

Geotechnical Properties of Two Siliceous Cores from the Central Indian Basin

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SYNOPSIS

Physical properties of the siliceous sediments from the Central Indian Basin are measured on two short cores. The properties such as water content, Atterberg limits, porosity specific gravity, wet density show the medium to high plastic sediment nature with low strength at the surface ($<1\text{kPa}$). Grain size study indicates silty clay to clayey silt composition. The cores are of same age and show wide variation in properties within small depth and close geographical spacing. Among clay minerals, illite is dominant over montmorillonite, chlorite and kaolinite. Montmorillonite of both detrital and volcanic origin is present. Textural analysis shows one core has more terrigenous influx from the North than the other.

INTRODUCTION

The Central Indian Basin (CIB) is an area of slow sedimentation with influence of terrigenous flux from the

North (Nath et al, 1989). In recent years potential metallic reserves of polymetallic nodules containing Mn, Fe, Cu, Ni and Co are identified by National Institute of Oceanography, Goa and an area of 150000 sqkm is identified as the Pioneer Area for their further development and exploitation with suitable techniques.

The pioneer area has varying topography with numerous seamounts of variable heights (Mukhopadhyay and Khadge, 1990; Kodagali et al, 1992). The sediments are dominated by siliceous ooze (Rao and Nath, 1988) with terrigenous flux (Kolla and Biscaye, 1973) which makes the textural variation notable. These factors have to be considered while making the strategy for deep-sea mining of mineral resources in the CIB. The basic requirement to do so is knowledge of geotechnical parameters of sediments and their variation with depth. Since they control the movement of mining system on sea floor, the in situ measurements are preferable, though they are rarely carried out. This is a first attempt to carry out such studies for the CIB sediments and reports only physical properties determined on two cores of short length. Their analyses give some idea about the siliceous sediment behaviour. This study is part of the geotechnical program to be conducted with more number of cores in the area in future.

METHODS

Two spade cores were collected from the CIB - core A at 10° and 77° and B at 11° and 78° - from a water depth of 5400 m. Both the cores were undisturbed and 32 cm in length. They

were subsampled at 4 cm interval onboard and kept in deep freeze at 4°C till various tests were conducted in laboratory. The index properties such as water content, Atterberg limits, specific gravity were measured by weight/volume method (ASTM, 1978). The density and porosity were estimated by formula (Bennett and Lambert, 1971) assuming cent percent saturation of siliceous sediments. The salt content correction was applied to all the properties mentioned here (Noorany, 1984). The grain size analysis was carried out following McManus (1988). The x-ray diffraction studies of oriented slides were conducted on Philips Diffractometer with CuK α tube. The identification of clay minerals was made using Carroll (1970) and semiquantitative analysis is carried out (Biscaye, 1965).

RESULTS AND DISCUSSION

All properties of both the cores are depicted in figure 1. Water content (WC): This is a measure of water holding capacity of pores in sediments and depends on water absorbing clay minerals. Both the cores show decrease in water content from top to middle part and then increase to bottom. This is due to the presence of radiolarian tests which increase the water content severely. The microscopic examination showed that radiolarian shells are abundant (>60 %, S.M.Gupta; personal communication) and water content through the full core length is high (335 %). The middle part shows lowering in wc due to increase in density and decrease in porosity as can be seen in figure 1. Moreover, the middle part does not

show any signs of bioturbation and hence more compact than top and bottom.

Atterberg limits: Average liquid limit (LL) of both cores is 166% and plastic limit (PL) is 110%. This shows that sediments are cohesive. Casagrande plasticity chart shows the sediments fall in a region of clays of medium-high plasticity (fig. 2). The plasticity index reduces to the minimum of 26% in core A and 20% in B due to low plasticity of sediments which is notable from the other properties at that depth.

Specific gravity: This indicates grain to grain relation within mineral assemblage and hence depends mostly upon specific gravity of the minerals. It varies between 2.25 and 2.39. Its change is also indicated by porosity and density. The siliceous sediments consists of opaline silica (sp.gr.2.1), the average specific gravity is about 2.45 (Poulos, 1988). The x-ray diffraction studies showed same clay minerals appearing with varying content. This shows that with increase in sand and clay content, specific gravity decreases and varies within a small range (2.25-2.39).

