HEAVY MINERAL SEPARATION AND IDENTIFICATION IN PARTS OF SOUTHEAST COASTAL AREA, TAMIL NADU, INDIA

Abstract

The current study concentrates on heavy mineral separation using the bromoform technique. The main structural element is the distribution of several heavy minerals in coastal areas along a stretch of India's southeast coast in Tamil Nadu. The observed variations in the distribution of heavy minerals in the area are connected to differences in sediment supply, sorting, and oceanographic processes, all of which cause the sediments to be sorted in a specific way. The main factors affecting how heavy minerals are distributed in the depositional basin are mineral stability, density, particle size, wave velocity, and dynamics of beach morphologies. The heavy mineral assemblage of the study region is determined by the distribution of various types of minerals, and each mineral was identified using microscope techniques in the main study area. The assemblage is dominated by a select few minerals, including garnet (colourless), garnet (pink), zircon, rutile, chlorite, etc. Numerous igneous rocks, high-grade metamorphic rocks, Precambrian gneissic, granitic, and basic rocks were present in the heterogeneous provenance that gave rise to the ubiquitous zircon, monazite, and sillimanite that can be found in both seashore and inland red teri sands. This provenance almost probably originated from a coastal region.

Keywords: Heavy mineral, Bromoform, Coastal zone, Source rock, Microscopy

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I. INTRODUCTION

Heavy minerals are economically important and are commonly deposited along the beach, if breaking wave height, period, beach grain size, and slope of morph dynamic beach state are favourable studied by Rajamanickam, G.V. (1983 & 2001). Rich concentrations of placer minerals that have high specific gravity resistant minerals occur on the southwest coast of India. Best known deposits are known as black sands. The sands are rich in Ilmenite, monazite, rutile, zircon, garnet etc. Heavy mineral deposits formed in modern beach environments or are older raised beach deposits formed during the Pleistocene. They serve as a source for many metals and nonmetals. A placer deposit is formed by flowing water, particularly streams and rivers, which causes an accumulation of mechanically separated minerals studied by Gandhi, M. S et al (2011). The concentration of more resistant and higher specific gravity (density) minerals are caused by the erosion of weathered rocks and minerals (2.89). In general, alluvial deposits (split into Bar, Channel Fill, Valley Delta, and Bench or Terrace Placers) and lateral placer deposits can be categorised based on the mode of origin and transportation. The effects of waves, winds, currents, tides, storms, and other variables have altered the natural coastal dynamics Magesh, N. S Chandrasekar, N & Kaliraj, S (2015). Deposits of ilmenite, garnet, zircon, rutile, and kyanite have been found along the Tamil Nadu central coast (Chandrasekar 1992 & 2000). The southern coast of Tamil Nadu has ilmenite, garnet, rutile, zircon, and magnetite beach placer deposits, which have been described by Rajamanickam (1994) and Anil Cherian (2003). There is a lower concentration of topaz, glaucophane, actinolite, sillimanite, and kyanite during the monsoon seasons. In general, alluvial deposits (split into Bar, Channel Fill, Valley Delta, and Bench or Terrace Placers) and lateral placer deposits can be categorised based on the mode of origin and transportation. The effects of waves, winds, currents, tides, storms, and other variables have altered the natural coastal dynamics. The bedrock of sandy beaches is highly unbalanced even though sand is constantly transported to the beach during accretion periods and detached from the beach during erosion events studied by Cherian, A et al (2011). The source rocks determine the composition of the economic minerals. Usually, granite is the source of zircon, Rutile, monazite, and some Ilmenite. The source of Ilmenite and garnet is ultramafic and mafic rocks, such as kimberlites or basalt. Garnet is sourced commonly from metamorphic rocks, such as amphibolites schist. The distribution, mineralogy, and provenance of heavy minerals on beaches have been the subject of an attempt to study. In addition to determining the origin of heavy minerals, our main objective is to provide an assessment of the mineral potential for this region of southeast coastal based on various data sources. (1) To study heavy mineral concentration southeast coastal dynamics. (2) To understand the inaugural heavy mineral concentration using microscopy study.

