

Lithological and Mineralogical Changes Observed in a Core from the Western Bay of Bengal

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ABSTRACT

Lithological and mineralogical studies were carried out on sediments from a 650 cm long core from the north western Bay of Bengal at a depth of 2700 m. These studies demarcate a boundary at 380 cm designated as unit I from 0-380 cm and unit II from 380-650 cm. The sediments of unit I are dark yellowish brown colour at the surface and light to dark olive grey colour downwards up to 380 cm. Texturally, it is comprised of clays and clayey silts. The coarse fraction contains well preserved foraminiferal skeletal remains. The total calcium carbonate (TCC) varies from 10 to 19% while the total organic carbon (TOC) ranges from 0.04 to 1.40%. Illite is the predominant mineral with concentrations varying from 49 to 60% followed by montmorillonite with concentrations between 22 to 36%. Chlorite content ranges from 12.8 to 29% and do not show any recognisable trend.

The sediments of unit II are dark grey in colour and are relatively coarser with silt as the dominant size fraction. The coarse fraction is characterised by low content of foraminiferal sand, presence of vivianite nodules, gypsum and pyrites. Vivianite nodules are found exclusively at 540 cm depth and are authigenic in nature and are associated with pyrite grains. The lowest values of TCC between 4 and 6% are registered in unit II with TOC remaining more or less constant at 1.40%. Highest concentration 80% of illite is observed in this unit in contrast to low values (3 to 8%) of montmorillonite.

A clear shift in the abundance of total foraminifera is observed at 380 cm core depth. *G. menardii* is a warm water species and is used to delineate palaeo-climatic variations. *G. menardii* complex abundance curves sharply increase at 380 cm depicting a clear shift from cold to warm climatic conditions. Further a fall in *G. menardii* complex concentrations at 530-550 cm depth indicate cold climate.

The boundary demarcated at 380 cm from the lithological, mineralogical and foraminiferal changes in the core is interpreted to be a transitional period of Pleistocene-Holocene.

INTRODUCTION

Bengal Fan receives enormous sediment influx from the Ganges and Brahmaputra rivers having an annual discharge of $1003 \times 10^3 \text{ m}^3/\text{yr}$ and this huge detritus floors 2.2 million sq. km. of Bay of Bengal (Lafond, 1966; Stow et al., 1989). The Bay of Bengal also receives its sediments from major peninsular rivers viz. Mahanadi, Godavari, Krishna and Cauvery. Most of the earlier studies related to Bengal Fan are confined to surface sediments (Siddiquie, 1967; Goldberg and Griffin, 1970; Kolla and Rao, 1990). Clay mineral studies in the sediments of western Bay of Bengal and eastern shelf of India was carried out by Subba Rao (1964), Ramamurthy and Srivastava (1979), Subramanian (1980), Naidu et al. (1985), Purnachandra Rao et al. (1988) and Reddy and Mohana Rao (1989). Chauhan et al. (1991) carried out clay mineralogical studies in a core from eastern Bay of Bengal. Rao et al. (1992) have worked on a sediment core from the slope of the east coast of India, off Pennar river and reported the Holocene-Pleistocene boundary at a depth of 90 cm in the core. Curray and

Moore (1974) indicated that the uppermost 6-7 m length of Bengal Fan sediments comprise of Quaternary sediments. The present work relates to inference of changing sedimentary environments during Pleistocene-Holocene in the western Bay of Bengal from sedimentological, mineralogical and coarse fraction studies of a core.

