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SEDIMENTOLOGY

INTRODUCTION

The sediments received by a sink manifest the geological history since their derivation from the pre-existing rocks in the provenance to their transportation in various energy mediums and post depositional modifications under the influence of the physicochemical environment of the sink itself. Thus, the sedimentological studies especially for the sediment texture and mineralogical as well as biological composition, shed light on its journey through the geological time. In the present chapter the textural analysis and clay mineralogy of the sediments from the active Meda creek bottom and ancient tidal flat (upstream of barrage) have been analysed and discussed.

METHODOLOGY

Sampling

The Meda creek bottom sediments were sampled during July 2004 using *Van Veen grab sampler*, within water depth of 1.5 to 4 meter from HWL (Figure 3.7). Grainsize analysis and clay mineralogy of the sediment samples was attempted. The topmost 1 cm thickness of the sediments was separated from each sample for the micro-palaeontological analysis.

Shallow subsurface samples were collected during pre monsoon (May, 2004) when the area of the Meda creek behind the barrage became totally dry. A trench of 2-meter depth was dug at N latitude 22° 52' 32" and E longitude 69° 24' 55".

Further, a core of 1-meter length was raised driving a PVC pipe from the bottom of the trench. The sub-sampling at 6 cm interval was carried out on the cleaned vertical face of the exposed trench wall. Total 45 sub-samples were collected along the profile of 2.9 meter that included the trench wall and the PVC pipe. All these samples were analyzed for their grain size and clay mineralogy by the methods discussed here under.

Grain size Analysis

The Sediment samples collected from various parts of the creek bottom as described before were dried in the oven at 60°C till it became completely dry. The sample weight of 10 gm was taken into a 1 litre beaker and added with tap water for soaking the sample. After a couple of hours, the sample was dispersed with hand gently and then water was added. This sample was kept for settling. Next day, the water was removed by siphoning without loosing the sediment particles, and once again water was added to beaker up to 1 litre mark. The process was repeated two/three times till all the salts got removed. Final wash was done using 1 litre distilled water. After removal of the 500 ml of distilled water, 20 ml of 10% Sodium hexameta-phosphate (2 gm in 20 ml) was added and sample was kept for overnight so that it gets well dispersed. Sample was then carefully transferred into a litre cylinder after sieving through 63-micron (230 ASTM) mesh. The fraction retained in the sieve represented the sand component while the fractions representing the silt and clay remain in the cylinder.

The sample collected in cylinder was subjected to the pipette analysis. A homogeneous suspension was prepared by vigorous stirring using a electrical stirrer. The settling rates of the particles were determined by taking the suspended particulates by a pipette, which was oven dried and weighed at pre-determined time intervals depending upon the temperature of the water as shown in table 3.4. 25 ml of sample 10 cm depth pipetted out of cylinder and oven dried. The dry weight of that was taken as clay fraction and calculated for 1000 ml.

An experiment was carried out for the correction for sodium hexametaphosphate weight in the dry fraction. For the purpose a 10 ml of solution (without sample) was pipette out at stipulated time and was oven dried. The weigh obtained came to around 0.0012 gm, which was minused from sample weigh in all cases.

Table 4.1 Suggested temperature and pipetting time for clay separation

Temperature	**Time interval**
For 28 degree C	1H:42M:45S
For 29 degree C	1H:40M:13S
For 30 degree C	1H:37M:42S
For 31 degree C	1H:35M:15S
For 32 degree C	1H:33M:51S

(Folk 1974)

Clay Mineralogy

Clay mineralogy was done following Poppe *et al* (2001). Rigaku's Ultima-II automatic XRD machine was used for the analysis. The X-ray diffractometer included a source of monochromatic radiation and an X-ray detector situated and slit to place specimen. The divergent slits are located between the X-ray source and the specimen, and receiving slits, located between the specimen and the detector. The detector and specimen holder are coupled with a goniometer so that a rotation of the detector through 2x degrees occurs in conjunction with the rotation of the specimen through x degrees, a fixed 2:1 ratio.

Preparation of clay slides: The clay sample was extracted from the settling cylinder of pipette analysis, just after the pipetting for grain size analysis. The aliquot was concentrated by centrifuging the sample.

The glass slides were kept at inclination of 1-2 degree. Few drops of concentrated clay aliquot were slowly released with the help of a dropper. The aliquot slowly spread over the slide making a thin uniform layer. The slides were allows to get dry by normal evaporation. Each sample was prepared in triplets.

