

Evidences for a Volcanic Province in the Central Indian Basin

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Abstract : Based on various lines of evidence such as the widespread occurrence of basalts, pumice, volcanic glass shards and their transformational products (zeolites, palagonites, and smectite-rich sediments), we suggest the presence of a volcanic province in the Central Indian Basin (CIB). In addition to the rocks studied, the occurrence of many morpho-tectonic features such as seamounts, abyssal hills and major fracture zones at 73°E, 75°45'E and 79°E, have helped in correlating and in deciphering the source of the rock types. Further, the large manganese nodule fields in the CIB are seen to occur in conjunction with the volcanic materials, since the latter forms nuclei and substrates for ferromanganese deposits. It is concluded that a spatial relation exists between the occurrence of the volcanic materials and the ferromanganese deposits in the CIB.

Keywords : Marine geology, Ferromanganese deposits, Volcanism, Central Indian Basin

INTRODUCTION

The source and magnitude of volcanic activity at local or regional scale can be deciphered by a study of volcanic products spread over the terrain but in deep-sea areas, particularly in the Central Indian Basin (CIB) such investigations are sparse.

An area of 4.2 million sq.km situated between latitudes 0° and 20° S and longitudes 70° and 84°E, covering most of the CIB was selected for this study. Sampling was carried out at 1840 stations during 46 cruises and more than 10,000 freefall grab samplers were deployed. The materials recovered largely include sediments, volcanic rocks, ferromanganese encrustations and weathered and their transformational products.

This report aims to provide details about the occurrence, type, and distribution of various volcanic materials in the CIB based on which a volcanic province is demarcated.

RESULTS AND INTERPRETATIONS

The CIB is bordered on three sides by the Ninety East Ridge, Mid-Indian Ridge and its southeastern and southwestern extensions; whereas to the north it is open to the influence of Ganges-Brahmaputra riverine sediments input.

Fig.1, shows a comprehensive map of distribution of pumice, and zeolites, together with major tectonic features and areas of potential nodule deposits in the CIB.

The CIB is mainly floored by siliceous sediments from 10°-15° S while beyond 15°S pelagic brown clays dominate. Small zones of terrigenous and calcareous sediments are also present to the north and west, respectively. Based on these sediment types and their distribution pattern, four distinct zones are identified (Fig.2).

These zones express distinct characteristics in terms of their seafloor morphology, tectonic features, occurrence and distribution of volcanogenic materials, and authigenic minerals such as zeolites and manganese nodules (Table I).

Although the occurrence of pumice extend from 10°-19°S and 68°-84°E (average water depth is 5000 m) the main concentration is in central deeper parts of the CIB. This concentrated zone closely follows the major tectonic features in the basin.

Pumice forms nucleus for nodules with very rough to rough surface textures and an apparent relationship was observed between the nucleus type and surfaces texture of nodules in the CIB. Such an observation convinces us to

