

# HEAVY MINERALS INVESTIGATION USING GEOSPATIAL TECHNOLOGY

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## ABSTRACT

*Detailed mapping of mineral deposits is essential for easy and sustainable exploration of heavy minerals in southern coastal regions of Tamil Nadu which is rich in mineral deposits. Mineral exploration through remote sensing is used in a way to reduce unsustainable sand mining and reduce negative environmental impacts along beach sands to prevent erosion and sea water intrusion. In the present study hyperion data for the year 2014 is used. In ENVI software standard hyperspectral process is carried out. The commercial tool Quick Atmospheric Correction is employed to correct the atmospheric effect. The standard spectra of the the minerals from the USGS are supplied as reference spectra in classifying the Hyperion image. The end members are then extracted and they are mapped through the Spectral Angle Mapper in the ENVI software. The standard approach is followed and the results of classification are validated with existing geological map. This study illustrates the high possibility of hyperspectral data for the exploration of heavy minerals.*

**Keywords:** *Hyperion, Spectral Angle Mapper, Mineral Exploration, Heavy minerals*

## INTRODUCTION

Large deposits of sediments carrying variable amounts of heavy, dense minerals that are naturally sorted and concentrated through actions of waves, longshore currents, wind and tides as referred as “heavy-mineral sands”. The origin of these heavy mineral sands have many geological reasons behind it such as the rivers passing by the western Ghats deposit the minerals in the sea and later deposited back in the shore line and the other reason found by Lovesonet *al* (1996) is that the basin structure of the coastal configuration, which acts as a trap to accumulate heavy minerals transported northwards by longshore currents. To focus on potential mineral mapping, the primary investigation of Hyperion data is performed. The spectral analysis is done for the hyperspectral data to perform lithological and mineral mapping studies. The objective of this study is to identify the heavy minerals and to prepare heavy mineral distribution map and perform integrated analysis in the study area and also to perform accuracy assessment.

## STUDY AREA

The coastal region around the Kudankulam town is taken as the study area. Kudankulam is a town in the Tirunelveli district in Tamil Nadu, India. It is situated 24 km north-east of Kanyakumari, 36 km from Nagercoil and about 106 km from Thiruvananthapuram. The place is notable as the construction site of the Kudankulam Nuclear Power Plant. It is also the location of hundreds of windmills used for power generation, eight of which are located inside the grounds of the nuclear plant. The base map of study area is shown in the figure 1.

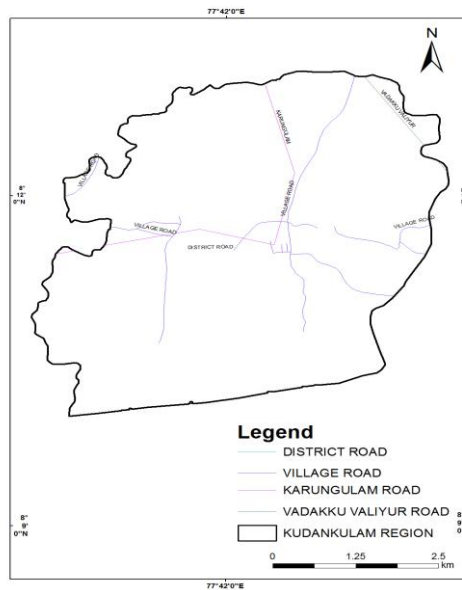


Figure 1 Base map of the study area

## SATELLITE DATA

Hyperion is the first space borne Hyperspectral instrument to acquire data in visible, near infrared and short wave infrared bands through two spectrometers and a single telescope. The Hyperion of March 2014 provides a high resolution Hyperspectral imager capable of resolving 242 spectral bands from 0.4 to 2.5  $\mu\text{m}$ . Hyperion has a 30m spatial resolution. The Hyperion VNIR sensor has 70 bands, and the SWIR has 172 bands providing 242 potential bands. The last 20 bands of VNIR sensor are overlapping with the first 20 bands of SWIR. It has a spectral range of 400 to 2400 nm.

