodal	2.54	83.34	14.12
7067	2508	6.93	1.83	0.03	0.97	Bimodal	2.31	82.81	14.87
7177	2574	6.90	1.75	0.05	1.08	Unimodal	3.79	84.34	11.87
7328	2640	7.14	1.77	0.02	1.03	Bimodal	3.05	84.76	12.19
7471.5	2706	7.04	1.75	0.06	1.06	Unimodal	1.95	82.75	15.30
7616.5	2772	6.91	1.74	0.09	1.04	Bimodal	2.97	84.63	12.40
7763	2838	6.68	1.86	0.04	1.00	Bimodal	6.64	82.00	11.36
7907	2904	6.94	1.77	0.04	0.98	Bimodal	3.79	83.32	12.88
8051	2970	6.95	1.71	0.07	1.02	Unimodal	4.48	84.74	10.78
8196	3036	6.71	1.76	0.10	1.07	Unimodal	4.29	83.38	12.33
8340	3102	6.90	1.77	0.04	1.04	Unimodal	5.82	81.84	12.34
8484	3168	6.97	1.78	0.08	1.05	Unimodal	3.54	83.03	13.42
8626	3234	6.87	1.78	0.09	1.03	Unimodal	3.84	83.73	12.42
8772	3300	6.72	1.88	0.08	0.96	Bimodal	7.25	82.18	10.57
8914.5	3366	6.85	1.80	0.06	1.01	Unimodal	4.47	83.16	12.37
9061	3432	6.77	1.84	0.08	0.98	Bimodal	4.66	83.02	12.32
9204	3498	6.79	1.81	0.08	1.00	Bimodal	4.54	83.26	12.20
9350	3564	6.04	2.10	0.09	0.97	Trimodal	16.33	74.48	9.19
9494	3630	6.52	1.87	0.09	0.98	Bimodal	4.47	82.99	12.54
9635	3696	6.06	1.96	0.16	1.00	Unimodal	13.36	77.93	8.71
9776.5	3762	6.86	1.79	0.07	1.03	Unimodal	3.86	84.36	11.78
9916.5	3828	6.92	1.73	0.09	1.02	Unimodal	11.08	79.54	9.38
9995	3894	6.83	1.75	0.09	1.05	Unimodal	3.09	84.11	12.80
10022.5	3960	6.95	1.73	0.09	1.06	Unimodal	16.71	73.77	9.53
10052	4026	6.11	2.24	-0.04	1.11	Trimodal	16.71	73.77	9.53
10079	4092	6.57	1.85	0.07	1.02	Bimodal	6.71	82.67	10.63
10105	4158	6.94	1.76	0.09	1.04	Unimodal	3.27	83.75	12.98
10129	4224	5.72	2.01	0.21	0.95	Unimodal	19.57	72.86	7.56
10155	4290	6.54	1.78	0.11	0.98	Bimodal	4.55	84.40	11.05
10180	4356	6.99	1.84	0.08	1.03	Unimodal	3.67	83.89	12.43

10205.5	4422	6.67	1.76	0.14	1.02	Unimodal	3.84	85.16	11.00
10233	4488	6.92	1.79	0.04	1.02	Unimodal	4.23	82.92	12.84
10260	4554	6.67	1.88	0.08	0.99	Unimodal	6.34	81.74	11.92
10283.5	4620	7.00	2.08	0.04	1.00	Polymodal	7.07	76.26	16.67
10310	4686	6.52	1.92	0.08	0.99	Bimodal	8.18	80.69	11.13
10337.5	4752	6.67	1.91	0.06	1.02	Unimodal	7.13	80.94	11.94
10361	4818	6.23	1.97	0.12	1.00	Unimodal	11.83	78.46	9.71
10387	4884	6.20	2.03	0.09	0.98	Bimodal	13.54	76.66	9.80
10418	4950	6.48	1.94	0.05	1.02	Unimodal	9.67	79.68	10.65
10452	5016	6.67	1.83	0.05	1.04	Trimodal	6.24	82.96	10.79
10464	5082	6.41	2.02	0.05	1.00	Trimodal	11.34	77.85	10.81
10474	5148	6.34	1.98	0.08	0.99	Bimodal	11.14	78.77	10.09
10478	5214	6.48	1.98	0.03	1.02	Unimodal	10.54	78.54	10.92
10485	5280	6.33	1.99	0.06	0.98	Bimodal	11.82	78.10	10.08
10492.5	5346	5.90	2.05	0.10	0.94	Bimodal	18.23	73.67	8.10
10498	5412	6.52	1.90	0.04	1.02	Bimodal	8.74	80.80	10.46
10502	5478	6.52	1.97	0.05	1.02	Bimodal	9.74	79.05	11.21
10507	5544	5.95	2.09	0.15	0.97	Unimodal	17.13	73.64	9.23
10512.5	5610	6.66	1.87	0.03	1.06	Trimodal	3.86	77.89	18.25
10517.5	5676	6.05	2.16	0.01	1.00	Trimodal	17.43	73.44	9.13
10521.5	5742	6.19	2.07	0.02	0.99	Trimodal	14.78	75.81	9.42
10527	5808	6.22	2.13	-0.03	1.02	Trimodal	15.75	74.56	9.69
10532	5874	6.77	1.78	0.06	1.03	Bimodal	4.98	83.63	11.39
10540	5940	6.61	1.87	0.04	1.05	Bimodal	7.49	81.63	10.88
10627	6006	6.60	1.91	0.08	1.00	Bimodal	7.27	81.00	11.73

Meghalayan Stage (4.2 kyr BP - recent) (7 m – 0 m)

The topmost part of the core shows minor variation in the silt fraction where it remains on the higher side, overall silt fraction average to 80 percent from this stage. The sand fraction is noted with a minor dip from 5 to 3 m reaching to its lowest value of 0.5 percent. This stage is marked by highest clay dominated environments compared to entire core records (least sand content) that indicate relatively lower energy of the environments (Figure 6.1 and Table 6.1). The sediments in this stage show characteristic light brown colour indicating the region might have been under a very shallow water column. The abundance of the marine microfossils in these sediments also advocates its active marine connectivity throughout this stage (Maurya et al., 2013). The dominance of unimodal mode of depositions is encountered throughout this stage contributing 80 percent participation of the total distribution.

Textural classification of Dhordo core

There are several textural classification schemes proposed over the years for textural classification. One of the primary schemes which covered the entire grain size of the sediments i.e. gravel to fine clay was first proposed by Folk and Warden, 1956. The fine-grained sediments textural classification was necessary for the gravel free environment deposition. One among the textural classification scheme was the classification proposed by Flemming, (1995). In the dominantly fined grained setting like Great Rann of Kachchh (GRK) textural classification based on wide range grain size (gravel to clay) do not appear to project the complete picture of sediment depositional condition and energy of its deposition. So, these setting needs more finer grain size classifications. Blot and Pye (2012) proposed scheme for the more finer sediment classification mainly dealing with the high silt dominated depositions. For this study Blot and Pye (2012) classification for the fine-grained sediments is taken into consideration due to the reasons discussed above (Figure 6.3 and Table 6.2).