Ethylene Glycol Treatment: X-ray diffractometer test after glycolation was used for the confirmation of swelling clays like smectites (e.g. montmorillonite, nontronite, and beidellite), some mixed-layer clays, and vermiculite.

Ethylene glycol was poured to 1 cm depth in the desiccator. Oriented aggregate mounts were placed on the shelf of desiccators. Desiccator was placed in oven at 60 to 70°C for overnight. Samples were used for X-ray diffractometry as soon as they were removed from desiccators.

Heat Treatments: Heating at various temperatures is commonly used to help identify clay minerals by revealing changes in crystal structure spacing or loss of the structure. Depending on the temperature and the mineral species, these treatments can collapse the structure by dehydration, or in the case of other minerals destroy the crystal structure.

Furnace was preheated to 550°C. The oriented aggregate mounts were placed in the furnace. Furnace was switched off precisely after half an hour. Sample were removed from furnace and taken for XRD analysis after they gained the room temperature.

RESULTS

Meda Creek Bottom Sediments

Grain size analysis

In general, grains size analysis of the Meda creek bottom sediments indicate domination of clays followed by silt (Table 4.2).

Table 4 2 Sand, silt and clay percentage in the creek bottom sediments at various stations

Sample No.	Sand	Silt	Clay
1	0.84	37.54	61.62
2	1.54	25.72	72.74
3	2.79	26.44	70.77
4	0.52	22.26	77.22
5	96.52	3.48	-

Station 5 being close to the mouth bar is dominated by sand fractions. This indicates the bottom sediments at this station have composition similar to that of the mouth bar. In fact, it indicates sub aerial continuity of the mouth bar. Station 2 and 3 have also recorded the sand although much lesser then station 5. This must be because the sample site lies to the deeper parts of tidal channels of the creek, where movement of water during tidal cycle leads to transportation and deposition of the sand. Station 1 represent shallow parts of the tidal channel of Meda creek, and has recorded good amount of silt accumulation. Station 4 being the most interior part of the creek, shows maximum amount of clays. With mouth bar absorbing maximum wave energy, the creek almost behaves as sheltered basin even from the landward side due to the barrage.

Clay Mineralogy

Peak values of XRD plots of the raw data indicate presence of clay minerals like, smectite, illite and kaolinite/chlorite (Figure 4.1).

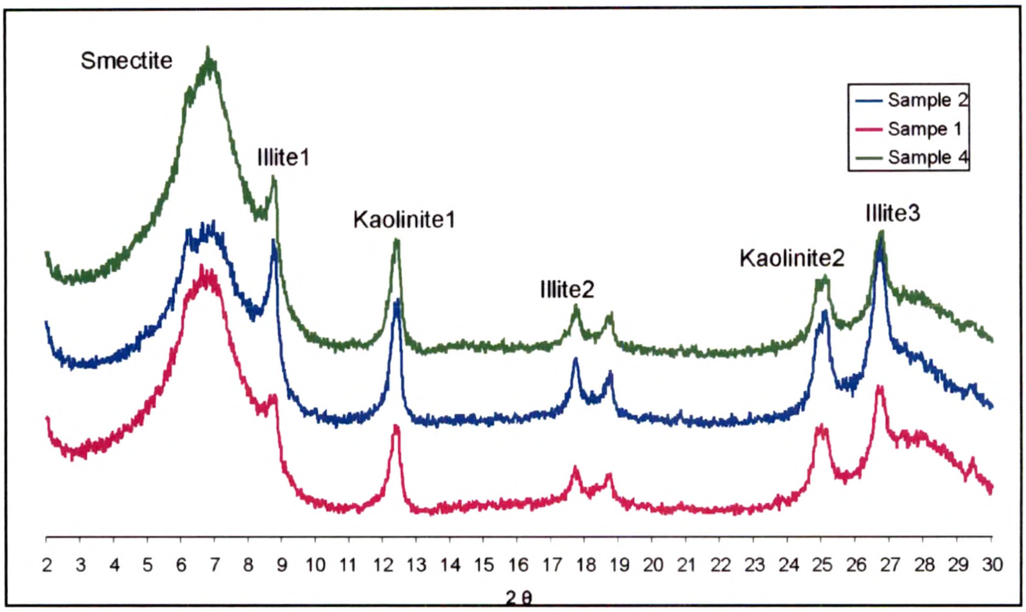

Figure 4.1 XRD pattern of the clay samples from the Meda creek bottom, showing prominent peaks of illite, smectite and kaolinite

