

# Favourable Environments for Mineral Exploration on the Western Continental Shelf of India

by

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## Introduction

The floor of the oceans represents a rich source of many minerals. Despite the very large resources, however only a fraction of these deposits can be considered economically exploitable at the present time and these are generally confined to the continental shelves of the world. Among the minerals already being mined from the nearshore areas of the shelf are placer deposits of tin off Malaysia, Thailand and Indonesia, gold, and platinum off Alaska, diamonds off the mouth of the Orange River, S. W. Africa. Another mineral which has great future potential are Phosphorite deposits found on the shelves off Peru, Chile, Mexico, California, S. Africa, Japan and around certain island shelves in the Indian Ocean. Excepting for one abortive venture to mine these phosphorites off California no attempt has yet been made at large scale exploitation elsewhere. Oil and natural gas from the continental shelves have to date formed the most spectacular mineral resource.

Approximately Rs. 180 x 10<sup>9</sup> (one hundred eighty billion rupees) worth of oil and natural gas were produced in 1967-68 from off shore oil fields in California, Persian Gulf, Lake Maracaibo.

New offshore discoveries reported in 1968 include shelves of S. W. Africa, Northern Java, North Sea, Eastern Italy, Eastern Brazil, South Eastern and Western Australia, Western New-Zealand, Northern Alaska, Southeastern Thailand and Northern Taiwan.

Perhaps less spectacular but most useful mineral commodity is sand and gravel which finds extensive use in the construction and manufacturing industry. The value of sand and gravel mined from the continental shelf, is however only next to oil and natural gas and approaches Rs. 800 x 10<sup>6</sup> (Eight hundred million) per year (1967-68). Recourse to the use of offshore sand and gravel generally becomes necessary along densely populated coastal areas which frequently have been known to draw upon the limited resources of beach sand at their disposal. This results eventually in the erosion of beaches which in turn adversely affects life and property along the shore. Beach stabilisation measures have then to be taken up by providing sand nourishment as well as the construction of engineering structures. Such has been the case for example at California and Florida where offshore sand deposits are actively being sought to replenish the eroded beaches.

Offshore areas of many parts of the world are well supplied with calcareous materials. Calcareous material on land in the form of limestone forms the raw material for cement and chemical industry. For economic reasons, only those

deposits, usually shell accumulations in coastal lakes and lagoons, are at present being mined.

A general classification of offshore mineral deposits, excluding oil and natural gas, is given in Table. I.

**Table I**

General classification of offshore Mineral Deposit's (Excluding oil & Natural Gas)

Unconsolidated		Consolidated	
Surficial	Insitu	Surficial	Insitu
1. Shallow placers, Beach or offshore iron sands, silica sands, calcareous sands.	Buried river & Beach placers of gold, tin, titanium, diamond.	1. Exposed stratified deposits of coal, iron stone, lime stone and coral	1. Massive vein or tabular deposits of sulfur, copper, iron, tin, coal etc.
2. Anthigenic nodular deposits (Mn, Co, Fe, Ni); phosphorite.		2. Anthigenic coating of manganese and phosphorite	

**Geological Characteristics of the Western Continental Shelf**

In the light of the available information about the geology of the western continental shelf, it may not be too premature to attempt to delineate areas favourable for exploration for the existence of some of the mineral deposits mentioned earlier. Before proceeding, it might be desirable to review the geological environment of the shelf.