II. STUDY AREA

The study area around Kanyakumari to Tiruchendur provides numerous examples of interesting coastal geomorphological features in the estuary the sand bar opens up under the force of gravity (**Figure 1&2**). Shallow fluvial marine landforms like salt marshes and tidal mud flats are associated with the estuary. Other associated major landforms are sandy beaches, rocky shores, oyster reefs, mangrove forests, and small river deltas Saravanan, S., et al (2011). The study area is completely made up of recent sand, sandstone, calcareous sandstone, gneiss, Garnetiferous Charnockite, and Khondalite of Western Ghats. The study area is mostly covered with recent quaternary and Archean rocks.

Most of the rocks are covered by Charnockite, Migmatite, genesis complex, and granite rocks are occupied in the southeast coastal area.

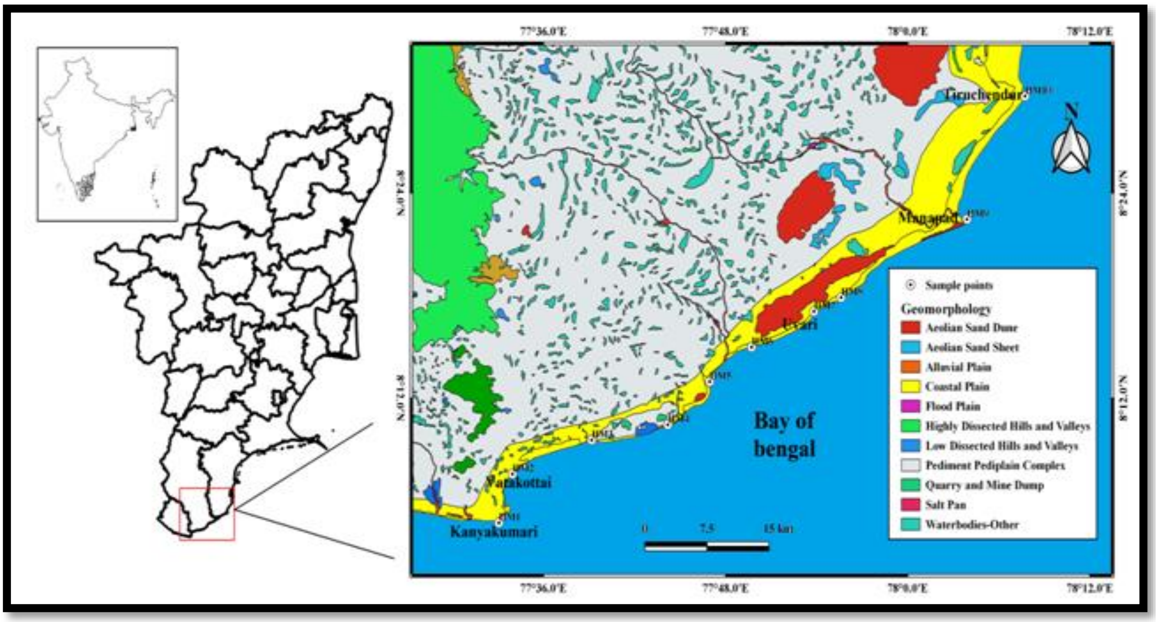

Figure 1: Location Map of Study Area

Figure 2: Heavy Minerals Deposit in Vattakottai and Kanyakumari Area

III. MATERIALS AND METHODS

The 10 samples of beach sediment were collected in the southeast coastal areas of Kanyakumari and Tiruchendur (Figure 3 & Table 1). To dry out the sediment samples, they were roasted at 30°C. An approximately 100g sediment sample is extracted using coning and quartering. After the fraction is divided, a precise total weight is recorded. The materials are stirred, allowed to settle for two minutes, and then stirred once more before the samples are placed for repeated washing. After that, the resultant solutions are decanted. At this phase, the sediments' related clay materials have been eliminated.

