

Mining of phosphorite resources from the Indian continental shelf will help food production

Introduction

Much of India's record breaking food production owes its success not only to the quality of the different varieties of seeds but also to the use of fertilisers. The raw material that goes into the production of phosphatic fertilisers is the phosphate rock. The main sources of phosphate are the phosphatic rocks largely exploited from the land. These are also found in substantial quantities in the sea. The global consumption of phosphate is increasing at the rate of 6.3 per cent per year. In India, the present requirement of 2 to 3 million tons per year of phosphate can hardly be matched with the existing annual production of about 600,000 tons. Thus most of the total requirement is obtained by imports and involves expenditure in foreign exchange. Moreover, its supply is seriously controlled by international politics.

World trade in phosphate rock flows from the major producing countries (Table 1) to both developed and developing countries. About 68 per cent of the supply of phosphate rock comes from the developed countries like the USA, USSR, South Africa. Only 22% is produced from the developing countries which are most populous, and therefore, have the maximum need for this commodity. To redress this imbalance, the developing countries must explore for phosphate deposits on land for their immediate needs and should also look to the offshore areas for this resource for their long-term needs.

With this aim in mind, the National Institute of Oceanography has, during the last few years, conducted a phosphate exploration programme in conjunction with other scientific studies on the continental margins of India. The dependence of India's agriculture-based

TABLE 1—PRODUCTION AND RESERVES OF PHOSPHATE ROCK IN DIFFERENT COUNTRIES

Country	1980 production (in million tons)	Reserves (in million tons)
USA	54.4	8000
USSR	26.1	6300
Morocco	18.8	44,000
China	6.7	10,000
Tunisia	4.6	500
Jordan	4.2	1100
S. Africa	3.3	700
Brazil	2.9	800
Israel	2.6	150
Nauru	2.1	20
Syria	1.3	833
Algeria	1.0	1000
India	0.6	108
Mexico	0.3	1000

economy on the supplies of fertiliser minerals is undeniable and the growing awareness of the insufficiency of land-based resources of phosphate in India makes it imperative that an extensive programme of offshore exploration for phosphate deposits be initiated.

Marine phosphorites

Sir John Murray of the Challenger Expedition fame (1873-76), was the first to report the presence of phosphorite grains in the samples dredged from the Black Plateau (South-eastern United States) and from the Agulhas Bank, off South Africa. Since then, many reports on the presence of phosphorite in the sea bed have been reported.

Fig. 1 shows the location of some of these deposits in different parts of the world. They occur in water depths ranging from 50 to 1000 metres. Most of the phosphorites occurring in the sea floor are associated with the areas of high biological productivity. These regions are also associated with upwelling in the sea.

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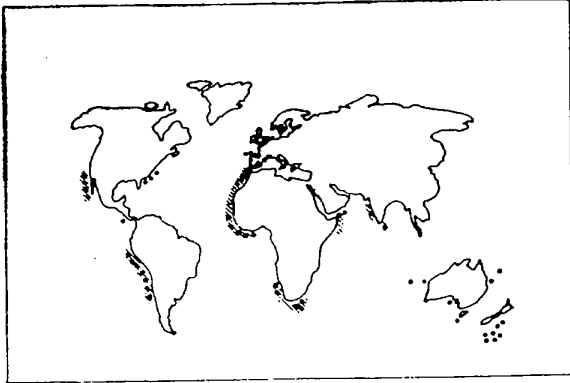


Fig. 1. Map showing the location of marine phosphorites (black dots) and regions of upwelling (hatched areas) in different regions of the world.

Thus the relationship between phosphorite deposits and upwelling can be summarised as follows:

There are basically two types of upwelling—the coastal upwelling and the open ocean divergence. Both these are important for the production and deposition of organic matter in the sediments. These, in turn, form the precursor of hydrocarbons which are of considerable interest to petroleum geologist. From the viewpoint of the origin of phosphorites, the coastal upwelling is of utmost importance. This phenomenon occurs when steady winds blow over the ocean, close to the coast in a particular direction. The transport of wind-driven upwelled water occurs at about 90 degrees to the right of the wind direction. In other words, the wind must blow parallel to the coast and keep the coast on the left. Such a feature is of common occurrence along the west coast of India during the monsoon. Thus the transport of upwelled water takes place offshore. The water which moves away from the shore is replaced from below (Fig. 2). Major coastal upwelling zones are found off the western North America, western regions of South America, north-western and south-western Africa, Somalia and western India. Off the western India, upwelling is associated with the south-west monsoon and is, therefore, seasonal in nature. The upwelled water drawn from a few hundred metres below