The first peak of the XRD graph is that of smectite, confirmed by 14 Å d-spacing of 001 peak (2θ value 7). Smectite peak is the tallest in sample 4 followed by sample 1 and sample 2. In the study area major source of smectite must be the weathering of Deccan Trap basalt in the upstream, which gets transported by seasonal rivers as suspension load during monsoon. Smectite is also contributed by rivers of adjacent basins discharging the smectite into the Arabian Sea, which in turn enters into the creek during high tides. In general, members of the smectite group include the dioctahedral minerals montmorillonite, beidellite and nontronite, and the trioctahedral minerals hectorite (Li-rich), saponite (Mg-rich) and sauconite (Zn-rich). From these, the presence of montorillonite was confirmed by XRD analysis after its treatment with ethylene glycol; as after glycolation the peak intensity has increased and is shifted towards lesser 2θ angle i.e., around 5 (Figure 4.2).

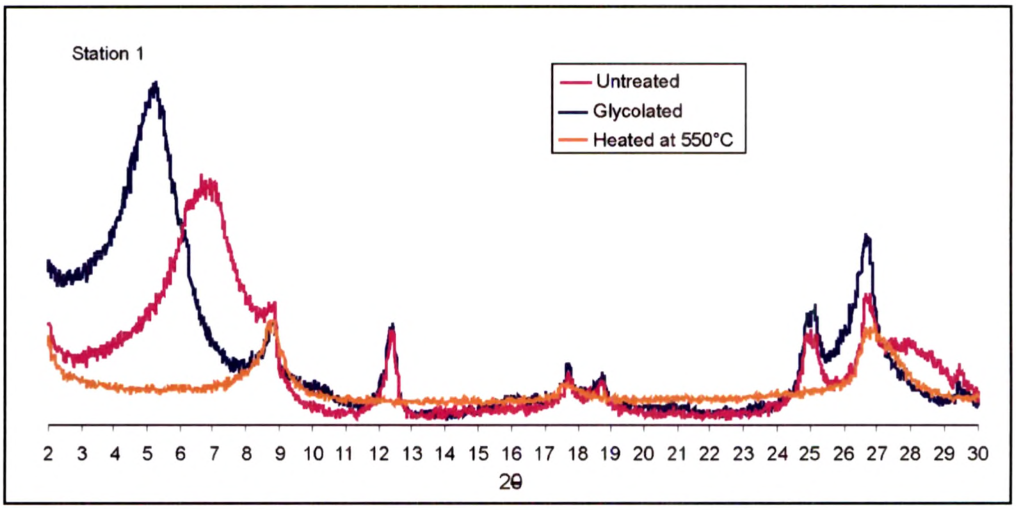

Figure 4.2 XRD plots of treated sample confirming presence of montmorillonite and kaolinite.

The next peak is that of illite characterized by a more intense peak at 10 Å (at 8° 2θ) and a less intense peak at 5.03 Å 002 (at 18° 2θ) and 3.35 Å (at 26° 2θ). Illite shows almost reverse trend compared to the montmorillonite, with maximum intensity at station 2 and minimum at 4. Illite is essentially a group name for non-expanding, clay-sized, dioctahedral micaceous minerals. It is structurally similar to muscovite, as that its basic unit is a layer composed of two inward pointing silica tetragonal sheets with a central octahedral sheet. Illite clay is a weathering product of alkaline rocks. However, upstream of Meda creek does not constitute major exposure of any alkaline rock, and therefore there are negligible chances of this mineral getting derived from the upstream provenance. The illite is well represented in the sea sediments and in sea water as suspension load. Therefore, the presence of illite can be linked with the suspension load entering during high tide in to the creek.

Third major clay mineral present is kaolinite group. It is confirmed by heating the sample at 500° C for ½ hour. Two distinct peaks of 7.18 Å (at 12.5° 2θ) and of 3.58 Å, 002 (at 12.5° 2θ) could be seen in untreated samples. There is not much variation in peak intensity of the kaolinite in the sample of the study area.

