

## Petrology of ocean floor rocks from Central Indian Ocean Basin

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Rocks encountered in Central Indian Ocean Basin (CIOB) are predominantly basalts exhibiting typical basaltic textures. They are composed of plagioclase (either twinned and/or zoned) together with olivine, augite and opaques. Gas cavities are either empty or filled partly with cryptocrystalline materials and dark globules (?). In addition to basalts, acid volcanic fragments represented by pumice of varying shape and sizes have also been observed. Correlation between areas of rocks and nodules is discussed. It is believed that the basalts might have been the product of episodic eruption of submarine volcanoes.

During the Deep Sea Drilling Project (DSDP) except for a single core drilling, not much work has been carried out in the Central Indian Ocean Basin (CIOB). Though information on petrological investigations of the Indian Ocean is available not much is known about the petrology of a major part of the CIOB.

During the course of surveys conducted by NIO for polymetallic nodules in CIOB, a large number of samples collected included rocks and encrustations. This paper presents the petrography of the rocks collected, and correlation between areas of rocks and nodules.

### Materials and Methods

Samples were collected between 10° to 16° S lat. and 70° to 85° E long, with spacings of stations at 25, 50 and 100 km, using dredges and grabs, during various cruises of *ORV Sagar Kanya*, *MV Skandi Surveyor* and *MV Farnella*. A number of thin sections of fresh and weathered samples were studied.

### Results and Discussion

**Petrography** - Basalts: Basalts exhibit typical textures like glomeroporphyritic (Fig. 1), intergranular (Fig. 2), intersertal (Fig. 3), flow (Fig. 4), ophitic (Fig. 5), porphyritic (Fig. 6) and holohyaline (Fig. 7).

Mineralogically, the fresh basalts consist of isotropic yellow-brown glass. The mineral components include plagioclase, olivine, rarely pyroxene (augite) and opaques, in the zones below the glassy surface. Plagioclase (An 32-58) occurs as phenocrysts and micro-phenocrysts which are twinned/zoned (Fig. 8). Two types of plagioclases are seen in a few instances as evidenced by cross-cutting plagioclases, changes in their crystal morphology and also by the change in anorthite contents (An 34-52). Olivine occurs as anh-

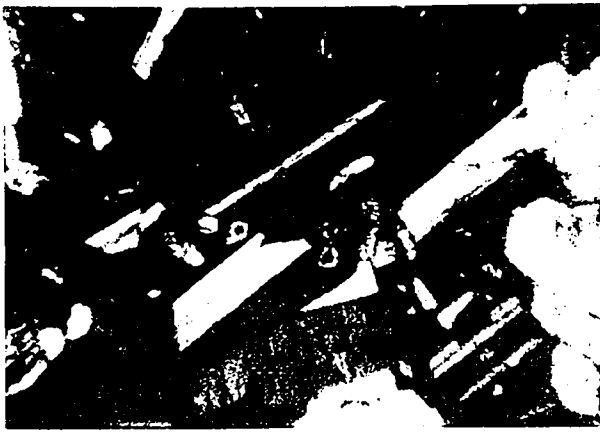
edral to subhedral crystals and at times is fractured. The opaques are mainly stubby crystals of magnetite and reddish-brown hematite. Often there is a sprinkling of opaques which occur as thin, fine needles forming dendrites. Augite, though rare, exhibits high extinction angle (38-45°). Gas cavities are few and are either empty or partly filled by cryptocrystalline materials, such as chalcedony or by dark globules (?) (Fig. 9).

The slightly weathered basalts have similar mineral phases but in addition they show the products of alteration. The glassy mesostasis form chlorophaeite and smectite with the presence of reddish-brown globular structures. Plagioclases are sericitized but at places smectite is seen. Olivine is replaced mainly by iddingsite and complete pseudomorphs after olivine is sparse.

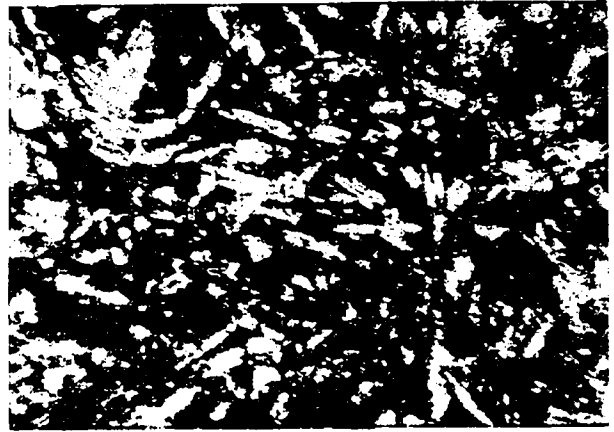
Some sections show granular quartz and feldspars which are strained and stressed in an unidirectional manner. The foliations are formed by the flaky mica minerals, mainly biotite (Fig. 10).

