

**AN EVALUATION OF MAJOR PLACER MINERALS ALONG THE VALINOKKAM -  
TUTICORIN COAST, SOUTHERN TAMIL NADU, INDIA**

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**Abstract**

The present investigation aims to understand the reserve of major placer minerals like garnet, ilmenite, zircon and magnetite from the beaches of Valinokkam- Tuticorin, Southern Tamil Nadu. The availability of garnet in the investigated area ranges from 2.58 to 41.78 %, ilmenite weight percentage ranges from 3.15 to 46.49. In the case of zircon, weight percentage increases from 0.42 to 9.09 % and that of magnetite accounts 2.91 % of the total heavy minerals along the study area. The present study depicts that beach sand deposits can be considered to be economically viable heavy mineral deposits for the exploitation of various major heavy minerals.

*Keywords: Resource, Heavy mineral, Placer mining, Tamil Nadu, Reserve*

## 1. Introduction

The beaches and seabed along the Southern Tamil Nadu coastline, present study area, is blessed with adequate quantities of placer minerals. The distribution of valuable minerals in placer deposits has fascinated the attention of various research agencies and private entrepreneurs to go for mining activities. The exploitation of mineral deposits in any country fetches all round development. Therefore, it is indispensable to make an assessment of total reserves, grade and their compatibility in the promising scientific advancements. The recent liberalisations of economic measures by the government of India and the exemption of certain minerals from the purview of mineral act have greatly enhanced the market potential of natural resources. Many private entrepreneurs have initiated the mineral based industries. In this juncture, it is requisite to meet the expectations of the prospective investors, in addition to the demands of various feeding industries, by stepping up the swiftness of exploratory and evaluation methods of natural resources. So it is imperative to understand the reserve of the deposit under consideration. Accordingly, this investigation has been sketched to appreciate the nature of major placers as compared to the placers in other regions both international and national arena and total inferred reserves of major placer minerals along the study area.

Placer minerals of assorted nature are distributed substantially in almost all the places. In Australia, rutile, zircon, ilmenite and monazite are exploited from Queensland and New South Wales (Mero 1965). Ilmenite, rutile, zircon, monazite and magnetite are also recovered from beach sands in northeast Sri Lanka (Wickremerante 1988). Sizable quantities of beach placer minerals, mainly ilmenite, rutile, zircon, are mined from Sierraleone and Mozambique (Beiersdorf et. al. 1980). Ilmenite, garnet, zircon, rutile and kyanite deposits are reported from central coast of Tamil Nadu (Chandrasekar 1992). Rajamanickam (1994); Angusamy (1995) and Anil Cherian (2003) have reported the beach placer deposits of ilmenite, garnet, rutile, zircon and magnetite along the southern coast of Tamil Nadu. Rajamanickam (2001) has projected the exploration and exploitation of beach placers in the Indian context. Chandrasekar and Sivasubramanian (2002) have dealt with the exploration, mining and processing of beach placers in India.

The coastal stretch between Valinokkam and Tuticorin extends over a distance of about 80 km in length. The area is located between 8° 45' to 9° 10'N and 78° 10' to 78° 40'E covering the districts of Ramanathapuram and Tuticorin (Fig.1). The study area is chiefly underline by Precambrian gneisses, Charnockites and granites besides Quaternary sediments. Geomorphologically, the coastal stretch can be classified as a shoreline of emergence as identified from the beach ridges scattered along the study area (Loveson 1994; Chandrasekar et al. 2000).