Shallow Subsurface Sediments

Grain size analysis

The grain size analysis has revealed the dominance of clay (60.1 %) over the silt (31%) and sand (8.9%) fractions. Clay percent ranges from 30 to 85%, the silt ranges from 20 to 52% whereas, the sand percent measured in range of 0.5 to 42 %. In general, sand percent increases from the bottom to the top (Table 4.3, Figure 4.3).

Table 4.3 Relative frequency of the sand-silt-clay in subsurface samples from the ancient tidal flat

Sample	Depth in cm	Sand	Silt	Clay	Sample	Depth in cm	Sand	Silt	Clay
1	15	20.62	29.92	49.46	24	162	5.66	46.99	47.35
2	30	42.40	27.95	29.65	25	168	11.77	52.84	35.40
3	36	41.32	20.70	37.98	26	174	8.20	45.40	46.40
4	42	25.91	35.08	39.01	27	180	8.93	45.37	45.70
5	48	3.32	40.20	56.48	28	186	3.64	44.72	51.65
6	54	3.21	49.64	47.15	29	192	7.07	43.23	49.70
7	60	1.78	39.22	59.00	30	198	1.93	35.37	62.70
8	66	16.72	34.08	49.20	31	204	1.86	36.69	61.45
9	72	5.29	28.31	66.40	32	210	0.72	14.93	84.35
10	78	16.86	47.99	35.15	33	216	0.48	25.17	74.35
11	84	18.78	35.87	45.35	34	222	2.23	31.67	66.10
12	90	21.91	34.09	44.00	35	228	5.79	34.11	60.10
13	96	13.79	38.21	48.00	36	234	0.54	47.96	51.50
14	102	19.45	33.70	46.85	37	240	6.02	41.13	52.85
15	108	1.86	31.74	66.40	38	246	2.87	46.93	50.20
16	114	1.17	31.68	67.15	39	252	4.90	40.20	54.90
17	120	0.80	31.50	67.70	40	258	1.67	33.28	65.05
18	126	1.00	20.95	78.05	41	264	1.72	36.73	61.55
19	132	0.94	31.71	67.35	42	270	2.40	38.45	59.15
20	138	37.70	25.30	37.00	43	276	4.05	42.30	53.65
21	144	6.66	41.94	51.40	44	282	3.05	46.40	50.55
22	150	4.95	41.05	54.00	45	290	4.50	31.50	64.00
23	156	3.66	39.99	56.35	Avg.		8.9	31.0	60.2

Domination of clay + silt almost though out the section indicates an overall low energy conditions for their deposition. However, the presence of sand in good amount at several levels especially in upper 1.5 m suggests pulses of elevated energy in the overall low energy tidal environment.

