**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 stability of the minerals, density, particle size, wave velocity, and dynamics of beach morphs are the primary variables influencing the distribution of heavy minerals in the depositional basin. 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). 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.

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, the materials are stirred, allowed to settle for two minutes, and then they are agitated once more. The resulting solutions are then 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

After a few minutes of swirling with a lab stirrer to get clear water, this is done. The weight is obtained following the drying and settling of the sand. 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.

Up until the mixture stops bubbling when it is agitated, H2O2 is added continuously. After that, distilled water is used to rinse and dry it. The weight loss is noted, and the decrease in weight is attributed to the weight of organic material. The samples are separated from the shelly components using a mild hydrochloric acid treatment. Adding mild HCl is done repeatedly until all traces of effervescence are gone. Once the effervescence on fresh addition has stopped, the complete dissolution of carbonate material has been established. The sand that has been put in the beaker is then 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 |

For the carbonate content, the weight loss following acid treatment is kept track of. The samples are filtered using ASTM sieves with a 1/2 phi interval between sieve sizes to remove silt and clay, organic debris, and carbonate detritus. Weighed and held in separate containers, the sieved components are separated. The overall weight loss as a result of sieving is carefully monitored to ensure that it does not exceed 0.05 gm. Each sample is divided into three fractions (coarse, medium, and fine), and using heavy liquid bromoform, heavy mineral separation is carried out on each fraction. All samples in one area were given the weight percentage and count percentage of the heavy minerals. The bulk of sedimentary rocks only have traces of heavy minerals, thus it is necessary to separate them in order to examine them.

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**

The Canada balsam is mounted with a representative sample of the total heavy mineral concentrations, which have been coning and quartered. The concentration's volume is chosen so 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 predominance of low grossularite, high-pyrope garnet populations in southern river sands and the research area. The basement in this area is made up of high-grade (granulite fancy) Charnockite and Met sedimentary rocks. Based on the data presented above, it is clear that source rocks, which are made up of metamorphic and recycled sediments, predominate. The different shapes (Zircon), colours (Garnet, Tourmaline), intergrowths (Ilmenite), and modification (Magnetite) of the grains result in less density. According to the nature of heavy minerals and the degree of roundness displayed by highly resistant minerals, the source is mainly recycled in conjunction with igneous and metamorphic rocks. In the catchment areas of the current research region, the source rock is made up of a variety of elements, including alluvium, composite gneiss, charnockite, quartzite, sandstone, granite mica gneiss, and others. Along the Southeast coast zone, heavy mineral concentrations are low to moderate. This might be as a result of the shoreline's NNE-SSW shape, which acted as a deterrent to the deposit of sediments delivered by vigorous littoral currents flowing 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 high-grade (granulite fancy) Charnockite and Met sedimentary rocks that make up the basement in this area are where garnet populations predominate in the study region and river sands from southern India, which are predominantly composed of low grossularite high-pyrope garnets. The catchment areas of the current research region contain Alluvium, Composite Gneiss, Charnockite, Quartzite, Sandstone, Granite, Mica Gneiss, and other types of source rock. 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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