Porosity: This is estimated from water content, specific gravity and void ratio. The nature of sediment though not uniform, the porosity values do not deviate from the average (89%). When clay content is more than 60%, porosity is high (89%); and it reduces to 85% with lowering in clay percentage. The high porosity values are also attributed to the presence of abundant microfossil tests of radiolaria. These are hollow in nature and thus increase the water content drastically in the small section of sediments

(Poulos, 1988).

Wet density: The deep-sea sediments are known to be highly saturated and hence estimation of wet density is reliable (Bennett and Lambert, 1971). The density varies between 1.19 and 1.25 gm/cc in both cores and is directly related to porosity as can be seen from Fig.1.

Shear strength: The shear strength measurements were made by hand operated vane tester and showed values less than 1 kPa. This is due to high water content and small core length. However, similar study on long core collected in this area showed shear strength of 3 kPa at the surface (manuscript in preparation).

Geological Studies

Grain size analysis: It showed different results for both the cores though they are closely spaced. In core A, clay and silt dominated and almost in equal amount with depth whereas core B indicates dominance of only clay except at bottom where silt content increases significantly. The colour and lithology are different in both cores. Core A shows that colour changes from light brown at the top to dark brown at the middle and again light brown at the bottom. In core B, the top part is dark brown followed by light brown at middle and again dark brown at the bottom section. Moreover this also implies the effect of the influx is sporadic and not uniform which may be due to the turbidity currents responsible for the influx. Kolla and Biscaye (1973) showed that there is a supply of volcanically originated material

erupted from the Mid Ocean Ridge or Ninety East Ridge. There is another observation that core B contains nodules at the top and through depth but core A does not have any nodule. Though it is known that nodules are sporadically distributed on sea floor, their total absence in second core is enigmatic. The microscopic examination of radiolarian assemblage indicates an age of 200ka for both the cores with two biostratigraphic zones which could be separable by faunal change at 22cm depth from the sediment water interface (SM Gupta; Pers.comm.). The zone 1 (0-22cm) shows presence of abundant *C. Invaginata* whereas the zone 2 (22-32cm) is represented by *C. Tubrosa*.

Clay mineralogy: The X-ray diffraction pattern showed presence of illite, montmorillonite, chlorite and kaolinite as clay minerals and quartz and feldspar as accessories in both the cores. But core B showed lesser developed, broad based peaks of smectite than core A which is due to complex origin (Kolla and Biscaye, 1973). Moreover though the clay content is higher than sill, the illite is dominating over other clay minerals and appear to control physical properties such as water content and density. Illite content, in this area is reported higher than smectite (Rao and Nath, 1988). Biscaye (1965) reported that well developed crystallised and abundant form of montmorillonite is of in situ nature whereas less developed and less abundant montmorillonite is of detrital origin. Applying this concept, the smectite in core A can be attributed to in situ origin and that in B to

terrigenous influx from north. In core A the illite is dominant over montmorillonite, chlorite and kaolinite. The higher illite content in core A shows that it has more terrigenous influence than B from the North. It is reported that the terrigenous influx to the CIB is upto 8°S (Nath et al, 1989) and beyond also (Debrabant et al, 1993). The present study shows similar observation.

CONCLUSIONS

The cores show notable variation in their physical properties, lithology, color and manganese nodule presence though they are closely spaced. This may be due to the variation in terrigenous flux from the north to these areas of the Indian Ocean. The textural studies show that sediments are silty clay to clayey silt in composition. It seems that core A has more detrital flux than B, but should be confirmed by using chemical data. Sediments are medium to high in plasticity. The shear strength is <1 kPa at the surface of cores due to high water content. The high water content is due to abundant radiolarian tests and montmorillonite content. More number of cores in the area are required for detailed study of sediment behavior.