The major textures recognised from the Dhordo core are (1) slightly sandy slightly clayey silt, (2) slightly clayey silt, (3) very slightly sandy slightly clayey silt (4) very slightly clayey sandy silt. Based on the grain size variation the sediment textures (Figure 6.3 and Table 6.2). The Dhordo core shows dominance slightly sandy slightly clayey silt texture where it covers 52 % from the entire core. The second vastly dominating texture recognised in the core is very slightly sandy slightly clayey silt where it dominates 32% from the entire core (Figure 6.3 and Table 6.2). The least occurring texture from the core are slightly clayey silt and very slightly clayey sandy silt contributing 15 and 8 % of presence respectively from the core. Based on the chronological division of the core Northgrippian Stage shows highest occurrence of sand up to ~35% (Figure 6.3 and Table 6.2). The texture translation towards more sandy texture i.e. very slightly clayey sandy silt from slightly sandy slightly clayey silt in this stage is a note worth change. The noted feature from the core is dominance of silt contribution to the origin texture. This dominance can be noted from the consistence presence of silt percentage between 70 to 80 (Figure 6.3 and Table 6.2).

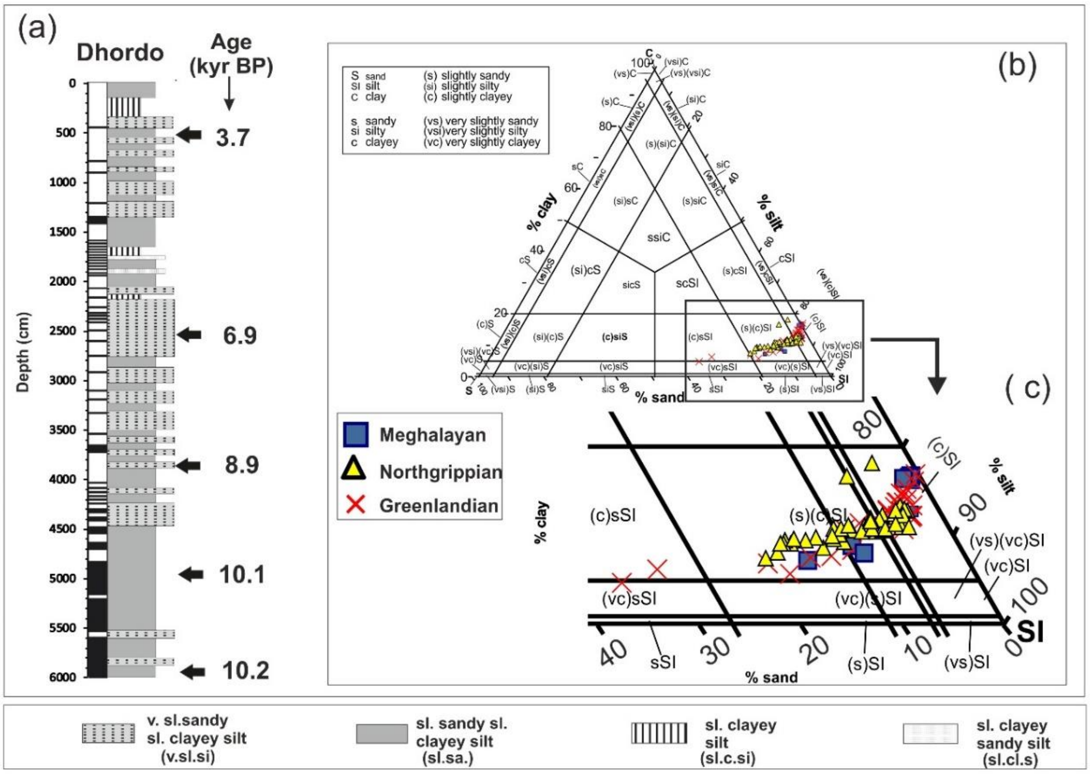


Figure 6.3. a) Lithology of the Dhordo core from GRK basin along with chronological age of the core. b) Triangular plot of grain size distribution in Dhordo core and its textural classification following Blott and Pye, (2011). c) Enlarge view of the textural attributes of GRK sediments in Dhordo core. Blue square box with cross showing sediments deposited during Meghalayan Stage, Yellow triangle reflects Northgrippian Stage and red cross showing Greenlandian Stage.

Table 6.2. Textural distribution of the sediments based on Blot and Pye, (2012).

Age (years)	Depth (cm)	Sand %	Silt %	Clay %	Particle Size Distribution Classification
494	66	6.32	83.27	10.40	slightly sandy slightly clayey silt
976	132	9.63	82.36	8.01	slightly sandy slightly clayey silt
1458	198	0.72	82.52	16.76	slightly clayey silt
1940	264	0.73	83.32	15.95	slightly clayey silt
2422	330	0.88	82.54	16.58	slightly clayey silt
2904	396	1.59	82.00	16.41	very slightly sandy slightly clayey silt
3386	462	2.51	84.75	12.74	very slightly sandy slightly clayey silt
3867.5	528	15.69	77.12	7.19	slightly sandy slightly clayey silt
4105	594	4.71	84.32	10.97	very slightly sandy slightly clayey silt
4207	660	10.43	80.81	8.76	slightly sandy slightly clayey silt
4308	726	2.77	82.33	14.89	very slightly sandy slightly clayey silt
4411	792	10.70	80.80	8.50	slightly sandy slightly clayey silt
4513	858	18.15	76.00	5.84	slightly sandy slightly clayey silt
4616	924	2.85	84.84	12.31	very slightly sandy slightly clayey silt