Figure 3: Sample Collection in Southeast Coast Area

To get clean water, this requires a few minutes of whirling with a lab stirrer. After the sand has dried and settled, the weight is acquired. The weight difference between the initial 100g and the final weight after decantation is caused by the clay and silt. A 30% H2O2 addition is agitated to eliminate organic material. The mixture is agitated as the H2O2 addition is continued until the evaporation process ends.

Continuous addition of H2O2 is made up until the liquid no longer bubbles when stirred. This is followed by rinsing and drying it with distilled water. The weight loss is observed, and the increase in weight is attributed to the weight of organic material. A little hydrochloric acid treatment is used to remove the samples from the shelly components. Repeatedly adding moderate HCl removes any remaining effervescence. The complete dissolution of carbonate material has been proven once the effervescence on fresh addition has ended. After being placed in the beaker, the sand is cleaned with distilled water and then dried.

The weight loss after treatment with acid is monitored for the carbonate content. To filter out clay and silt, organic waste, and carbonate detritus, the samples are run through ASTM sieves with a 1/2 phi interval between sieve sizes. The sieved components are divided, weighted, and kept in separate containers. To guarantee that the overall weight loss caused by sieving does not exceed 0.05 gm, it is constantly monitored. Each sample is split into three fractions (coarse, medium, and fine), and each fraction is then subjected to heavy mineral separation using heavy liquid bromoform. The weight percentage and count percentage of the heavy minerals were determined for all samples in one location. Heavy minerals are mainly present in trace amounts in sedimentary rocks.

Table 1: Sample Location Data from the Study Area

Station ID	X	Y	Location
HM1	8.07809	77.5509	Kanyakumari
HM2	8.12578	77.5658	Vattakottai
HM3	8.15893	77.6528	Perumanal
HM4	8.17389	77.7365	Idithakarai
HM5	8.21595	77.7824	Kuthenkuly
HM6	8.24962	77.8285	Navaladi
HM7	8.28453	77.897	Uvari
HM8	8.29808	77.9268	Koduthalai
HM9	8.37443	78.0651	Manapad
HM10	8.49465	78.1288	Tiruchendur

A thick liquid is typically used in either a separator funnel or a centrifuge to separate heavy minerals. Bromoform, tetrabromoethane, tribromoethane, methylene, iodide, and polytungstate liquids are all used.

1. Laboratory Analysis

There are two important analyses of heavy mineral separation

- **Specific gravity:** The specific gravity of a mineral is the ratio of its density to that of water. Hence the specific gravity is often defined as the weight of the sample divided by the weight of the equal volume of water. This is done by using a specially designed 25 ml container.

Specific gravity calculation is given below for the zircon minerals.

Calculation

Weight of bottle	W1= 18.4 g
Weight of bottle and sand	W2 = 20.70 g
Weight of bottle + sand +water	W3 = 48.6 g
Weight of bottle + water	W4 = 46.8 g
Weight of sand	(W2-W1) = (20.7-18.4) g = 2.3 g
Weight of water	(W4-W1) = (46.6-20.7) g = 28.4 g
Weight of water with sand	(W3-W2) = (48.6-20.7) g = 27.9 g
Water displaced by sand	(W4-W1) – (W3-W2) = (28.4 -27.9) g = 0.5 g
Specific gravity	(W2-W1) ÷ (W4-W1) – (W3-W2)
	= 2.3 g ÷ 0.5 g
	= 4.6 g

The zircon specific gravity is 4.6

2. **Bulk density:** Bulk density is the weight of heavy minerals in a given volume. The example for the calculation is the zircon sample.

