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Analysis of Hyperion Satellite Data for Discrimination of Banded Magnetite Quartzite in Godumalai Hill, Salem District, Tamil Nadu, India

S. Aravindan[1] and B. Poovalinga Ganesh[2]

[1]Department of Earth Sciences, Annamalai University, Annamalai Nagar, Tamil Nadu, India
[2]Center for Research and Development, PRIST University, Vallam, Thanjavur, Tamil Nadu, India

Correspondence should be addressed to S. Aravindan, aravindan_rs@yahoo.com

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Abstract In order to determine mineralogy of rock and soil samples, reflectance and emittance spectroscopy in the near-infra red and short-wave infra-red is used extensively and found to be inexpensive. Hyper spectral remote sensing satellite data are found to be prospective to deliver in depth physico-chemistry like mineralogy, chemistry, morphology of the earth's surface. Therefore hyper spectral data is useful for mapping potential host rocks, alteration assemblages and mineral characteristics. In the present study EO-1, Hyperion data had been used for delineating magnetite mineral in Godumalai hill, Salem region, Tamil Nadu, India. The requirements for extracting magnetite from Hyperion images is to be first compensated for atmospheric effects using flag mask correction, cross track illumination correction and FLAASH model. Minimum Noise Fractionation transformation was applied to reduce the data noise and for extracting the extreme pixels. Some pure pixel end member for the target mineral and backgrounds were used in this study to account for the Spectral Angle Mapping & matched filtering techniques and the arrived results were validated with field study. Those mapping techniques have proved that the magnetite mineral can be mapped with high precaution by Hyperion preprocessing adopting methods.
Keywords *Hyper Spectral Analysis; Magnetite; Spectral Angle Mapping; Matched Filtering*

1. Introduction

The hyper spectral sensors represent one of the most important technological trends in remote sensing. Hyperion sensors have 242 contiguous spectral bands to sample the electromagnetic spectrum from 400 to 2,400 nanometer (visible to short wave infrared) wave length. Hyper spectral Remote Sensing or Imaging Spectroscopy are concerned with the measurement, analysis & interpretation of spectra acquired from a region or part of the Earth by an airborne or satellite sensor (Gupta, 2003). Each mineral has a unique reflectance and absorption pattern across different wavelength region. So, each mineral can be identified by their unique absorption and reflectance property. Geological remote sensing is performed through the atmospheric windows where Hyperion uses two atmospheric windows as VNIR and SWIR regions for mapping surface mineralogy as these wavelengths are highly sensitive to a wide range of diagnostic EMR interactions with rock materials. In particular,

1) The mineral-spectral features in the VNIR region were largely related to the transfer of electrons between energy levels of constituent elements, especially the transition metals Fe, Mn and Cr (Hunt et al., 1971).
2) The mineral-spectral features in the SWIR were largely related to the overtones and combination tones in vibrations of octahedral coordinated captions (typically Al, Fe and Mg) bonded with OH groups (Hunt et al., 1968).

Banded iron formations occur in many parts of the world and have been described under a variety of names such as banded hematite quartzite, banded magnetite quartzite, Calico rock, ironstone, itabirite, jasper bars, jaspilite, ribbon rock, striped magnetite jasper, taconite, zebra rock and so on. Iron ores occurs in different geological formations practically in different states of India, economically workable deposits is found to occur in Precambrian banded iron formations of Jharkhand, Orissa, Chhattisgarh, Goa, Karnataka, Tamil Nadu and Andhra Pradesh.

In Tamil Nadu, there are extensive bands of magnetite quartzite in Salem and Trichirappalli districts (King and Foote, 1864; Holland, 1892; Middlemiss, 1896). They form a series of ridges and hillocks like Kanjamalai, Godumalai, Tirthamalai and Kollimalai, many of those peaks are about 1000 m high (Aiyangar, 1941; Krishnan and Aiyangar 1944).

The primary aim and objectives of the present work is to study and analyze the spectral signatures of magnetite deposits in the Godumalai hill and to find out the application of hyper spectral remote sensing techniques in mapping magnetite mineral of the study area. The study area Godumalai region lies between north latitude 78°18' to 78°24' and east longitude from 11°38' to 11°42' in part of Salem district of Tamil Nadu state, India and the hill has a structural trend in east-west direction (Figure 1).