ACKNOWLEDGEMENTS

I am thankful to Shri.R.R.Nair Dy. Director, NIO for review of the manuscript; to Mr.S.T.Bhat and G.Prabhu for analytical help. Financial help came from DOD, Govt. of India, New Delhi.

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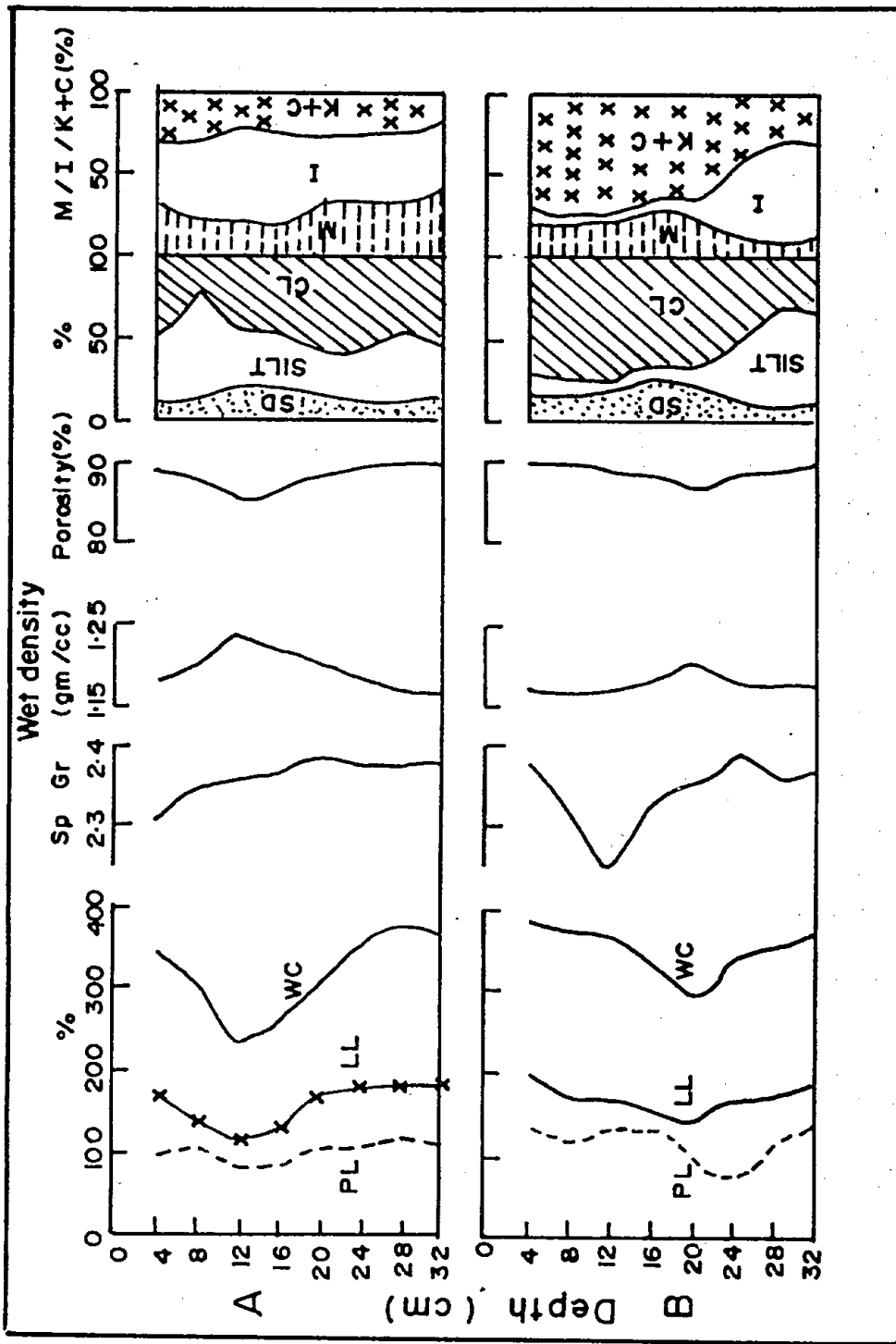


Fig. 1. Depthwise variation of physical properties of core A & B.