4717.5	990	6.27	82.57	11.16	slightly sandy slightly clayey silt
4821.5	1056	2.52	82.75	14.73	very slightly sandy slightly clayey silt
4924	1122	3.65	82.40	13.95	very slightly sandy slightly clayey silt
5026.5	1188	7.43	81.61	10.97	slightly sandy slightly clayey silt
5129	1254	4.78	82.82	12.40	very slightly sandy slightly clayey silt
5232	1320	2.96	83.17	13.87	very slightly sandy slightly clayey silt
5335	1386	6.97	81.69	11.34	slightly sandy slightly clayey silt
5439	1452	13.04	79.08	7.88	slightly sandy slightly clayey silt
5536	1518	8.54	79.87	11.59	slightly sandy slightly clayey silt
5638	1584	5.01	82.09	12.90	slightly sandy slightly clayey silt
5741	1650	15.24	77.14	7.63	slightly sandy slightly clayey silt
5843	1716	0.78	82.98	16.24	slightly clayey silt
5944	1782	35.26	60.03	4.72	very slightly clayey sandy silt
6045	1848	10.39	78.84	10.77	slightly sandy slightly clayey silt
6148.5	1914	31.03	62.68	6.28	slightly clayey sandy silt
6248	1980	5.06	81.87	13.08	slightly sandy slightly clayey silt
6351	2046	19.72	73.32	6.96	slightly sandy slightly clayey silt
6454	2112	4.18	82.48	13.34	very slightly sandy slightly clayey silt
6556	2178	0.26	82.71	17.03	slightly clayey silt
6657	2244	3.59	82.49	13.92	very slightly sandy slightly clayey silt
6759	2310	4.26	83.99	11.74	very slightly sandy slightly clayey silt
6863	2376	2.30	84.12	13.59	very slightly sandy slightly clayey silt
6965	2442	2.54	83.34	14.12	very slightly sandy slightly clayey silt
7067	2508	2.31	82.81	14.87	very slightly sandy slightly clayey silt
7177	2574	3.79	84.34	11.87	very slightly sandy slightly clayey silt
7328	2640	3.05	84.76	12.19	very slightly sandy slightly clayey silt
7471.5	2706	1.95	82.75	15.30	very slightly sandy slightly clayey silt
7616.5	2772	2.97	84.63	12.40	very slightly sandy slightly clayey silt
7763	2838	6.64	82.00	11.36	slightly sandy slightly clayey silt
7907	2904	3.79	83.32	12.88	very slightly sandy slightly clayey silt
8051	2970	4.48	84.74	10.78	very slightly sandy slightly clayey silt
8196	3036	4.29	83.38	12.33	very slightly sandy slightly clayey silt
8340	3102	5.82	81.84	12.34	slightly sandy slightly clayey silt
8484	3168	3.54	83.03	13.42	very slightly sandy slightly clayey silt
8626	3234	3.84	83.73	12.42	very slightly sandy slightly clayey silt
8772	3300	7.25	82.18	10.57	slightly sandy slightly clayey silt
8914.5	3366	4.47	83.16	12.37	very slightly sandy slightly clayey silt
9061	3432	4.66	83.02	12.32	very slightly sandy slightly clayey silt
9204	3498	4.54	83.26	12.20	very slightly sandy slightly clayey silt
9350	3564	16.33	74.48	9.19	slightly sandy slightly clayey silt
9494	3630	4.47	82.99	12.54	very slightly sandy slightly clayey silt
9635	3696	13.36	77.93	8.71	slightly sandy slightly clayey silt
9776.5	3762	3.86	84.36	11.78	very slightly sandy slightly clayey silt
9916.5	3828	11.08	79.54	9.38	slightly sandy slightly clayey silt
9995	3894	3.09	84.11	12.80	very slightly sandy slightly clayey silt
10022.5	3960	16.71	73.77	9.53	slightly sandy slightly clayey silt

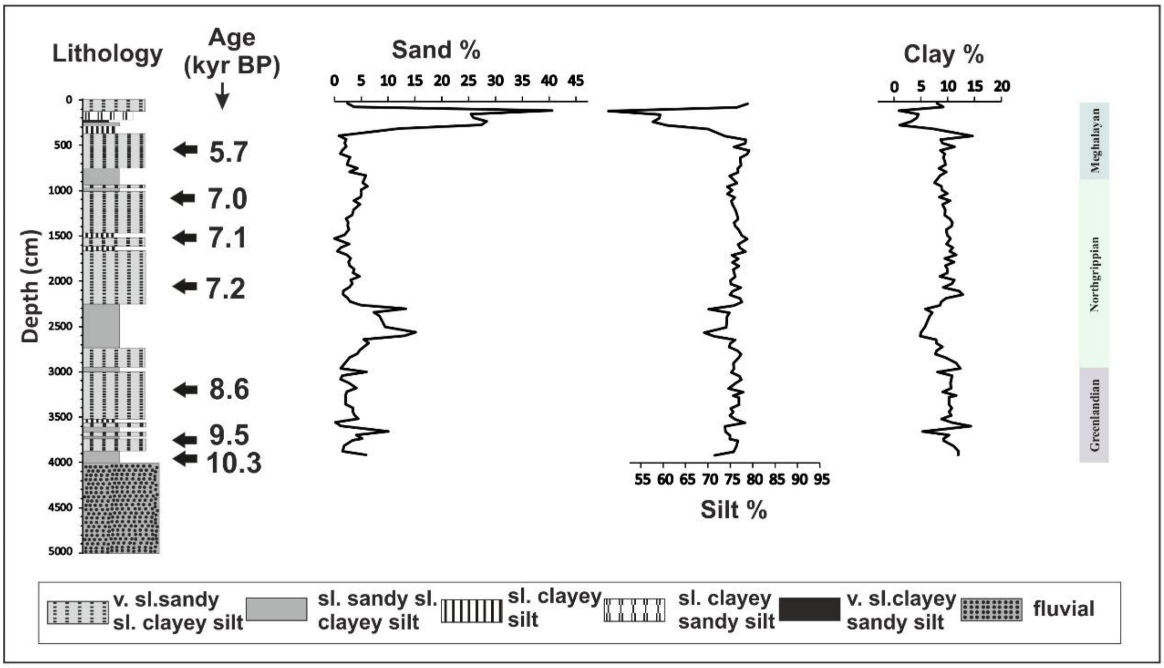
10052	4026	16.71	73.77	9.53	slightly sandy slightly clayey silt
10079	4092	6.71	82.67	10.63	slightly sandy slightly clayey silt
10105	4158	3.27	83.75	12.98	very slightly sandy slightly clayey silt
10129	4224	19.57	72.86	7.56	slightly sandy slightly clayey silt
10155	4290	4.55	84.40	11.05	very slightly sandy slightly clayey silt
10180	4356	3.67	83.89	12.43	very slightly sandy slightly clayey silt
10205.5	4422	3.84	85.16	11.00	very slightly sandy slightly clayey silt
10233	4488	4.23	82.92	12.84	very slightly sandy slightly clayey silt
10260	4554	6.34	81.74	11.92	slightly sandy slightly clayey silt
10283.5	4620	7.07	76.26	16.67	slightly sandy slightly clayey silt
10310	4686	8.18	80.69	11.13	slightly sandy slightly clayey silt
10337.5	4752	7.13	80.94	11.94	slightly sandy slightly clayey silt
10361	4818	11.83	78.46	9.71	slightly sandy slightly clayey silt
10387	4884	13.54	76.66	9.80	slightly sandy slightly clayey silt
10418	4950	9.67	79.68	10.65	slightly sandy slightly clayey silt
10452	5016	6.24	82.96	10.79	slightly sandy slightly clayey silt
10464	5082	11.34	77.85	10.81	slightly sandy slightly clayey silt
10474	5148	11.14	78.77	10.09	slightly sandy slightly clayey silt
10478	5214	10.54	78.54	10.92	slightly sandy slightly clayey silt
10485	5280	11.82	78.10	10.08	slightly sandy slightly clayey silt
10492.5	5346	18.23	73.67	8.10	slightly sandy slightly clayey silt
10498	5412	8.74	80.80	10.46	slightly sandy slightly clayey silt
10502	5478	9.74	79.05	11.21	slightly sandy slightly clayey silt
10507	5544	17.13	73.64	9.23	slightly sandy slightly clayey silt
10512.5	5610	3.86	77.89	18.25	very slightly sandy slightly clayey silt
10517.5	5676	17.43	73.44	9.13	slightly sandy slightly clayey silt
10521.5	5742	14.78	75.81	9.42	slightly sandy slightly clayey silt
10527	5808	15.75	74.56	9.69	slightly sandy slightly clayey silt
10532	5874	4.98	83.63	11.39	very slightly sandy slightly clayey silt
10540	5940	7.49	81.63	10.88	slightly sandy slightly clayey silt
10627	6006	7.27	81.00	11.73	slightly sandy slightly clayey silt