The Western Continental Shelf has a total area of 300,000 sq. Kilometers when considered to the 70 fathom (120 metre) isobath which marks the edge of the shelf. The shelf has a width of 280 Km. off Bombay and gradually tapers to its narrowest point off Cran-

ganore (Kerala) south of which it widens to 60-70 Km. Topography and gradient is generally smooth, except towards the outer parts where irregularities of the order of 10 meters become common and the shelf drops precipitously to the continental slope. Over the entire width of the shelf, the sediment distribution may be broadly divided into two major categories. The nearshore facies upto 60 meters consists of geologically recent material contributed by the present day river drainage of the west coast. This material is commonly olive green, silty clays and forms a continuous nearshore band from Bombay to Quilon in the south where the band thins out and is replaced by quartz sand. Succeeding these nearshore silty clays are the calcareous sands consist-

ing of sand sized material mixed with an abundance of calcareous matter in the form of shells and skeletons of various organisms. A special type of sediment associated with this belt of calcareous sand which extends to the shelf edge are oolites. These are small, 1-5 mm in diameter, spherical to ovoid grains of carbonate matter enclosing a nucleus of carbonate or non-carbonate matter and are considered to form in shallow waters only. On the basis of the occurrence of oolites, iron-stained quartz grains, shallow water foraminifera and molluscs and radio-carbon dating, it has been concluded that these sediments were deposited in the geological past (Late Pleistocene, 12,000 years before Present), when the sea-level probably stood at 120 meters below the present level. In this context, it may be relevant to indicate that to account for the origin of hot brines and heavy metals in the Red Sea, a crucial requirement was the isolation of the Red Sea from the Indian Ocean, specifically the Arabian Sea, in order to create the requisite evaporative conditions. This isolation has been brought about by a lowering of the sea-level during Pleistocene to at least 120 meters which represents the sill depth at the southern end of the Red Sea. There is thus a general uniformity about the depth of the Pleistocene low stands of sea-level over the western and eastern regions of the Arabian Sea. The effect or imprint of such lowered sea-levels, however, will be similar in general but will vary in detail depending upon the characteristics of the shelf in question. It is

thus of cardinal importance whether for merely understanding the geological evolution of the shelf or for applying the results obtained to matters of mineral exploration, that a comprehensive understanding of the conditions prevailing during the Pleistocene period be sought. Such information will not only be of use in explaining the origin of existing mineral deposits but will also help in predicting future mineral resources on the continental shelf.

Sub-surface data relating to the western continental shelf is very meagre and what is available is confined to the southern and northern parts, particularly off Bombay and Kerala. Geophysical studies, particularly seismic methods have indicated that the coastal formations extend to the edge of the shelf. These formations off Bombay are Cretaceous to Eocene basalts overlain by sedimentary formations of Tertiary age. It might therefore be reasonable to assume that a similar pattern exists throughout the length of shelf, with the rock types on the shelf being merely extensions of rocks found on the coast. Seismic work and drilling on the shelves of many parts of the shelf has indicated the essential validity of this assumption and has proved beneficial in the location of oil and natural gas fields.

Within the framework of the above information, an attempt may now be made to seek such areas on the shelf which may be fruitful in the search for minerals (Fig. 1.)