## METHODOLOGY

The methodology is mainly focused on hyperspectral image processing. First the atmospheric correction is processed over image through Quick Atmospheric Correction tool. The spectral hourglass wizard is the next process to be done for the mineral end member identification and mapping the minerals. This spectral hourglass wizard is an interactive tool which includes minimum noise fraction (MNF), Pixel purity Index (PPI), automatic endmember

prediction from the n-D Visualizer, and Spectral angle aping (SAM) methods. The field data collection is carried out for the verification of the mineral exploration sites. Then the standard separation methods are carried out for the separation of minerals from the insitu samples and then the comparison is done with the classified pixels at their respective locations. Then the spectral signatures of the minerals are to be verified using field spectrometer. Thus the accuracy assessment is done and the spatial distribution of the minerals map is done finally.

## **HYPERSPETRAL IMAGE PROCESSING**

The hyperion data with 242 bands are used for the mapping process in this study. The hyperion band data is opened and load true color is loaded. Using the Quick Atmospheric correction tool the reduction of noise bands is done over the data. The band levels are reduced from 242 bands to 175 bands in the atmospheric correction process. Then the entire analysis process is done in spectral hourglass wizard, a standardized method for analysis which provides a consistent way to extract spectral information from the hyperspectral data.

## **SPECTRAL HOURGLASS WIZARD**

In the first step of analysis, the atmospherically corrected data is given as input file. Then the Minimum Noise fraction transformation (MNF) is done. The MNF transform is used to determine the inherent dimensionality of image data, to segregate and equalize the noise in the data, and to reduce the computational requirements for subsequent processing. The bands containing only noise are not used in subsequent processing. The relevant bands from the MNF data are selected and used to create PPI image that contains the most spectrally pure pixels correspond to the mixing endmembers. The PPI is computed by continuously projecting n-dimensional scatter plots on to a random vector. The SAM method treats both (the image and known) spectra as vectors and calculates the spectral angle between them. SAM measures the spectral similarity by calculating the angle between the two spectra, treating them as vectors in n-dimensional space.

## **RESULTS AND DISCUSSION**

The satellite data is taken and the required study area is demarcated. Then the atmospheric correction and the hyperspectral image processing is done to the image. After the atmospheric correction, the MNF processing is done for the image. The resulting bands of the MNF transformed data are ranked with the largest amount of variance in the first few bands and decreasing data variance with increasing band number until only noise and no coherent image remains. The bands containing only noise are not used in subsequent processing. The MNF plot is shown in figure 2.

## ENDMEMBER EXTRACTION

Theoretically the existing pure features in mixed pixels are referred to as endmembers. Pixel Purity Index (PPI) requires the user to manually search and define the endmembers. The endmembers spectra is produced and then compared to the mineral spectral library from USGS to examine its likeliness to known mineral spectra.

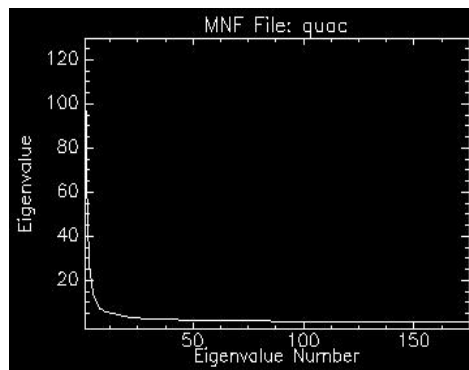


Figure 2 MNF plot

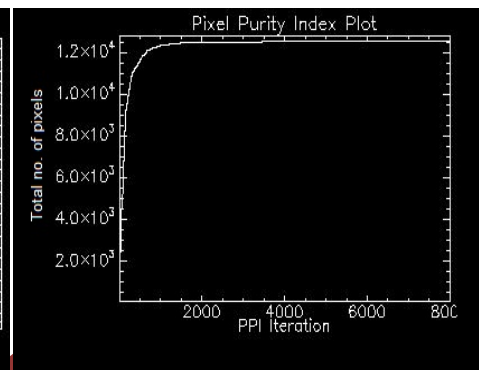


Figure 3 PPI plot

In PPI, the extreme pixels for each projection are recorded and the total number of hits is stored into an image. These pixels are excellent candidates for selecting endmembers which can be used in subsequent processing. The PPI plot is shown in figure 3.