MATERIALS AND METHODS

During the 42nd cruise of ORV Sagarkanya, about 650 cm long sediment core was collected using a gravity corer at a depth of about 2700 m in the western Bay of Bengal (Lat $16^\circ 00' \text{ N}$ and Long $87^\circ 05' \text{ E}$) (Fig.1). Subsampling of core was done onboard at 10 cm depth interval. The samples are subjected to textural analysis. Less than $2 \mu\text{m}$ fraction of the sediment was separated following Folk (1968) and rendered free of calcium carbonate and organic matter by treating with acetic acid and hydrogen peroxide respectively. Oriented clay slides were prepared and scanned from 3 to $30^\circ 2\theta$ on a Philips X-ray diffractometer using nickel $\text{Cu K}\alpha$ radiation at $2^\circ 2\theta$ per minute. These samples were rescanned after ethylene glycol treatment (for 1 hr

at 100°C, Carrol, 1970) for confirmation of montmorillonite. Clay minerals were identified following Brindley and Brown (1980). Semi-quantitative evaluation of clay minerals was done by the method of Biscaye (1965). The principal peak areas of the clay minerals kaolinite plus chlorite, illite and montmorillonite were multiplied by the weighting factors 2, 4 and 1 respectively. The samples were also scanned from 24 to 26° 2 θ at 1/2° 2 θ per min interval for the resolution of kaolinite and chlorite (Biscaye, 1964). The total organic carbon and total calcium carbonate were determined following El Wakel and Riley (1957) and weight loss method, respectively.

RESULTS AND DISCUSSION

Based on the sedimentological and mineralogical characters of the sediments, the core has been divided into two units viz. unit I (0 to 380 cm) and unit II (380 to 650 cm) (Fig.2). The sediments of unit I are dark yellowish brown colour at the surface and light to dark olive grey colour downwards up to 380 cm depth. Texturally, it is comprised of clays and clayey silts. The sediments of unit II are relatively coarser, with blackish grey silts as the

dominant size fraction. The coarse fraction content of the sediments show a significant change at depth of 380 cm. The top unit contains foraminiferal skeletal whereas unit II is characterised by low content of broken foraminiferal sand, vivianite nodules, gypsum and pyrite grains.

Total calcium carbonate and total organic carbon

The total calcium carbonate (TCC) content in the core varies from 4 to 19% (Fig.2). It is clearly observed that highest concentration 12 to 19% is noticed in unit I and the lowest values between 4 and 6% are registered in the sediments of unit II. The distribution pattern of TCC closely follows coarse fraction content of the sediments. During the Late Pleistocene a drop of sea level by about 80 m has been established along the east coast of India (Rao, 1957). Such drop in the sea level favours the extension of the rivers into the exposed shelf and the discharge of sediments directly at the shelf edge or onto the slope. With increase in the sea level there is a fall in the supply of terrigenous sediment with concomitant increase in the deposition

of calcareous sediment. Sudden increase in the forams content and total calcium carbonate support such sedimentation in the Holocene. Calcium carbonate is one of the criteria that has been used to define the Pleistocene-Holocene boundary in the sediments. In the present study area the carbonate content is higher during the Holocene and lower during the Pleistocene. This is mainly due to dilution by siliciclastics (Broecker, Turekian and Heezen, 1958 and Volat, Passouret and Vergaurd-Grazzini, 1980) with carbonate dissolution having a secondary role (Olausson, 1969; Berger, 1973a and Gardner, 1975) as reported for Atlantic Ocean. It is an established factor that in marine sediments, TCC shows inverse relationship with terrigenous material (Hays and Peruzze, 1972; Shey and Huang, 1989). Thus the low concentrations of TCC below 380 cm clearly suggest the continuous and large supply of terrigenous material diluting the biogenic carbonate content.

Total organic carbon (TOC) content varies from 0.04 to 1.40% with a decreasing tendency from unit II to unit I. The TOC values of the sediments in unit II are more or less constant and is

relatively higher than unit I. The distribution trend of TOC is opposite to that of the TCC in the sediment core. Since higher terrigenous influx based on low TCC is envisaged below this level it is inferred that the organic carbon in this part of the core reflects terrigenous contribution. Therefore, the enrichment of TOC in unit II during Pleistocene is due to the terrigenous deposition and relative lower values in unit I may be due to local productivity and also due to the nature of particles present in water column as suggested by Ramaswamy (1992). Further it is well established that the productivity in the Bay of Bengal has decreased since the beginning of Holocene (Fontugne and Dupplessey, 1986). The sediments at 540 m depth are layered with black organic-rich layers. The bottom water was probably oxygen poor, resulting in a better preservation of organic matter.