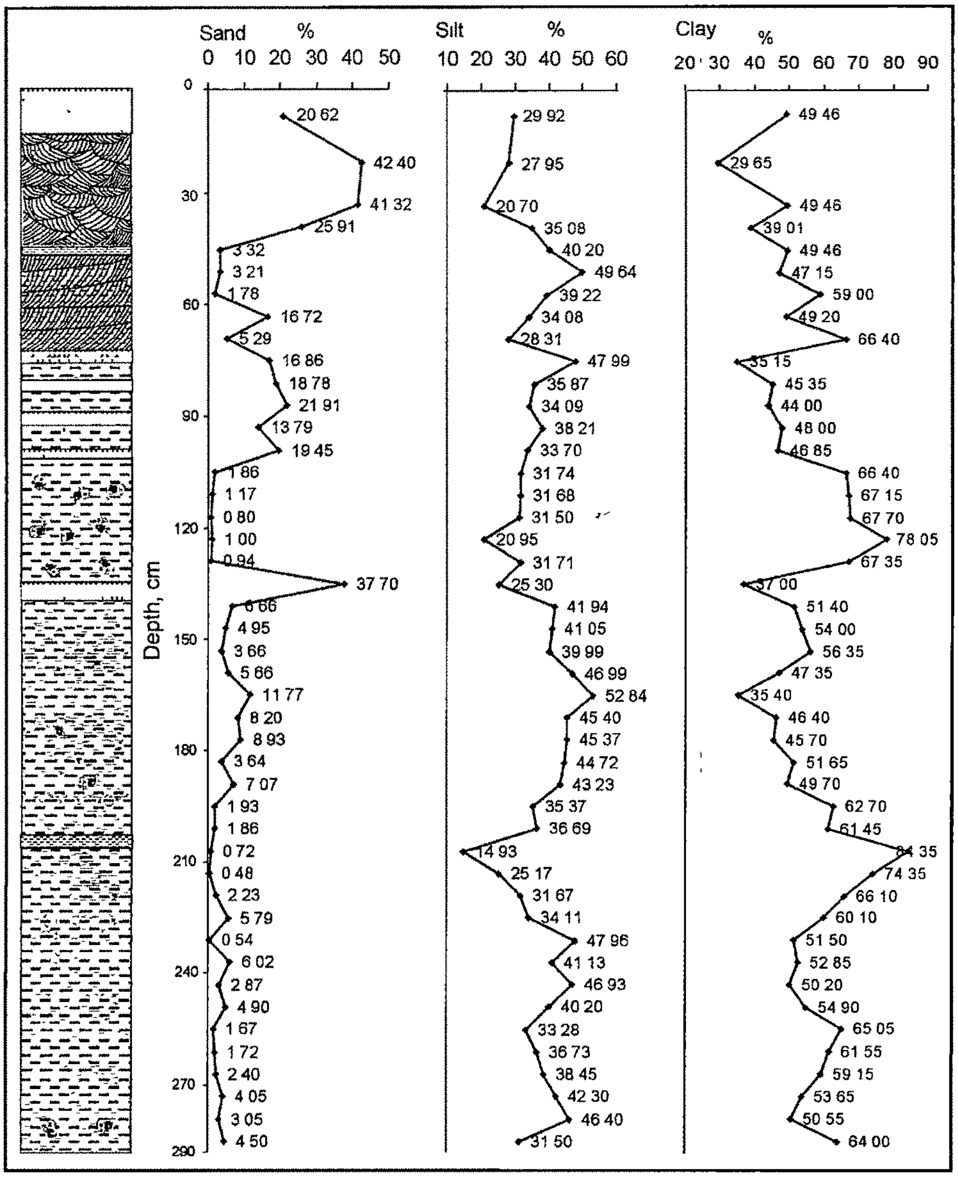

Figure 4 3 A plot showing relative variations in grain size along the subsurface profile.

From the bottom upto the 100 cm depth level, in almost all samples sand remains below 10 percent except, the sample No. 20 and 25 which have 37 and 11% of sand, respectively. Between 100to 60 cm, levels the sand proportions occurs more than 10%. Field observations here indicated that it has laminated sand and clay unit. Between 60 to 40 cm sand fraction reduces to less then 5%, and the unit is marked by presence pollens of mostly brackish water plants indicating swampy conditions. The upper 40 cm unit again shows an increased amount of sand, mostly deposited by the fluvial system or an increased rainfall in the catchment areas of the Vartu and Sorti basins. The top 15 cm has a mixed nature with more or less equal amount sand, silt and clay. This could be due to a resetting of the energy conditions after the construction of barrage about 30 years back. Figure 4.1 depicts the variations in the relative proportions of the sand, silt and clay fractions in the samples against profile. It can be clearly seen from this that the lower 1.9 m thickness have a strong relationship between silt and clay proportions with negligible amount of sand, where as the upper 1.5 shows and increasing trend of sand against a decrease in silt. Clays remains constant around 40-50% in this depth range.

Clay mineralogy

The XRD plots of the raw data indicate presence of clay minerals like, montmorillonite (smectite), illite and kaolinite/chlorite. The predominance smectite increases from bottom to top whereas kaolinite and illite shows almost reverse trend. However peakedness of smectite reduces in the depth range from 66 cm to 54 cm, which indicates reduction in its percent and increase in relative amount in of that of the other clay minerals (Figure 4.4).

The confirmation of various clay minerals was made by the XRD analysis the glycolated and preheated slides. Figure 4 5 represents selected XRD plots of the samples that reveals the glycolation where as, the peak towards lower 2θ value after the glycolation whereas, the peak of kaolinite gets destroyed after heating at 550°C.

