MARINE PLACER MINERAL EXPLORATION – A CASE STUDY

G. VICTOR RAJAMANICKAM
Dept. of Industries
Tamil University, Thanjavur
Tamilnadu – 613 005

A. R. GUJAR and M. V. RAMANNA
National Institute of Oceanography
Donapaula, Goa – 403 004

ABSTRACT

The future mineral demand on the basis of exist-
gross national product has been estimated to be of-
percent by the year 2000 with the existing resource potent-
on land it will be very difficult to meet such high dem-
for minerals in the near future. The advanced countries
are moving fast to the marine mineral resources to meet a
order of scarcity of minerals. So far, the world has a
partial success in the oil exploration from the offsh-
areas. Though the occurrence of hard minerals as black sa-
are known from many localities along the Indian coast ri-
from the year 1936, attempts to explore the extension of s-
placers in the offshore could not be ventured till 1975, 
which year NIO came out to initiate the exploration
ilmenite placer along the Konkan coast. The survey for
offshore placer minerals taken up in the offshore z
extending from Jaigad to Vijaydurg for a distance of ab
130 kms. This survey was comprised of a sediment sampl-
using Vanveen Grab, (1320 nos), Peterson’s Snapper and Co
(66 nos), surveys using echosounder (1889 l km) magnetom
(1228 lkm), side scan sonar (340 lkm), and shallow seis
profiles (895 l km). The type of survey along the Kon-
coast has thrown much informations. The various stages
exploration has been discussed in detail especially
relation to the mode of data collection and the vari-
interpretational techniques applied. The present case at
has been used to substantiate the advantages of marine mi-
and the feasibilities of such mining in our country, and
so the requirements to meet such venture.

INTRODUCTION

The growing population and rapid industrialisation
have caused the depletion of land resources. Inspite
advanced methods of beneficiation and substitution of
alternate metals and minerals, the demand for indus-
minerals is progressing very rapidly. This growing demand
indirectly bringing the explorers and the economists, to t
for the ocean mineral resources as the only best substitute for depleting land sources. The technological advancement in the offshore mining, the case with which the different deposits are located and the quick exploratory methods are special directions of ocean mining. However, ocean mining is still in embryonic stage, but for the exploitation of oil and gas, in which the world has shown astounding success. Only a few countries such as South Africa (Gold, diamond and chromite), USA (gold, platinum and other placers), Malaysia, Indonesia, Taiwan (Tin) and Australia (Monazite, Zircon, ilmenite and Rutile) have come out with the exploitation of offshore minerals. The mining of monazite in the Southern tip of the Indian continent has brought India in the world map of countries carrying out marine mining for hard minerals. The future mineral demand on the basis of existing gross national product has been estimated to be of 407 percent by the year 2000. The advancement of scientific oceanography exposes what is beneath the sea, and the technology development permits activities that we are historically thwarted by the hostile and strenuous marine environment, and has thus made the world more and more conscious about the presence of an alternative. The successful exploitation of offshore oil and gas has given impetuous for marine mineral exploration and exploitation, not only in the shelf but also to the margin areas.

Continental margin, the zone that encompasses a wide transition zone that spreads oceanic from continental realm, include the continental shelf, slope and rise, but it also embraces the land extension on this Geologic province. Generally, mineral deposits have been grouped as consolidated and unconsolidated. On the basis of genesis, the mineral deposits have been classified into Terrigenous, biogenous and chemogenous. The terrigenous deposits are mainly the derivatives from the land sources. It includes dominantly the placer minerals. Since these minerals have a higher specific gravity, they are not transported over a long distance offshore depending on previous sea floor gradient (placer deposits off Mozambique and Senegal). Occurrence of such placers usually known as black sands are known from many
localities along Indian coast. (Fig.1). Many earlier workers like Krishnan and Roy (1958), Jacob (1956), Mahadevan and Sriramadasa (1954), Officers of GSI (1949), Siddiquie, et.al (1975), Rajamanickam (1983) and Rajamanickam et.al (1988) have shown the vast distribution of placer minerals in our country. It is observed that mineral resources for ilmenite, rutile, zircon, garnet, sillimanite, Kyanite are sufficient to meet the demands for the year 2000. But the minerals like monazite, will be in short supply and in the same way are native metals like gold, platinum, and precious diamond. By the turn of the century, it is accepted that demand in these minerals will increase more than 2 or 3 folds. (Brooks and Lloyds, 1968).