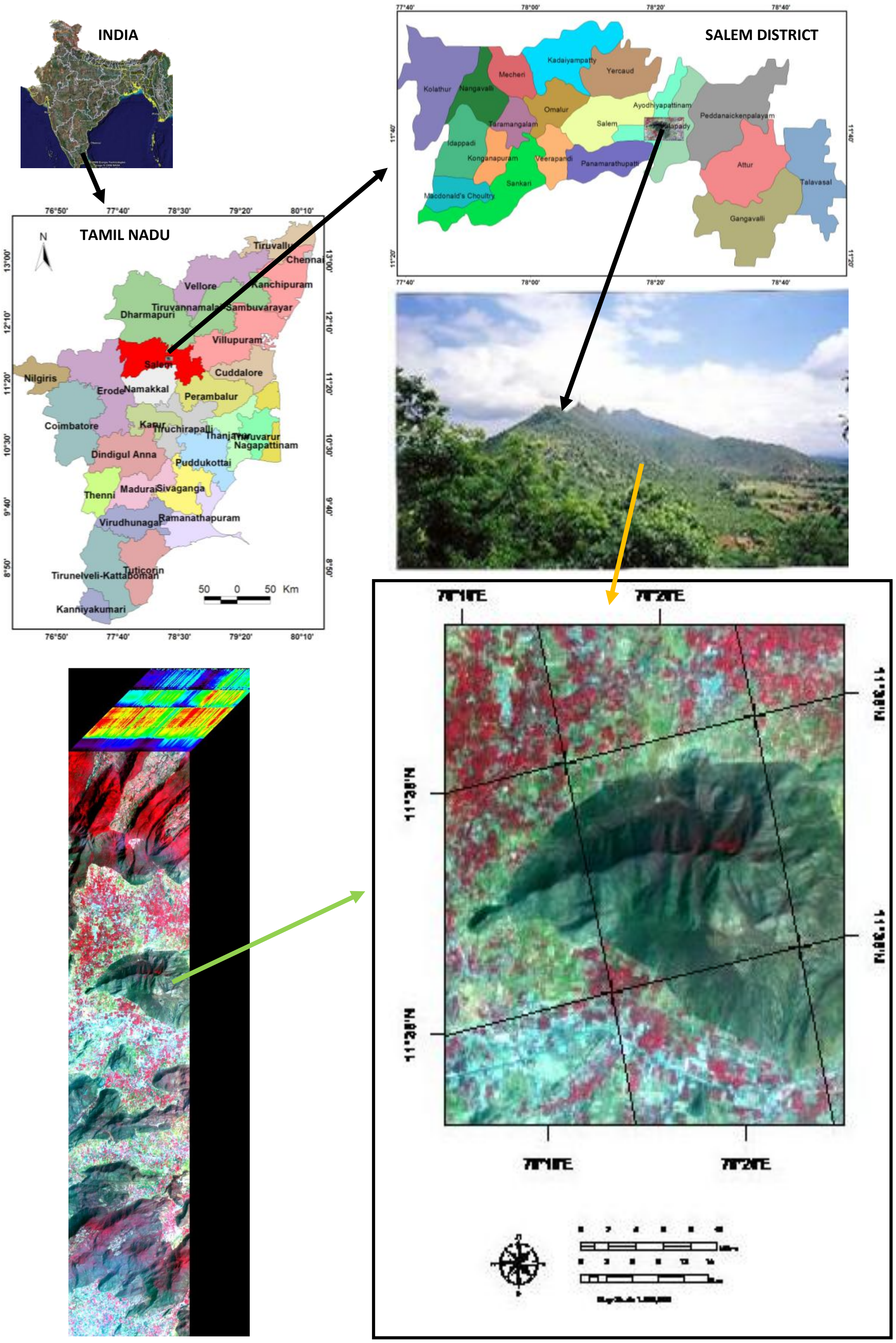


Figure 1: *Study Area Godumalai Hill Shown in Hyperion Image (R40, G30 & B20) with 3D Cube (242 Band Data)*

Geologically the ores are found in rocks of different ages throughout the Precambrian by far most importantly they comprise magnetite deposits in the study area. Metamorphism in those areas has converted hematite into magnetite and the jasper into quartz. These ore bodies are found in the Salem and Trichirapalli districts of Tamil Nadu (Krishnan, 1964). The study area consists of mixed rock types namely gneisses, charnockite, magnetite quartzite and the study area is about 50 sq. km.

2. Data Used and Methodology

Hyperion data of onboard EO-1 satellite acquired on 14.02.2010 was used for this study. The Hyperion was a push-broom Image with 242 bands, 10 nm band widths covering the spectrum from 400 nm – 2400 nm. ASD field spectroradiometer was used, 45 rock samples collected from the field with different composition of magnetite quartzite samples and with different grain size and ancillary data of geology map obtained from Geological survey of India was used for field study. The detailed methodology adopted here is given in Figure 2.