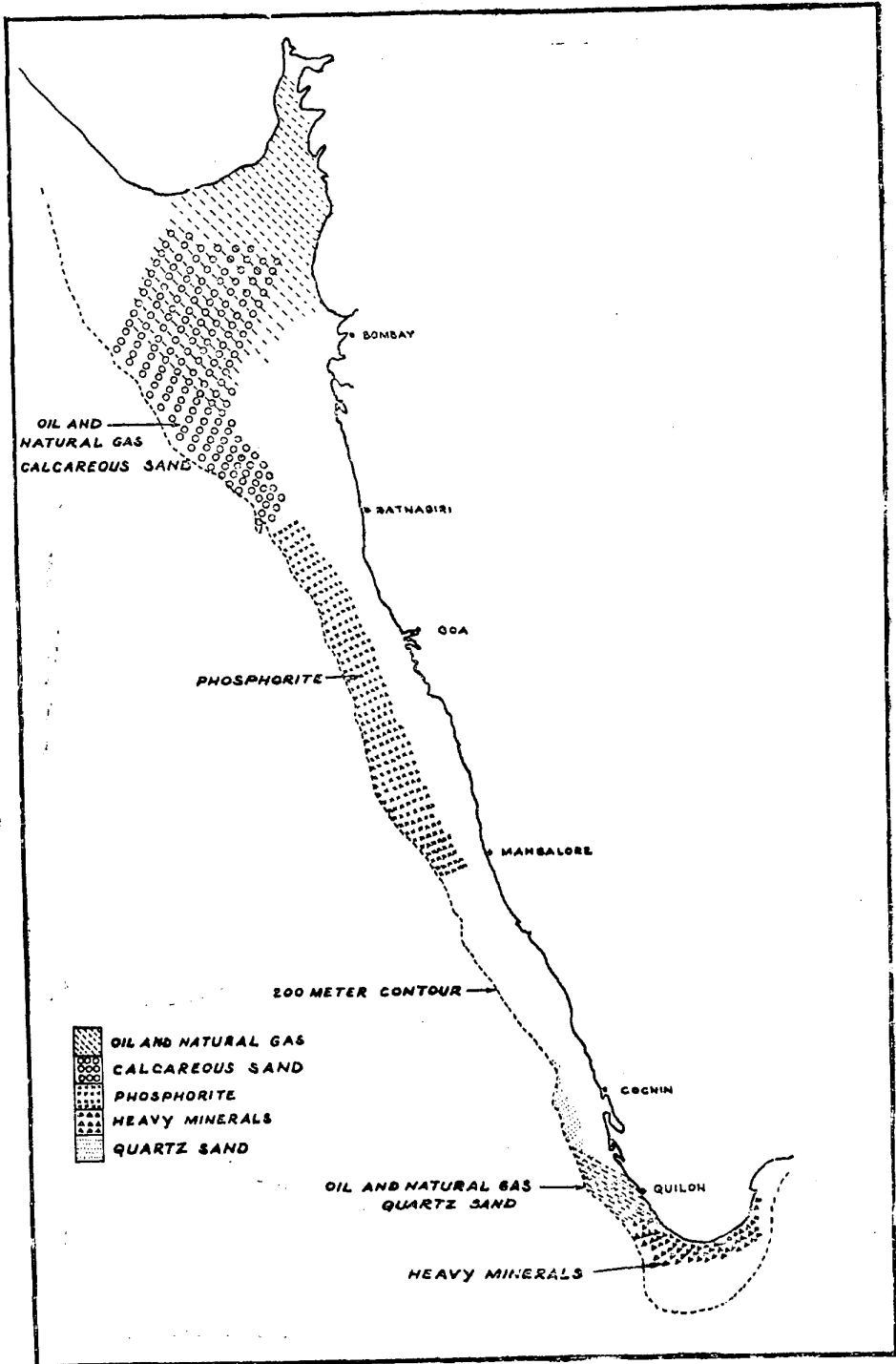


Fig. 1 Areas on the Western Continental Shelf which are favourable for the occurrence of certain minerals.

### Heavy Mineral Deposits

Placer deposits of heavy minerals such as elements, magnetite, monazite, zircon occur in discontinuous patches on the beaches along many parts of the west coast of India. Examples of such deposits are ilmenite, magnetite ( $Fe_3O_4$ ) and monazite (source of thorium and rare earths) on the Kerala coast. Concentration of these minerals on the beaches have come about by natural processes, particularly through wave action which winnows out the light minerals such as quartz and felspar and leaves behind the heavy minerals. Extension of these deposits on to the sea-bed is possible, particularly when one recalls that during lowered periods of sea-level much of the continental shelf was exposed land, with the processes and products of sedimentation largely similar to that prevailing at the present day. Subsequent to rise in sea-level and resumption of sedimentation, these deposits if present will be buried under the newer sediments. This probably is the case over the length of the shelf except towards the southern parts where the nearshore blanket of silts and clays thins out and gives way to sands. Therefore, a potentially favourable area for exploring heavy mineral deposits will be the off-shore area south of Quilon on the Kerala coast. Under the action of prevailing southerly current, it is also possible that heavies may be transported southwards into the Gulf of Mannar. Concentration in the Gulf will then take place by the barrier of the Adam's Bridge by preventing further egress (exit) into Palk bay.