**Pumice:** Pumice occurs in almost all the free-fall grabs and dredges<sup>1</sup>. These are highly vesicular and siliceous rocks resembling froth with a specific gravity as low as 0.3, which enables them to remain afloat for long periods of time. They occur in various shapes and sizes (Fig. 11). Pumice are either non-encrusted or partially or fully encrusted by ferromanganese deposit, thus serving as nuclei for the nodules (Fig. 11).

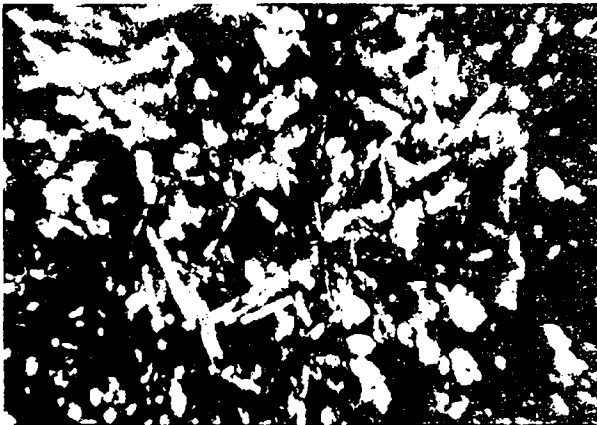
At the DSDP site 215, 14 basaltic flows occur each separated by glassy surfaces (> 2 cm) and containing veins of calcite and palagonite<sup>2</sup>. Chemically, these basalts are similar to the abyssal pillow basalts but the unusually high and uniform K<sub>2</sub>O content has been attributed to alteration<sup>2</sup>. However, based on high Ba,



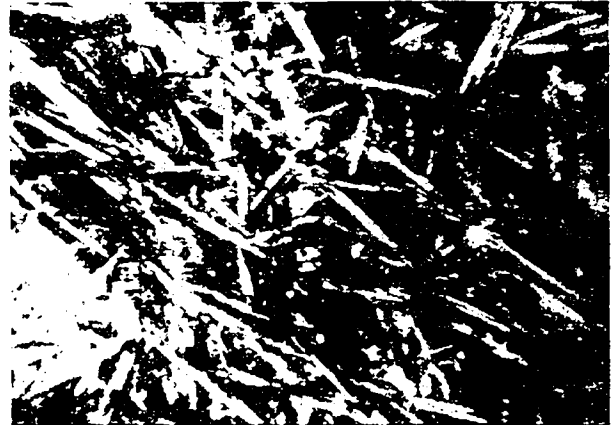
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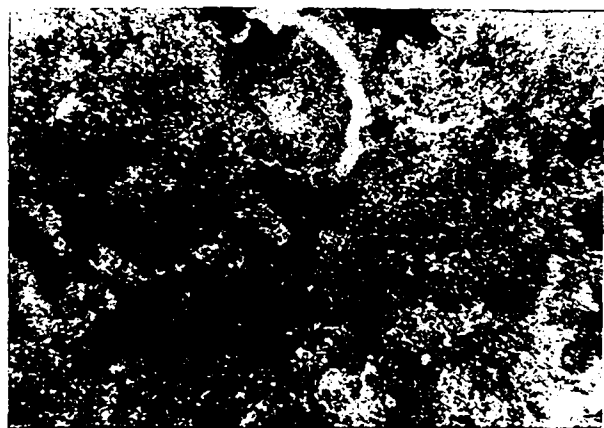
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Fig. 1—Cluster of plagioclase forming a glomeroporphyritic texture (crossed nicols). Fig. 2—Intergranular texture formed by plagioclase and olivine. Fig. 3—Intersertal texture with glass in the interstices of plagioclase (crossed nicols). Fig. 4—Flow texture formed mainly by plagioclase and olivine. Fig. 5—Ophitic texture of plagioclase and augite (crossed nicols). Fig. 6—Plagioclase phenocrysts constituting a porphyritic texture [Figs 1 to 6,  $\times 20$ ]

Sr and Zr abundances<sup>3</sup> it has been concluded that site 215 basalts are distinctly more 'alkaline' and classified as a KP type (high  $K_2O$  and  $P_2O_5$  content)<sup>4,5</sup>.

