

## PHOSPHORITES FROM THE ERROR SEAMOUNT, NORTHERN ARABIAN SEA

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### ABSTRACT

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Phosphorites were dredged from the flanks of the Error Seamount, off the Somali coast from depths of 400–460 m. These occur as dense slabs and irregular lumps associated with limestones. Polished and thin section studies show that the phosphorites are algal foraminiferal limestones of shallow water origin. X-ray diffraction study shows that calcite is the dominant mineral followed by francolite, fluorite and goethite.  $P_2O_5$  concentration of the phosphorite varies between 18.0 and 21.5%. It appears that these phosphorites were formed in Tertiary times by diagenesis and the subsidence of the seamount due to sea floor spreading and eustatic sea level variations might have terminated the processes of phosphatization and resulted in residual phosphorites on the Error Seamount.

### INTRODUCTION

Phosphorites are generally found in the marine environment on continental margins and on some elevated portions of the sea floor such as seamounts. Marginal phosphorites are formed mainly due to the coastal upwelling phenomena, whereas the phosphorites formed on the seamounts are in general different from those of marginal phosphorites in their composition and conditions of occurrence (Baturin, 1982). Phosphorites reported in the Indian Ocean region are from the western continental margins of India (Chugunnyy and Orlova, 1970; Nair, 1985), the shelf of Andaman Islands (Tipper, 1911), the shelf of Socotra Islands (Gevork'yon and Chugunnyy, 1970) and on the seamounts in the western Australian Basin, on Christmas Islands and Cocos Ridge (Baturin, 1982). The paper presents preliminary results of studies of the hitherto unreported occurrence of phosphorites and their formation from the Error Seamount.

Error Seamount is located in the northwestern part of the Arabian Sea, close to the Owen Fracture Zone and about 600 km from the Somali coast (Fig.1). It is a flat-topped mount (guyot) and apparently devoid of recent sediments either on the top or on the slopes of the mount (Fig.2). The water depth at the top of the Seamount is 370 m; below this level the northeastern and northern slopes of the seamount drop to a depth of 4700 m. The adjacent