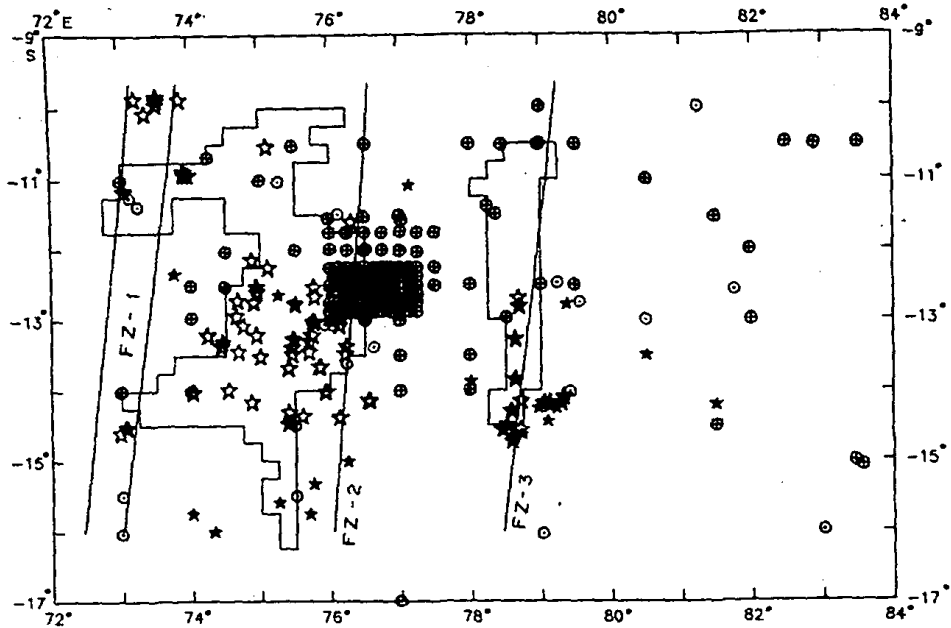


Fig.1. Comprehensive location map of morpho-tectonic features, potential manganese nodule fields and distribution of pumice and zeolites in the Central Indian Basin. FZ-1, FZ-2, FZ-3 are Fracture Zones; open stars are seamounds recorded by multibeam swath system; filled stars are seamounds recorded by single beam echosounding; circles with plus are locations of pumice; and circles with dot are locations of zeolites.

conclude that pumice clasts play a vital role in deciding the shape and size of nodules. A paucity of manganese nodules to the north of 10°S was believed to be due to rapid influx of terrigenous sediments from the Ganges and Brahmaputra (Nath *et al.* 1989), whereas we attribute this paucity to the limited occurrence of pumice and other volcanics in this region (Table I). Northern boundary of pumice field is delimited at around 10°S. To the south of this region distribution of paramarginal grade nodules dominate. Such juxtaposed fields of pumice and nodules suggest a close relationship between the two.

Frick and Kent (1984) proposed that pumice in and around the Indian Ocean was largely derived from 1883 eruption of Krakatoa. Svalnov (1981) reported a pumice of 20 cm size derived from Krakatoa near the Ninety East Ridge and suggested that bigger pumice west of this is not possible. Frequent occur-

rence of pumice of various sizes, especially the larger ones (~30 cm) in the CIB precludes their origin and/or derivation from Krakatoa and suggest an *in situ* origin (Iyer and Sudhakar, 1993a).

Large pumice clasts in the CIB are deemed to be derived locally as hot pumice near the eruptive source and floated for short times. Occurrence of pumice deposit in the vicinity of fracture zones, seamounds, and abyssal hills probably suggests a morpho-tectonic control. We envisage that pumice may be locally derived during eruptive phase of seamount(s) and/or due to reactivation along the fracture zones.

Three types of pillow basalts and basaltic fragments are identified: fresh, moderately altered and highly altered, which occur abundantly on the summits and flanks of the seamounds and abyssal hills. Numerous seamounds and abyssal hills seem to have served as conduits for outpourings of basaltic magma which

