

NODULES OF THE CENTRAL INDIAN OCEAN BASIN

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The Central Indian Ocean Basin (CIOB) extends from 0° S to 25° S latitudes and 70°E to 90° E longitudes (Fig. 7). The major portion of CIOB is an abyssal plain and the plains are believed to be developed by the Ganges Fan turbidity currents which distribute the sediments to the far south. Four sedimentary facies are reported in CIOB. Terrigenous sediments dominating above 5°S latitude, siliceous sediments between 5°S and 15°S latitudes with isolated patches of calcareous sediments within, and pelagic sediments south of 15°S latitude.

Prior to the launching of the project, very little data was available on the Indian Ocean nodules compared

to those of Pacific. This chapter summarises the findings of the project staff as far as CIOB nodules are concerned.

BATHYMETRY IN CIOB

The CIOB is punctuated by numerous uncharted seamounts and hills (Fig.8). The prominent seamounts are at 13° 15'S and 74° 12'E (height - 1200 m); 13° 30'S and 80° 30'E (height - 1600 m); 14° 10'S and 81° 30'E (height - 1000m) and 13°S and 75° 45'E (height - 1000 m). It is observed that the seamounts are generally trending north-south. Apart from the seamounts

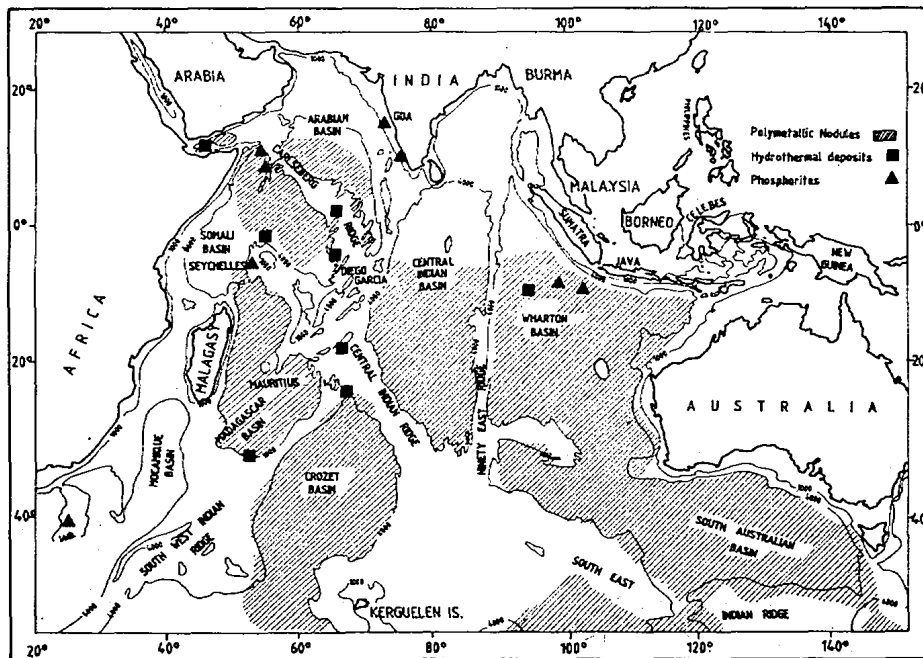


Fig 7 Distribution of deep sea minerals in the various basins of Indian Ocean.