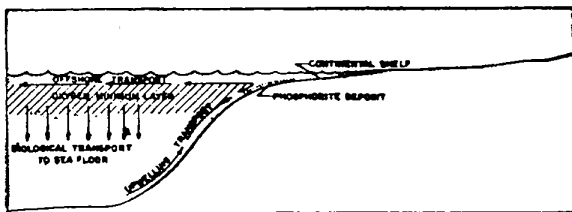


Fig. 2. Relationship between coastal upwelling, oxygen minimum layer and phosphorite deposition.

the sea surface replenishes the depleted nutrients (phosphates, silicates and nitrates) in the surface layers and thus enhances the biological productivity of the area. A combination of these processes gives rise to very high biological productivity in the upwelling areas. Much of the food material thus produced remains unconsumed and the surplus quantities sink to the bottom and increase the organic matter of the sediments. Generally, the oxygen in the upwelling areas gets utilised for the oxidation of large quantities of surplus organic matter resulting in an oxygen depleted layer or an offshore anoxic environment. The Arabian Sea is one such area where the enrichment of sediments with organic matter underlying the upwelled water leads to reducing conditions in the interstitial waters of the sediments. Under such reducing conditions, a large amount of phosphate gets liberated. At times the liberated phosphate may be even 100 times greater than the concentration normally found in the open ocean waters.

We thus have a sequence of events: upwelling, high production of organic matter, enrichment of sediments with organic matter, liberation of phosphate in the interstitial waters by phosphate deposition. The other two factors which contribute to phosphorite deposition are the absence of heavy river discharge in the area and the presence of carbonate sediments which act as catalyst to the formation of phosphorus-containing apatite. The exact mechanism of the formation of apatite is still a matter of debate and the most probable geochemical cycle of phosphorus is somewhat complex and it need not concern us here. However, it would be a matter of interest to note that 30 to 35 per cent P_2O_5 content in the phosphorite, as is the case in most regions, would mean a two million times of enrichment from the sea water.

The principal phosphate mineral in marine phosphorite is carbonate-fluorapatite or francolite with the general formula $Ca_5(PO_4)_3(CO_3, OH)_3(OH, F, Cl)$. In its texture the sea floor phosphorites may be nodular, concretionary or in fragments. Their colour may vary from dark brown to yellow or black. The older phosphorites are hard and have a glazed surface while those younger in age are dull coloured.

A characteristic of marine phosphorites which is of considerable interest is the presence of uranium in the samples to the extent of 100 to 200 parts per million (average). Uranium extracted from the phosphoric acid is expected, according to the estimate, to be about 12% of the world output in the near future and as much as 25% of the total uranium supply by 1990, according to another estimate.

Phosphorites of the western continental shelf of India
The western continental shelf up to 200 metres isobath

has an area of about 300,000 square kilometres. The outer parts of this shelf, between 60 to 100 metres, is of late Pleistocene origin (about 11,000 years old). These are of age similar to that of the carbonate sediments and limestones. The carbonate content of these sediments is as high as 90% in the northern parts of the shelf, constituting in itself a potential raw material resource of lime, sand and limestone. A notable feature of the outer shelf is the extensive occurrence of calcareous algal ridges ranging in height from 1 to 5 metres. They also occur, although less extensively, in waters greater than 200 metres. The phosphorites are largely associated with these algal ridges.

The waters overlying the western shelf have all the characteristics necessary for the formation of phosphorites. Reconnaissance dredging along the outer continental shelf during many cruises of R. V. Gaveshani has yielded either phosphatised sediments and limestones or only phosphorites. The phosphorites appear to be distributed north-west of Goa in water depths of 70 to 150 metres (Fig. 3). These phosphorites are

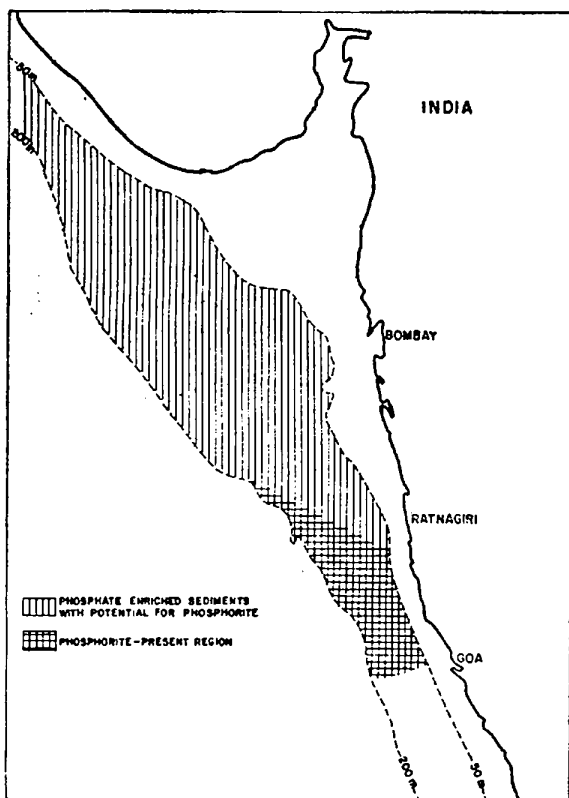


Fig. 3. Map showing the location where phosphorite has been obtained by dredging, and also the possible area for the occurrence of phosphorite on the western continental shelf of India.