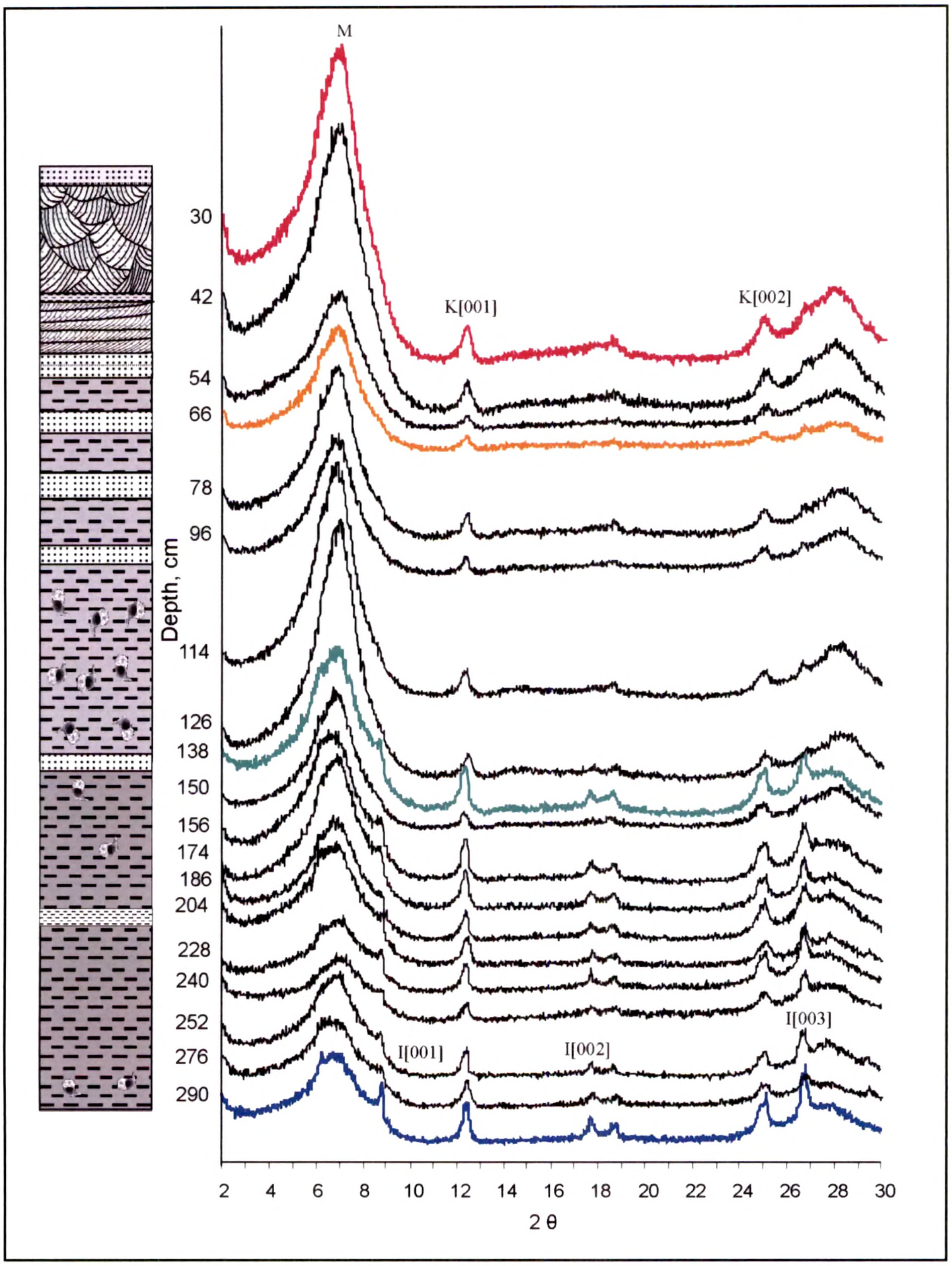

Figure 4.4 XRD patterns of subsurface samples against it relative positions on the profile.