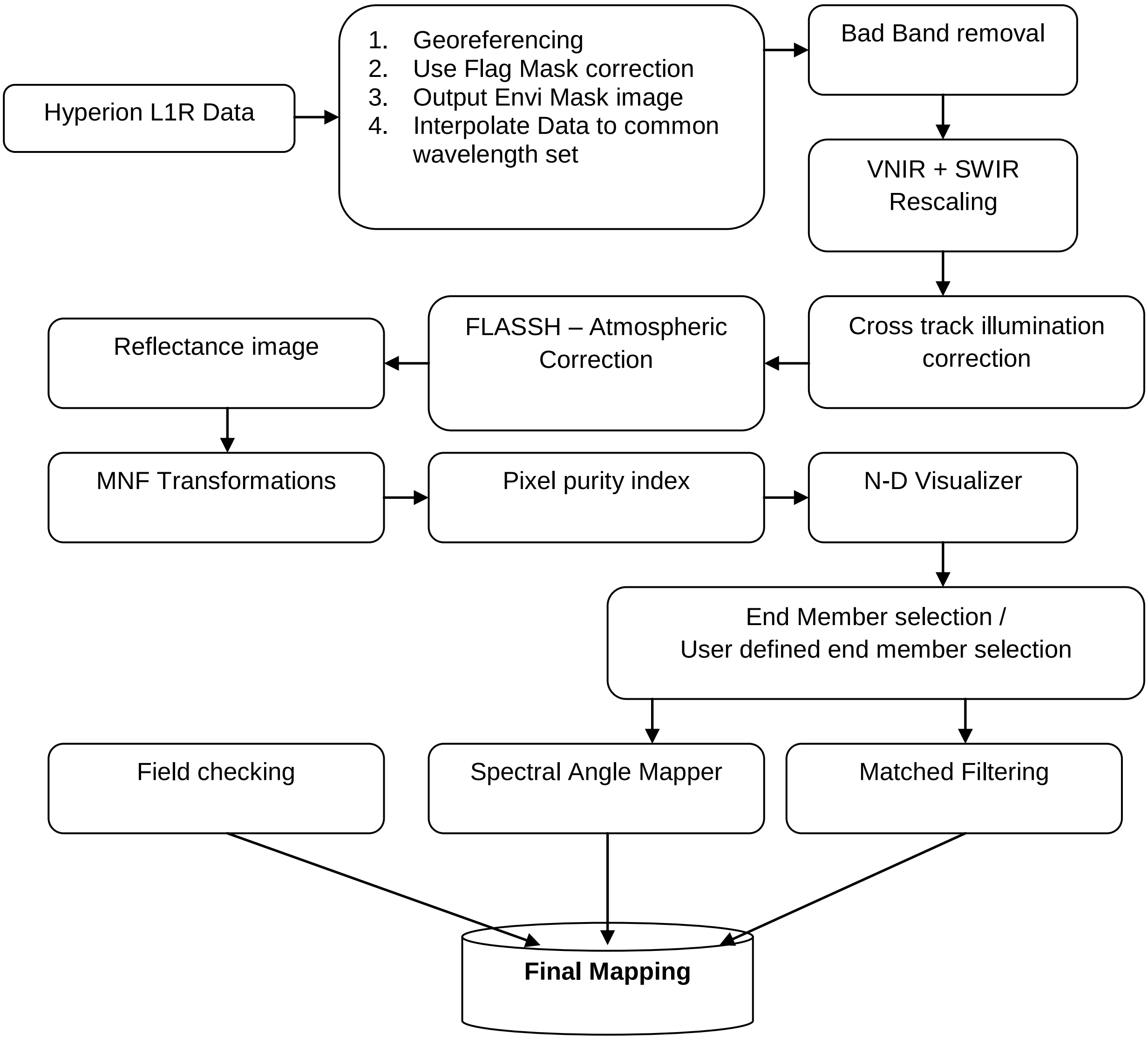


Figure 2: *Processed Data Flow for Mapping Magnetite Mineral Deposits*

Data Pre-Processing of Hyperion L-1R data require several phases of pre-processing to enable different hyper spectral analysis technique for production of mineral index maps.