BERADA CORE

The Banni plain is a unique geomorphic entity of the Great Rann of Kachchh basin. The tidal waters from the Arabian sea do not reach the plain, as it is at slightly higher elevation than mean sea level and also due to chocking/filling of older creek, tidal channel/s which were active until a few thousand years ago (Kar et al., 1993, Maurya et al., 2013). The overall elevation of the Banni plain surface varies from 3 to 12m compared to the present day msl (Biswas et al., 2021; Kar et al., 2003). During the monsoon season (July to September), the low-lying area of Banni plain gets ponded by the fresh water from precipitation and northerly draining rivers from the Northern Hill range. The surface will remain covered under thin sheet of water column for few weeks to a month of two.

Interestingly, the overall evolution of Banni plain is not well understood due to lack of subsurface studies using sediment cores or geophysical surveys. Here in the present study, we present a high-resolution dataset on grain size analysis to decipher depositional condition of the Banni basin.

In the ~51 m deep sediment core, particle size analysis of 89 selected samples was carried out using Laser Diffraction Particle Size Analyser (Beckman Coulter). The sampling interval for the sedimentary core was ~60 cm. The samples were measured from the range of coarse sand to clay. Standard procedure proposed by Folk, 1966 was followed, in which the samples were air dried and mildly crushed before treating them with a mixture of 30% HCL (Hydrochloric Acid) and Hydrogen Peroxide for the removal of carbonate and organic matter. After removal of organics and carbonates, samples were treated with Sodium hexametaphosphate $(NaPO_3)6$ for dispersion and then mixed well using shaker/sonicator before measurements. The processed samples were then run on the particle size analyser and the data obtained was processed and compiled using Gradistat program in Microsoft Excel (Blott and Pye, 2001).



Figurer 6.4. Grain size variation of sand silt clay along with lithological variation of the Berada core from GRK basin.

Berada core shows significant variation in grain size. The core shows cyclic sedimentation pattern of fining upward sequences with at least three cycles (Figure 6.4 and Table 6.3). The abundance of sand and silt sized particle varies between 0.2 to 40 % and 60 to 85 % whereas, the clay ranges between 4.1 to 17 % (Table. 6.1). This points towards a mud dominated settings with variations in the energy of depositional conditions. The lower part of the core from 40 to 50 m samples has been skipped for grain size analysis as it is fluvial dominated sediments and was not possible to carry out grain size analysis (Maurya et al., 2013). Calculation for all the parameters like mean grain size, kurtosis, mode, standard deviations and skewness are included and taken into consideration for better analysis of palaeoenvironmental and depositional conditions. Depositional conditions variation in Berada core are as follows.

The grain size analysis was carried out on selected samples from the Berada core to understand the variation in grain size and texture. The variation in the mean, median, mode sorting, skewness and kurtosis were carefully analysed.

Grain size variations

Fluvial sediments (51 m to 39.6 m)

The sediment from this unit can be categorize as coarse sand deposited under the influence of fluvial medium. It consists of pebbly poorly sorted, massive sands that occur between ~51 m to 39.6 m depth and it forms the bottommost part of the core and consist of unconsolidated brown coloured coarse sands. The sand comprises highly angular and unsorted grains. The sand fraction is very high with silt as minor component. The clay content is negligible in this portion of the core. Mineralogically, the sand fraction is dominated by quartz followed by feldspars. The general textural characteristics of the sand suggest fluvial origin. The angular and unsorted nature of the sand suggests a proximal source for the sediments. The source of the sand is more likely the rocky Mainland Kachchh to the south that exposes Mesozoic sandstones and limestones (Maurya et el., 2013; Khonde, 2014).

Greenlandian Stage (10.6 -8.2 kyr BP) (60 m – 30 m)

This section of the core is dominated by silt fraction with negligible fine sand fraction. The clay fluctuations with an average value of 12.5% can be noted following the trend of silt fraction. (Figure 6.4 and Table 6.3). The noted trend is encountered looking at clay parameter where it shows rhythmic fluctuation throughout this stage varying between 8% to ~17%. The mode of deposition varies in cluster manner between unimodal to bimodal implying the influence of bidirectional deposition (Table 6.3). The transition in skewness is noted in negative at ~38 m depth (Figure 6.5 and Table 6.3). The origin of the sediments are noted to be deposited under transgression. The mud dominated setting is noted from this unit which suggests the deposition under lower but fluctuation energy conditions (Maurya et al., 2013; Khonde, 2014). The upward decrease in sand content and change in sediment colour from yellowish brown to greyish to blackish colour in the preceding section sediments, indicates increased water column and reduced energy condition which supports our interpretation of advancement of marine condition at the core site under estuarine to marshy settings.

Northgrippian Stage (8.2-4.2 kyr BP) (30 m – 4 m)

The clay fraction follows upwards increasing tread from 23 – 21 m thereby becomes consistent in the range of ~8%. Interesting change is noted from the mean ration of the unit which shows coarsening upwards trend up to ~26 m thereafter decline in the mean ratio is noted at ~24 m depth (Figure 6.4 and Table 6.3). The consistency in the sand fraction coupled with silt fraction is noted throughout this stage. These features can also be noted from the mode of deposition which also shows dominance in unimodal deposition. The particle size parameter is mainly dominated by silt/clay fraction where the increase in energy conditions is mainly reflected in silt fraction from 13 to 7 m depth (Figure 6.4 and Table 6.3). The sand mud ratio shows decreasing trend where sand reaches 0% at ~15 m thereafter sand increases to ~5 % at around ~9 m. The fine sand fraction continues to remain on the lower side of the average value (0.9 %). However, a little increase towards the average value mark is noted at 14 m and 11 m (Table 6.3) depths. Overall, the upward increase in sand fraction suggests the deposition under high energy conditions.