## **2. Materials and methods**

In view of the feasibility of exploiting major beach placers like garnet, ilmenite, zircon and magnetite, it is felt that prediction can be made on the possible inferred reserves of these minerals. Other placer minerals in the study area are in minor quantity, that is not viable for exploration and hence not been considered for the present study. The resourceful area has been divided into zone of enrichment and lean on the basis of a cut off percentage of 21 % in heavy mineral concentrate. Accordingly, the percentage variation of each auger samples up to 2 m depth has been averaged and accounted as the average vertical variation. Likewise, the different stations along the study area have been carefully evaluated and wherever the concentrations of placers are found to reach the optimum cut off, it is noted down as the zone of enrichment and lean. The length and breadth of each zone was measured for a year and the average of the same is used for further calculations (Anil Cherian 2003). In order to get uniform evaluation from berm to lowtide, two-metre thickness of these placers is used for the present investigation. From each patch, wherever there is variation in colour, grain size and concentration of black material or shelly material that sand is taken for the measurement of density by using pycnometer. As there is not much variation in these impurities, the average of such measurements has been made for the reserve estimation. The individual mineral percentage for the reserve estimation is obtained from the average count percentage of all the samples analysed along the study area. After getting the average value of the length, breadth, specific gravity and the percentage of each mineral, the reserve was estimated using the formula given below (CIM Standards, 2000).

$$\text{Resource} = \frac{\text{Area} \times \text{depth} \times \text{bulk density} \times \text{weight \%}}{100} \times 10^{-6}$$

= Million tonnes

### 3. Results and Discussion

The study area is enriched with valuable beach placer deposits as evidenced from the total heavy mineral concentration (Anil Cherian 2003). In places of heavy mineral exploitation, the total heavy mineral percentage is found to range from 4 to 56 % in west coast of India (Siddiquie et.al. 1981, 1984); 45 to 55 % in Manavalakurichi region; 10-30 % in the beach sands of Gopalpur region (Mallik 2002); 11-20 % in the central coast of Tamil Nadu (Chandrasekar 1992); 2.63 to 86.88 % in the southern coast of Tamil Nadu (Rajamanickam 1994); 5-14 % in northern Taiwan (Macdonald 1971); 5-14 % in Pulamodai beach deposits of Sri Lanka (Meyer 1993); 1.7 to 6.2 % in Kuntan area beach sands of east coast of Malaysia and 2-25 % of the black sands of Umgababa, South Africa (Hess 1965).

In order to realize the value of placers, the weight percentage of important economic minerals are calculated and presented in the Table 1. It is remarkable to mention here that in the case of zircon even the weight percentage of 0.22 is considered to be a minable deposit (Emery and Noakes 1968). 3 to 5 percent of ilmenite in the offshore has been accounted as an economically viable deposit (Tixeront et. al. 1978). In the study area, ilmenite weight percentage ranges from 3.15 to 46.49. In the case of zircon, weight percentage increases from 0.42 to 9.09 % and that of garnet from 2.58 to 41.78 %. The magnetite accounts 2.91 % of the total heavy minerals along the study area.

The inferred reserve of garnet, ilmenite, zircon, and magnetite is presented in the Table 5. When one compares the plant's production at east coast of Orissa (2000 tons) and Chavara (1200 tons) where even with extension the production crossing only 7500 tons annually, so the presence of 0.952616 million tonnes of garnet in the enriched zone of the study area can promise the possibility of establishing garnet industry in this region. At present garnet is produced from different parts of the Tamil Nadu coast. Similarly, 1.087234 million tonnes of ilmenite and 0.206405 million tonnes of zircon are definitely

economically viable for exploitation. However, our country is producing exportable quantity of ilmenite from Tamil Nadu and Kerala coast, it is worth to analyse the necessity of going for its extraction. At present the export is not going in a favourable phase of its resistive nature to rutile conversion. If the ilmenite along the study area is susceptible to rutile conversion, this material can be exploited and put up for sale in the market in the form of synthetic rutile. The separation of ilmenite and magnetite can be carried out easily. If a plant is run primarily for garnet, ilmenite and zircon, the expected reserve of 0.046023 million tonnes of magnetite can always be obtained as secondary production.