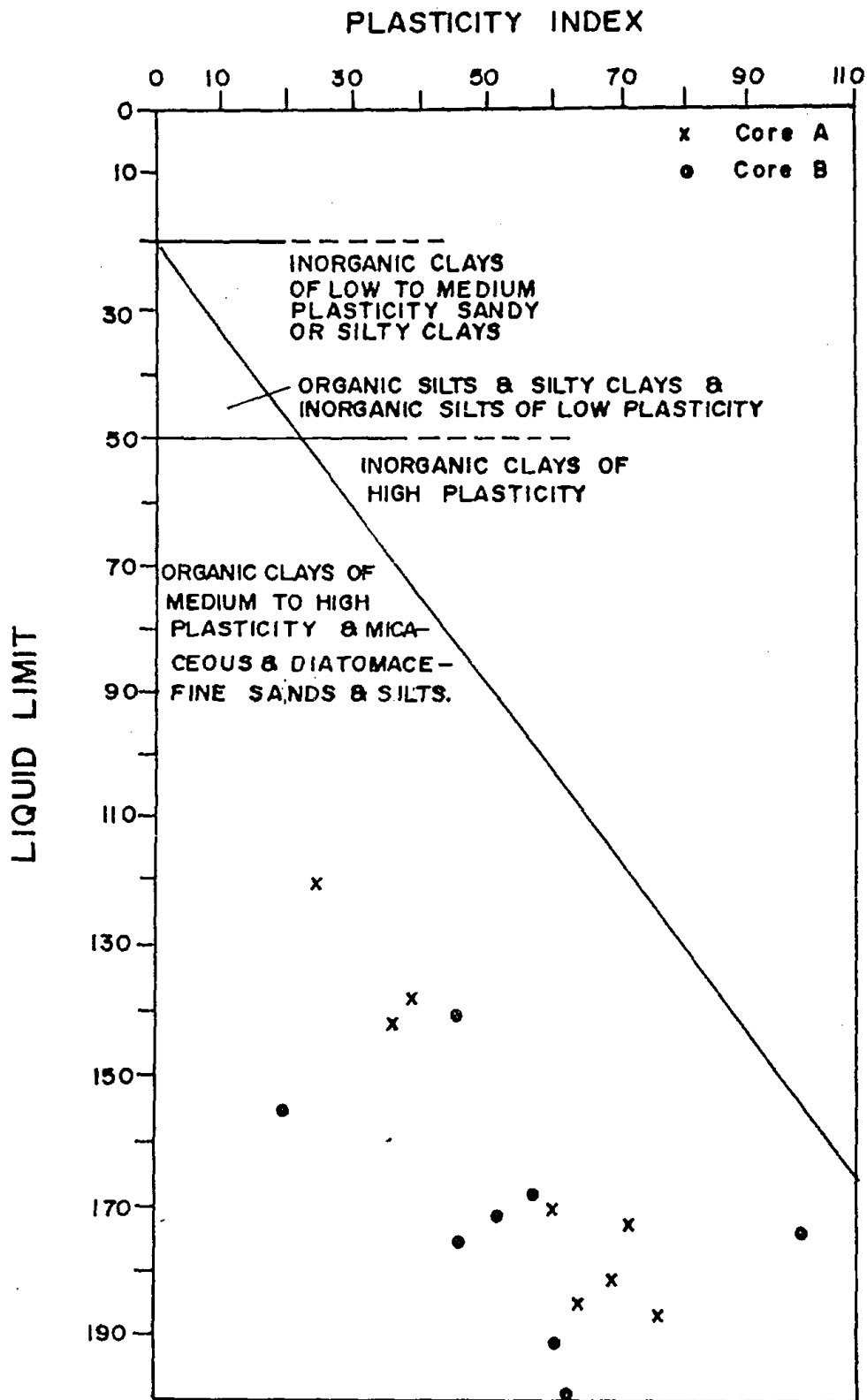


Fig. 2. Casagrande plasticity chart.