Meghalayan Stage (4.2 kyr BP - recent) (4 m – 0 m)

An abrupt change in the sand fraction is noted from this stage where the sand fraction reaches upto 40% at ~1 m depth (Figure 6.4 and Table 6.3) thus this stage is marked by the highest peak for the sand fraction. The clay remains on the lower side but consistent with an average of 10.4% from this stage. The silt fraction is noted with an average of ~78% from this stage. This stage reflects deposition under regressive sea where the deposition of sand particle appears to be abrupt. The dominance of unimodal mode of depositions is encountered throughout this stage contributing 80 percent of its distribution which quantifies for its supra tidal deposition (Tyagi et., 2012; Khonde, 2014, Sharma et al., 2020).

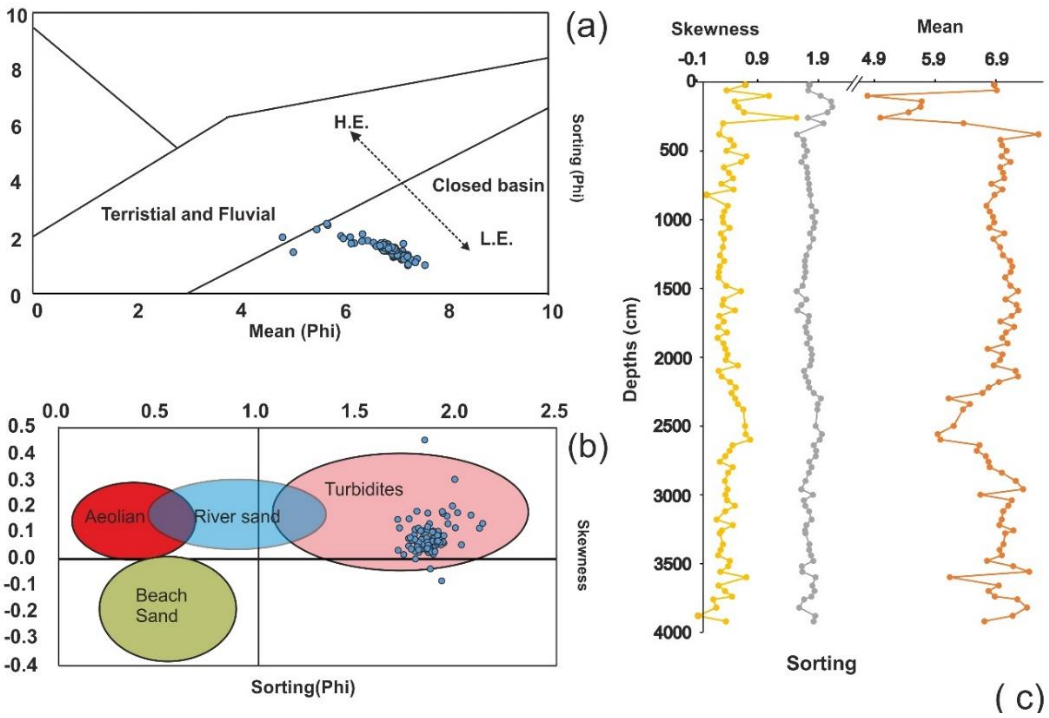


Figure 6.5. a) Diagram of mean grain size versus sorting of sediments from Berada core showing different energy and depositional environmental conditions (modified after Tanner (1991). b) Bivariate plot of grain-size distribution parameters of sorting and skewness showing energy of depositional environment. (after Bjørlykke, 2010). c) Line graphical presentation of mean, sorting and skewness along with the depths.

Table 6.3. The grain size distribution of the Berada core.

Age (years)	Depth (cm)	Mean (φ)	Sorting (φ)	Skewness (φ)	Kurtosis (φ)	Mode	Sand %	Silt %	Clay %
87.5	20	6.871	1.751	0.699	3.678	Unimodal	2.42706	86.50104	11.0719
241	60	6.914	1.733	0.391	3.019	Unimodal	3.651675	84.09363	12.25469
394	100	4.787	1.937	1.086	4.252	Bimodal	40.53176	55.43541	3.960076
548	140	5.680	2.108	0.524	2.630	Polymodal	25.44198	66.96542	7.592606
702	180	5.662	2.129	0.580	2.821	Polymodal	25.87184	66.81447	7.31369
856	220	5.463	2.049	0.676	2.940	Bimodal	28.35113	65.33753	6.311344
1009.5	260	4.999	1.729	1.537	6.066	Unimodal	27.36937	68.52254	4.108082
1163	300	6.367	1.984	0.334	2.656	Bimodal	12.07357	77.62844	10.29799
1470	380	7.601	1.545	0.271	3.117	Unimodal	0.828118	81.48366	17.68822
1623	420	6.976	1.658	0.451	3.143	Unimodal	2.213714	86.06065	11.72563
1777	460	7.001	1.663	0.512	3.197	Unimodal	1.931898	85.98119	12.08691
1928.5	500	7.077	1.713	0.388	2.832	Unimodal	2.213684	83.46409	14.32223
2083	540	6.994	1.675	0.718	3.684	Unimodal	1.471814	86.81728	11.7109
2234	580	7.139	1.621	0.631	3.524	Unimodal	1.08504	86.39052	12.52445
2386	620	6.969	1.707	0.346	2.967	Unimodal	2.891261	84.84954	12.2592
2539	660	7.017	1.721	0.431	3.185	Unimodal	2.581603	84.90782	12.51058
2693	700	7.036	1.723	0.497	3.281	Unimodal	2.345553	85.01813	12.63631
2843.5	740	6.826	1.746	0.303	2.875	Bimodal	4.294226	84.28895	11.41682
2997	780	7.005	1.748	0.507	3.244	Unimodal	2.828562	84.3777	12.79374
3148	820	6.879	1.768	0.057	2.937	Bimodal	5.8456	82.4996	11.6548
3454.5	900	6.744	1.782	0.408	3.255	Bimodal	5.279001	84.12325	10.59774
3607	940	6.797	1.861	0.354	3.091	Trimodal	6.12685	81.96143	11.91172
3758	980	6.852	1.802	0.324	2.976	Bimodal	4.946498	83.07655	11.97695