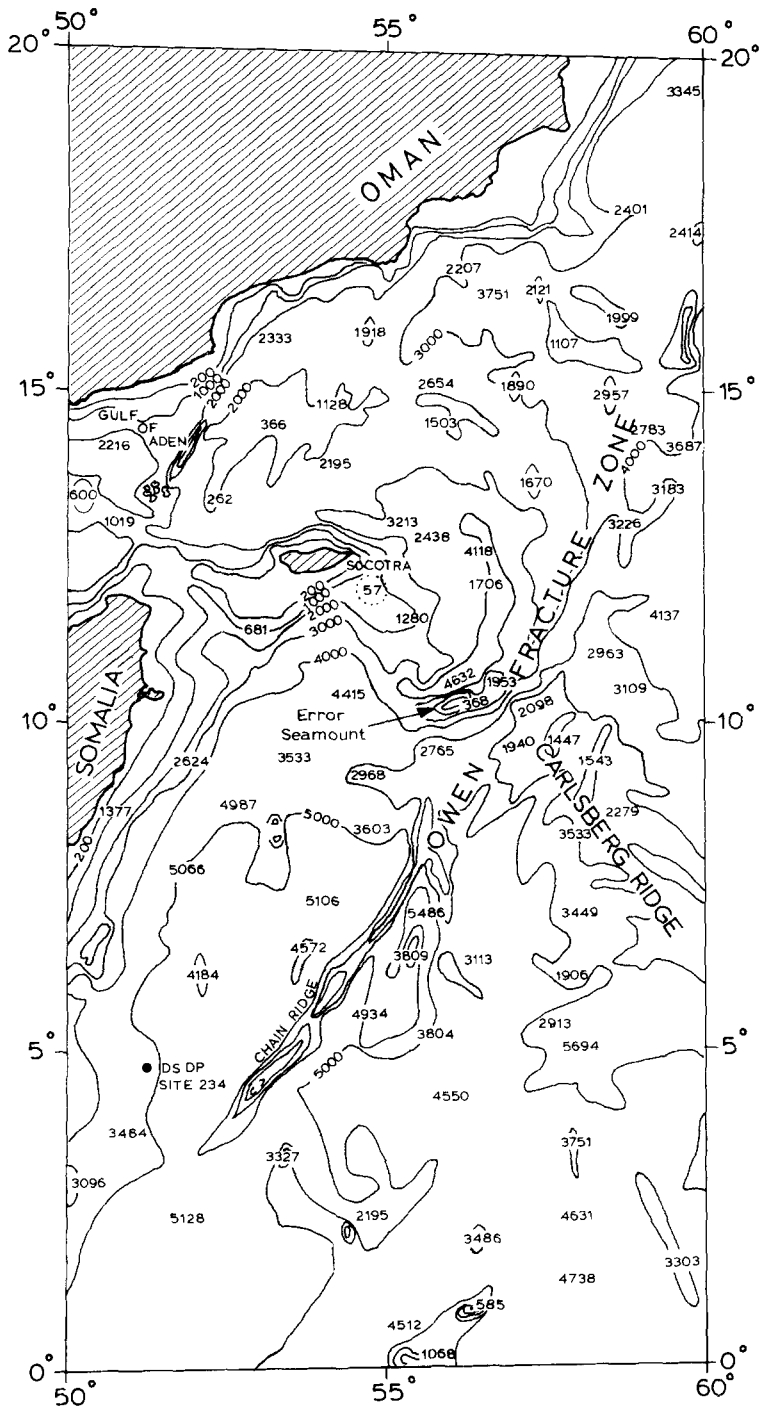


Fig. 1. Location of the Error Seamount.