COARSE FRACTION

Authigenic Gypsum

These grains are colourless to brown with translucent to transparent nature. Most of these grains are well crystallised with perfect hexagonal shape (Fig.3).

The overall size of the grains vary from moderate to coarse and are found at two horizons only, i.e. at 455 and 530 cm. Their perfect euhedral shape indicate that they are authigenic and not transported. Few crystals show interpenetrate twinning. Presence of authigenic gypsum in deep sea sediments was earlier described by (Xavier, 1979; Gupta, 1980 and Vaz, 1995). The association of pyrite with gypsum in these sediments is indicative of an anaerobic sulphide rich environment (Seisses and Roger, 1976). The organic rich sediments undergo decomposition giving rise to sulphides which ultimately got oxidised to sulphate ions. The required calcium ions are released from CaCO_3 where the calcareous tests are subjected to dissolution. The presence of corroded skeletal remains of foraminifera explains the dissolution of calcium carbonate. When both sulphate and calcium ions reached over saturation, crystallization of gypsum takes place.

Vivianite Grains

Vivianite grains (Fig.4) are found exclusively at 540 cm depth. Vivianite is a stable ferric phosphate mineral and

the X-ray diffractogram of the vivianite from the present core is shown in Fig.5. At depth in sediments where all available sulphur has been used in pyrite, different authigenic iron minerals form, for example siderite and vivianite (Emery and Uchchupi, 1984). These minerals also occur in some lacustrine sediments that contain little or no sulphate iron (Berner, 1981) and in the Baltic Sea (Suess, 1979). These vivianite are authigenic in the strict sense, because they form in pore spaces as a result of bacterial modification of interstitial waters.

Earlier work (Hutson and Prell, 1980) in the northern Indian Ocean has revealed that both the Bay of Bengal and the Arabian Sea were more saline during the Last Glacial Maxima (LGM) than in the Holocene indicating less precipitation and run off. The vivianite grains might have formed during LGM, i.e. 18,000 ybp.

Foraminifera

Foraminiferal studies have been used as a potential tool to evaluate climatic conditions of the sediment depositional times as they are sensitive to the

climatic conditions and temperatures. It is very well established that *G. menardii* abundance curves are used to delineate palaeo-climatic variations. *G. menardii* is a warm water species (Be and Hutson, 1977). Schott (1935) proposed that the reappearance of *G. menardii* be used to denote the Pleistocene/Holocene boundary. In the Indian Ocean, sediments also *G. menardii* complex peaks and depressions correlate very well with the warm and cold isotopic stages respectively (Volat et al., 1980). The down core variation of *G. menardii* complex (Fig.6) in the present study is used to demarcate the Pleistocene/Holocene boundary. *G. menardii* complex sharply increases at 380 cm depicting a clear shift from cold to warm conditions. The vertical distribution of *G. menardii* in cores was used by Ewing, Ericson and Heezen (1958) and Phlegar (1960) to map the distribution of Holocene sediments in the Gulf of Mexico. The variations in the *G. menardii* complex can be used to delineate warm and cold periods. From Fig.6, it is noticed that at 530-550 cm depth the concentration of *G. menardii* complex falls to 5% indicating cold climate. From the presence of vivianite grains and fall in the concentration of *G.*

menardii complex this period is inferred to be of LGM.

Clay mineralogy

Illite is the predominant mineral throughout the core followed by montmorillonite and chlorite. Kaolinite is present in traces (Fig.7). Typical X-ray diffractograms of clay minerals are shown in Fig.8. Illite concentration varies from 49 to 60% in unit I, whereas it increases to 85% in unit II. Montmorillonite content ranges from 22 to 36% in unit I with higher values in the upper 20 cm. Low values (3 to 8%) of montmorillonite are observed in unit II. Chlorite ranges from 12.8 to 29% but do not show any recognisable trend.