**Phosphorites :** Favourable conditions for the formation of phosphorites on the continental shelf have been shown by a number of investigators to be as

follows : a) presence of up-welling whereby the cold, phosphate and nitrate rich waters from the bottom approach the surface. b) presence of a zone of calcareous material which will form nuclei for phosphatisation. c) low rates of sedimentation to prevent excessive dilution and interferences with the process of phosphatisation. The existence of these conditions have been shown to exist on the outer continental shelf between 30 and 70 fathoms. Favourable evidence in the form of phosphatised oolites have also been found on the outer shelf between Mangalore and Bombay. South and north respectively of these two areas, rivers like the Periyar and Narmada and Tapti will adversely effect the conditions by discharging large quantities of sediments to the shelf. It would seem therefore that exploration of phosphorites may well be confined to the outer shelf between Bombay and Mangalore.

**Oil & Natural Gas:** Geophysical evidence, as mentioned earlier, has shown that the oil bearing coastal formation on land bordering, the gulf of Cambay extend into the Gulf and beyond to the shelf edge. Further more evidence has also been advanced for the presence of a suitable sub-surface structure on the shelf known as the Bombay High. Drilling for oil in the Gulf of Cambay is already under way and no doubt drilling on the shelf will be the next logical step. Another area which may have oil possibilities is the shelf off Kerala. Unlike in the Cambay region, there are at present no oil deposits on the land. The factor which still makes it a favourable area is the presence on the coast of a sequence of rocks of Tertiary age which extend to the shelf. In the absence of positive evidences to the contrary, the area may

still be considered as interesting from the point of view of oil possibilities.

**Calcareous Sand and Quartz Sand:** The foregoing three mineral commodities have a high price per unit volume and as such are prime targets for offshore exploration. Interest in the exploration and exploitation of minerals with low cost per unit volume is understandably much less. Amongst these are the sand and calcareous material of the outershelf. Though used in large quantities by the constructional and manufacturing industry, existing deposits on land in most cases are adequate to meet the needs. Acute shortage of sand, is however met with in coastal areas due to the large population density and the corresponding greater demand. Sand resources having been rapidly depleted, usually from the beaches, additional sources have to be looked for not only for the building and manufacturing industry but also to replenish the beaches which due to prolonged extraction of sand have either partially or completely eroded away. The functional and aesthetic value of beaches need hardly be emphasised. Offshore deposits of sand, particularly off the southern coast of Kerala (Quilon and southwards) are present. These are either recent or relict quartz sand with low carbonate content and may need to be tapped in future to meet the needs of the coastal areas of Kerala at least

where erosion of beaches continues despite construction of sea walls and groynes. A sand inventory program scaled to the needs of the country, undertaken concurrently with other exploration projects will no doubt be of great use in future.

Calcareous material, dominantly in the calcium carbonate form, is present on the outer continental shelf in sufficiently concentrated form (70-80% by wt.) to be sufficiently attractive provided adequate demand is present and the necessary technological expertise in extraction, transportation, beneficiation are available. For instance, in India, albeit a rare one, of the exploitation of shell deposits for the manufacture of cement, is from the Vembanad lake in Kerala. Therefore, despite the occurrence of calcareous deposits on the continental shelf, the prospects for its exploitation are not very promising, to say the least.

In conclusion, it may be said that though not all the information that we may desire is at hand, we have some data which enables us to distinguish potentially favourable areas from those which even from the existing knowledge indicate to be uninteresting. With further addition to our knowledge of the shelf, it will be possible to narrow down and define better the more interesting and hopefully fruitful areas.