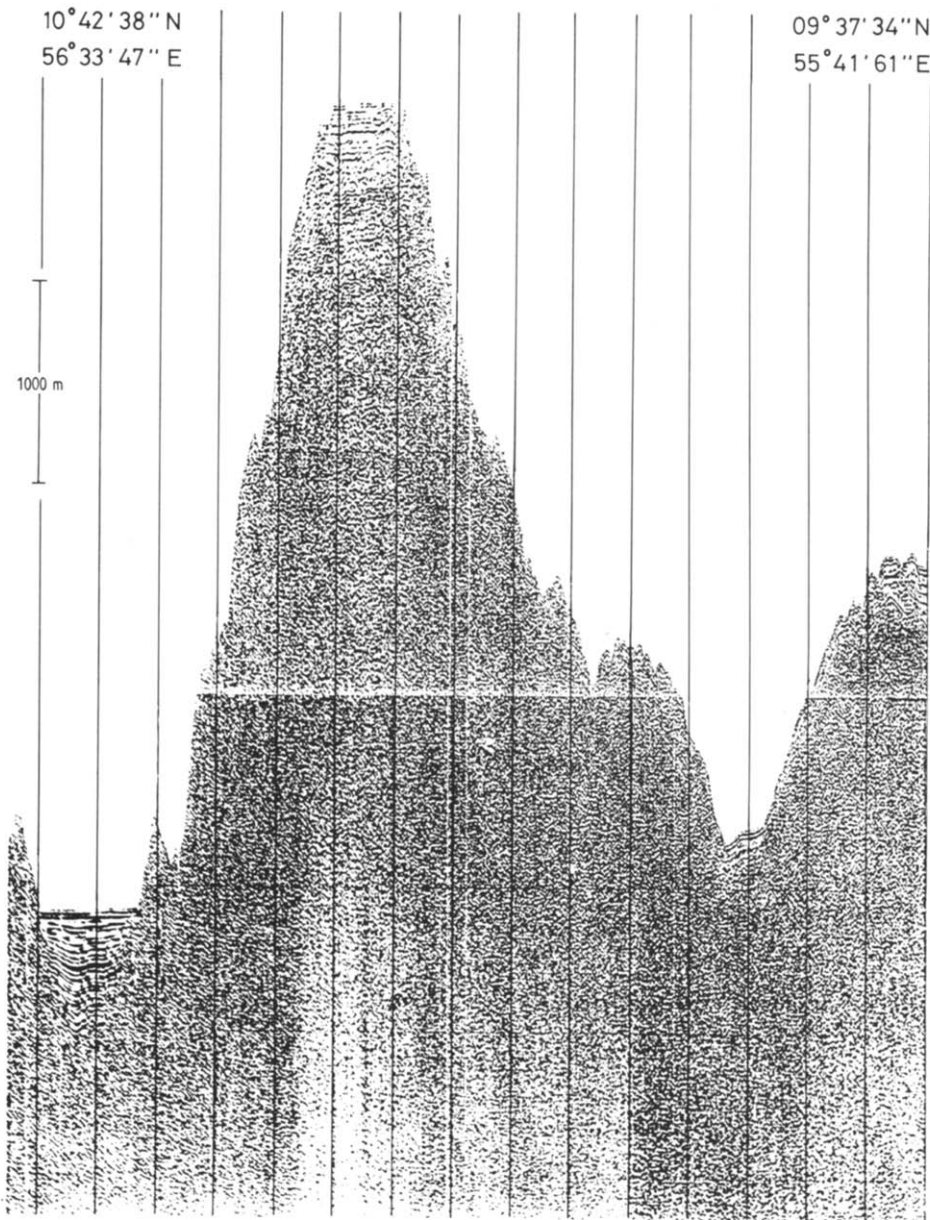


Fig.2. Seismic profile of the Error Seamount.

deep-sea valley is filled with about 600 m thick sediments. The basal age of the sediments in the region of the Error Seamount is Eocene (Bunce et al., 1967).

#### MATERIALS AND METHODS

During the third test cruise of ORV "Sagar Kanya", on her voyage from Germany to India, a dredge sample was collected on the Error Seamount in water depths between 400 and 460 m. The retrieved material comprised largely of limestones and phosphorites. Dead corals, bivalves and bryozoans are attached to the limestones and phosphorites. Phosphorite occurs as hard dense slabs and irregular lumps (Fig.3). The thickness of these slabs ranges from 2 to 4 cm. The three samples selected for the present study are: (1) light brown (5YR5/6) to greyish orange (10YR7/4) laminated phosphorite; (2) dusky brown (5YR2/2) phosphorite; and (3) moderate brown (5YR3/4) phosphorite. Subsamples of the above were washed with distilled water, dried and powdered to 63  $\mu\text{m}$  size.

Polished and thin sections were prepared and studied under the microscope.

0.1 g of subsample powder was treated with HF using teflon bombs.  $\text{P}_2\text{O}_5$  concentration in these samples were analysed in duplicate by the colorimetric method described by Strickland and Parsons (1968). Standard USGS rock samples were also analysed for  $\text{P}_2\text{O}_5$  to evaluate the accuracy and reproducibility of the results.

The powdered samples were analysed on a Philips X-ray diffractometer using nickel filtered,  $\text{Cu K}\alpha$  radiation from  $25^\circ$  to  $53^\circ$  at  $2^\circ 2\theta \text{ min}^{-1}$ . The minerals were identified and the intensity of basal reflections of major minerals measured above the base line (Table 1).

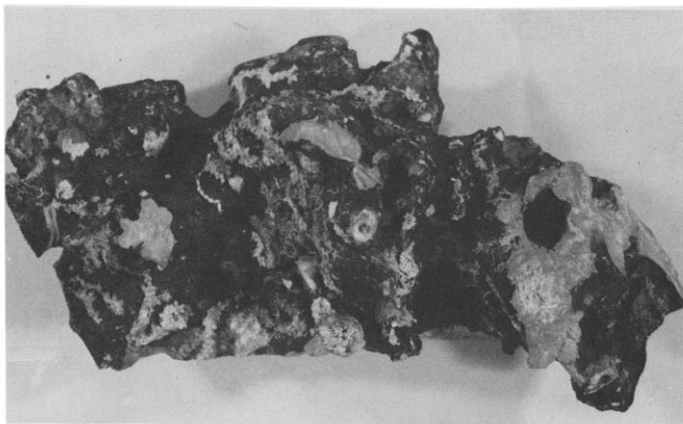


Fig.3. Dusky brown phosphorite (length of the specimen 11 cm).