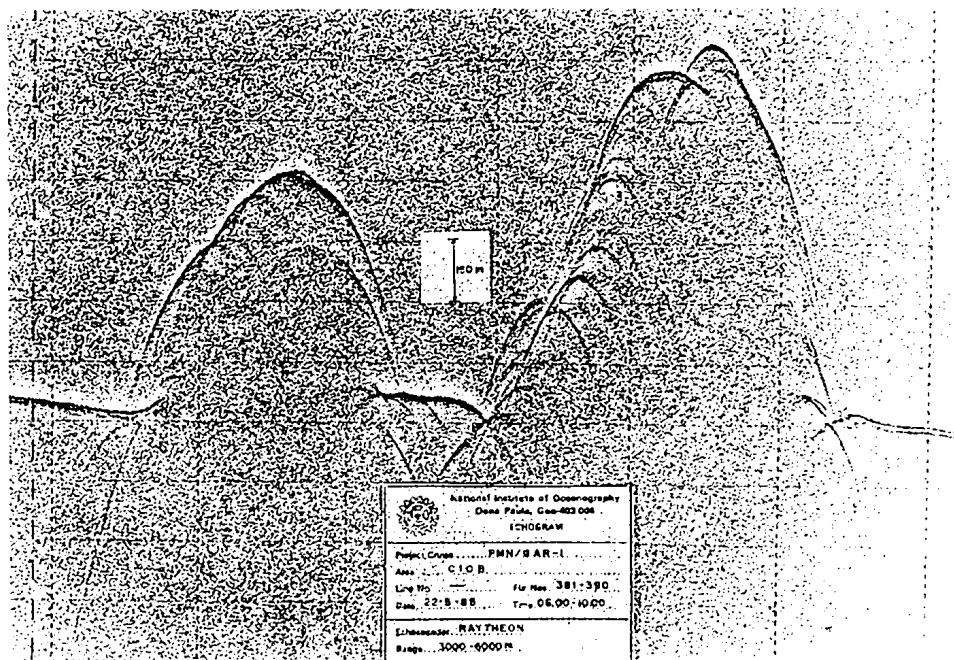


Fig. 8 Echogram of a seamount in CIOB. The height of the seamount is 1200 m.

there are a number of abyssal hills (height 100 - 600 m) and valleys (depth upto 500 m). It is found that extensive plain area comprises the major portion of the CIOB between 10° - 15° S and 77° - 80°E. There are no prominent fracture zones in the basin. Morphometric and slope angle studies have been carried out on a part of the basin. It is found that gentle slopes (0° to 3°) predominate in the area. 91.8% of the study area have slope angles in this range whereas only 8.2% of the area has angles higher than 3°. These results are relevant to problems relating to the development of mining systems.

MORPHOLOGY AND INTERNAL FEATURES OF THE CIOB NODULES

Shape and size of the nodules vary to a large extent and depend upon the geometry and the size of the nucleating agents like basaltic fragments, clay lumps, bones and shark teeth. The CIOB nodules in general range in size from 2 to 6 cm and the smaller nodules (< 4 cm) are subspheroidal to spheroidal in shape. The increase in size is usually associated with increasing elongation of the nodules (Figs. 9 & 10). The studies also indicated that polynucleation is more abundant in larger size class (> 6 cm) and near the vicinity of oceanic ridge system. The roughness of the nodules is

related to the thickness of the acoustically transparent layer of the underlying sediments. The layer comprises the major thickness of the zone of the diagenetic remobilization of the metals. It is reported that the highest abundance is associated with the rugged topography like submarine hills, slopes and valleys but with poor metal values (Cu + Ni + Co%) whereas the high metal value nodules occur on the plains. In terms of size, the 2-4 cm size nodules have highest trace metal content (> 2.0% Cu + Ni + Co). Morphological variations and the internal structures of nodules also show considerable variation with topography. Nodules from the abyssal hills show parallel laminations while the nodules from abyssal plain show well developed columnar structures and in turn are related to the depositional environments.

MINERALOGICAL STUDIES

The morphological features of the nodules are observed to have distinct control over their mineralogy. The rough surface nodules which are predominant in siliceous sediments of northern parts of CIOB have todorokite as the principal Mn phase, while smooth surface nodules which are predominant in red clays of southern parts of CIOB have Fe rich MnO₂ as principal Mn phase (Fig. 11).

