

## A Note on Incipient Spilitisation of Central Indian Basin Basalts

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**Abstract.** Rocks dredged in the vicinity of the 79°E fracture zone, in the Central Indian Basin, are sub-alkaline basalts, which are regarded as precursors to spilites. The Minerals identified are mainly albitic plagioclase, augite, olivine, and less of chlorite, epidote and opaques. The oxide variation plots indicate a mid-ocean ridge basalt trend for the samples, which have been spilitised to varying degrees. It is suggested that the basalts formed as a result of a fissure type of eruption along the fracture zone. Subsequently, some of the basalts were spilitised probably due to hydrothermal solution, possibly the result of tectonic activity along the fracture zone.

**Keywords:** Basalts, Spilitisation, Fracture Zone, Central Indian Basin, Petrology.

### INTRODUCTION

Basalts erupted at Mid-Ocean Ridges (MOR) have characteristic dissimilarities compared to the ones from seamounts and abyssal plains of the ocean basins (Batiza and Vanko, 1984). Petrological investigations of the Central Indian Basin (CIB) are relatively less in contrast to the other ocean basins. Initial studies of the Deep Sea Drilling Project (DSDP) at Site 215 on the eastern part of the CIB, revealed the presence of 14 basaltic flows, each flow being separated by glassy surface (>2 cm), the origin of which was postulated to be of fissure eruption (Hekinian, 1974). Other than the DSDP studies, the occurrence of pumice and petrology of the CIB basalts were reported recently by Iyer and Karisiddaiah (1988, 1990). Here we report the nature and occurrence of basalts dredged in the vicinity of a fracture zone.

### MATERIALS AND METHODS

The area studied is an abyssal plain

lying between 12°25' to 12°45' S and 79° to 79°20'E at a water depth of 5100 m to 5300 m, with a major fracture zone at 79°E (Fig. 1a).

Out of 37 dredge operations (Fig. 1b), 36 were successful and about 8500 kg of nodules and 900 kg of rocks and ferromanganese crusts were recovered. On board examination of the dredge hauls showed the presence of ferromanganese nodules, and thick ferromanganese crusts. Basalt fragments and few pumice pieces were also recovered. These fragments are fresh to highly altered and sometimes exceed 25 cm in size, with sparse glass selvages.

The fresh and partly altered rocks were studied petrographically. Major elements were determined by standard techniques, while FeO was determined by titration. USGS rock standards were simultaneously run in order to check the precision and accuracy of the analyses. The error is within the limits of the reported values.

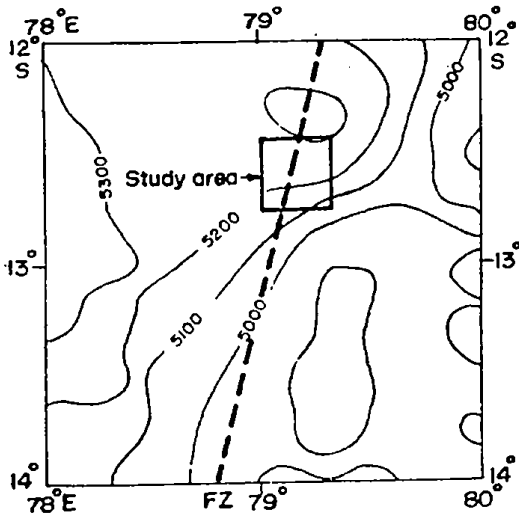


Figure 1a.

Study area with 79°E fracture zone (FZ) and bathymetric contours (in metres).

## RESULTS AND DISCUSSION

The samples are fine- to medium-grained with textures such as porphyritic, hyalopilitic, intersertal and glomeroporphyritic. The minerals observed were plagioclase, clinopyroxene, and olivine and less of chlorite, epidote, hematite, opaques and smectite, set in a holohyaline to hypohyaline mesostasis. Untwinned plagioclase laths of albitic type ( $An_{14-20}$ ) are dominant, while bent and twinned ones are less common. Twinned augite ( $2V = 44^\circ$ ) is conspicuous. Olivine occurs as colourless or as green coloured (bowlingite) grains with numerous cracks. Chlorite exhibits a typical microlitic intersertal texture which is considered to be characteristic of spilitic rocks (Juteau and Rocci, 1974). Epidote minerals with characteristic interference colours were noted in few sections. Opaques are few and dispersed throughout the sections.