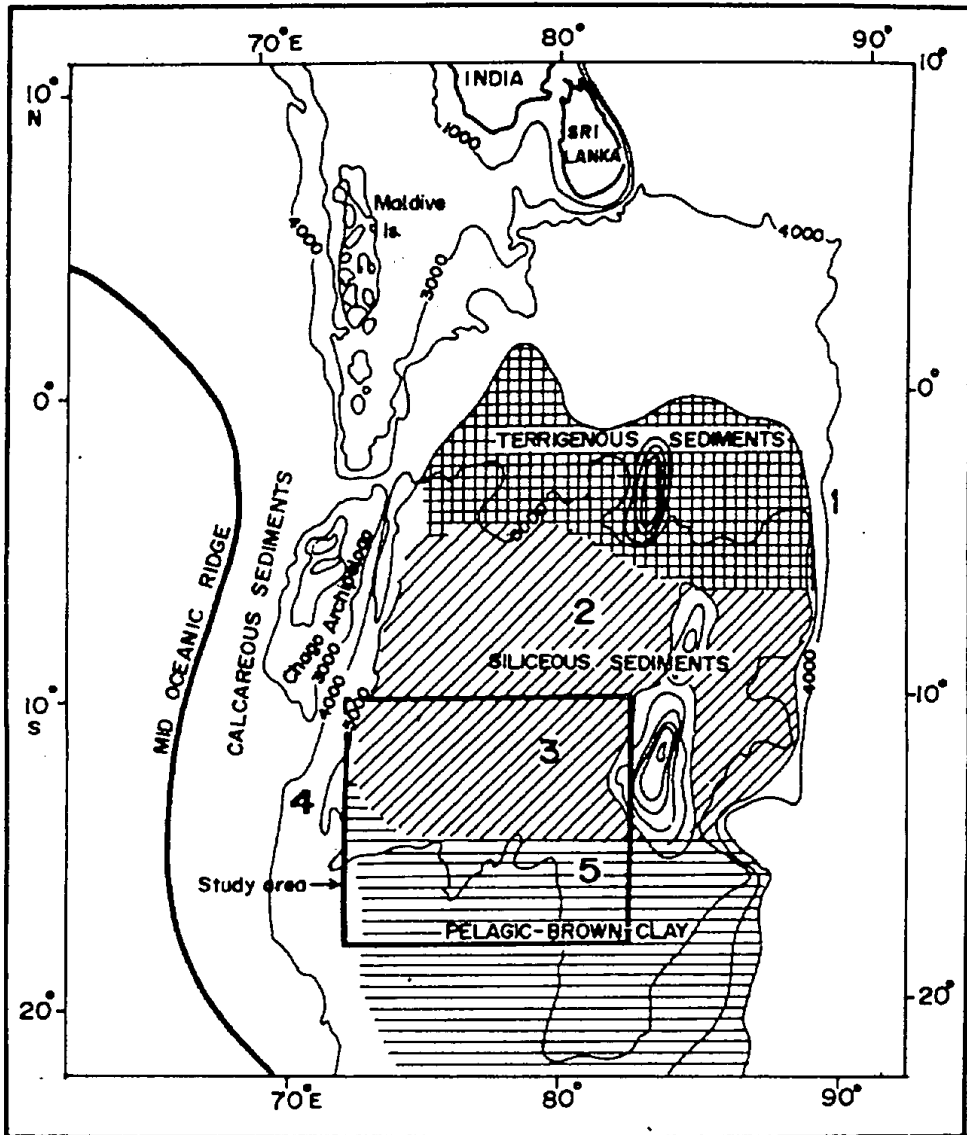


Fig.2. Map showing description of important parameters (discussed in Table I) in four sediment zones of the Central Indian Basin. Area-1 terrigenous sediments, Area-2 & 3 are siliceous sediments, Area-4 calcareous sediments and Area-5 pelagic-brown clay. Area-4 is not discussed in Table I due to lack of data.

on subsequent cooling and crystallization formed pillow lavas. Such central type of volcanic eruptions might have been either episodic or as single eruptions. Subalkali basalts near 79°E fracture zone were spilitized to varying degrees. These were suggested to be similar to fissure type of eruptions, indicating a fault-controlled basaltic field (Karisiddaiah and Iyer, 1992).

Unique indurated slabs were recovered in

the CIB. Based on their dominant mineralogy of phillipsite-harmotome group, we termed them as 'zeolitites' (Iyer and Sudhakar, 1993b). Entrapment of pumice were noted within these slabs. Zeolitic materials form nucleus and substrate for ferromanganese oxide deposition. Such slabs are derived by a series of chemical reactions, wherein volcanic precursors are transformed into palagonites and zeolites.

Based on distribution of zeolites in sedi-

Table 1. Description of important parameters in four sediment zones of the Central Indian Basin (modified after Nath and Sudhakar, 1992).