TABLE 1

Mineralogical and chemical characteristics of phosphorites from the Error Seamout

Sample no.	Sample	Minerals present	Ica/Ifr	P <sub>2</sub> O <sub>5</sub> (%)
1	Light brown (5YR5/6) to greyish orange (10YR7/4) laminated phosphorite	calcite, francolite fluorite and goethite	85/58	19.7
2	Dusky brown (5YR2/2) phosphorite	calcite, francolite fluorite and goethite	74/60	21.5
3	Moderate brown (5YR3/4) phosphorite	calcite, francolite and goethite	46/43	18.0

Ica/Ifr are peak heights of calcite and francolite principal reflections above base line.

## RESULTS

Polished sections of the phosphorite rock (Fig.4a) show a very distinct iron oxide layer on the outer edges and laminated structures of algae and some bryozoans. The thickness of the oxide layer is more (1.0 cm) in moderate brown phosphorites than in dusky brown phosphorites (ranges from 0.3 to 0.5 cm). Algal mats are restricted to the basal parts of the rock and the innermost layer is in the form of domal laminae reflecting the surface on which it is formed. These mats surrounded by brown matrix suggest phosphatization. Algal borings on the skeletal fragments are also noticed.

Thin sections show that the rock consists of fragments of coralline algae, bryozoans, planktonic and benthonic foraminifera and molluscan shells (Fig.4b, c and d). Algal fragments are the most wide spread among the various components present, followed by foraminifera and bryozoans. Molluscan shells are sparsely distributed. The phosphatized material occurs as infillings in foraminifera and molluscan shells and as a replaced material in the cavities of bryozoans (Fig.4b) and algae without any morphological changes. The cementing material is mainly colophonane and calcite while goethite is also noticed in the oxidized part of the rock. In the oxidized part the rock consists of pelletoidal bodies which might have been originally precipitated by algae.

Minerals present in the phosphorites are calcite, francolite, fluorite and goethite (Fig.5). Calcite is by far the most abundant mineral in the first two samples followed by francolite and fluorite with minor amounts of goethite. In case of moderate brown phosphorites the amount of calcite and francolite are represented almost equally (Table 1), while goethite is relatively high compared to the other two phosphorites.

P<sub>2</sub>O<sub>5</sub> concentration in the phosphorite ranges between 18.0 and 21.5%. Moderate brown phosphorites show relatively less P<sub>2</sub>O<sub>5</sub> content (Table 1).