*Correlation of areas of occurrence of nodules and rocks*—It has been observed, from underwater photo-

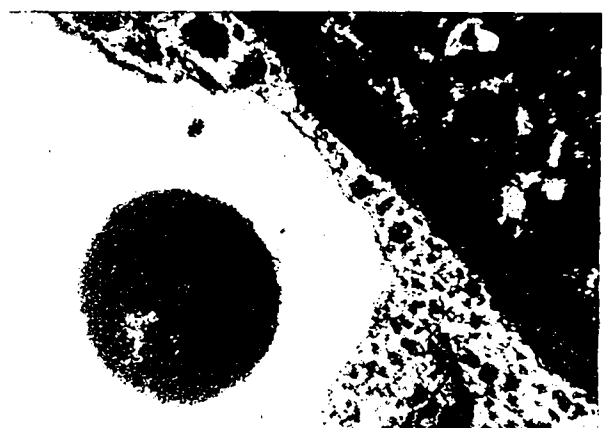
graphs and during sample collections, that wherever nodules are predominant the occurrence of rocks is either sparse or totally absent and *vice versa*. Studies<sup>6</sup> have indicated that 6 phases of nodule distribution in the CIOB are discernible. These phases depend on



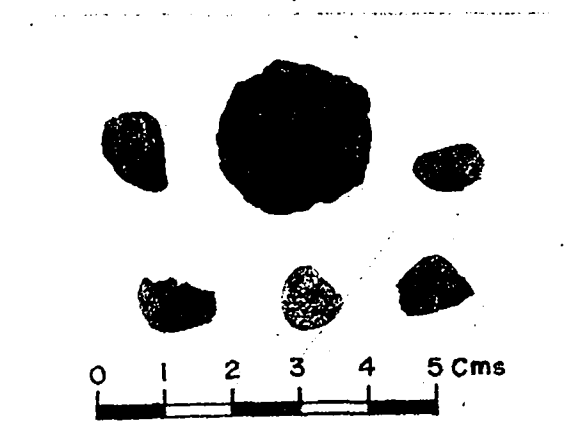
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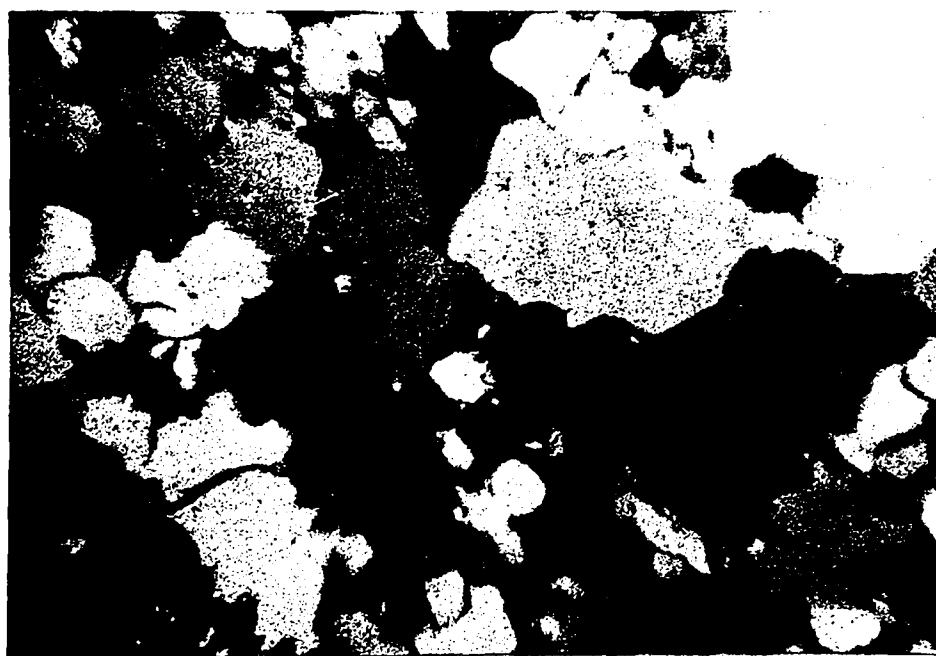
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Fig. 7—Holohyaline texture. Fig. 8—Twinned and zoned plagioclase (crossed nicols). Fig. 9—Vesicle with a dark globule (?). Fig. 10—Crushed rock with quartz, feldspar and biotite. Fig. 11—Pumice of various shapes and sizes, some encrusted with ferromanganese deposits [Figs 7 to 10,  $\times 20$ ]

the control of topography, rock outcrops and thickness of the sediment cover. The topographic highs of the seafloor are dominantly constituted of encrustations, whereas exposed nodules of  $> 5 \text{ kg. m}^{-2}$  tend to occur along the hill slopes and flanks. This has been attributed to the availability of rock fragments as nuclei for ferromanganese accretion. Availability of these nuclei decreases away from the source and are buried under thick sediment cover which has also been observed in the Pacific Ocean<sup>7,8</sup>.