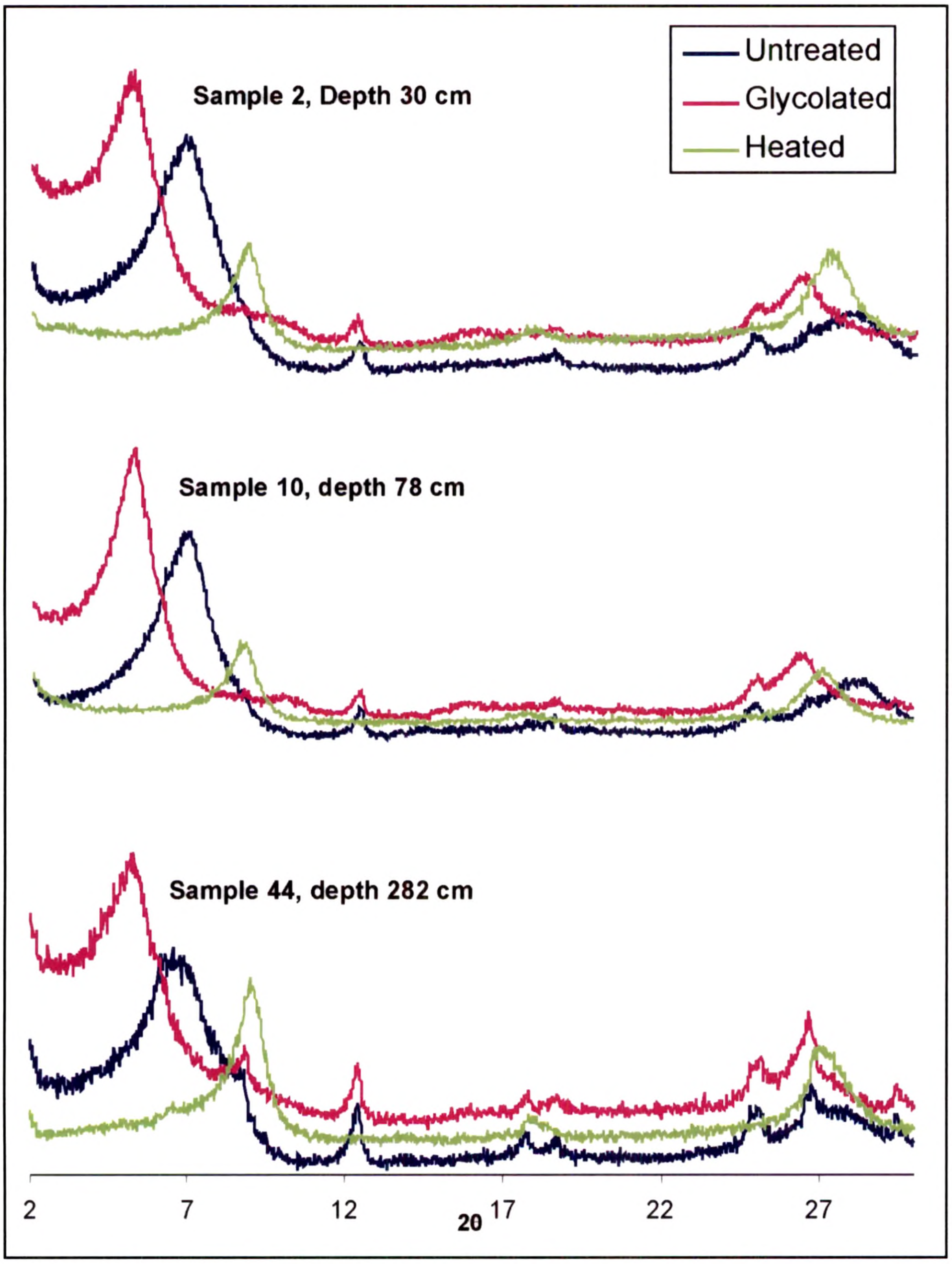

Figure 4.5 XRD pattern of clay samples after suitable treatments for confirmation of montmorillonite and kaolinite peaks.

Intensity analysis

Relative abundances of the clay minerals were calculated from the ratios of intensities (areas) of peaks from minerals of the untreated sample. In principle the peak intensity is associated with the number density of each emitting species in the plume and this, in turn is associated with the concentration of specific elements in the ablated material. This principle has been used to calculate relative abundance of montmorillonite, kaolinite and illite in the samples from various ranges (table 4.4).

Table 4.4 Relative percentage of montmorillonite, kaolinite and illite in the profile samples

Sample number	Montmorillonite	Kaolinite	Illite	Sample number	Montmorillonite	Kaolinite	Illite
2	72.45	22.04	5.51	24	54.09	29.06	16.85
4	72.05	20.82	7.13	26	53.01	28.72	18.27
6	71.65	19.60	8.75	28	52.98	27.93	19.09
8	75.45	18.90	5.65	31	52.95	27.14	19.91
10	79.67	14.64	5.69	35	30.63	41.35	28.02
13	80.13	15.56	4.31	38	38.63	37.35	24.02
16	82.49	14.17	3.34	39	50.85	29.35	19.80
18	84.85	12.78	2.37	41	37.73	32.58	29.69
20	70.13	15.56	14.31	43	46.62	35.81	17.57
22	55.17	29.40	15.43	45	34.13	36.39	29.47

Table shows percentage variation of montmorillonite in the range of 34% to 85%, being the dominant clay in the sediment. Whereas, kaolinite occurs in the range of 13 % to 42% and illite in the range of 3% to 30%. In general, the montmorillonite amount increases from bottom towards the top (Figure 4.6).