3911	1020	6.873	1.841	0.334	2.887	Unimodal	5.044472	81.94619	13.00934
4062.5	1060	6.790	1.821	0.438	3.081	Bimodal	4.885553	83.59833	11.51611
4216	1100	7.037	1.760	0.295	2.952	Unimodal	3.60949	82.86135	13.52916
4368.5	1140	6.860	1.814	0.347	3.047	Bimodal	4.772495	83.15517	12.07233
4522	1200	6.967	1.752	0.330	2.983	Bimodal	3.594262	83.78951	12.61623
4825.5	1260	7.015	1.702	0.281	2.902	Bimodal	3.2973	84.17433	12.52837
4981.5	1300	7.135	1.678	0.352	3.046	Unimodal	2.174032	84.35911	13.46686
5134	1340	7.169	1.680	0.279	3.061	Unimodal	2.565719	83.49756	13.93672
5284	1380	7.142	1.689	0.263	3.055	Unimodal	2.460488	83.74547	13.79404
5436.5	1420	7.054	1.670	0.259	2.918	Unimodal	2.694619	84.52101	12.78437
5584.5	1480	7.139	1.640	0.383	3.124	Unimodal	1.878969	85.15928	12.96175
5815	1520	7.264	1.542	0.626	3.121	Bimodal	0	86.39149	13.60851
5891.5	1580	7.059	1.701	0.342	3.066	Unimodal	2.760887	84.39375	12.84536
6197	1620	7.238	1.618	0.319	2.936	Bimodal	1.157063	84.83519	14.00775
6353	1660	7.272	1.555	0.528	3.267	Unimodal	0.55556	86.02974	13.4147
6502	1700	7.158	1.743	0.272	2.859	Bimodal	2.3319	83.02221	14.64589
6655.5	1740	6.974	1.733	0.343	2.896	Bimodal	3.043929	84.43269	12.52338
6808	1780	7.199	1.688	0.247	3.019	Trimodal	2.617651	83.11999	14.26236
6961	1820	7.066	1.705	0.394	3.180	Bimodal	2.820004	84.54946	12.63054
7115.5	1860	7.004	1.756	0.242	2.969	Unimodal	3.703511	83.28458	13.0119
7273.5	1900	7.092	1.713	0.340	3.230	Bimodal	3.477757	83.5102	13.01204
7412	1940	6.764	1.777	0.371	2.811	Unimodal	4.682834	83.71276	11.60441
7468	1980	7.007	1.794	0.407	2.854	Unimodal	3.025451	82.66256	14.31198
7524	2020	6.967	1.785	0.377	2.846	Unimodal	3.343207	82.79179	13.86501
7582	2060	6.865	1.761	0.576	3.149	Unimodal	2.797469	85.0068	12.19573
7639.5	2100	7.223	1.663	0.260	2.804	Unimodal	1.694469	83.15234	15.15319
7696.5	2140	7.263	1.689	0.310	2.818	Unimodal	1.591919	82.52136	15.88672
7752.5	2180	6.948	1.735	0.448	2.933	Bimodal	2.452292	84.80069	12.74701
7810.5	2220	6.780	1.750	0.541	2.912	Bimodal	2.915134	85.24445	11.84042
7864	2260	6.678	1.823	0.473	2.819	Bimodal	4.965318	83.43565	11.59903
7925.5	2300	6.123	1.941	0.530	2.839	Unimodal	13.30368	77.80618	8.89014
7982.5	2340	6.472	1.890	0.575	3.162	Unimodal	7.365646	82.42052	10.21384
8035	2380	6.358	1.884	0.665	3.157	Unimodal	8.369621	81.94149	9.688886
8199.5	2500	6.206	1.854	0.695	2.999	Unimodal	9.434647	81.74905	8.816303
8281.5	2560	5.943	1.956	0.703	3.237	Unimodal	15.13733	76.80975	8.05292
8342	2600	5.987	1.922	0.779	3.374	Unimodal	13.04864	79.01567	7.935689
8397	2640	6.631	1.822	0.490	2.952	Bimodal	5.41593	83.69363	10.89044
8451.5	2680	6.585	1.862	0.439	2.937	Trimodal	6.390443	82.64067	10.96888
8506	2720	6.734	1.856	0.369	2.943	Bimodal	5.534343	82.39186	12.0738
8560	2760	6.778	1.751	0.278	2.879	Bimodal	4.721003	84.24187	11.03713
8618	2800	6.796	1.788	0.491	3.480	Unimodal	4.241522	85.02384	10.73464
8674	2840	6.996	1.743	0.414	3.122	Unimodal	2.851951	84.45936	12.68869
8758	2900	7.227	1.687	0.362	3.082	Unimodal	2.011038	83.36118	14.62779
8844.5	2960	7.349	1.618	0.406	3.090	Unimodal	1.164806	83.42193	15.41326
8901	3000	6.646	1.811	0.370	2.767	Bimodal	5.990399	82.87283	11.13677
8955.5	3040	7.161	1.661	0.397	3.037	Unimodal	1.488788	84.64636	13.86485
9012	3080	7.103	1.686	0.526	3.067	Bimodal	1.143178	85.09557	13.76125
9069	3120	7.019	1.748	0.367	2.867	Bimodal	2.630723	83.79966	13.56962
9152	3180	6.995	1.788	0.225	2.932	Unimodal	4.089506	82.25042	13.66007
9210	3220	6.958	1.702	0.494	3.114	Unimodal	2.324886	85.53339	12.14172
9270	3260	7.189	1.678	0.312	2.902	Unimodal	2.067951	83.27389	14.65816
9314	3280	7.053	1.687	0.277	2.837	Unimodal	2.103051	84.57797	13.31898
9382	3360	7.023	1.753	0.330	2.840	Bimodal	2.103051	84.57797	13.31898

9409	3400	6.961	1.747	0.292	2.685	Unimodal	3.449372	82.72415	13.82648
9434	3440	6.998	1.779	0.251	2.642	Bimodal	3.39998	83.29495	13.30507
9459.5	3480	6.753	1.817	0.443	2.899	Unimodal	3.720823	82.53445	13.74473
9486	3520	7.184	1.628	0.416	2.858	Unimodal	4.433106	83.65923	11.90766
9512	3560	7.446	1.636	0.286	2.912	Unimodal	0.194198	85.90792	13.89789
9538	3600	6.142	1.851	0.714	3.290	Unimodal	1.157951	81.45652	17.38553
9576.5	3660	6.947	1.800	0.257	2.684	Bimodal	10.05301	81.5876	8.359393
9602	3700	6.778	1.834	0.364	2.843	Bimodal	4.100969	82.59436	13.30467
9628.5	3740	6.883	1.783	0.481	3.041	Bimodal	5.165453	82.53639	12.29816
9641	3760	7.253	1.664	0.171	2.850	Bimodal	3.387258	84.30776	12.30498
9679	3820	7.410	1.584	0.221	3.173	Unimodal	1.820727	83.98949	14.18978
9734.5	3880	7.175	1.847	-0.079	3.229	Bimodal	1.54585	83.3764	15.07775
9864	3920	6.711	1.821	0.379	2.874	Unimodal	5.888689	79.12219	14.98912