Calculation

This is done by using a specially designed	5×5×5 cm Cubic box
Weight of empty box	W0 = 114.7 g
Weight of substance	W1= 499.1 g
Weight of empty box	W1-W0 = (499.1 – 114.7) g = 384.4 g
Weight of substance	W2= 500.2 g
Weight of empty box	W2-W0 = (500.2 – 114.7) g = 385.9 g
Weight of substance	W3 = 500.9 g
Weight of empty box	W3-W0 = (500.9 – 114.7) g = 386.2 g
Mean of the substance	=384.4 + 385.9 + 386.2 ÷ 3 g = 1156.6 ÷ 3 = 385.5 g

The Bulk density is calculated using the formula,

$= \text{Mean weight of sample} \times 100 \times 100 \times 100 / 5 \times 5 \times 5 \times 100 \quad kg/m^3$

$= (385.5 \times 100 \times 100 \times 100) \div (5 \times 5 \times 5 \times 1000)$

$= 385500000 \div 125000$

$= 3084\ kg/m^3$

The zircon Bulk density is 3084 kg/m^3

IV. RESULT AND DISCUSSION

A coninged and quartered representative sample of the total heavy mineral concentrations is placed on the Canada balsam. The concentration volume is selected to provide the section with at least 10 to 15 grains. Put two to three drops of glycerine over a tiny slide. On this glycerine, transfer the substance to be counted. Place an 18mm-thick tiny cover glass on top of this. After that, lightly press over the lid to scatter the grains evenly (**Figures 4 -8**).