### **3.1. Ilmenite**

Ilmenite of the investigated area shows a percentage distribution from 3.15 to 46.49 % (Table 1). Tixeront et. al. (1978) reported that the 3-5 % of ilmenite concentration is recommended for exploitation. In the Republic of Korea, 4-5% concentrations of ilmenite are recommended as economically feasible for exploitation (Macdonald 1971). Rajamanickam (1983) has assessed the total reserves of offshore ilmenite placer deposits (1 MT) in the Konkan coast for economic exploitation. In Florida beach sand deposits, ilmenites are concentrated in extremely low amount of 2-3 % only with  $TiO_2$  of 60 %. Yet, second largest production of ilmenite is reported from this deposit. The concentration of  $TiO_2$  in the ilmenites of present study area (45.38 -46.35 %) is showing close affiliation with ilmenites of Canada, USA and Brazil, currently under exploitation (Table 2). The higher concentration of Ti, and Fe in the ilmenite reveals that the same is suitable for application in paint industries. Moreover, the concentration of ilmenites in medium to fine sand shows a greater degree of homogeneity. The development of new techniques and beneficiation processes has greatly enhanced the market value of ilmenite and the increasing demand for titanium oxide as greater bearing on the exploitation of ilmenite. These ilmenites can even be considered for usage in paint industries, in view of its enrichment and better grade. In the vista of the necessity of removing the V and Cr in the paint industries, a minor enrichment may also be considered in segregating V and Cr as economically viable by-products. The production data of ilmenite reserves expresses a momentous concern for the continuous supply.

The worked resources of ilmenite are placed at 1.7 billion tonnes with major reserves in Australia, Canada, Norway, South Africa, India and USA. The total reserves in India are estimated to be 146 million tonnes and the cumulative demand for this mineral by the 2010 is estimated to be 13.40 million tonnes (News letter 1992).

### **3.2. Garnet**

The availability of garnet in the investigated area ranges from 2.58 to 41.78 % (Table 1) is considered to be a good concentration because 7.1% of garnet in the heavy mineral concentrate is exploited even today in the Republic of Korea (Macdonald 1971). In spite of 2.58 to 41.78 % of garnet in the study region, it is possible that any garnet industry can get established. When the composition of the garnet in the study region is compared with that of elsewhere, it is found that the garnet under study is in no way substandard to the nature of garnet presently exploited in Australia and New York (Table 3).

### **3.3. Magnetite**

The magnetite concentration is not present up to the mark for exploitation. In the present study area magnetite varies from 0 to 2.91 %. Since it can be easily removed by magnetic separation, it is under consideration for placer deposits. When the magnetite of the study area is compared with that of Philippines, Taiwan and west coast of India, the quality is not up to the mark for economic evaluation (Anil Cherian 2003) (Table 4). In spite of the presence of higher concentration of vanadium and chromium, these magnetites can be considered for extracting them as by-products in course of time.

### **3.4. Zircon**

Noticeable concentration of zircon along the study area indicates the prospect for establishing mining industry in the near future (Table 1). When Australia has perfected the technology of economic extraction of even 0.22 % zircon from beach sands, why can't India afford to be lagging behind in making use of the enriched placer deposits with a maximum concentration of 9.09 % of zircons? (Table 1). At present, zircon is mined as by-products from the placers of Manavalakurichi (4-6 %) and Gopalpur (0.33 %). With the existing capacity of the production of zircon, the country has not attained the

maximum scope of expansion. Further, zircon is considered to be a strategic mineral but of short supplied one (Siddique et. al. 1981). The identified world resources of zircon exceed 20,000 million tonnes and that of the total reserve in India is 12 million tonnes having a growth rate of 2.9 % with a projected demand of 0.0572 million tonnes by the year 2010 clearly indicates the necessity of exploiting new reserves (Anil Cherian 2003). The zircon deposits identified during the present investigation (0.42 to 9.09 %) may be of enormous value to curtail the imports of zirconium oxide for local demand and to take the country in the international market.

#### **4. Conclusion**

At present 0.952616 million tonnes of garnet estimated from the enriched zone of study area. Similarly, 1.087234 million tonnes of ilmenite and 0.206405 million tonnes of zircon are definitely economically viable for exploitation. If a plant is run primarily for garnet, ilmenite and zircon, the expected reserve of 0.046023 million tonnes of magnetite can always be obtained as secondary production.

