**Heavy mineral separation and identification in parts of southeast coastal Area, Tamil Nadu, India**

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**Abstract**

The current research focuses on heavy mineral separation utilizing the bromoform method. The distribution of several heavy minerals in coastal habitats over a section of Tamil Nadu southeast coast in India serves as the main structural component of this study. The observed variations in the distribution of heavy minerals in the region are related to variations in sediment supply, sorting, and oceanographic processes, all of which lead to the sediments being sorted in a particular way. The main factors affecting the distribution of heavy minerals in the depositional basin include the stability of the minerals, density, grain size, wave velocity, and beach morph dynamics. The distribution of different types of minerals determines the study region's heavy mineral assemblage and the identified each mineral using microscopy techniques in the prevalent study area. However, a few specific minerals, such as garnet (colorless), garnet (pink), zircon, rutile, chlorite, etc., dominate the assemblage. Zircon, Monazite, and Sillimanite are ubiquitous in both beach and inland red Teri sands, and they may have formed as byproducts of a heterogeneous provenance that included igneous rocks, high-grade metamorphic rocks, and Precambrian gneissic, granitic, and basic rocks. This provenance probably originated from the coastal environment.

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

**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). Alluvial (Subdivided into Bar, Channel Fill, Valley Delta, and Bench or Terrace Placers) and Lateral Placer Deposits can be broadly classified based on the mode of origin and transportation. Natural coastal dynamics; it has changed due to the action of waves, winds, currents, tides, storms, and other factors carried out from 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. Similar investigations on the sediments of the Vaippar River (Udayaganesan, 1993) and the beaches in northern Tamilnadu in Mohan, (1995) have demonstrated the insignificant supply of heavy minerals by the rivers to the mentioned coastlines. In the Indian context, Rajamanickam (2001) predicted the investigation and utilization of beach placers. The exploration, mining, and processing of beach placers in India have been covered by Chandrasekar and Sivasubramanian (2002). 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.

loc.tiff

**Fig 1.**Location map of study area

field photo 1.tif

**Fig 2.**Heavy minerals deposit in Vattakottai and Kanyakumari area

**III. Materials and Methods**

The 10 beach sediment samples were taken in the southeast coastal regions of Kanyakumari to Tiruchendur (**Figure 3 & Table 1**). The sediment samples were baked at 30°C to dry them out. Through coning and quartering, a sediment sample of about 100g is taken out. A precise total weight is recorded once the fraction has been divided. The samples are placed for repeated washing, after which the stirred materials are allowed to settle for two minutes before being repeatedly stirred and the resulting solutions are decanted. At this point, the clay materials that were associated with the sediments have been removed.

Field photo.tif

**Fig 3**.Sample collection in Southeast coast area

This is done after a few minutes of stirring by a laboratory stirrer until clear water is achieved. After the sand has dried and settled, the weight is taken. The clay and silt are responsible for the weight difference between the initial 100g and the present after decantation. To remove organic material, 30% H2O2 is added and agitated. The H2O2 addition is continued until the evaporation process stops when the mixture is stirred.

The addition of H2O2 is continued until the effervescence stops when the mixture is stirred. It is then rinsed and dried with distilled water. The weight loss is recorded, and the drop is assigned to the weight of organic stuff. It is treated with weak hydrochloric acid to liberate the samples from the shelly materials. The addition of weak HCl is repeated until the appearance of effervescence disappears completely. The complete dissolution of carbonate material is established once the effervescence on fresh addition is halted. As a result, the sandy material deposited in the beaker is cleaned with distilled water and dried.

**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 |

The weight loss after acid treatment is recorded to account for the carbonate content. After removing silt and clay, organic matter, and carbonate detritus, the samples are placed in ASTM sieves with a 1/2 phi spacing between sieve sizes. The sieved materials are weighed and kept in separate containers. It is carefully monitored to ensure that the total weight loss due to sieving does not exceed 0.05 gm. According to normal techniques, heavy mineral separation is performed on three fractions of each sample (coarse, medium, and fine) using heavy liquid bromoform.

The heavy mineral wt% and count% were obtained for all samples in a specific location. The majority of sedimentary rocks contain only trace amounts of heavy minerals, thus to study them, they must be separated. 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

1. 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

ii. 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 substance 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,

= Mean weight of sample×100×100×100 **/** 5×5×5×100 kg/m3

= (385.5 × 100 × 100 × 100) ÷ (5 × 5× 5 × 1000)

= 385500000 ÷ 125000

= 3084 kg/m3

The zircon Bulk density is 3084 kg/m3

**IV. Result and discussion**

A representative portion of the total heavy mineral concentrations, separated through coning and quartering, is mounted in Canada balsam. The volume of the concentration is decided in such a way that at least 10 to 15 grains are made available in the section. Take a microscopic slide; put 2 to 3 drops of glycerine over this. Transfer the material to be counted on this glycerine. Put a microscopic cover glass of 18mm over this. Then give mild smooth pressure over the cover and gently spread the grains evenly (**Figures 4 -8**).