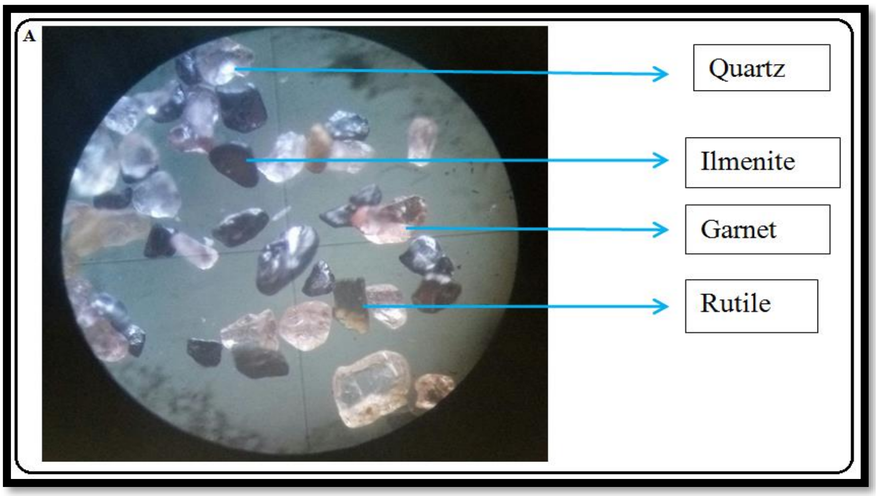

Figure 4: Microscopy View of Heavy Minerals in Section A

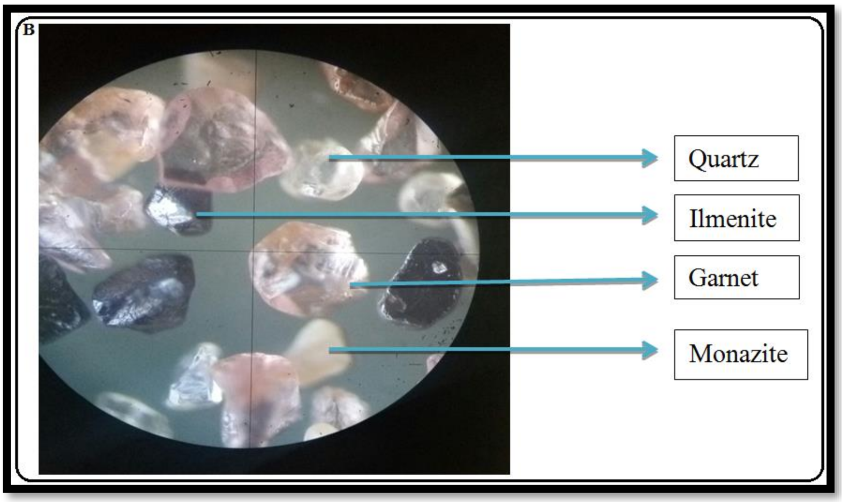

Figure 5: Microscopy View of Heavy Minerals in Section B

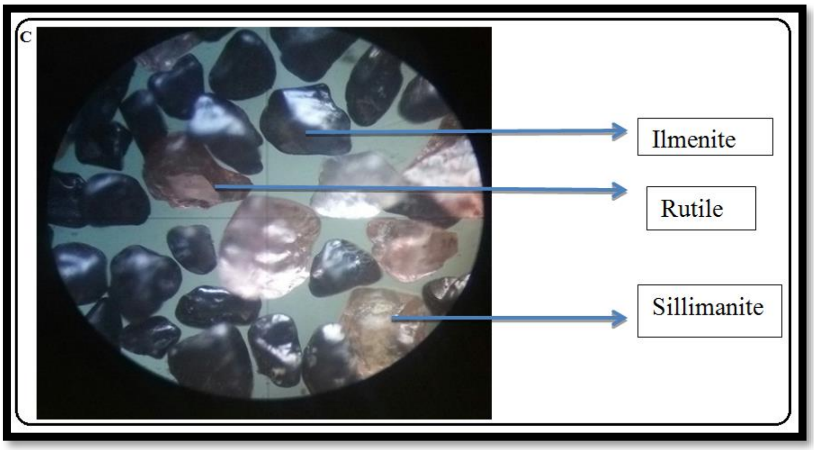

Figure 6: Microscopy View of Heavy Minerals in Section C

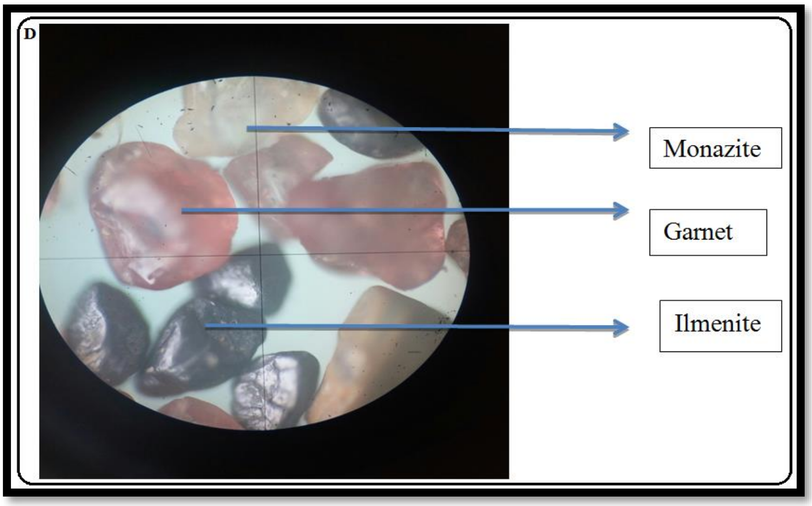

Figure 7: Microscopy View of Heavy Minerals in Section D

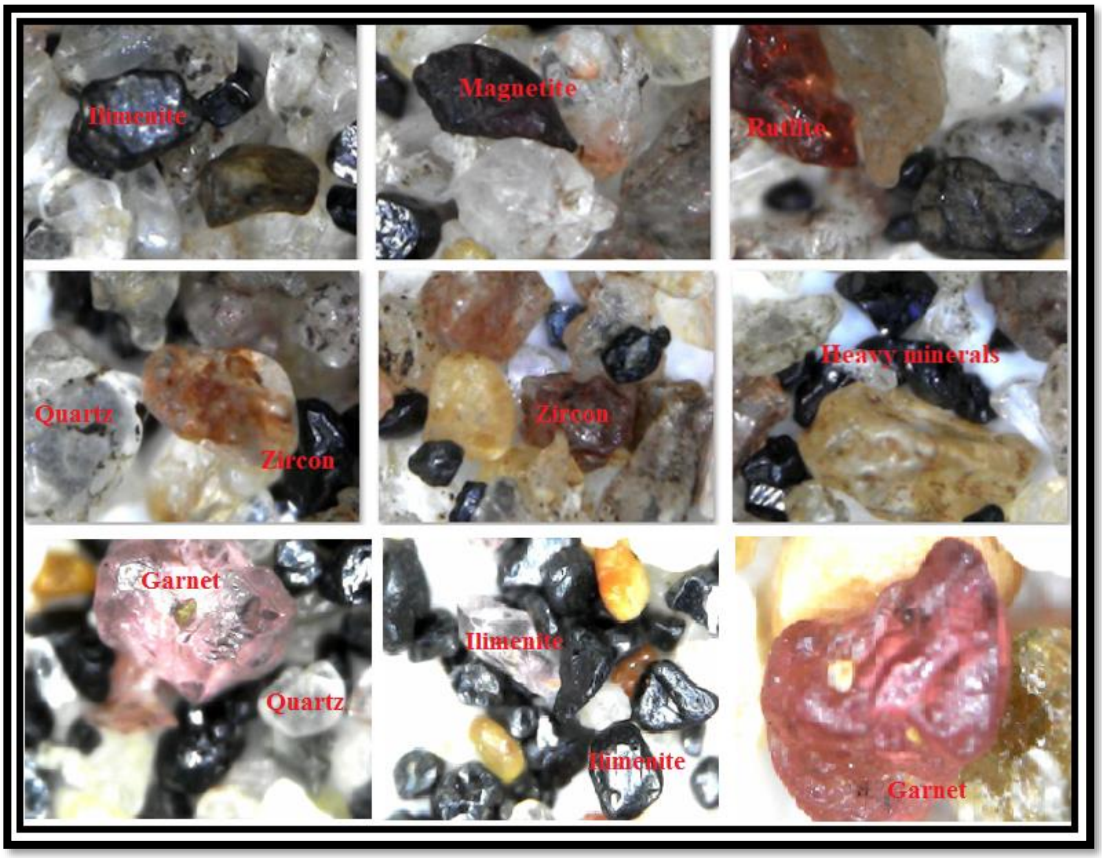

Figure 8: Microscopy View of Heavy Minerals in Overall Samples

1. Mineralogy and Petrography

- **Garnet**
  Garnets have the following characteristics:
  - General Formula - Fe3Al2 (SiO4)3
  - Chemistry - TiO2 -1.0%; FeO –26% Fe2O3 -2.9%; Mgo – 6.8%; SiO2 – 40%; Al2 O3- 21%; P2O5-0.03%
  - Colour - Fine deep red
  - Crystal system - Rhombohedra
  - Lustre - Vitreous
  - Cleavage - Imperfect
  - Transparency - Translucent to sub translucent
  - Hardness - 5 to 5.5
  - Specific gravity - 4.11
  - System - isotropic
  - Relief - high
  - Bulk density - 2200 to 2300 kg /m^3