Beach placer minerals like garnet, ilmenite and zircon are being the strategic minerals of immense utility, a plant of that nature at this hour of economic crisis faced by the country may unquestionably help us to magnify our foreign trade. A technology should be designed to exploit the lower percentage of these minerals into valuable economically viable resource for the benefit of the future generations.

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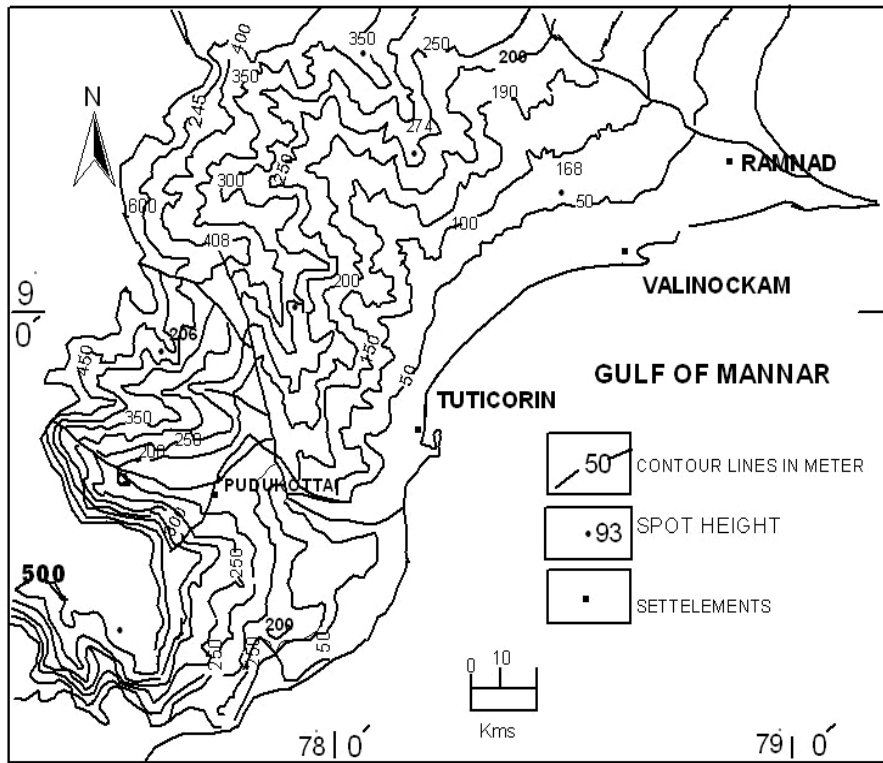


Fig 1. Location map of the study area

Table 1. Weight percentage distribution of beach placer minerals from the investigated area