Chemical composition of the ten analysed samples are presented in Table I. Samples 1, 8 and 9 are highly altered as seen from low CaO and high  $K_2O$  whilst the remaining samples have lower CaO than typical MORBs. On the alkali-

silica plot (Fig. 2A; Schwarzer and Rogers, 1974), the samples display a sub-alkaline affinity. The CIPW norms show excess albite (28.82 – 38.78%) indicating probable spilitisation of these rocks although the samples follow a MORB trend (Fig. 2B, Sun *et al.*, 1978). On the  $(K_2O + Na_2O)$  vs.  $[K_2O / (K_2O + Na_2O)] \times 100$  plot (Fig. 2C; Hughes, 1972) samples 1, 8 and 10 fall in the igneous spectrum, whereas others fall either on the border of spilites and igneous fields or within the spilite field. Although spilites are considered to have low  $K_2O$  contents, the higher  $K_2O$  values in the present instance apparently are precursors for the formation of typical spilites. Few of the high  $K_2O$  values could also be due to seawater alteration subsequent to spilitisation (Fodor *et al.*, 1980).

## PETROTECTONICS AND GENESIS OF THE ROCKS

Spilites are not uncommon on the ocean floor but are outnumbered when compared to basalts (Cann, 1969). Various modes of spilite formation have been proposed such as primary origin, auto hydrothermalism or auto metamorphic, secondary, diagenetic or metamorphic origin (Amstutz, 1974 and references therein), and recently due to the unmixing of initial magma (Tane, 1989). A metamorphic origin was ascribed for spilites of the MOR considering the prevalent fault zones in the study area (Melson *et al.* 1968; Cann, 1969).

In addition to the above modes of spilite formation, another possible mode could be due to the influence of tectonic structures and the circulation of hydrothermal solution as seen in the present study. It has been reported that seamounts and abyssal hills exist in the CIB (Mukhopadhyay and Khadge, 1990), but these are absent within the present study area. In the absence of any volcanic

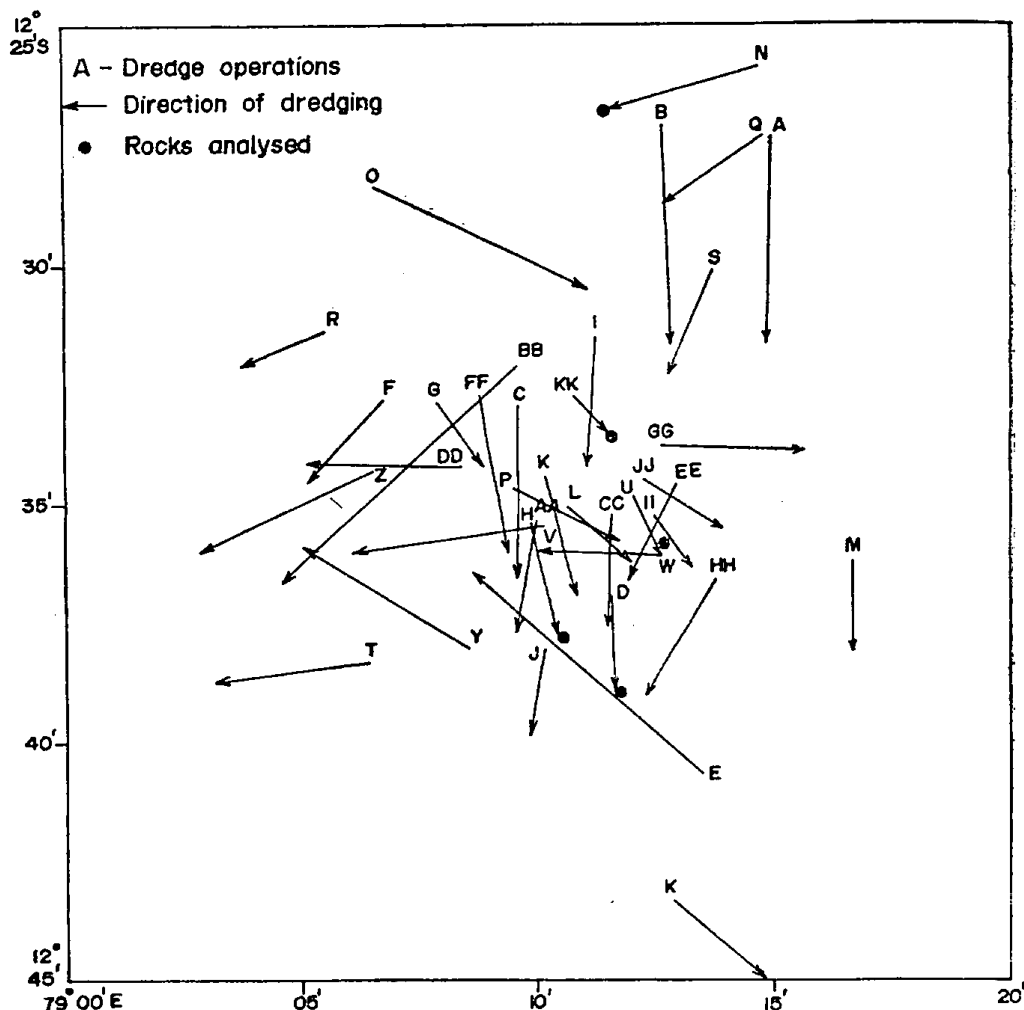


Figure 1b. Location of dredge operations and samples collected in the study area.