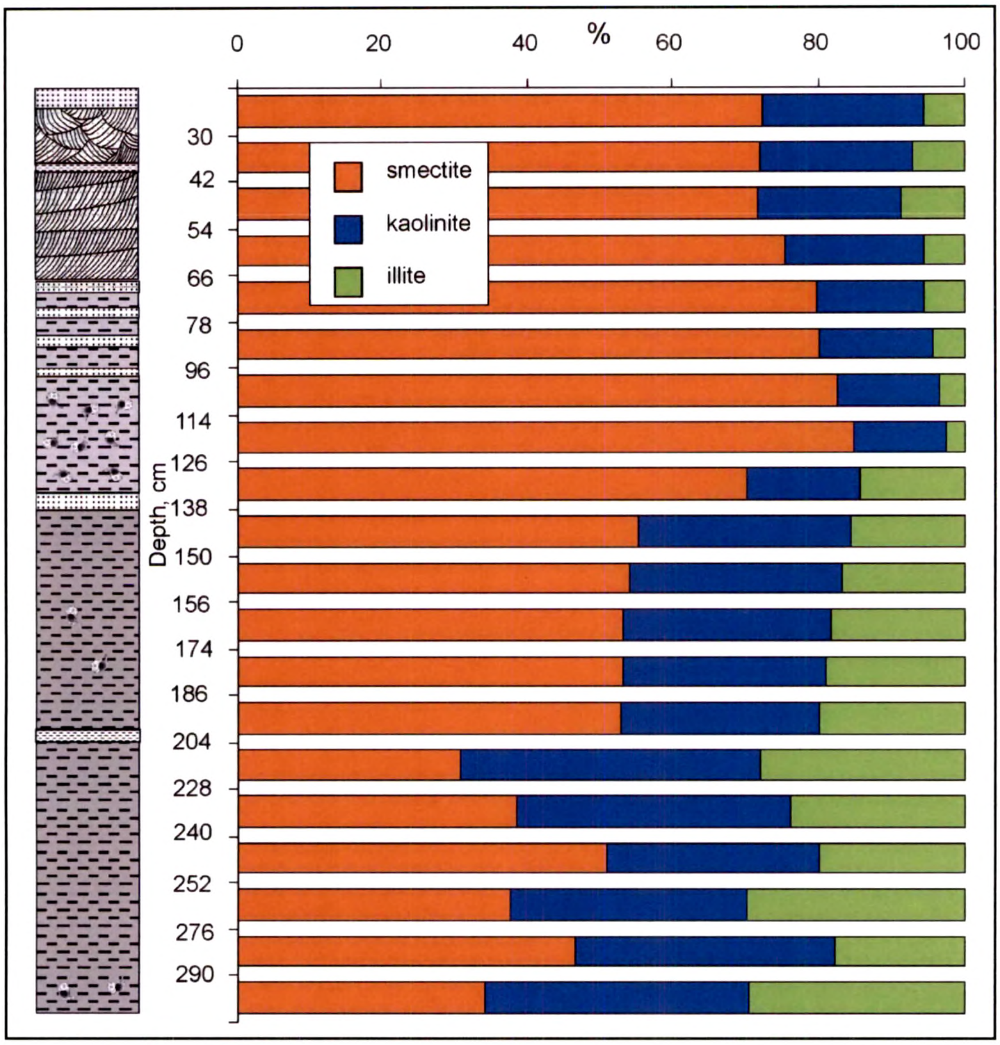

Figure 4.6 Relative abundance major clay minerals along the depth profile

There is a sudden increase in montmorillonite peak intensity at 140 cm depth. From this level upwards, illite drops below 10%. At 54 cm depth the illite contribution increases marginally to 8.75 %. From the bottom upto 140 cm depth kaolinite reduces from 36% to 30% with minor variations in between. From 140 cm to 80 cm depth remains constant around 15% and again increases in the top 40 cm to 20%.

It can be deduced that the montmorillonite has mainly contributed by the land word source whereas the source of illite and kaolinites could be offshore area or some authigenic processes.