<b>Minerals</b>	<b>1</b>	<b>2</b>	<b>4</b>	<b>5</b>	<b>Average</b>	<b>21</b>	<b>22</b>	<b>24</b>	<b>25</b>	<b>27</b>	<b>28</b>	<b>29</b>
<b>Garnet</b>	12.36	20.92	16.86	16.74	<b>16.72</b>	9.00	8.24	8.80	7.93	6.33	4.76	5.68
<b>Ilmenite</b>	17.68	15.28	16.32	16.11	<b>16.35</b>	16.56	13.03	9.91	10.97	6.25	7.89	7.31
<b>Magnetite</b>	0.10	0.06	0.00	0.08	<b>0.06</b>	0.21	0.10	0.22	0.14	0.00	0.19	0.20
<b>Zircon</b>	0.82	1.65	2.66	2.10	<b>1.81</b>	1.37	1.82	2.59	1.78	1.59	1.18	1.32
<b>Minerals</b>	<b>30</b>	<b>37</b>	<b>38</b>	<b>39</b>	<b>40</b>	<b>Average</b>	<b>41</b>	<b>42</b>	<b>43</b>	<b>45</b>	<b>47</b>	<b>48</b>
<b>Garnet</b>	5.13	8.72	7.54	6.50	3.99	<b>6.89</b>	16.76	34.95	29.27	25.22	23.19	21.04
<b>Ilmenite</b>	6.81	5.48	5.06	5.66	4.06	<b>8.25</b>	29.79	45.24	35.13	35.62	34.36	36.60
<b>Magnetite</b>	0.23	0.13	0.17	0.14	0.14	<b>0.16</b>	1.75	1.84	1.67	1.23	1.57	0.98
<b>Zircon</b>	1.26	1.52	1.50	1.02	0.42	<b>1.45</b>	2.63	6.79	7.94	9.09	7.96	7.49
<b>Minerals</b>	<b>50</b>	<b>51</b>	<b>Average</b>	<b>140</b>	<b>141</b>	<b>143</b>	<b>144</b>	<b>146</b>	<b>147</b>	<b>149</b>	<b>150</b>	<b>Average</b>
<b>Garnet</b>	14.03	8.07	<b>21.57</b>	24.45	30.98	23.98	24.49	25.13	17.29	13.84	11.14	<b>21.41</b>
<b>Ilmenite</b>	39.64	24.26	<b>35.08</b>	23.89	46.49	43.58	40.05	40.50	32.29	35.64	30.22	<b>36.58</b>
<b>Magnetite</b>	1.21	0.76	<b>1.38</b>	1.64	1.90	2.57	0.96	1.78	0.70	2.26	1.76	<b>1.70</b>
<b>Zircon</b>	5.31	3.03	<b>6.28</b>	5.19	5.21	5.16	5.42	5.84	4.79	3.83	3.04	<b>4.81</b>
<b>Minerals</b>	<b>239</b>	<b>240</b>	<b>242</b>	<b>243</b>	<b>245</b>	<b>246</b>	<b>248</b>	<b>249</b>	<b>Average</b>	<b>350</b>	<b>351</b>	<b>352</b>
<b>Garnet</b>	27.58	38.60	31.01	41.78	24.86	40.40	38.19	18.35	<b>32.60</b>	21.62	34.80	38.54
<b>ilmenite</b>	29.35	40.28	37.68	27.60	29.72	25.31	21.88	22.63	<b>29.31</b>	23.56	25.29	21.27
<b>Magnetite</b>	1.53	2.91	2.00	1.92	1.71	1.59	1.34	0.86	<b>1.73</b>	0.70	0.92	1.12
<b>Zircon</b>	4.79	5.45	4.60	4.18	2.93	4.33	4.52	2.48	<b>4.16</b>	5.75	9.09	8.38
<b>Minerals</b>	<b>353</b>	<b>355</b>	<b>356</b>	<b>358</b>	<b>359</b>	<b>Average</b>	<b>459</b>	<b>460</b>	<b>462</b>	<b>463</b>	<b>465</b>	<b>466</b>
<b>Garnet</b>	39.21	26.60	26.40	21.24	15.35	<b>27.97</b>	13.11	22.98	19.02	23.88	20.46	17.59
<b>Ilmenite</b>	20.96	20.02	22.62	18.50	17.52	<b>21.22</b>	11.73	17.98	21.63	16.83	19.79	18.79
<b>Magnetite</b>	0.65	0.39	0.55	0.73	0.41	<b>0.68</b>	0.35	0.44	0.69	0.32	0.60	0.32
<b>Zircon</b>	7.58	5.43	5.25	4.99	3.48	<b>6.24</b>	4.19	7.26	5.56	7.58	4.89	3.55
<b>Minerals</b>	<b>468</b>	<b>469</b>	<b>Average</b>	<b>512</b>	<b>513</b>	<b>515</b>	<b>516</b>	<b>Average</b>	<b>538</b>	<b>539</b>	<b>540</b>	<b>Average</b>
<b>Garnet</b>	17.27	11.63	<b>18.24</b>	5.09	5.87	4.52	3.60	<b>4.77</b>	4.22	2.58	2.63	<b>3.14</b>
<b>Ilmenite</b>	17.57	12.16	<b>17.06</b>	6.25	5.93	5.62	3.97	<b>5.44</b>	4.88	3.15	4.08	<b>4.04</b>
<b>Magnetite</b>	0.38	0.09	<b>0.40</b>	0.33	0.29	0.30	0.22	<b>0.29</b>	0.28	0.07	0.13	<b>0.16</b>
<b>Zircon</b>	2.94	2.92	<b>4.86</b>	1.03	1.38	1.01	0.83	<b>1.06</b>	0.79	0.59	0.55	<b>0.64</b>

1,2,4, etc represent sample nos.