edifice the other viable alternative could be a fault-controlled volcanic field, in a manner similar to that existing at the Mid-Atlantic Ridge (MAR). Recently Kamesh Raju and Ramprasad (1989), Kamesh Raju (1990), and Kamesh Raju *et al.* (1991, comm.) reported fracture zones at 73°E, 75°45'E, and 79°E in the CIB. Along such major fracture zone, vertical tectonism could have influenced the formation of various rock types (Bonatti, 1978). Hekinian (1974) had postulated a fissure eruption for the DSDP Site 215 basalts. Chemical composition

revealed an enrichment in potash and phosphorous, which was attributed to factors such as seawater alteration (Hekinian, 1974), and the possibility of these flows being a potassium-phosphorous (KP) variety (Frey *et al.* 1977).

The alteration and metamorphism of ocean floor rocks leading to greenschist facies could be due to hydrothermal action and metamorphism at MORs, where temperatures of 200–300°C are reached at 1–2 km depth and wherein hydrothermal systems are likely to exist (Cann, 1969; Bonatti *et al.* 1976; Fodor *et al.* 1980).

TABLE I. Major element analyses.

|                                | 1                  | 2     | 3                  | 4     | 5     | 6                  | 7                  | 8                  | 9                  | 10    |
|--------------------------------|--------------------|-------|--------------------|-------|-------|--------------------|--------------------|--------------------|--------------------|-------|
| SiO <sub>2</sub>               | 51.05              | 50.40 | 46.37              | 46.99 | 46.38 | 45.41              | 44.41              | 53.70              | 41.98              | 47.96 |
| Al <sub>2</sub> O <sub>3</sub> | 14.54              | 14.48 | 14.75              | 18.67 | 16.30 | 16.41              | 16.96              | 14.35              | 13.37              | 17.49 |
| TiO <sub>2</sub>               | 2.55               | 1.95  | 1.90               | 2.05  | 1.85  | 2.05               | 2.05               | 1.65               | 2.00               | 1.85  |
| MnO                            | 1.40               | 0.36  | 0.31               | 0.13  | 0.20  | 0.27               | 0.27               | 3.50               | 0.64               | 0.28  |
| FeO                            | n.d.               | 1.94  | n.d.               | 3.08  | 3.22  | n.d.               | n.d.               | n.d.               | n.d.               | 3.72  |
| Fe <sub>2</sub> O <sub>3</sub> | 14.98 <sup>t</sup> | 15.46 | 18.10 <sup>t</sup> | 13.68 | 12.31 | 17.37 <sup>t</sup> | 17.52 <sup>t</sup> | 12.81 <sup>t</sup> | 21.50 <sup>t</sup> | 12.18 |
| MgO                            | 2.10               | 2.59  | 3.79               | 2.97  | 3.46  | 4.48               | 4.59               | 2.54               | 1.56               | 3.92  |
| CaO                            | 0.29               | 5.00  | 7.07               | 5.89  | 7.07  | 6.48               | 6.77               | 0.59               | 1.77               | 5.63  |
| Na <sub>2</sub> O              | 4.19               | 4.31  | 5.08               | 3.58  | 6.26  | 4.03               | 4.03               | 3.71               | 6.48               | 3.21  |
| K <sub>2</sub> O               | 2.39               | 0.82  | 1.00               | 0.74  | 0.84  | 0.25               | 0.49               | 1.94               | 2.34               | 1.76  |
| P <sub>2</sub> O <sub>5</sub>  | 0.31               | 0.33  | 0.33               | 0.32  | 0.33  | 0.35               | 0.35               | 0.44               | 0.29               | 0.30  |
| LOI                            | 5.68               | 1.84  | 1.22               | 1.48  | 1.08  | 2.65               | 2.65               | 4.60               | 8.08               | 1.50  |
| Total                          | 99.48              | 99.48 | 99.92              | 99.58 | 99.30 | 99.75              | 100.09             | 99.83              | 100.01             | 99.80 |