Distribution of clay minerals is expressed in terms of M/I ratio. M/I ratio decreases from 0.75 to 0.30 in unit I indicating a steady increase in montmorillonite content since the beginning of Holocene. Rao (1991) has suggested M/I ratio of 0.3 to 0.5 to Brahmani-Mahanadi province sediments. Large part of the drainage basin of Brahmani and Mahanadi rivers consists of Quaternary sediments and metamorphic gneisses respectively.

These metamorphic gneisses include gneissess and schists with local acid and basic igneous bodies (Krishnan, 1982). Montmorillonite and kaolinite being chemical weathering products are relatively enriched in this province. This increase is also reflected in the unit I sediments of the core particularly in the top 20 cm. The reduced terrigenous input during the Holocene to the present core site may be due to the recession of the mouth of the rivers resulting from sea level rise since last glacial maxima. This is also reflected by the higher CaCO_3 content as seen above. In unit II, M/I ratio is less than 0.04 and reveals the total predominance of illite. Rao (1991) has reported 0.3 M/I ratio for Ganges and Brahmaputra province sediments with 70-80% of Illite and traces up to 2% Montmorillonite. Similar assemblage is noticed in unit II and it reflects glacial weathering products carried by Ganges from the Himalayas and it appears that in this zone large quantities of sediments must have been transported and deposited from the Ganges province during late Pleistocene period when the sea level was below, thereby not getting diluted with other source of sediment.

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FIGURE CAPTIONS

1. Core location map
2. Lithological, textural and geochemical log of the core
3. Photomicrograph of gypsum
4. Cluster of vivianite nodules
5. X-Ray diffractogram of vivianite
6. Down core variation of G. menardii complex (%)
7. Down core distribution of clay mineral percentage
8. X-Ray diffractograms of clay minerals of representative samples.

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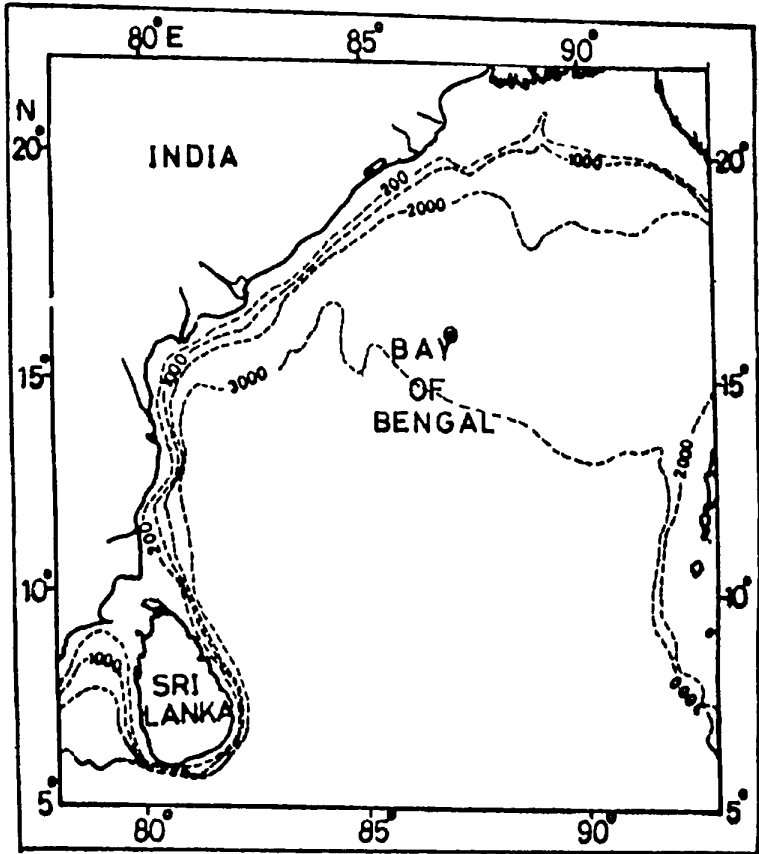