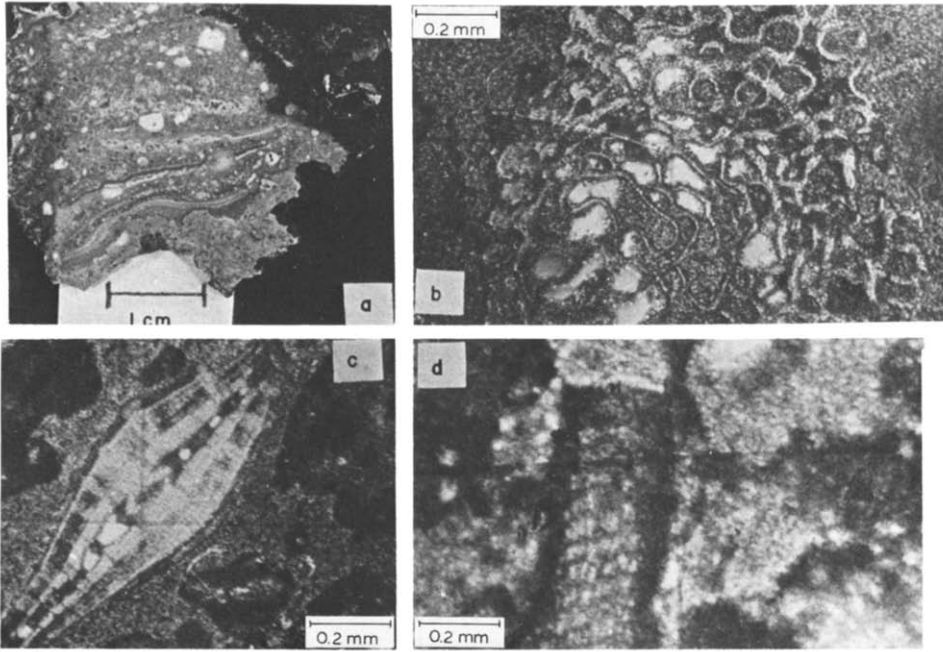


Fig.4. (a) Polished section of the phosphorite (b, c and d are thin sections); (b) partly phosphatized bryozoans; (c) larger foraminifera with algal fragments in collophane matrix; (d) algal fragments with calcite cement being replaced by collophane.

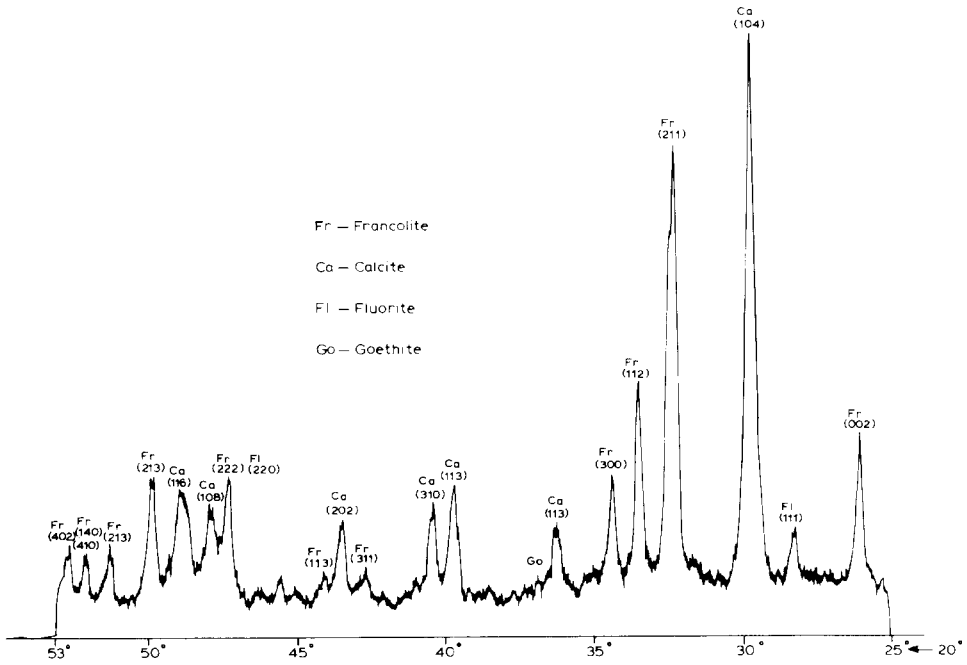


Fig.5. X-ray diffractogram of dusky brown phosphorite.

## DISCUSSION

Petrographic and mineralogical studies on the phosphorites indicate that these phosphorites are algal foraminiferal limestones. The possible mechanism of phosphatization is as follows. The phosphorites are mainly composed of algal mats, bryozoans and foraminifera indicating shallow water environment. Planktonic foraminifera are few and might have been transported by seasonal currents and upwelling and deposited in the sediments of the seamount. The DSDP Site 234 data indicate that the sediments of the Somali Basin range from Oligocene to Recent with reducing conditions from Oligocene to lower Miocene (Vincent, 1977). Therefore it is possible that the phosphatization took place during Oligocene to lower Miocene reducing conditions and thus it is inferred that the phosphorites are of Tertiary age, in conformity with the age of other seamount phosphorites (Baturin, 1982; and Table 2).