## SPECTRAL ANGLE MAPPER

The Spectral Angle Mapper Classification (SAM) is an automated method for directly comparing image spectra to known spectra or an endmember. SAM is a classification method that permits rapid mapping by calculating the spectral similarity between the image spectrums to reference reflectance spectra. The standard spectra for the minerals are shown in figure 4. The SAM classification results for ilmenite, Zircon and Sillimanite are shown in figure 5.

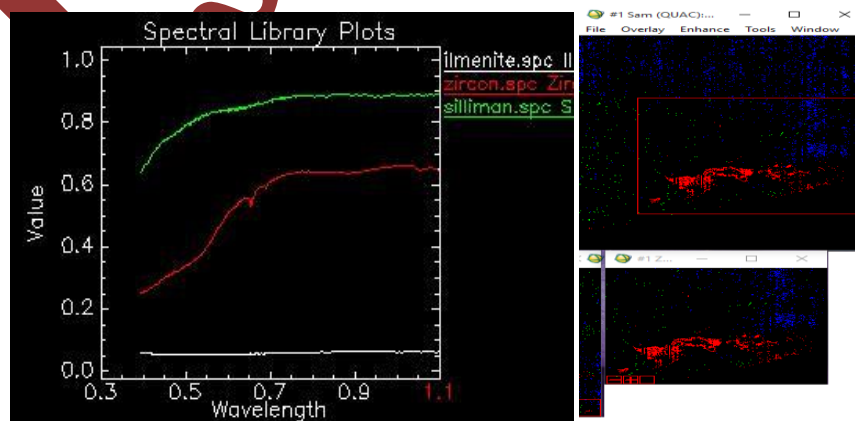


Figure 4 Standard spectra of Ilmenite, sillimanite and Zircon Figure 5 SAM classification results

## SITE SAMPLE COLLECTION

Ground verification of mineral resources has been performed to access accuracy of the classification. The sediment samples are collected over around 15 locations along the coast of kudankulam based on systematic sampling in the study area. Each sample is weighed 100gm is taken in the field. The geographic locations of these sites were also noted with help of global positioning system (GPS).

## ACCURACY ASSESMENT

The accuracy assessment is done by comparing the classified pixel with the heavy mineral contents in the sediment samples. Each sample is dried and then the minerals are separated by magnetic and conductive separation method. Then the percentage weight of each mineral in the sample is noted. The classification of minerals to the field sample is done with the maximum percentage weight availability at the respective field location. The classification of the minerals by their percentage weight is shown in the table I.

Table I Percentage weight of heavy minerals in samples

sample no.	ILMENITE	ZIRCON	SILLIMANITE	OTHERS	Classified mineral
1	32.5	15.5	3.2	48.8	ILMENITE
2	27.2	9.3	4.7	58.8	ILMENITE
4	19.7	7.4	3.7	69.2	ILMENITE
5	36.3	14.3	6.6	42.8	ILMENITE
9	12.8	8.5	3.4	75.3	ILMENITE
10	16.2	7.6	1.5	71.9	ILMENITE
11	24.3	13.6	3.2	58.9	ILMENITE
12	30.4	11.7	5.6	52.3	ILMENITE
13	42.2	19.4	7.3	31.1	ILMENITE
3	20.7	31.2	7.1	41	ZIRCON
7	11.5	12.5	6	70	ZIRCON
8	14.6	18.7	3.2	63.5	ZIRCON
15	12.3	23.1	1.9	62.7	ZIRCON
6	10.7	12.1	12.8	64.4	SILLIMANITE
14	9.8	7.6	14.3	68.3	SILLIMANITE

The accuracy assesment is done through Erdas software. The classified minerals input is given and then compared to the classified image and the final accuracy of 86.4% is obtained.

## FIELD SPECTRAL REFLECTANCE

The spectral reflectance values were calculated for the classified minerals such as illmenite, Zircon and Sillimanite using the field Spectrometer at Tamil Nadu Agriculture University, Coimbatore. The field spectrometer used has wavelength ranging from 300nm to 1050nm. All the minerals samples were kept under the field spectrometer and the range values are noted and spectral refelctance values for the heavy minerals are plottedis shown in figure 9.