Textural classification of Berada core

The major textures recognised from the Berada core are (1) slightly sandy slightly clayey silt, (2) slightly clayey silt, (3) very slightly sandy slightly clayey silt (4) very slightly clayey sandy silt (5) slightly clayey sandy silt (Figure 6.6 and Table 6.4). Based on the grain size variation the sediment textures from the Berada core shows dominance of slightly sandy slightly clayey silt texture where it covers 55 % from the entire core (Figure 6.6 and Table 6.4). The second vastly dominating texture recognised in the core is very slightly sandy slightly clayey silt where it dominates 30% from the entire core. The texture slightly clayey sandy silt is 25 % present in the core (Figure 6.6 and Table 6.4). The least occurring texture from the core are slightly clayey silt and very slightly clayey sandy silt having 11 and 8 % presence respectively. (Figure 6.6 and Table 6.4). Based on the chronological division of the core Meghalayan Stage shows highest occurrence of sand up to ~40% (Figure 6.6 and Table 6.4). The texture translates towards more sandy texture i.e., very slightly clayey sandy silt from slightly sandy slightly clayey silt. The noted feature from the core is dominance of silty origin of texture which is due to constant presence of silt percentage between 55 to 75% (Figure 6.6 and Table 6.4).

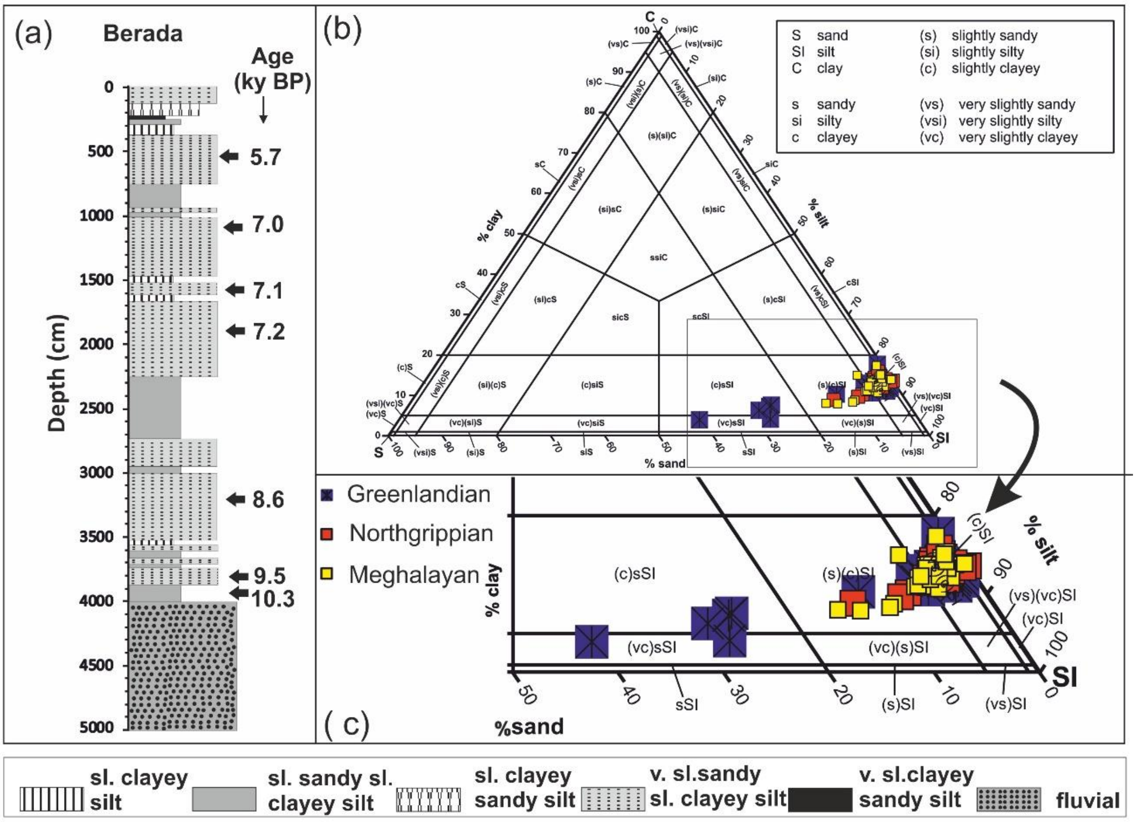


Figure 6.6. a) Lithology of the Berada core from GRK basin along with chronological age of the core. b) Triangular plot of grain size distribution in Berada core and its textural classification following Blott and Pye, (2011). c) Enlarge view of the textural attributes of GRK sediments in Berada core. Blue square box with cross showing sediments deposited during Greenlandian Stage, red square showing Northgrippian Stage and Yellow square reflects Meghalayan Stage.

Table 6.4. Textural distribution of the sediments based on Blot and Pye, (2012).

Age (years)	Depth (cm)	Sand %	Silt %	Clay %	Particle Size Distribution Classification
87.5	20	2.42706	86.50104	11.0719	slightly sandy slightly clayey silt
241	60	3.651675	84.09363	12.25469	very slightly sandy slightly clayey silt
394	100	40.53176	55.43541	3.960076	very slightly sandy slightly clayey silt
548	140	25.44198	66.96542	7.592606	very slightly sandy slightly clayey silt
702	180	25.87184	66.81447	7.31369	very slightly sandy slightly clayey silt
856	220	28.35113	65.33753	6.311344	very slightly sandy slightly clayey silt
1009.5	260	27.36937	68.52254	4.108082	slightly sandy slightly clayey silt
1163	300	12.07357	77.62844	10.29799	very slightly sandy slightly clayey silt
1470	380	0.828118	81.48366	17.68822	very slightly sandy slightly clayey silt
1623	420	2.213714	86.06065	11.72563	very slightly sandy slightly clayey silt
1777	460	1.931898	85.98119	12.08691	very slightly sandy slightly clayey silt
1928.5	500	2.213684	83.46409	14.32223	very slightly sandy slightly clayey silt
2083	540	1.471814	86.81728	11.7109	very slightly sandy slightly clayey silt
2234	580	1.08504	86.39052	12.52445	very slightly sandy slightly clayey silt
2386	620	2.891261	84.84954	12.2592	very slightly sandy slightly clayey silt
2539	660	2.581603	84.90782	12.51058	very slightly sandy slightly clayey silt
2693	700	2.345553	85.01813	12.63631	very slightly sandy slightly clayey silt