FIG.1

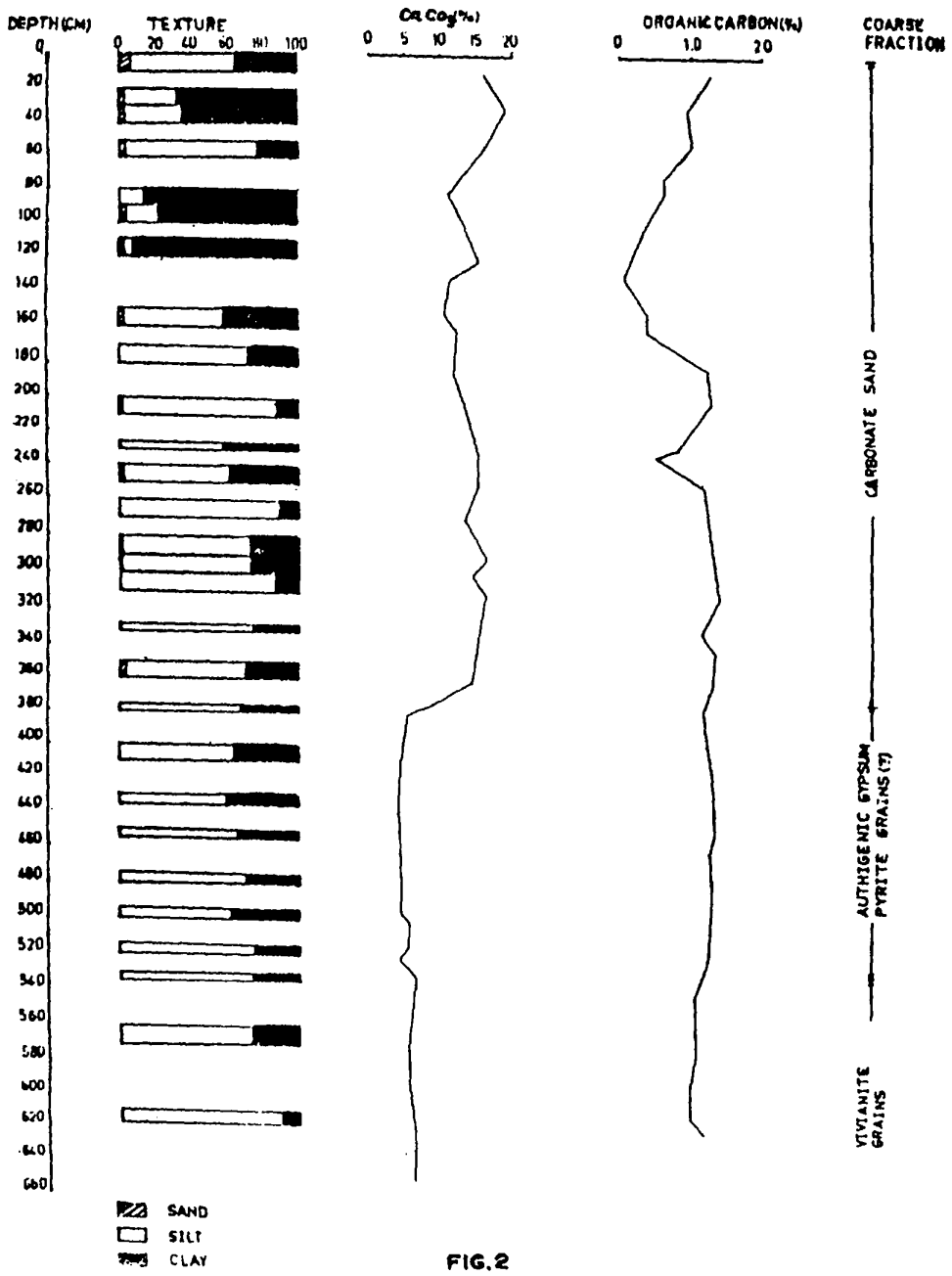


FIG. 2



FIG.3