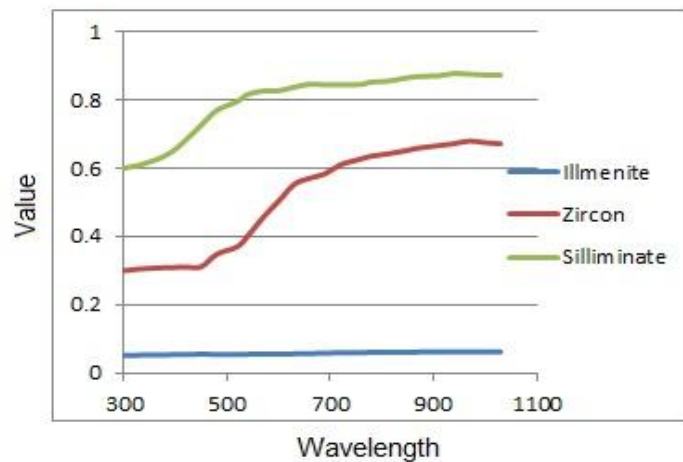


Figure 6 Spectral reflectance of the field heavy mineral samples

Preparation of various minerals maps is performed using GIS and overlaid with the existing geology map. In this study, the heavy minerals like zircon, ilmenite, sillimanite show different distribution patterns. The ilmenite is mostly concentrated in the Marine- Paleo – Tidal flat deposits. Then they are sparsely distributed over the other regions. The Zircon shows some good distributions in both consolidated and unconsolidated quaternary sediments. The heavy mineral map of kudankulam is shown in figure 7

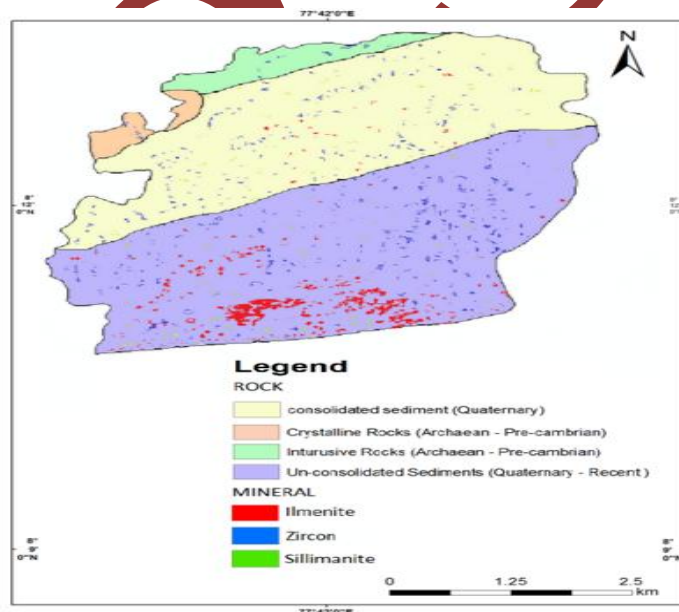


Figure 7 Heavy mineral map of kudankulam

The sillimanite is sparsely distributed throughout the kudankulam region. The identification of these minerals and mapping their distribution pattern provides a framework for exploration of these mineral concentrations. The study shows these three heavy minerals are mainly concentrated in coastal unconsolidated quaternary sediments in kudankulam. The spectral

reflectance of the minerals derived from the field spectrometer also matches the standard spectral reflectances of ilmenite, Zircon and Sillimanite.

## CONCLUSION

The present study is carried out to identify and map the minerals using hyperspectral imagery and GIS. The data integration, management and visualization in GIS environment are relatively efficient. The study used hyperion for the year 2014. Hyperspectral processing involves atmospheric correction, MNF transform, endmember extraction and spectral angle mapping. The results obtained from SAM are overlaid with existing geology mapping. In hyperspectral sensor each narrow band is sensitive to absorption and reflection properties of a particular mineral or element and therefore used to identify individual mineral and its distribution pattern in the rocks and soils.

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