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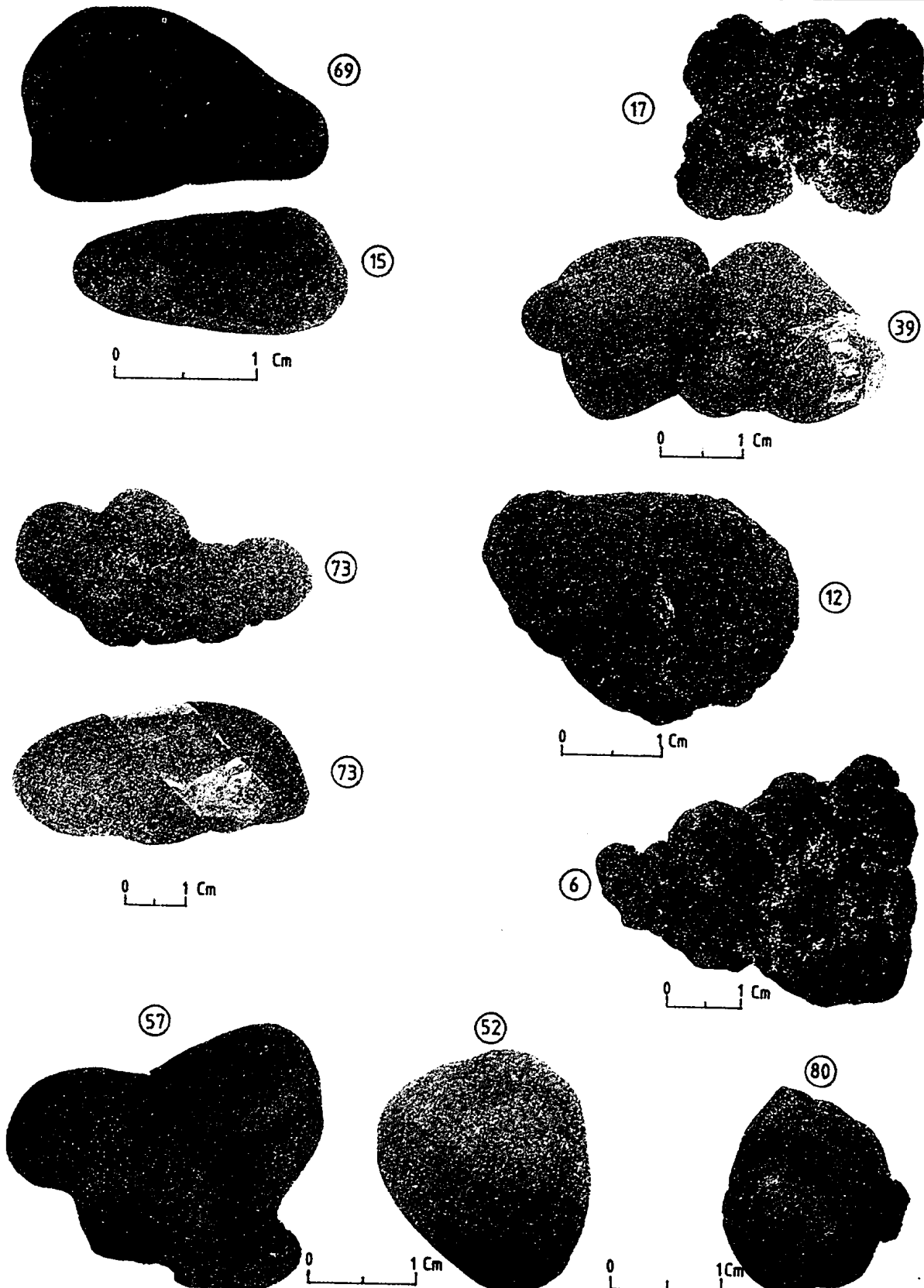


Fig. 9 The various size and shape of the CIOB nodules : 52 & 80 - spheroidal, 12 - sub-spheroidal; 69, 15, 71 & 73 elongated, remaining are polynucleate nodules