With the realization of the economic potential of marine placer deposits, significant headway has been made in the technology towards exploration and exploitation. The exploration and exploitation of offshore placers involved entirely new technology. Along the coast of Japan, magnetite sands are excavated with a grab from a depth of 27.5 meters. This has costed only half as much as the extraction of Iron ore of land. The high technological economic indices of Underwater exploration of minerals are achieved because in many cases there is no need for uncovering the wastes values of overburden, the capital trenches are much smaller or there is no need for them at all. In addition to this, it is not necessary to build dumps and places for residue. The excavation of deposits with sea suction dredgers permits exploitation of mineral resources without special expensive work. The power equipped dredges permit excavation independent of electric power line and power sources. Therefore, the exploitation of underwater deposits of minerals can be done in a very short time, and with considerable lower specific capital investments than or necessary for construction of mining enterprises under usual condition. (Table 1).

Though the occurrence of beach placers and subsequently offshore placers have been reported for many years, exploitability has not been promoted and the attempt
<table>
<thead>
<tr>
<th>Economic Effectiveness Between Conventional and Underwater Exploration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Exploration on land</td>
</tr>
<tr>
<td>----------------------------------</td>
</tr>
<tr>
<td>Cost price of production of one carat of diamond (in shillings)</td>
</tr>
<tr>
<td>Specific capital investment (in percent)</td>
</tr>
<tr>
<td>Cost price of the production of cassiterite (in cents)</td>
</tr>
<tr>
<td>Extraction of magnetite vanadium sands</td>
</tr>
<tr>
<td>Cost price of the production of one ton of mineral (in dollars)</td>
</tr>
<tr>
<td>Capital investment for one ton of mineral (in dollars)</td>
</tr>
</tbody>
</table>
exploration of marine placer minerals has not been made in our country till 1975. Only in 1975, NIO has taken up the survey of Konkan coast for ilmenite placer minerals. This paper is an attempt to present the methods applied and experiences gained in such exploratory work in our country.

**Positioning**

In order to locate the sampling positions in the offshore, detailed triangulation was done for this area, such astal triangulation has taken sufficient time before we proceed for sand sampling. If we do one month coastal triangulation, we can cover an area suitable for only one week offshore sampling. In the beginning the offshore positioning was done by using marine sextants and subsequently one of the radio wave positioning system mini anger has been deployed in the area. Generally, the traverses for the survey are decided depending upon the type of minerals to be explored (Moore 1979). Accordingly, 200-300 meters of traverse distance has been considered for ilmenite placer mineral exploration in this area. During the course of triangulation considerable shift in the coastline on the admiralty prepared in the year 1960 was observed. In order to improve the accuracy in our offshore positioning, beachline traversing was done with 10 foot pole method and a new beachline has been mapped and the same has been used in preparing the sampling map. As the traverses are so closeby, large scale map is not found suitable and so 1:10,000 base map was prepared for all the field work.

**Sampling**

As the van-veen grab (0.04m²) was used for sampling in the area where the sediments are mainly made up of black sands, in many occasions it was brought only about 50-100 gms of sands. On such occasion, Peterson's snapper has been used. The length of the traverses was decided on the appearance of the clayey sediments. In order to confirm the continuity of the sandy sediments below the clay
representative piston gravity corer has been used and the same has shown the penetration successfully upto the sandy sediments underlying the clay. The surficial sediments have been analysed for their total heavy mineral content and percentage of magnetic and non-magnetic minerals. Among the non-magnetic minerals the ilmenite fraction has been separately estimated through Isodynamic Separator. As the distribution of this ilmenite is found to vary considerable, bulk sampling to a level of 25 kg in one area has been prepared separately (Table 2) and the same has been compared with the mineral distribution, prepared out of individual samples.

Echoc Sounding

The continuous echo sounding was done throughout the surveys during the sampling as well as the underwater towing surveys. Proper bar checking before the start of the survey as well as the close of the survey on each day helped us to determine the sensor correction accurately. A bathymetric map was prepared after giving the due tidal correction. It led us to understand the inner shelf topography and type of sediment distribution prevailing along that coast. It has also aided to eliminate the irregular topographic areas for further studies.