**Petrogenesis**—The presence of flow texture could be attributed to the more basic and highly fluid nature of the basaltic magma. The ophitic texture points to crystallization under more static conditions of basaltic lava consolidation<sup>9</sup>. The basalts of the CIOB may be the products of the central type of volcanoes<sup>10</sup>, unlike those of the Carlsberg Ridge basalts<sup>11</sup> and the basaltic microlapilli of the Vityaz fracture zone<sup>12</sup>. These central type of volcanoes are represented by the seamounts and abyssal hills. The volcanic outbursts could have been either episodic (the case in point being site 215 basalts), or as a single eruption.

The growth of plagioclase phenocrysts could be due to their crystallisation at great depth during the earlier stages of liquid-melt cooling. The occurrence of zoned plagioclases can be attributed to changes in the chemical composition of the melt consequent to the pressure-temperature conditions. The basalts under investigation are less vesicular, thus reflecting the low volatile content of the extruded magmas<sup>13</sup>.

The rocks with granular quartz and feldspars may represent high grade metamorphic ones which could have been formed when siliceous sediments in the vicinity of the erupting submarine volcanoes were metamorphosed.

The non-coated pumice may be the product of Krakatau<sup>14,15</sup>, whereas the encrusted ones probably represent their origin from silicic volcanism which had existed during Pliocene-Pleistocene period<sup>16-18</sup>, and subsequently coated by ferromanganese deposit, but the fortuitous nature of faster accumulation of ferromanganese deposit on the pumice is also a possibility<sup>19</sup>. The influence of submarine volcanoes as sources for pumice may be possible for CIOB samples, similar to those reported for the Atlantic Ocean<sup>20</sup>.

It is envisaged that the uprising magma was basic and highly fluid in nature and underwent changes in its composition due to varying pressure-temperature conditions. This has resulted in basalts which are dominantly constituted of plagioclase and olivine with less vesicles. The variations in the anorthite content of

the plagioclase probably indicate the changing chemical composition of the melt during its ascent and on its subsequent crystallization. The influence of submarine volcanoes as a source for pumice cannot be ruled out.

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#### References

- Iyer S D & Karisiddaiah S M, *Indian J Mar Sci*, 17 (1988) 333.
- Hekinian R, in *Initial Rep of the Deep Sea Drilling Project*, Vol. 22, edited by C C von der Borch, J G Sclater, et al. (US Govt Printing Office, Washington) 1974, 413.
- Thompson G, Bryan W B, Frey F A & Sung C M, in *Initial Rep of the Deep Sea Drilling Project*, Vol. 22, edited by C C von der Borch & J G Sclater, et al. (US Govt Printing Office, Washington) 1974, 459.
- Melson W G, Vallier T L, Byerley G & Nelen J, in *The geophys of the Pacific Ocean basin and its margin* (Amer Geophys Union, Monogr. Series, 19) 1975, pp. 351.
- Frey F A, Dickey (Jr) J S, Thompson G & Bryan W B, in *Indian Ocean geology and biostratigraphy*, edited by J R Heirtzler, H M Bolli, T A Davies, J B Saunders & J G Sclater (AGU, Lithocrafters, USA) 1977, 189.
- Iyer S D & Sharma R, *Mar Geol*, (1989) (in press)
- Horn D R, Horn B M & Delach M N, *Factors which control the distribution of ferromanganese nodules*, Tech. Rep. No. 8 NSF GX 33616 (IDOE-NSF, Washington) 1973, 20.
- Glasby G P, *New Zealand J Geol Geophys*, 16 (1973) 1.
- Augustithis S S, *Atlas of the textural patterns of basalts and their genetic significance*, (Elsevier, Amsterdam) 1978, pp 323.
- Kanaev V F, in *Rift zones of the world oceans*, edited by A P Vinogradov & G B Udintsev (John Wiley, New York) 1975, p 32.
- Banerjee R & Iyer S D, *Indian J Mar Sci*, 18 (1989) 124.
- Nath B N & Iyer S D, *J Geol Soc India*, 34 (1989) 303.
- Cousen B L, Chase R L & Schilling J G, *Can J Earth Sci*, 21 (1984) 157.
- Francis P & Self S, *Sci Amer*, 249 (1983) 146.
- Frick C & Kent L E, *Trans Geol Soc S Africa*, 87 (1984) 19.
- Kolla V & Biscaye P E, *Mar Geol*, 15 (1973) M11.
- Vallier T L & Kidd R B, in *Indian Ocean geology and biostratigraphy studies following DSD Legs 22-29*, edited by J G Heirtzler, H M Bolli, T A Davies, J B Saunders & J G Sclater (AGU Lithocrafters, USA) 1977, 87.
- Lonsdale P & Hawkins J, *Geol Soc Amer Bull*, 96 (1985) 940.
- Cherdintsev V V, Kadrov N B & Novichkova N, *Geochemiya*, 3 (1971) 339.
- Dietrich P C, Wernert K D, Klemm W & Schren W, *Oceanology*, 27 (1987) 69.