2843.5	740	4.294226	84.28895	11.41682	very slightly sandy slightly clayey silt
2997	780	2.828562	84.3777	12.79374	very slightly sandy slightly clayey silt
3148	820	5.8456	82.4996	11.6548	slightly clayey silt
3454.5	900	5.279001	84.12325	10.59774	very slightly sandy slightly clayey silt
3607	940	6.12685	81.96143	11.91172	slightly sandy slightly clayey silt
3758	980	4.946498	83.07655	11.97695	very slightly sandy slightly clayey silt
3911	1020	5.044472	81.94619	13.00934	slightly sandy slightly clayey silt
4062.5	1060	4.885553	83.59833	11.51611	very slightly sandy slightly clayey silt
4216	1100	3.60949	82.86135	13.52916	very slightly sandy slightly clayey silt
4368.5	1140	4.772495	83.15517	12.07233	very slightly sandy slightly clayey silt
4522	1200	3.594262	83.78951	12.61623	slightly sandy slightly clayey silt
4825.5	1260	3.2973	84.17433	12.52837	slightly sandy slightly clayey silt
4981.5	1300	2.174032	84.35911	13.46686	very slightly sandy slightly clayey silt
5134	1340	2.565719	83.49756	13.93672	very slightly sandy slightly clayey silt
5284	1380	2.460488	83.74547	13.79404	very slightly sandy slightly clayey silt
5436.5	1420	2.694619	84.52101	12.78437	very slightly sandy slightly clayey silt
5584.5	1480	1.878969	85.15928	12.96175	very slightly sandy slightly clayey silt
5815	1520	0	86.39149	13.60851	slightly sandy slightly clayey silt
5891.5	1580	2.760887	84.39375	12.84536	very slightly sandy slightly clayey silt
6197	1620	1.157063	84.83519	14.00775	very slightly sandy slightly clayey silt
6353	1660	0.55556	86.02974	13.4147	very slightly sandy slightly clayey silt
6502	1700	2.3319	83.02221	14.64589	very slightly sandy slightly clayey silt
6655.5	1740	3.043929	84.43269	12.52338	very slightly sandy slightly clayey silt
6808	1780	2.617651	83.11999	14.26236	very slightly sandy slightly clayey silt
6961	1820	2.820004	84.54946	12.63054	very slightly sandy slightly clayey silt
7115.5	1860	3.703511	83.28458	13.0119	very slightly sandy slightly clayey silt
7273.5	1900	3.477757	83.5102	13.01204	very slightly sandy slightly clayey silt
7412	1940	4.682834	83.71276	11.60441	very slightly sandy slightly clayey silt
7468	1980	3.025451	82.66256	14.31198	very slightly sandy slightly clayey silt
7524	2020	3.343207	82.79179	13.86501	very slightly sandy slightly clayey silt
7582	2060	2.797469	85.0068	12.19573	slightly clayey silt
7639.5	2100	1.694469	83.15234	15.15319	very slightly sandy slightly clayey silt
7696.5	2140	1.591919	82.52136	15.88672	slightly sandy slightly clayey silt
7752.5	2180	2.452292	84.80069	12.74701	very slightly sandy slightly clayey silt
7810.5	2220	2.915134	85.24445	11.84042	slightly sandy slightly clayey silt
7864	2260	4.965318	83.43565	11.59903	very slightly sandy slightly clayey silt
7925.5	2300	13.30368	77.80618	8.89014	very slightly sandy slightly clayey silt
7982.5	2340	7.365646	82.42052	10.21384	very slightly sandy slightly clayey silt
8035	2380	8.369621	81.94149	9.688886	slightly sandy slightly clayey silt
8199.5	2500	9.434647	81.74905	8.816303	slightly sandy slightly clayey silt
8281.5	2560	15.13733	76.80975	8.05292	very slightly sandy slightly clayey silt
8342	2600	13.04864	79.01567	7.935689	very slightly sandy slightly clayey silt
8397	2640	5.41593	83.69363	10.89044	very slightly sandy slightly clayey silt
8451.5	2680	6.390443	82.64067	10.96888	very slightly sandy slightly clayey silt
8506	2720	5.534343	82.39186	12.0738	very slightly sandy slightly clayey silt
8560	2760	4.721003	84.24187	11.03713	slightly sandy slightly clayey silt
8618	2800	4.241522	85.02384	10.73464	very slightly sandy slightly clayey silt
8674	2840	2.851951	84.45936	12.68869	very slightly sandy slightly clayey silt
8758	2900	2.011038	83.36118	14.62779	very slightly sandy slightly clayey silt
8844.5	2960	1.164806	83.42193	15.41326	very slightly sandy slightly clayey silt
8901	3000	5.990399	82.87283	11.13677	very slightly sandy slightly clayey silt
8955.5	3040	1.488788	84.64636	13.86485	very slightly sandy slightly clayey silt

9012	3080	1.143178	85.09557	13.76125	very slightly sandy slightly clayey silt
9069	3120	2.630723	83.79966	13.56962	very slightly sandy slightly clayey silt
9152	3180	4.089506	82.25042	13.66007	very slightly sandy slightly clayey silt
9210	3220	2.324886	85.53339	12.14172	very slightly sandy slightly clayey silt
9270	3260	2.067951	83.27389	14.65816	very slightly sandy slightly clayey silt
9314	3280	2.103051	84.57797	13.31898	very slightly sandy slightly clayey silt
9382	3360	2.103051	84.57797	13.31898	slightly clayey silt
9409	3400	3.449372	82.72415	13.82648	very slightly sandy slightly clayey silt
9434	3440	3.39998	83.29495	13.30507	slightly sandy slightly clayey silt
9459.5	3480	3.720823	82.53445	13.74473	very slightly sandy slightly clayey silt
9486	3520	4.433106	83.65923	11.90766	slightly sandy slightly clayey silt
9512	3560	0.194198	85.90792	13.89789	very slightly sandy slightly clayey silt
9538	3600	1.157951	81.45652	17.38553	very slightly sandy slightly clayey silt
9576.5	3660	10.05301	81.5876	8.359393	very slightly sandy slightly clayey silt
9602	3700	4.100969	82.59436	13.30467	slightly sandy slightly clayey silt
9628.5	3740	5.165453	82.53639	12.29816	slightly sandy slightly clayey silt
9641	3760	3.387258	84.30776	12.30498	very slightly sandy slightly clayey silt
9679	3820	1.820727	83.98949	14.18978	very slightly sandy slightly clayey silt
9734.5	3880	1.54585	83.3764	15.07775	very slightly sandy slightly clayey silt
9864	3920	5.888689	79.12219	14.98912	very slightly sandy slightly clayey silt