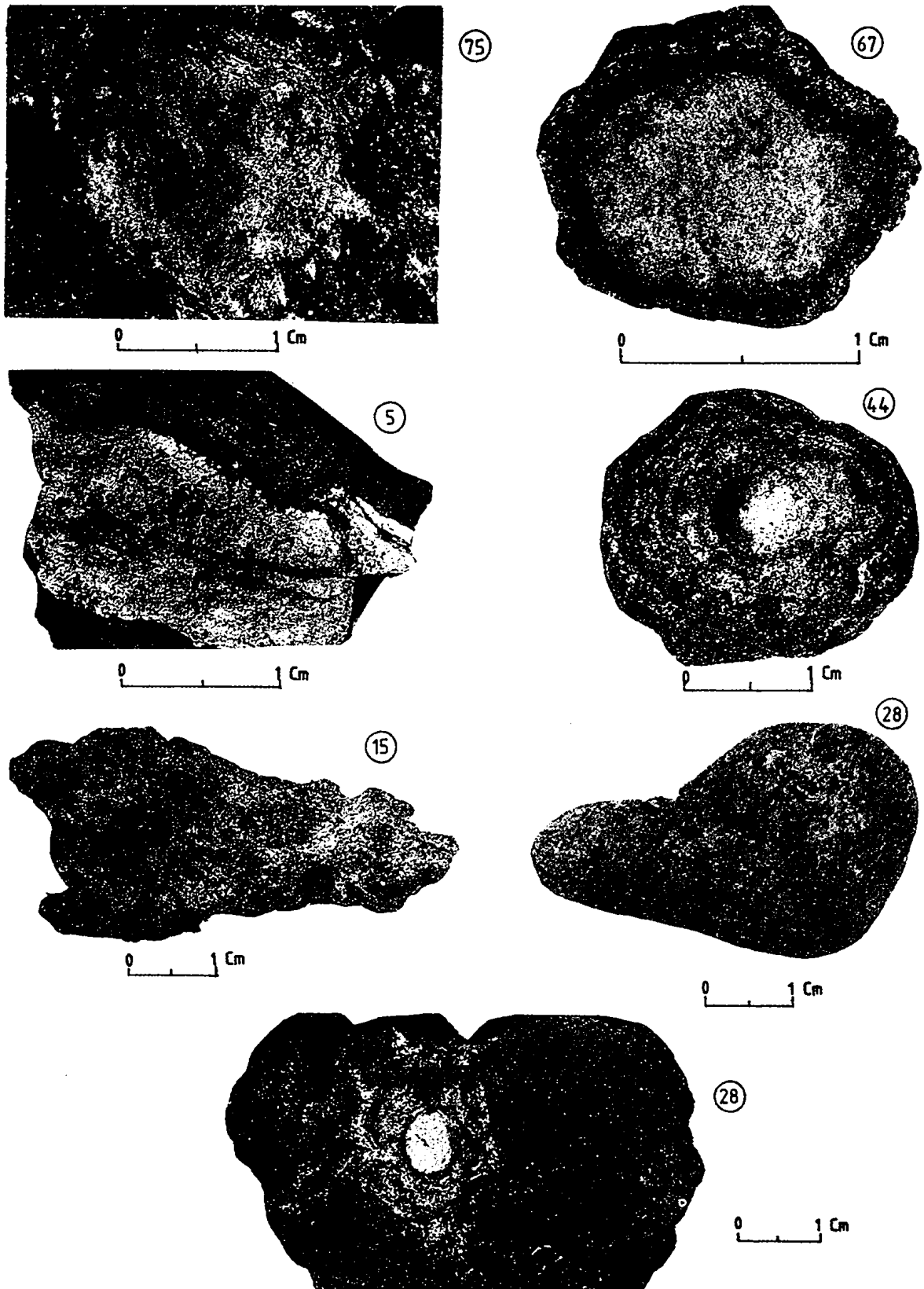


Fig. 10 Cross sections of the various type of nodules from ClOB. Central white portion is the nucleus and the blackish portions in concentric layers are the polymetallic oxides with different textures