- **Rutile**

  Rutile has following characteristics:
  - General Formula - Tio2
  - Chemistry - TiO2 -94%; FeO –0.09%
    Fe2O3 -2%; Mgo – 0.06%;
    SiO2 – 1.8%; Cr2O3-0.09%;
  - Colour - Black to brown
  - Crystal system - Tetragonal
  - Lustre - Metallic to adamantine
  - Cleavage - Prismatic
  - Transparency - Translucent to opaque
  - Hardness - 6 to 6.5
  - Specific gravity - 4.18 to 4.25
  - System - tetragonal
  - Relief- Very high
  - Bulk density - 2500 to 2800 kg /m3
  - PPL Colour - brown to red brown

- **Zircon**

  Zircon has following characteristics:
  - General Formula - ZrSiO4
  - Chemistry - TiO2 -0.25%; FeO –0.09%
    Fe2O3 -0.10%; Al2O3 –1%;
  - SiO2 – 32.5%; ZrO2 – 65%
  - Colour - colourless, yellowish
  - Crystal system - Tetragonal
  - Lustre - Adamantine
  - Cleavage - Imperfect
  - Transparency - Opaque
  - Hardness - 7.5
  - Specific gravity - 4.68 to 4.70
  - System - tetragonal
  - Relief - high
  - Bulk density - 2800 to 3000 kg /m3
  - PPL Colour - Colourless to pale brown