Upwelling is an important phenomenon at present off the Somali coast and the upwelled waters of the Somalia flow east to several hundred kilometres (Wyrтки, 1973). Evidence of upwelling has also been recognised in the sediments of the Somali Basin from late Miocene (6.3 m.y. B.P.; Vincent, 1977). It is visualized that as a consequence of upwelling, the accumulated organic matter in the early sediments capping the Error Seamount led to anoxic environment in the overlying and interstitial water of the sediments. Under anoxic conditions phosphate is liberated from the phosphorus-bearing skeletons by bacterial decomposition and the phosphate thus liberated replaces the surrounding material (Baturin, 1982). In the present case, the phosphate replaced some of the original cementing material, infilled the shells and the cavities of bryozoans.

High-magnesium calcite is the principal constituent of coralline algae and benthic foraminifera, and aragonite is the constituent of bryozoans and molluscan shells (Milliman, 1974). Though the present samples of phosphorites largely consist of fragments of coralline algae, bryozoans, benthic foraminifera and molluscs, the original constituent minerals of these fragments are absent in the phosphorites. Instead calcite, francolite, fluorite and goethite are present in order of abundance. It appears that the transformation of high-magnesium calcite or dissolution of aragonite mineral phases must have taken place without change of algal structures and foraminifera tests. Goethite in the phosphorites indicates its deposition in an oxidizing environment (Birch, 1980; Baturin, 1982). It is possible that the seamount might have been exposed subaerially during a low sea level. However water depth of the seamount being of the order of 370 m, eustatic sea level alone cannot account for its submergence. Following Hess (1965) it is suggested that since the seamount is located close to the Owen Fracture Zone, it could have subsided with the progressive subsidence of the flanks of the fracture zone. Hess (1965) further gave a descent rate of  $30 \text{ m m.y.}^{-1}$  for spreading rate of  $1 \text{ cm yr}^{-1}$ . The spreading rates of Carlsberg Ridge are of the order of  $1.2\text{--}1.3 \text{ cm yr}^{-1}$  (McKenzie and Sclater, 1971) and it is therefore possible that the submergence of the seamount could be due to seafloor spreading and Tertiary

TABLE 2

## Comparison of the Indian Ocean phosphorites

Sample no.	Location	Depth (m)	Host rock	P <sub>2</sub> O <sub>5</sub> (%)	Age	References
1	Western Indian Continental margin					
	a. off Goa	150	algal nodules	11	11,040	Nair (1985)
	b. off Cochin	260-300	sediments	4.9-7.6	6500-33,000	Chugunny and Orlova (1970)
2	Agulhas Bank	100-500	limestones	14-18	Miocene/Pleistocene	Cronan (1980)
3	Socotra Islands	210	nodules and concretions	28.6	Meso-Cenozoic	Gevork'yon and Chugunny, (1970)
4	Remire Islands, Amirantes	2	limestones	37.9	Tertiary	Braithwaite (1968)
5	Christmas Islands	--	limestones	--	Miocene/Pleistocene	Trueman (1965)
6	13° 45' S 99° 56' E					
	(Unnamed seamount)	3689	limestones	22.7-32.5	Late Cretaceous	Bezrukov (1973)
7	Error Seamount, Northern Arabian Sea	360	limestones	18-21.5	Tertiary	this article



sea level fluctuations. Friedman (1964) and Gavish and Friedman (1969) explained the progressive diagenetic changes in Quaternary to late Tertiary carbonate sediments due to subaerial exposure. Early diagenesis results in the removal of high-magnesium calcite dissolution of aragonite and the formation of low-magnesium calcite. Because in the present samples some calcite continues to be present as cementing material and the borings of algae have not been filled, the phosphatization of the limestones appears to be the product of late diagenesis.

The variations in the amount of goethite in phosphorites occur because there are variations in the thickness of the oxide layer. The phosphorites which contain less  $P_2O_5$  are associated with rocks rich in goethite indicating that the oxidizing environment minimized phosphatization.

Fluorite is present in the first two samples (Table 1). It is identified from the X-ray diffractogram reflections at (220) and (111) (Fig.5). Fluorite is a constituent of volcanic gases (Deer et al., 1967) and it forms in phosphorites only when excess fluorine is present after the uptake of fluorine by calcium phosphate (Dietz et al., 1942; Baturin, 1973).

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