**Table 2. Percentages of various constituents of minable ilmenites from placer sands of some countries**

Constituents	Australia		Sri Lanka	Canada	New Zealand		Norway	Malaysia	India	Brazil	Portugal	Senegal	South Africa	USA
	West coast	East coast							Quilon					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TiO <sub>2</sub>	54.00	47.20	53.29	45.90	34.30	22.40	42.50	51.96	59.90	48.30	52.20	56.80	49.30	45.60
FeO	22.30	26.40	20.78	39.68	27.50	36.90	32.60	38.80	9.30	32.40	42.10	1.60	38.70	36.80
Fe <sub>2</sub> O <sub>3</sub>	18.10	0.01	23.50	1.66	25.20	31.20	13.80	5.30	25.20	16.60	-	28.60	8.40	15.80
P <sub>2</sub> O <sub>5</sub>	0.05	2.50	0.09	0.21	0.02	0.93	0.03	0.20	0.18	-	0.27	-	-	-
Cr <sub>2</sub> O <sub>3</sub>	0.03	-	0.08	0.02	0.10	-	0.02	0.02	0.13	0.50	0.03	0.32	0.09	0.27
V <sub>2</sub> O <sub>5</sub>	0.11	-	-	0.03	0.27	-	0.23	0.03	0.25	0.06	0.41	0.10	-	-
Al <sub>2</sub> O <sub>3</sub>	0.86	-	-	2.95	3.50	6.01	1.30	1.50	1.60	0.30	-	-	-	0.70
MnO	1.50	-	0.87	2.09	0.16	-	0.40	0.80	0.48	0.60	0.29	-	-	-
CaO	0.02	-	-	0.65	0.90	0.55	0.60	0.10	0.10	0.00	5.00	-	-	0.12
MgO	0.35	-	-	0.31	3.10	1.50	3.90	0.08	0.95	0.10	0.09	-	-	0.50
SiO <sub>2</sub>	0.53	-	0.68	4.73	4.30	1.00	4.00	0.40	0.70	1.40	0.03	-	-	1.10
Nb <sub>2</sub> O <sub>5</sub>	-	-	-	-	-	-	0.01	0.22	0.17	-	-	-	-	-
SnO <sub>2</sub>	-	-	-	-	-	-	-	-	0.01	0.00	-	-	-	0.07
CoO	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-
WO <sub>3</sub>	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-
Au	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-
Pt	-	-	-	-	-	-	-	-	0.02	-	-	-	-	-
Cd	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-
CuO	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01
ZnO	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Li <sub>2</sub> O	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NiO	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PbO	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1 to 5 - Macdonald,(1971);

6 to 14 -Altekar and Desai (1964) ;