A.tif

**Fig 4**.Microscopy view of heavy minerals in section A

B.tif

**Fig 5**.Microscopy view of heavy minerals in section B

C.tif

**Fig 6**.Microscopy view of heavy minerals in section C

D.tif

**Fig 7**.Microscopy view of heavy minerals in section D

**hm micro.tif**

**Fig 8**.Microscopy view of heavy minerals in overall samples

1. **Mineralogy &Petrography**

**a.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 /m3

**b. 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

**c. 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

**d. 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

**e. Sillimanite**

Sillimanite has following characteristics:

General Formula - (Ce, La, Nd,Th) [PO]4

Chemistry - TiO2 -0.44%; SiO2 –36. 9%

P2O5 -0.02%; Al2O3-38.7%;

ZrO2 – 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

**f. Ilmenite**

Ilmenite has following characteristics:

General Formula - FeTiO3

Chemistry - TiO2 -55% ; FeO – 19.6%

Fe2O3 -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

In sediments from rivers and the ocean, the distribution of heavy minerals is more prevalent. The distribution of heavy minerals is less abundant during post-monsoonal depositional periods, possibly as a result of longshore flow movements that transport heavy materials to the northeast side studied by Gandhi M S & Raja M (2014). The enrichment of heavy minerals is advantageous in marine sediments. The dominance of garnet populations in the research area and southern river sands, which almost entirely consist of low grossularite high-pyrope garnets. These are from the high-grade (granulite fancy) Charnockite and Met sedimentary rocks that make up the basement in this region. The information shown above demonstrates the dominance of source rocks, which are composed of metamorphic and recycled sediments. The differences in shape (Zircon), color (Garnet, Tourmaline), intergrowth (Ilmenite), and alteration (Magnetite) make the grains less dense. The nature of heavy minerals and the level of roundness exhibited by highly resistant minerals indicate that the source is primarily recycled in conjunction with metamorphic and igneous rocks. The source rock in the catchment areas of the current research region is composed of alluvium, composite gneiss, charnockite, quartzite, sandstone, granite mica gneiss, and other materials. Heavy mineral concentrations are low to medium along the Southeast coast zone. This can be due to the shoreline's NNE-SSW configuration, which served as a barrier to the deposition of sediments brought by strong littoral currents going southeast.

**V. Conclusions**

There are numerous placer deposits along India's wide coastline, including magnetite, zircon, ilmenite, garnet, and monazite. One of the significant locations for heavy mineral deposition is Tiruchendur, Manapad, Uvari, Vattakodai, and Kanyakumari. The composition of the economic minerals is determined by the parent rocks. Zircon, rutile, monazite, and a little amount of ilmenite are typically found in granite. Rocks that have undergone metamorphism, such as amphibolite schist, are a typical source of garnet. The dominance of garnet populations in the study region and river sands from southern India, which primarily consist of low grossularite high-pyrope garnets are from the high-grade (granulite fancy) Charnockite and Met sedimentary rocks that make up the basement in this region. Alluvium, Composite Gneiss, Charnockite, Quartzite, Sandstone, Granite, Mica Gneiss, and other types of source rock are present in the catchment areas of the current research region. The stability of the minerals, density, grain size, wave velocity, beach morph dynamics, and other factors have a major role in controlling 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.

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**Reference**

Anil Cherian. 2003. Sedimentological studies in the beaches between Valinokkam and Tuticorin, Tamil Nadu. Unpubl. Ph.D. Thesis, Tamil University, Thanjavur, 189p.

Chandrasekar, N. & Sivasubramanian, P. 2002. Exploration, mining, and processing of beach placers in India. V.O.C.College Publ., Tuticorin.

Chandrasekar, N. 1992. Placer mineral exploration along the central Tamil Nadu coast. Unpubl. Ph.D. thesis, Madurai Kamaraj Univ. Madurai. 293 p

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.

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.

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>

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*.

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>

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.

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.

Rajamanickam, G.V. 2001. Handbook of placer mineral deposits. New Academic Publishers, Delhi.

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.

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.

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>

Udayaganesan, P. (1993). *A study of detrital minerals from the sediments of Vaippar basin, Tamilnadu* (Doctoral dissertation, M. Phil. thesis, Tamil Univ., Thanjavur.