Side Scan Sonar

This equipment was used in the surveys to a limited extent. A reconnaissance run using this equipment aided to delineate the rocky and sandy seabeds. In turn, the rocky areas have been eliminated for sampling and coring. Almost all promontories have also been eliminated for placer studies, due to non-availability of sands. Side Scan Sonar has shown the presence of ripples even in 8 to 9 meters. It has suggested the possibilities of the reach of waves to that depth in that area.
### RESULTS OF BULK SAMPLE ANALYSIS

<table>
<thead>
<tr>
<th>Different fraction</th>
<th>Jaiagd</th>
<th>Varvada</th>
<th>Ambawh</th>
<th>Kalgadevi</th>
<th>Marla</th>
<th>Tiltek</th>
<th>Vengan</th>
<th>Poorvagad</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td>I</td>
<td>II</td>
<td>I</td>
<td>II</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Coarse Silt</td>
<td>0.15</td>
<td>3.54</td>
<td>0.75</td>
<td>0.47</td>
<td>1.32</td>
<td>2.00</td>
<td>1.794</td>
<td>5.213</td>
</tr>
<tr>
<td>Shells</td>
<td>9.09</td>
<td>40.46</td>
<td>16.00</td>
<td>19.74</td>
<td>66.20</td>
<td>58.60</td>
<td>13.743</td>
<td>22.281</td>
</tr>
<tr>
<td>Quartz &amp; Feldspar</td>
<td>7.23</td>
<td>29.47</td>
<td>32.85</td>
<td>29.83</td>
<td>18.90</td>
<td>24.34</td>
<td>44.897</td>
<td>17.494</td>
</tr>
<tr>
<td>Bromoform-light</td>
<td>52.30</td>
<td>18.48</td>
<td>4.63</td>
<td>5.54</td>
<td>5.02</td>
<td>6.81</td>
<td>12.486</td>
<td>28.183</td>
</tr>
<tr>
<td>(illite and other weathered product)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bromoform-heavy</td>
<td>17.15</td>
<td>4.80</td>
<td>35.25</td>
<td>41.29</td>
<td>6.34</td>
<td>6.62</td>
<td>19.439</td>
<td>16.060</td>
</tr>
<tr>
<td>(illite)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titanomagnetite</td>
<td>6.08</td>
<td>3.25</td>
<td>10.52</td>
<td>4.13</td>
<td>2.22</td>
<td>1.63</td>
<td>7.640</td>
<td>12.768</td>
</tr>
</tbody>
</table>
Shallow Seismic

As the survey was conducted in the offshore region, the estimation of vertical thickness of the placer sands could not be carried out like the one done along the beaches by putting pits or boring the strata. In order to estimate the vertical thickness and the continuity of the placer sands below the clays, continuous shallow seismic survey was applied. First time, Huntex Hydrosonde 2A system was used. There was good resolution from the surface reflection, but penetration in the black sand could not be achieved as expected. And so, EG & G Boomer and Sparker system were used. Once again the EG & G Boomer with the power source of 300 joules could not provide the penetration in the sands.

At the same time, EG & G Sparker even with 200 joules energy source could able to reach the basement. Deploying minifinger for offshore positioning, continuous seismic profiling was done keeping 200 m interval between traverse up to a water depth of 22 m. As one could see the penetration up to the basement detail seismic profiling was prepared (Fig.2) and from that the isopach lines of the respective reflectors of clay, sand, murrum, altered traps and traps were calculated. The vertical thickness of the placer sands was measured from the isopach lines and distribution map of sand thickness was prepared, (Fig.3) In order to confirm the hypothetical conclusion of the continuity of placer sands gravity coring was done in the clayey zone and almost all the cores could able to bring black sand material. The reflector of the various seismic profiles have been corroborated with the strata found out in the bore hole logs of Mirya bay. These bore holes have been taken for the purpose of harbour development. Wherever bore hole data available close to the beaches, those bore hole logs have also been utilized to check the vertical thickness arrived at from the profiles.