**Table 2. Percentages of various constituents of minable ilmenites from placer sands of some countries**

Mosanbique	Central Tamilnadu			Central Tamilnadu			Southern Tamilnadu			Investigated area	
	Ratnagiri	coast		South	Central	North	Kanya.	Kal-Vai	Lean	Enriched zone	Lean zone
<b>15</b>	Jaigad	Ambwah	Varvada	<b>19</b>	<b>20</b>	<b>21</b>	<b>22</b>	<b>23</b>	<b>24</b>	<b>25</b>	<b>26</b>
49.50	47.96	51.38	52.30	43.56	43.43	40.95	47.63	42.61	43.20	46.35	45.38
33.10	27.55	27.82	30.81	39.31	38.21	35.03	20.50	25.50	22.85	51.76	53.00
14.60	15.66	16.54	11.58	12.57	13.56	18.83	26.51	27.60	29.15	-	-
-	0.89	0.41	0.64	0.46	0.44	0.26	0.46	0.48	0.52	-	-
0.10	0.06	0.09	0.10	0.05	0.06	0.03	0.03	0.03	0.02	0.05	0.00
-	-	-	-	0.17	-	-	0.38	0.32	0.50	3.04	2.74
0.25	1.10	1.18	1.09	1.74	1.60	2.50	0.10	0.09	0.07	0.06	0.03
0.40	0.35	0.32	0.39	0.31	0.31	0.30	0.31	0.13	0.39	0.97	0.94
1.50	0.61	0.16	0.03	0.61	0.33	0.20	0.35	1.32	1.24	0.01	0.00
-	2.52	0.87	1.06	0.31	0.13	0.11	0.38	0.49	0.31	0.69	0.61
0.20	2.93	1.88	1.83	0.13	0.61	0.37	0.92	1.10	0.45	0.09	0.03
-	-	-	-	-	-	-	0.03	0.05	0.05	-	-
0.18	-	-	-	0.00	0.00	-	-	-	-	-	-
-	0.02	0.02	0.02	0.03	0.03	0.02	-	-	-	0.01	0.00
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	0.06	0.04	0.06	0.26	0.09	0.10	-	-	-	0.00	0.00
-	0.03	0.04	0.04	0.68	0.01	0.01	-	-	-	0.13	0.04
-	0.01	0.00	0.00	0.02	0.01	0.01	0.01	0.02	0.01	-	-
-	0.06	0.04	0.05	0.04	0.04	0.02	-	-	-	0.00	0.00
-	0.00	0.02	0.01	0.01	0.00	0.00	-	-	-	-	-

15 - Beiersdorf et.al., (1980);

16 to 18 - Rajamanickam, (1983); 19 to 21 - Chandrasekar, (1992);

22 to 24 - Angusamy (1995); 25 to 26 - Anil Cherian (2003) (Present study)

**Table 3. Percentage of various constituents of minable garnet from placer sands of some countries**

Constituents	New York 1	Australia 2	Central Tamilnadu		Kanyakumari 5	Southern Tamilnadu		Investigated area	
			Enriched zone 3	Lean zone 4		Kallar-Vaippar 6	Lean zone 7	Enriched zone 8	Lean zone 9
SiO <sub>2</sub>	38.03	36.89	38.17	37.13	31.28	39.13	38.37	39.80	36.81
TiO <sub>2</sub>	-	-	0.13	0.03	0.63	-	-	0.04	0.06
Al <sub>2</sub> O <sub>3</sub>	22.05	20.92	21.17	21.11	27.19	25.17	23.21	22.07	21.93
Cr <sub>2</sub> O <sub>3</sub>	-	-	0.04	0.06	-	-	-	0.04	0.00
Fe <sub>2</sub> O <sub>3</sub>	0.88	-	3.76	2.10	3.90	1.30	4.85	-	-
FeO	29.17	29.82	29.08	31.00	31.42	28.10	26.02	26.60	29.41
MnO	1.57	9.26	0.96	0.64	0.74	0.93	0.92	1.36	1.27
MgO	6.49	1.82	4.68	5.14	4.57	3.79	5.21	7.56	7.15
CaO	1.80	1.06	1.01	0.95	0.74	1.34	1.39	2.53	3.37
Na <sub>2</sub> O	-	0.05	0.01	0.02	0.01	-	-	0.00	0.00
K <sub>2</sub> O	-	0.04	0.02	0.03	0.02	0.01	0.03	0.01	0.00
H <sub>2</sub> O	-	0.15	-	-	-	-	-	-	-
Zr <sub>2</sub> O	-	-	0.23	-	-	0.23	-	-	-
P <sub>2</sub> O <sub>5</sub>	-	-	0.78	1.85	-	-	-	-	-
CuO	-	-	0.02	0.01	-	-	-	0.03	0.00
CoO	-	-	0.01	0.01	-	-	-	0.03	0.00
NiO	-	-	0.01	0.02	-	-	-	0.00	0.00
V <sub>2</sub> O <sub>5</sub>	-	-	1.05	0.72	0.02	0.03	0.02	0.01	0.00