greyish in colour, irregularly shaped, dull lustered lumps with black encrustation. Their diameter ranges from 5 to 10 cm and in cross sections they show irregular concentric bands. The shape and the laminated nature of the lumps indicate that they are rhodoliths. These rhodoliths are composed of spheroidal forms of algal stromatolitic structures. They commonly occur on the sea floor at depths of 50 to 150 metres. Mineralogical study of the phosphorites by X-ray diffraction methods shows that they contain calcite as the dominant carbonate mineral and that the apatite in them occurs in the form of well crystallised francolite. The maximum P_2O_5 recorded in the HCL soluble fraction of the sample is of the order of 11%. In the total sample the yield of P_2O_5 is fairly high. Sea floor phosphorites generally have a P_2O_5 content ranging from 8 to 30 per cent. Geologically older forms have the highest values. The phosphorites of the western shelf of India have a P_2O_5 content of the same order of magnitude as the offshore phosphorites of Chile/Peru and south-west Africa (Namibia). Phosphorites occurring at depths greater than 200 metres are likely to have a higher phosphate content because at these depths the oxygen depleted water provides the optimum conditions for phosphatisation.

Economic aspects

The commercial value of phosphorite deposits would depend on several technical and economic factors. For example, a minimum of 28% P_2O_5 in the phosphate rock is necessary to be used as phosphate fertilisers. Much of the present technology of the manufacture of phosphate fertiliser, its transport, and its use is associated with a high grade ore as the starting point. Low grade ores, normally, tend to be neglected by the manufacturers. However, it should be noted that their P_2O_5 content can be increased by beneficiation, such as washing and screening, desliming, magnetic separation, flotation and calcination. The development of an appropriate technology tailored to suit the Indian conditions will, no doubt, go a long way in the utilisation of the existing onshore and offshore phosphorites.

Low grade ores as such can easily find use in the Indian conditions. The application of powdered ores can directly be used for improving the acidic soils. Tropical soils frequently have clay minerals which are poorly crystallised and hence these tend to absorb the phosphate. Thus they prevent the plants from making use of the phosphate content. The absorptive capacity of such soils can be satisfied by the application of a large amount of low grade ore so that the further use of fertilisers can become effective for plants.

Mining of the shallow water phosphorites, at least on an experimental basis, can be carried out by a variety

of mechanical dredges. The distance to the western shelf deposits from the major ports is about 100 to 200 kilometres. Water transport of these ores from the potential regions to the shore would be cheaper than their transport over similar distance on land. This is particularly important because the freight charges constitute a substantial part of the cost of all such ores which have low grade minerals. However, it would be premature at this stage to discuss the various economic implications. The need for the present appears to be intensive exploration of phosphorite deposits in the identified areas, totalling about 100,000 square kilometres of the western continental shelf, so that reliable data on cost-benefit ratio could be worked out.

In July 1982 the *New Scientist* featured the following report:

"A new form of mineral nodules that can be mined from the sea is exciting to scientists and engineers. Although the deposits were found in the last century, phosphorite nodules have remained an unexploited resource until recently.

The nodules form near coasts where cold water, rich in nutrients, meets ocean currents and is forced to the surface. The nodules, which are to be found within coastal boundaries (and therefore do not attract the controversies that deep manganese nodules have) contain phosphate—a vital mineral for the fertiliser industry.

Phosphorite nodules form in significant amounts in many places on the continental shelves. These include the Blake Plateau, and off Georgia and California in the USA; South West Africa; the Agulhas Bank, South Africa; Goa, India; East Japan and the Chatham Rise, off New Zealand.

But if these deposits have been known about for over a century, why is there growing commercial interest now? There is no one simple explanation but there are three main reasons. First, although demand for phosphate has fallen in recent years, most people expect it to grow over the next decade or so, especially in industrial countries in the Third World.

Secondly, the production costs of land-based alternatives are rising as known deposits are used up and because environmental regulations become increasingly severe. Thirdly, because phosphate has a low value per unit volume and is expensive to transport, "local" supplies, even if they cost more to produce, compete successfully with imports.

The fertiliser industry uses the most phosphate, although food and detergent manufacturers use some. There is no adequate substitute for phosphate as a plant nutrient in fertilisers. So despite the present low prices investors believe that its prospects are good in the long term, and are looking seriously at mining the sub-sea deposits."