- **Monazite**

  Monazite has following characteristics:
  - General Formula - (Ce, La, Nd,Th) [PO] 4
  - Chemistry - REO -55%; ThO2 –9.2%
    P2O5 -29.2%;
    Insoluble -4%
  - Colour - Reddish and yellowish
  - Crystal system - Tetragonal

- Lustre - Resinous
- Cleavage - Perfect
- Transparency - Sub transparent to translucent
- Hardness - 5 to 5.5
- Specific gravity - 5.54
- System - monoclinic
- Relief - high
- Bulk density - 3200 to 3400 kg /m3
- PPL Colour - Colourless to pale brown

- **Sillimanite**

Sillimanite has following characteristics:

- General Formula - (Ce, La, Nd,Th) [PO]4
- Chemistry - TiO_2 -0.44%; SiO_2 –36. 9%
  P_2O_5 -0.02%; Al_2O_3-38.7%;
  ZrO_2 – 2%
- Colour - Colourless, Yellowish Grey
- Crystal system - Orthorhombic
- Lustre - Vitreous
- Cleavage - Perfect
- Transparency - Transparent to translucent
- Hardness - 6 to 7
- Specific gravity - 3.23 to 3.24
- System - Orthorhombic
- Relief - high
- Bulk density - 1950 to 2050 kg /m3
- PPL Colour - brown to pale blue

- **Ilmenite**

Ilmenite has following characteristics:

- General Formula - $FeTiO_3$
- Chemistry - TiO_2 -55% ; FeO – 19.6%
  Fe_2O_3 -21.8% ; Mgo – 1%;
- Colour - Black to black brown
- Crystal system - Trirhombohedra
- Lustre - Sub metallic
- Cleavage - Imperfect
- Transparency - Opaque
- Hardness - 5 to 5.5
- Specific gravity - 4.5 to 5
- System - Tri rhombohedra
- Relief - high
- Bulk density - 2600 to 2850 kg /m3
- PPL Colour - black to brown

Heavy minerals are more widely distributed in sediments from rivers and the ocean. According to research by Gandhi M S & Raja M, heavy materials are transported to the northeast side of the earth by longshore flow movements, which may explain why the distribution of heavy minerals is less abundant during post-monsoonal depositional periods (2014). In marine sediments, enrichment of heavy minerals is favourable. The abundance of low grossularite, high pyrope garnet populations in southern river sands in the study area. High-grade (granulite fancy) Charnockite and Met sedimentary rocks make up the basement in this location. The information previously provided makes it abundantly evident that source rocks, which are composed of metamorphic and recycled sediments, are dominant. There is less density as a result of the grains' various geometries (Zircon), hues (Garnet, Tourmaline), intergrowths (Ilmenite), and modifications (Magnetite). The source is primarily recycled alongside igneous and metamorphic rocks due to the nature of heavy minerals and the degree of roundness demonstrated by highly resistant minerals. The source rock in the catchment areas of the current research region is composed of several substances, including alluvium, composite gneiss, charnockite, quartzite, sandstone, granite mica gneiss, and others. Heavy mineral concentrations are modest to moderate along the Southeast coast zone. This may be due to the NNE-SSW form of the shoreline, which prevented the deposit of sediments brought by ferocious littoral currents going southeast.

V. CONCLUSIONS

There are various placer deposits along India wide coastline, including magnetite, zircon, ilmenite, garnet, and monazite. Tiruchendur, Manapad, Uvari, Vattakodai, and Kanyakumari are a few of the prominent places where heavy minerals are deposited. The parent rocks influence the composition of the economic minerals. Granite commonly contains zircon, rutile, monazite, and a trace of ilmenite. The typical source of garnet is metamorphosed rocks, such as amphibolite schist. The high-grade (granulite fancy) Charnockite and Met sedimentary rocks that form the basement in this area are where garnet populations predominate, as are river sands from southern India, which are largely made of low grossularite high-pyrope garnets. The current research region's catchment regions include Alluvium, Composite Gneiss, Charnockite, Quartzite, Sandstone, Granite, Mica Gneiss, and other types of source rock. Mineral stability, density, particle size, wave velocity, beach morph dynamics, and other factors all play a significant influence in determining the distribution of heavy minerals in the depositional basin. Due to the coastline's NNE-SSW configuration, which served as a barrier to the deposition of sediments delivered by northerly migrating currents, the southeast region has a lower percentage of heavy particles.