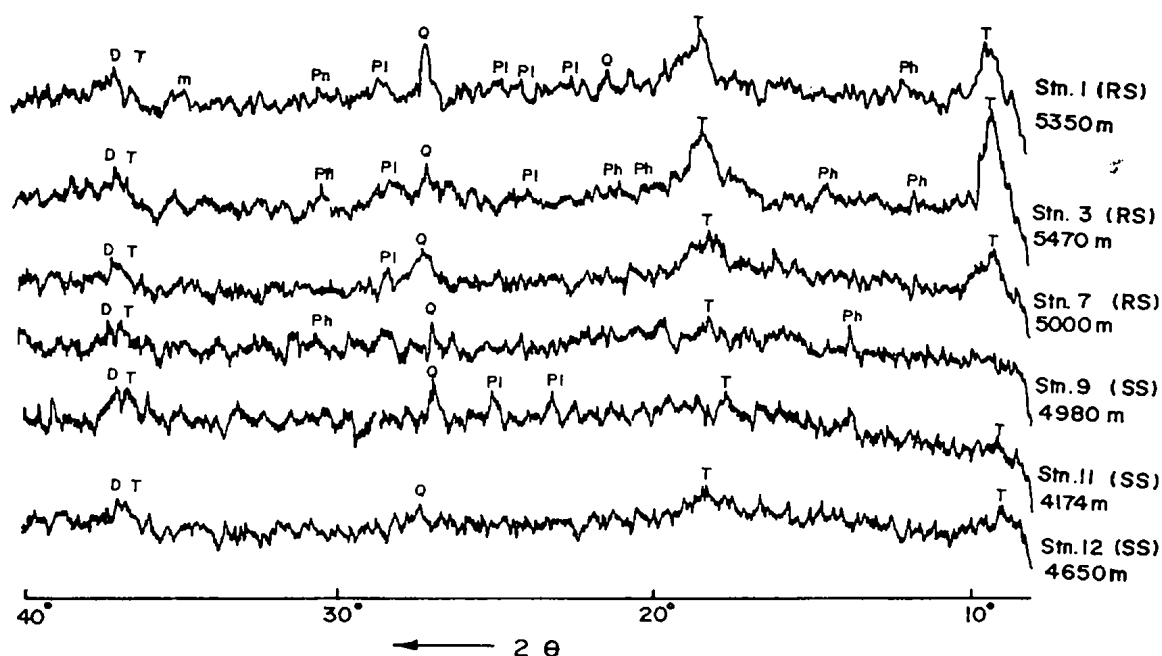


Fig. 11 X-ray diffractograms of the polymetallic nodules. RS - rough surface, SS - smooth surface. The number below the station indicates the depth at which nodules were collected. T - todorokite, D - δ - MnO_2 , Ph - phillipsite, Q - quartz, Pl - plagioclase and m - montmorillonite

This indicates that the high biological productive equatorial zones facilitate the precipitation of todorokite which is rich in trace metals like Cu, Ni, Zn. The consumption of the available oxygen by decaying organic matter under the biologically productive zones induces the decrease in redox potential of the depositional environments. This in turn facilitates the mobilization of Mn^{+2} through the upper few cm thick sediment layer initiating the precipitation of todorokite rather than δ - MnO_2 . The mineralogy may not be uniform throughout the thickness of the polymetallic oxide layer. The sublayers with characteristic mineralogy, chemistry and internal structures give clue to their genesis. Thus, the different layers of the polymetallic oxide in a given nodule with different mineralogy and internal structure might have different source supply of metals and origin. The layers with lower Mn/Fe ratios and from topographic highs with δ - MnO_2 as principal mineral phase have distinct hydrogenetic origin and those of abyssal plains with todorokite as principal mineral phase with well developed columnar structure indicate early diagenetic origin.

GEOCHEMICAL AND RADIOCHEMICAL STUDIES

The compositional heterogeneity of the polymetallic nodules geographically, topographically and environmentally is a well known phenomenon. Geochemical studies of nodules and encrustations from various

basins of the Indian Ocean and from different topographic features yield a vast variation in their chemical composition. This variation is directly attributed to the difference in source supply of metals to the accreting body of the nodule. The nodules of CIOB in broad have accreted hydrogenetically ('B' type nodules) showing a tendency towards early diagenetic growth ('A' type nodules) which include intermediate type AB (Figure 12) as revealed by the detailed chemical studies. The high concentration of Mn, Cu, Ni, and Zn is associated with the nodules accreting in siliceous sedimentary environments while high Fe, Co, Ph associated with nodules accreting in pelagic red clay environments. In the biologically high productive equatorial zones it is believed that the removal of trace metals from the oceanic environments is by organisms like radiolarians and diatoms for the building of their skeletal parts. These trace metals are released to the bottom environment below carbonate compensation depth by the settling organisms enriching the bottom waters with trace metals. During post depositional process they are diagenetically incorporated into the accreting nodule matrix. Thus the nodules of AB and A type show higher content of trace metals than the nodules accreting by incorporating metals directly from sea water (hydrogenetic, type B). The study of the biological hard parts as nucleating agents was also carried out. An ear bone of a minke whale which is in the stage of incipient nucleating agent has shown the enrichment of these trace metals in the