From that the vertical thickness have been collected for preparation of isopach map. The reserve of all ilmenite placers has been calculated on the basis of the average vertical thickness, the percentage distribution of ilmenite and specific gravity of the total sand (Table 3). The percentage of ilmenite distribution noticed in the core
<table>
<thead>
<tr>
<th>Ilmenite concentration (in %)</th>
<th>Jaigad bay</th>
<th>Ambwah bay</th>
<th>Varvada bay</th>
<th>Total area</th>
<th>Inferred reserves 1m thick</th>
<th>4m thick</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>-</td>
<td>0.40</td>
<td>1.40</td>
<td>1.80</td>
<td>0.84</td>
<td>3.36</td>
</tr>
<tr>
<td>25-35</td>
<td>2.01</td>
<td>1.23</td>
<td>1.98</td>
<td>5.22</td>
<td>1.75</td>
<td>7.00</td>
</tr>
<tr>
<td>15-25</td>
<td>4.27</td>
<td>0.96</td>
<td>0.93</td>
<td>6.16</td>
<td>1.50</td>
<td>6.00</td>
</tr>
<tr>
<td>15</td>
<td>8.50</td>
<td>3.61</td>
<td>0.80</td>
<td>12.91</td>
<td>1.81</td>
<td>4.72</td>
</tr>
<tr>
<td>Total</td>
<td>14.78</td>
<td>6.30</td>
<td>8.11</td>
<td>28.09</td>
<td>5.27</td>
<td>21.08</td>
</tr>
</tbody>
</table>
samples available and bulk samples have also been taken into account for computing percentage of mineral distributions. The method applied here on experimental basis is found to be not only economical but quick to arrive at approximate workable placers along the coast.

From the existing capabilities available in our country, it is presumed that it is possible for us to estimate the economically workable placer along the coast with very limited resources. In order to complete this survey, NIO has spent nearly Rs. 50 lakhs including capital investments. As the methodology and planning has been evolved in our country, the surveys in other areas can be carried out still faster and cheaper. It is worth mentioning here that the comments of Bouysee, Chairman during the International Seminar of Offshore Mineral Resources organised by Bureau de recherches geologiques et minieres, Orleans, France, on the presentation of Marine Mineral work in India by Siddique and Victor Rajamanickam (1979) that India is setting an example for other developing countries by continuous and coherent effort to explore and assess her surveys on mineral resources, completely by herself.

From the experience gained by carrying out a detailed survey for nearly 130 km stretch along Konkan coast, it is felt that with the existing facilities combined with some Marine Equipments, one can carry out the evaluation of the placer resources in our country. The survey can be successfully implemented with the boat having following facilities and equipments:

Survey Boats (20 m and 12-15 in length), Navigation and position fixing equipment, Radar, Satellite Mini. Ranger, Hydrographic Sextant, Tellurometer, Theodolite, Communication such as Walkie-Talkie, Batteries (12 volts).

Bathymetry:

Dual Frequency Echosounder
Seismic/other Geophysical Surveys:

Shallow seismic profiler, Magnetometer, Side Scan Sonar, Gamma ray detector, Generator (7.5 KVA), Electrical and Electronic Servicing equipments.

Sea bed sampling:

Equipments, (Grab, amapper, piston corer, vibrocorer & dredge).

Camping material/transport:

Tents, Trucks, Jeep

With these efforts of equipping ourselves, the exploration of mineral placer along our coast can be carried out on the five thrust areas proposed by the Government. While carrying out the survey it is suggested that sampling and Geophysical data collection using under water towing instruments have to be separated each time and each region has to be surveyed twice. First, the Geophysical exploration and then the sampling. From the geophysical studies one can eliminate certain areas like the places, where there is either no thick sediment deposits or there is no strong magnetic anomalies or rocky sea bed. In general, the tracks spacing for seismic kept for 200 km while the magnetic studies can be 2 km grid pattern and the grab sampling can be maintained for even 500 m, grid for all the reconnaissance studies. From the reconnaissance studies one can select half of the area proposed for detailed surveys with the track spacings of 500 m for seismic and 500 m grid for magnetics and 250 grid for sampling. However, during the time of detail exploration, if anyone comes across with the occurrence of placers like gold, platinum, they have to reduce the sampling grid to 50 m.

Subsequently, coring bulk sampling and representative bore hole data would be collected for the purpose of evaluating the prospects for mining. In case, if vibro-corer can be used for coring, it will be of great use in estimating
the thickness of sediments. If one accomplishes such an effort, the time involved to carry out both reconnaissance and detail surveys is roughly estimated to be of 19,805 boat working days having each boat working day of 8 hours. Here one has to account the mobilisation time involved in carrying out the surveys. In the previous experience, the mobilisation time involved is almost 100 percent additional days of the boat working days.