REFERENCE

[1] Anil Cherian. 2003. Sedimentological studies in the beaches between Valinokkam and Tuticorin, Tamil Nadu. Unpubl. Ph.D. Thesis, Tamil University, Thanjavur, 189p.
[2] Chandrasekar, N. & Sivasubramanian, P. 2002. Exploration, mining, and processing of beach placers in India. V.O.C.College Publ., Tuticorin.
[3] Chandrasekar, N. 1992. Placer mineral exploration along the central Tamil Nadu coast. Unpubl. Ph.D. thesis, Madurai Kamaraj Univ. Madurai. 293 p
[4] Chandrasekar, N., Anil Cherian, Rajamanickam, M. & Rajamanickam, G.V. 2000. Coastal landform mapping between Tuticorin and Vaippar using IRS – IC Data. Ind. J. Geom. 5: 114-120.

[5] Cherian, A., Chandrasekar, N., Rajamanickam, G. V., & Gujar, A. R. (2011). An evaluation of major placer minerals along the Valinokkam-Tuticorin coast, southern Tamil Nadu, India.
[6] Gandhi, M. S., & Raja, M. (2014). Heavy mineral distribution and geochemical studies of coastal sediments between Besant Nagar and Marakkanam, Tamil Nadu, India. Journal of Radiation Research and Applied Sciences, 7(3), 256-268. https://doi.org/10.1016/j.jrras.2014.06.002
[7] Gandhi, M. S., Solai, A., Kaveri, S., Kanan, K., Dhamodharan, V., Baskar, K., & Rajamanickam, V. (2011). Post Tsunami heavy mineral distribution between Cuddalore to Kanyakumari along the Tamil Nadu Coast, India–a review.
[8] Magesh, N. S., Chandrasekar, N., & Kaliraj, S. (2015). Mapping of heavy mineral placers through marine GIS expert system: a case study in Kalaignanapuram coastal stretch, southeast coast of Tamil Nadu, India. Arabian Journal of Geosciences, 8(1), 195-206. https://doi.org/10.1007/s12517-013-1193-x
[9] Mohan, P. M., & Rajamanickam, G. V. (1995). Distribution of heavy minerals in Parangipettai (Porto Novo) Beach, Tamil Nadu. JOURNAL-GEOLOGICAL SOCIETY OF INDIA, 46, 401-408.
[10] Rajamanickam, G.V. 1983. Geological Investigations of offshore heavy mineral placers of Konkan Coast, Maharashtra, India. Unpubl. Ph.D. thesis, Indian School of Mines, Dhanbad. 257 p.
[11] Rajamanickam, G.V. 2001. Handbook of placer mineral deposits. New Academic Publishers, Delhi.
[12] Rajamanickam, G.V.1994. Beach placer mineral exploration along the coast between Mandapam and Kanyakumari. Unpubl.Tech. Rep. submitted to Dept. of Ocean Dev., New Delhi.
[13] Rajamanickam, M., Chandrasekar, N., Dajkumar, D., Loveson, J., SARAVANAN, S., & LOVESON, V. SPATIAL DATA BASED SYSTEM FOR COASTAL PLACER CONCENTRATION: A CASE STUDY AT KALLAR-VEMBAR COAST, TAMILNADU.
[14] Saravanan, S., Chandrasekar, N., Mujabar, P. S., & Hentry, C. (2011). An overview of beach morphodynamic classification along the beaches between Ovari and Kanyakumari, Southern Tamilnadu Coast, India. Physical Oceanography, 21(2), 129-141. https://doi.org/10.1007/s11110-011-9110-x
[15] Udayaganesan, P. (1993). A study of detrital minerals from the sediments of Vaippar basin, Tamilnadu (Doctoral dissertation, M. Phil. thesis, Tamil Univ., Thanjavur.