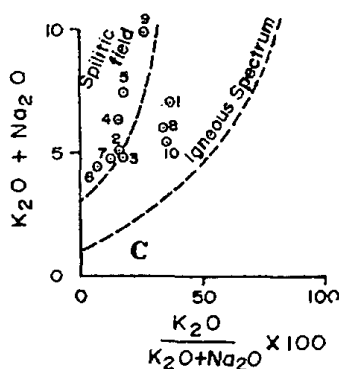
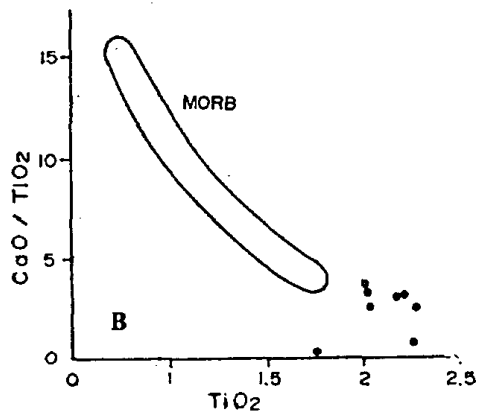
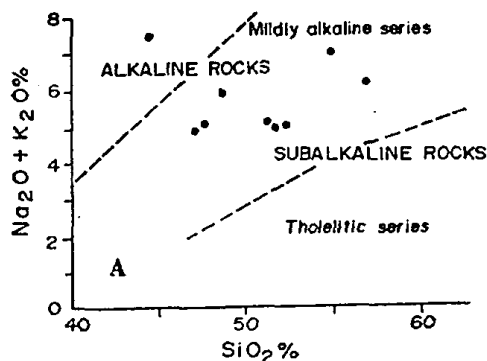
t=Total iron as Fe<sub>2</sub>O<sub>3</sub>; n.d.=not detected; LOI=Loss on ignition

It has also been noted that fracture zones which occur further away from ridge crests may also have conditions conducive for hydrothermalism and spilitisation processes (Bonatti and Honnorez, 1976). High heat-flow along fracture zones, which can be as great as and greater than those at spreading centres (Langseth and Hobart, 1976) also helps in the process of greenschist facies metamorphism.

Thus, it is noticed that hydrothermal circulation is not rare within fracture zones. During vertical tectonic activity along the 79°E fracture zone, the compressional and tensional stresses (Bonatti, 1978) might have resulted in the release of hot hydrothermal solutions. Such hydrothermal solutions could vent or seep through the fracture zones and bring

about the metamorphism and alteration of the pre-existing basaltic lava piles leading to the formation of spilites. Probably the effect of hydrothermal solution might have been less prevalent and localised since not in all cases our samples are spilites (cf. Fodor *et al.* 1980). The possibility of such dilute low temperature hydrothermal solution on two ferromanganese crusts occurring in the vicinity of the 75°45'E fracture zone was indicated by Iyer (1991).

The occurrence of alkali to sub-alkali basalts are not uncommon in CIB fracture zones (Banerjee and Iyer, 1991). The sub-alkali basalts, in the present case, may be precursors to spilites, and are suggested to be products of a fissure type of eruption. It is likely that there were



Figures 2A, 2B and 2C.

Fig. 2A. Plots of alkalis against silica for basalts of CIB.

Fig. 2B. Plots of  $\text{CaO}/\text{TiO}_2$  against  $\text{TiO}_2$ .

Fig. 2C. Plots of  $(\text{K}_2\text{O} + \text{Na}_2\text{O})$  against  $[\text{K}_2\text{O}/(\text{K}_2\text{O} + \text{Na}_2\text{O})] \times 100$ .

quiescent flows of basaltic lava, along the  $79^\circ\text{E}$  fracture zone, which chilled rapidly to form pillow basalts with glassy selvages. Such fissure type of flows could be compared to typical flood basalts such as the Deccan Traps and to the DSDP Site 215.

Hence, it is conceived that the role of hydrothermal solution along the  $79^\circ\text{E}$  fracture zone might have played an important role in the spilitisation of the ocean floor rocks in the area studied. More extensive dredging along, across and within the fracture zones should help to locate basalts and precursor rocks of spilites.

We conclude that fissure type basaltic flows occurred within and in the vicinity of the  $79^\circ\text{E}$  fracture zone, indicative of a fault-controlled basaltic field. The erupted basalts were tholeiitic to sub-alkalic in composition. Subsequently, some of the basalts were spilitised to varying degrees by the action of hydrothermal solutions, which had seeped during the activation of tectonic movements along the fracture zones. These basalts are similar to the Sao Paulo basalts of the southwestern Atlantic Ocean (Fodor *et al.* 1980).

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