Areas/ Sediment type	General Description	Morpho-tectonics	Nuclei for Nodules	Nodule Characteristics	Volcanic/ Weathered Materials
Area 1 Terrigenous	Influence of Ganges- Brahmaputra rivers. Rapid sedimentation leading to burial of nodule nuclei.	Absence of seamounts, abyssal hills and extensions of fracture zones.	Sparse	Very low/negligible abundance; small irregular nodules	Sparse
Area 2 Siliceous	Diluted influence of Ganges-Brahmaputra rivers up to 8°S. High sedimentation rates.	Few seamounts; abundant abyssal hills.	Limited	Patchy distribution, small flattened nodules	Glass shards, palagonite, phillipsite in sediments.
Area 3 Siliceous	High biological productivity and low sedimentation rates.	High relief area with number of seamounts (few cratered) and abyssal hills. Three major fracture zones at 73°E, 75°45'E and 79°E.	Most Abundant	Prime areas of nodule deposits High abundance (>10 kg/m ²) and high grade (>2.5%) Fe-Mn crusts.	Basalts (as outcrops and fragments), pumice clasts dominant, glass shards, volcanic spherules. A large pumice field demarcated. Occurrence of zeolite slabs.
Area 4 Calcareous					
Area 5 Pelagic - Brown clay	Low biological productivity.	Chains of seamounts and abyssal hills, number of small ridges extensions of all three major fracture zones.	Abundant	Extensions of prime areas. High abundances (5-10 kg/m ²), low grade nodules (<2.5%).	Basalts, few pumice. Part of the pumice field falls in this area. Few locations of zeolite slabs.

— DATA NOT AVAILABLE —

* Areas are demarcated and shown in Fig.2.

ments, Venkatarathnam and Biscaye (1973) suggested that during Cretaceous-Eocene times, local silicic volcanism had existed in the Indian Ocean. Vallier and Kidd (1977) indicated that abundant silicic volcanic glass was derived during Pliocene and Pleistocene times and that a strong input of silicic glass did not begin until the late Miocene.

Ferromanganese crusts were recovered from different physiographic settings. Suspected hydrothermal input (Iyer, 1991) and faster hydrogenous growth rates (Shyam Prasad, 1994) were suggested for the growth of these crusts. These findings suggest that there are areas in the CIB where low temperature hydrothermal activity prevailed.

Montmorillonite and Fe-rich montmorillonite, derived by the alteration of volcanic materials are reported (Rao and Nath, 1988). Considering the average Ti/Al quotient, excess SiO₂ and Ba, from the sediment chemical data of Nath *et al.* (1989), it is observed that SiO₂ is high in siliceous sediments than expected, even after accounting for an average excess silica of ~28%. We believe that this high amount of SiO₂ may be due to presence of andesitic-rhyolitic glass shards and pumice fragments in the sediments. These findings are corroborated by the average SiO₂ (~62%) composition of the pumice lying on these sediments (Iyer and Sudhakar, 1993a). Further, chemical composition of pumice indicate two types, viz., trachyandesite and rhyolitic types (Manuscript under preparation).

Enrichment of Ba content in the CIB sediments was solely attributed to dissolution residue by Nath *et al.* (1989). But it has been opined that Ba also occurs by dehydration and cation exchange with effusive lava and with volcanic particulates or through hydrothermal transport from the magma and that Ba is intimately distributed between the seawater and

the exchangeable cation sites of harmotome (Arrhenius and Bonatti, 1965). We suggest Ba input to the CIB sediments/zeolites to be from more than one source i.e., biological, hydrothermal, diagenetic or a combination of these. High Ba contents (> 700 ppm) in pumice further explains Ba enrichment in the CIB sediments.

A valuable and direct evidence for in situ volcanism is the occurrence of volcanic magnetite spherules in association with silicic glass shards in the basin recovered from the vicinity of a large seamount (M. Shyam Prasad, *pers. comm.*). Radiolarian biostratigraphic studies indicate an age of ~10 Ka for the associated sediments. Thus, it is inferred that in the recent past there has been volcanic eruption(s) in the CIB.

Based on the above observations we summarize that (a) fracture zones and seamounts are possible source for pumice deposits, (b) basalts are ubiquitous, especially in the vicinity of seamounts and fracture zones, (c) zeolites had their origin from volcanic precursors, (d) nucleating agents for nodules are volcanic materials and their derivatives, (e) nodule deposits of first generation mine-sites occur in juxtaposition to that of pumice field and (f) fields of pumice and nodules suggest a tectonic control to their distribution.

Hence, it is inferred that the occurrence of smectite-rich sediments, association and distribution of zeolites, presence of basalts, volcanic glass shards and pumice imply a province of widespread volcanism and formation of various authigenic minerals in the CIB.

ACKNOWLEDGEMENTS

We thank the Director and Mr R.R. Nair, NIO for the facilities provided and the referee for thoughtful comments.

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(Received : 6 September, 1993; Revised form accepted : 20 October, 1994)