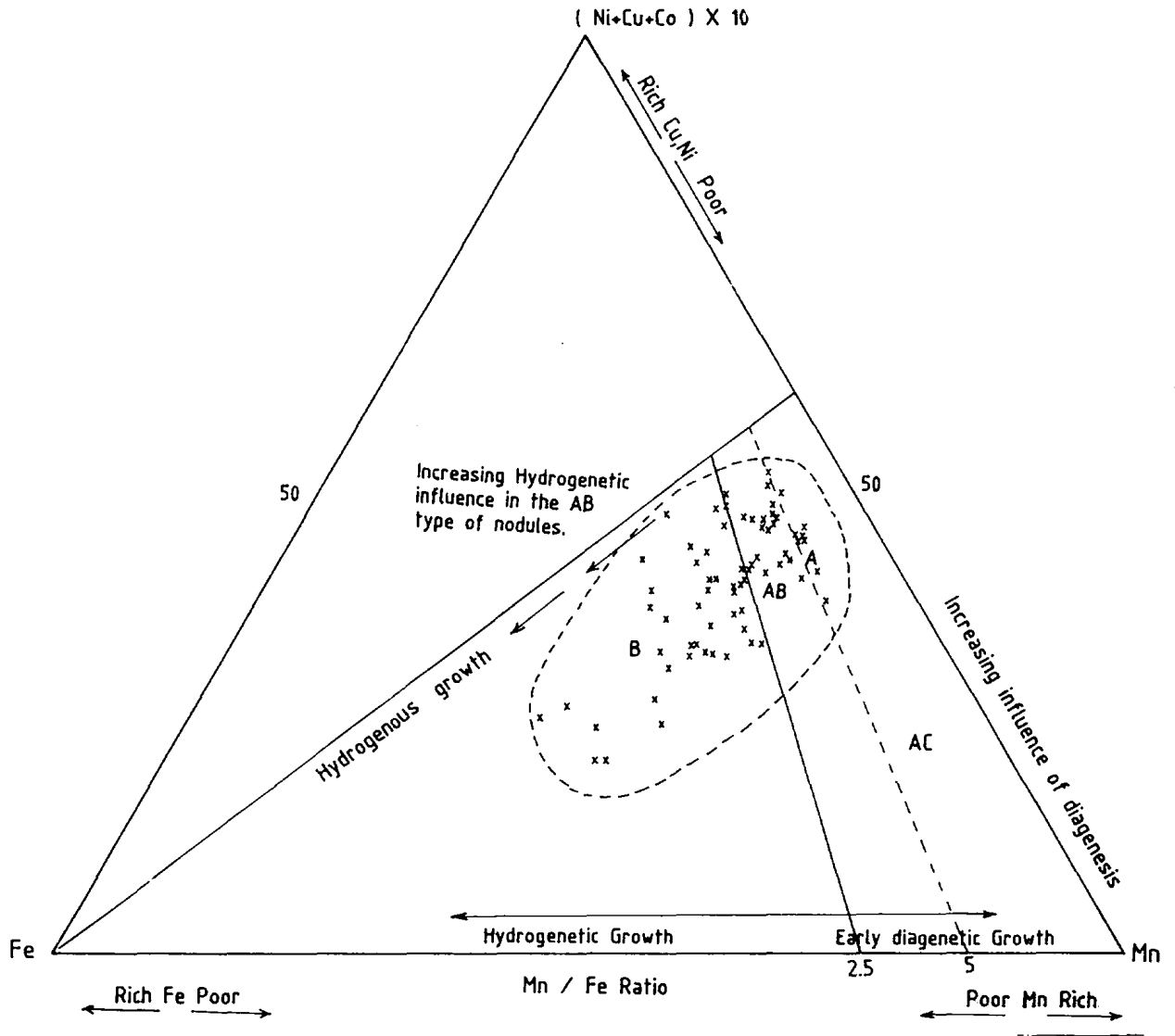


Fig. 12 Genetic Classification of Nodules from The Central Indian Ocean Basin

inner fresh parts indicating the probable replacement of Ca by the trace metal in the hydroxyapatite structure or concentration of trace metals in gaps of collagen prior to the beginning of the growth of nodules.

The growth rate of nodules has been estimated by using the uranium series radionuclides like thorium isotopes, protoactinium which are incorporated within

the nodule matrix during its growth period. The nodule from Somali basin has growth rate of 1.5 mm per million years. The growth rate estimation of CIOB nodules and encrustations indicate that only less than 10% of the oceanic authigenic flux of Mn and Fe is being incorporated into the nodule matrix and the growth rates vary between 1.4 to 3.0 mm per million years.

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