FIG. 4

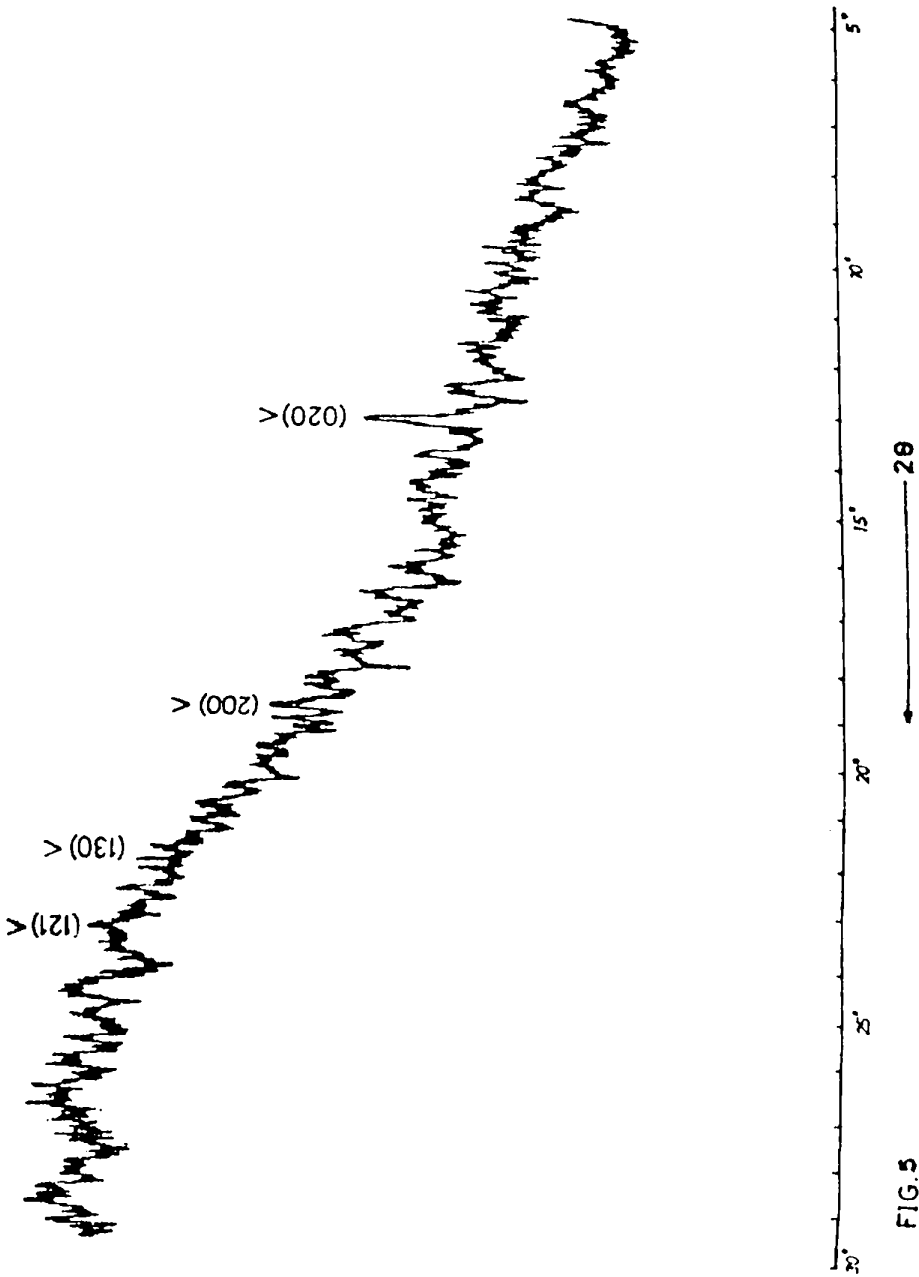


FIG. 5