MINING AND EXTRACTION

It is felt that a brief account on the present status of mining and extraction in the world may help to understand our future goal in this aspect. It is worth to mention here that many countries in the world have already started mining from the shelf, either by tunneling or pumping or dredging. Mining companies extract coal from the seas beneath the shelf off Australia, Chile, Turkey, Taiwan, Japan, Great Britain and Canada. In U.K. it is roughly estimated that 14,000 miners extract coal from tunnels thrust seaward for more than 3 miles. Japan has 8,500 undersea miners who produce approximately 9 to 10 million tonnes of coals annually. Undersea tunneling for minerals is expensive and sometimes hazardous business, too. Sinking shafts onshore and pushing shafts seaward, present formidable challenges to the engineers and potentially dangerous working conditions of the miners. Such problems of subsea tunneling extraction add to mining costs, making competition with on land producers and make projects uneconomical and difficult.

Marine dredging is increasingly becoming important and commonly used for extracting heavy mineral sands, mineral precipitates (aragonite) and biogenic materials (coral, shells, etc.). Four different types of dredgers are used in the offshore mining for bulk minerals. They are bucket ladder dredge, surface pump hydraulic dredge, wire line dredge (grab dredge) and air lift hydraulic dredge. Selection of mining methods depends on many factors such as water depth, type of materials to be mined and its density, weather conditions, nature of sea bottom, i.e. whether smooth
topography or irregular topography, underwater currents, etc. In the offshore mining of tin placers of SE Asia (Hosking 1971) technologists first used small bucket dredges, which later were substituted by grabs, dredges and lastly airlift hydraulic dredges, because of the weakness of bucket and grab dredges against rough weather, topography and high operation cost. Recently, offshore tin-deposits of Indonesia in the protected water are being mined by using chain bucket dredges (capable of providing a speed of 40 buckets/minute) and the suction dredges (with an average through out 1245 m³/h suction pipe diameter 9.65 m) (Donkers, 1979). Whereas in open sea conditions the airlift dredge is used in the tin placer mines of England (Beckman 1975) and in the mining of diamond placers off South Africa. From the experience gained through tin placer mining of Indonesia, Malasia, Taiwan and gold placer mining off Alaska, Donkers (1979) has worked out the relationships of dredging capacity with wave conditions.

Simple gravity techniques such as Tabling, Diester, Universal Plat-O, Whifley table and Humphreys are used for separating different placer minerals having distinct specific gravities ranging 3.0 – 5.3 for zircon, ilmenite, monazite, magnetite, 6.8 –21 for tin and gold placer and 2.5 – 2.8 for gangue minerals. Within the heavies, high tension separation can be used to monazite and zircon (high tension pinned non-conductors) from ilmenite rutile. (high tension thrown conductors).

So, exploitation of these placer deposits has to be considered with out specific problems like monsoon and rough weather. As we do not have much experience in our country it has to be thoroughly experimented before one comes out with the solution. The organisers involved in land mining should come forward to carry out research on these lines, for example, Donkers (1979) has reported that for every period of 2 m wave height, one percent efficiency in dredging has come down.
If every exploring organisation intensifies its reciprocating sister organisation in carrying out the research and developmental Programmes for mining and processing of the respective regions, it will be of great help in speeding up the exploitation of the resources. For example, National Institute of Oceanography's surveys, the Regional Research Laboratory, Bhubaneswar jointly worked to evaluate a method for proper mining and extraction. Likewise, the exploring agencies have to provide the facilities for a feed back of the base line data in a proper time to the organisation involved in research and development of mining and extraction.

Since there is no much experience in our country in offshore mining, it will be unrealistic to project economic returns. However, one is optimistic in this field of interest because countries like Australia and Korea are able to mine five percent concentration of ilmenite and 0.22 percent of zircon as economical. Biersdorf, et.al (1980) are highly optimistic utilizing the buried deposit of Mozambique with the concentration of 3 percent ilmenite at a water depth of 60 m. With the anticipation of an average of 15-20 percent ilmenite concentration in our near shore along with other placer minerals like zircon, garnet, magnetite, rutile, topaz, corundum, our offshore mining is considered to be positively economical.

REFERENCES