**Table 4. Percentage of various constituents of minable magnetite from placer sands of some countries**

Constituents	India				North Taiwan	Central Tamilnadu			Investigated area	
	Phillipines	Jaigad	Ambwah	Varvada		South	Central	North	Enriched	Lean zone
	1	2	3	4	5	6	7	8	9	10
SiO <sub>2</sub>	2.34	2.08	0.72	1.92	4.8	5.92	2.7	5.79	0.07	0.04
TiO <sub>2</sub>	6.17	18.47	23.65	29.52	6.3	16.9	15.34	13.1	23.32	0.29
FeO	25.21	20.43	22	22.65	21.84	21.35	28.9	23.08	74.87	97.98
Fe <sub>2</sub> O <sub>3</sub>	59.44	51.98	46.31	38.94	55.29	38.89	43.09	45.46	-	-
P <sub>2</sub> O <sub>5</sub>	-	1.33	0.64	0.82	0.06	0.38	0.11	0.34	-	-
Al <sub>2</sub> O <sub>3</sub>	3.03	3.28	3.18	4.06	4.71	7.15	7.96	10.3	0.31	0.55
CaO	0.66	0.22	0.49	0.13	-	1.02	0.39	0.45	0.01	0
MgO	2.4	1.52	2.29	1.25	-	0.03	0.01	0.02	0.37	0.05
MnO	0.58	0.55	0.53	0.48	-	0.38	0.44	0.39	0.79	0.61
Zr <sub>2</sub> O	-	-	-	-	-	1.28	1.06	1.18	-	-
PbO	-	0.06	0.11	0.47	-	0.21	0.2	0.05	-	-
ZnO	0.08	0.95	1.11	0.67	-	1.25	1.24	0.09	0.07	0.01
NiO	0.01	0.81	0.61	0.63	-	0.66	0.51	0.15	0.05	0.1
Cr <sub>2</sub> O <sub>3</sub>	0.02	2.2	1.56	0.5	-	2.26	1.76	0.35	0.1	0.16
CuO	0.01	0.73	0.47	0.66	0.01	0.88	0.76	0.83	0.02	0.04
BiO	0.004	-	-	-	-	-	-	-	-	-
S	0.1	-	-	-	0.01	-	-	-	-	-
LiO	-	0.22	0.25	0.18	-	0.22	0.22	0.68	-	-
SnO <sub>2</sub>	-	-	-	-	-	0.01	0.01	-	-	-
V <sub>2</sub> O <sub>5</sub>	-	-	-	-	0.75	2.17	2.17	3.54	1.61	0.18
CoO	-	0.33	0.33	0.34	-	0.31	0.38	0.07	0.07	0.12
As	-	-	-	-	0.01	-	-	-	-	-

1 & 5 - Macdonold (1971); 2 to 4 - Rajamanickam (1983); 6 to 8 - Chandrasekar (1992); 9 to 10 - Anil Cherian (2003) (Present study)

**Table 5:** Inferred Reserve of Beach Placer Minerals from the Inverstigated Area (in Millions tonnes)

Minerals	Enriched zone						Lean zone				
	Vembar	P.S.puram	K.Puram	Sippikulam	Kallar	Total	Valinokkam	T.mukkaiyur	Taruvaikulam	Tuticorin	Total
<b>Ilmenite</b>	0.304354	0.260102	0.230113	0.178227	0.114438	<b>1.087234</b>	0.174591	0.078862	0.032546	0.015833	<b>0.301832</b>
<b>Garnet</b>	0.187109	0.152243	0.255946	0.234948	0.122371	<b>0.952616</b>	0.108570	0.065821	0.028525	0.012566	<b>0.215481</b>
<b>Magnetite</b>	0.011940	0.012060	0.013604	0.005744	0.002675	<b>0.046023</b>	0.000641	0.001490	0.001704	0.000535	<b>0.004370</b>
<b>Zircon</b>	0.054485	0.034199	0.032664	0.052448	0.032609	<b>0.206405</b>	0.019304	0.013838	0.006354	0.002587	<b>0.042083</b>

P.S.puram - Periyasampuram  
K.puram - Kalaignanapuram  
T.mukkaiyur - Terkumukkaiyur