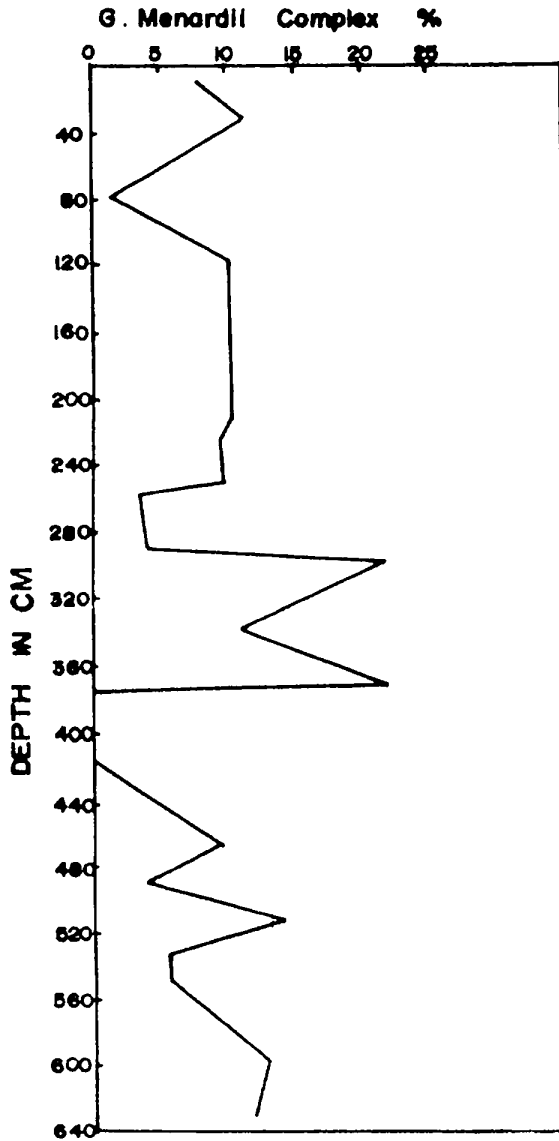


FIG. 6

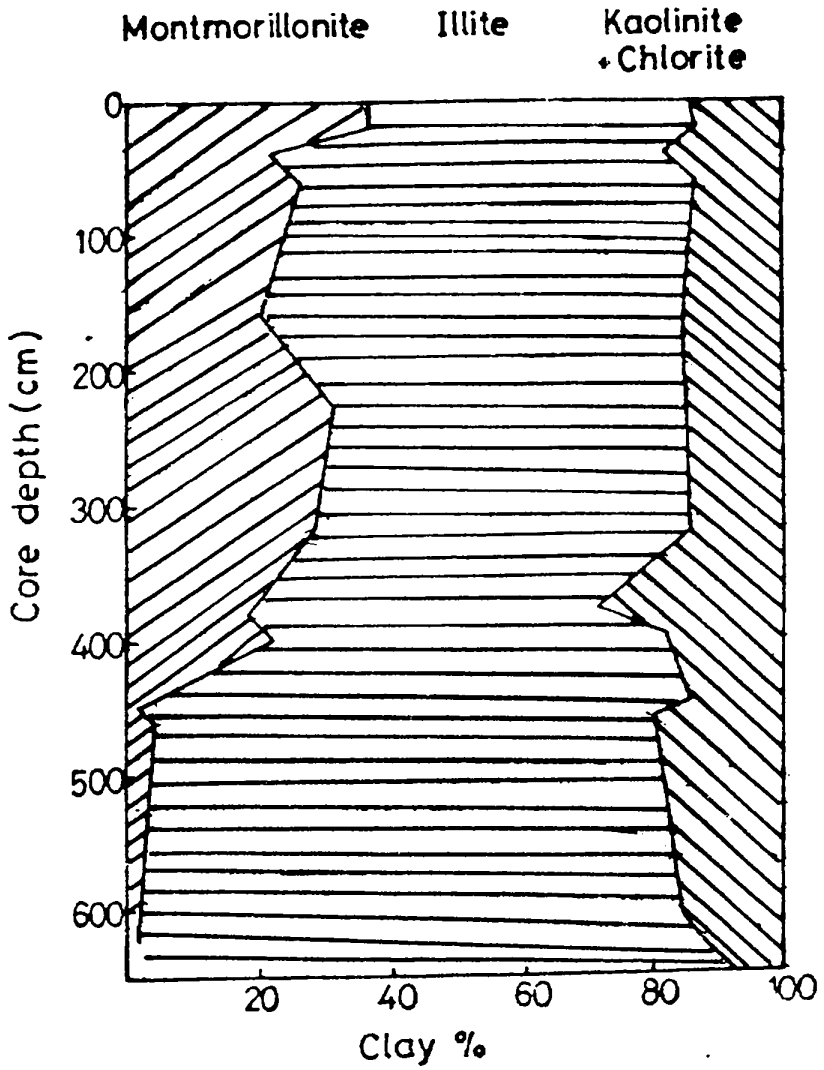


FIG. 7

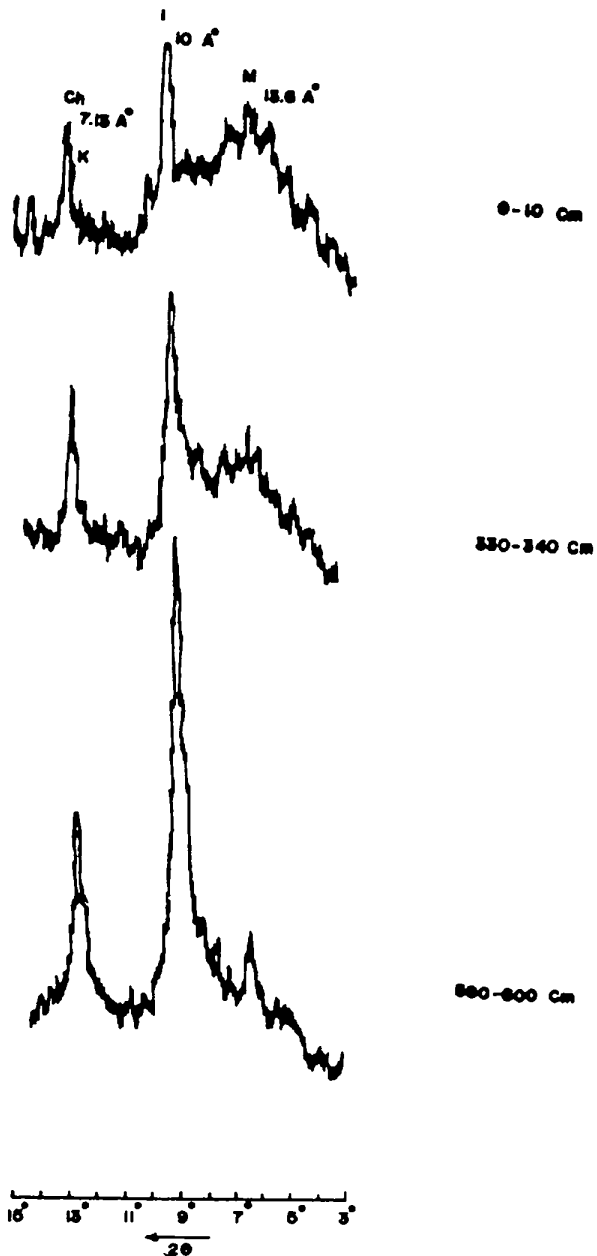


FIG. 8