The apparent strips frequently found in several bands to reduce the errors caused by the de stripping effect were reduced by screening all spectral bands and manually rejected a total of 88 bands with apparent stripping effects from VNIR to SWIR spectral range. Thus in total 158 bands were taken for the present study. 3D Cube in Figure 1 shows the study area Godumalai hill in Hyperion image (R40, G30 & B20) with a 3D Cube (242 band data) Hyperion L1R Data 1. 2. 3. 4. Georeferencing using Flag Mask correction Output Envi Mask image Interpolates Data to a common wavelength set with bad Band removal of VNIR + SWIR rescaling Reflectance image of FLASSH – Atmospheric Correction Cross track illumination correction MNF Transformation, Pixel purity index n-D Visualizer of End Member selection/User defined end member selection Field checking Spectral Angle Mapper, Matched Filtering of Final Mapping is shown in Figure 2. Processing flows for mapping magnetite mineral deposits with rescaling the L1R digital values represent absolute radiance values stored as 16-bit signed integer. To get that sensor radiance value, the data must be rescaled. The scaling factors, 40 for VNIR band and 80 for SWIR bands detailed descriptions were mentioned in EO-1 User Guide, 2003. Accordingly, Cross-Track Illumination corrections were applied to remove the variations in the cross-track illumination on image (Envi user guide, 2003). Cross track illumination variations may be due to shifting effects of sensor, off set of instrument scanning or other non-uniform illumination effects. A polynomial function is fit to the mean value which is used to remove the variation in Atmospheric Correction. In order to obtain the correct and fruitful results, hyper spectral data should be preprocessed though the data has its own ability to discriminate the surface materials especially in geological aspects. Owing to the atmospheric gases and aerosols, atmospheric or radiometric corrections are required. Different gases in the atmosphere absorb or transmit the light which depends on the respective wavelength of the energy. Atmospheric correction of hyper spectral data is therefore an obligation for radiance to reflect conversion. Hyperion data carry the influence of a number of external factors, which masks the fine spectral features of ground objects. The factors are due to

1) Effects of the solar irradiance curve;
2) Atmosphere and Topography: The effect of the solar irradiance curve arises from the fact that solar radiation intensity peaks at 0.48 µm and the radiation intensity drops off towards longer wavelengths, therefore the effects of solar irradiance is not uniform throughout the image. Atmospheric effects arise due to the fact that the Hyperion image data are collected over a wide wavelength range, which includes atmospheric windows as well as atmospheric absorption and scattering. Topographic effects arise due to local landscape orientation. Above factors must be adequately normalized in order to compute ground reflectance values in different channels. In order to retrieve the surface reflectance and to study the surface reflectance properties atmospheric effects has to be removed. This is referred to as atmospheric correction and was applied to Hyperion data set. Atmospheric correction was achieved by using ENVI's fast line-of-sight atmospheric analysis of hyper spectral-cubes (FLAASH) model. Necessary parameters for the FLAASH were determined from the metadata of the image files. The scaling factors, 40 for VNIR and 80 for SWIR bands has a detailed descriptions mentioned in EO–1 user Guide 2003. Accordingly cross– Track illumination corrections were applied to remove the variations in the cross-track illumination on image units (Envi User Guide, 2003). An ASCII file was prepared for each band of the selected 158 bands, with a scaling factor of 40 for the first 43 bands of VNIR and 80 for the rest SWIR bands and provided as the scale factor file for the FLAASH to convert the DN values of the L1 data in to the units of radiance. Parameters used for the atmospheric correction is provided below in the Table 1. The results after the FLAASH atmospheric correction on the Hyperion image is shown with the respective spectral profiles in the Figure 3.1 and Figure 3.2 below with Spectral profile (Z-profile) Vegetation pixel, a) before Atmospheric corrections and b) after Atmospheric corrections with FLAASH.

Table 1: *Parameters used in the FLAASH Atmospheric Correction*

Scene Canter Location	11.68E and 78.34N	Initial Visibility	30 Km
Sensor Altitude	705Km	Spectral Polishing	Yes
Ground elevation	0.6 Km	Width (no of bands)	9
Pixel Size	30m	Wavelength Recalibration	No
Flight date	14-Feb-2010	Aerosol scale height	2.00Km
Flight time	20:42:42	Co_2 mixing ratio (ppm)	390 ppm
Atmospheric Model	Tropical	Use adjacency correction	Yes
Water retrieval	Yes	Modtran Resolution	15 cm^{-1}
Water absorption feature	1135 nm	Modtran Multiscatter Model	Scaled DISORT
Aerosol model	Urban	No of Disort streams	8
Aerosol retrieval	None	Output reflectance scale factor	10000

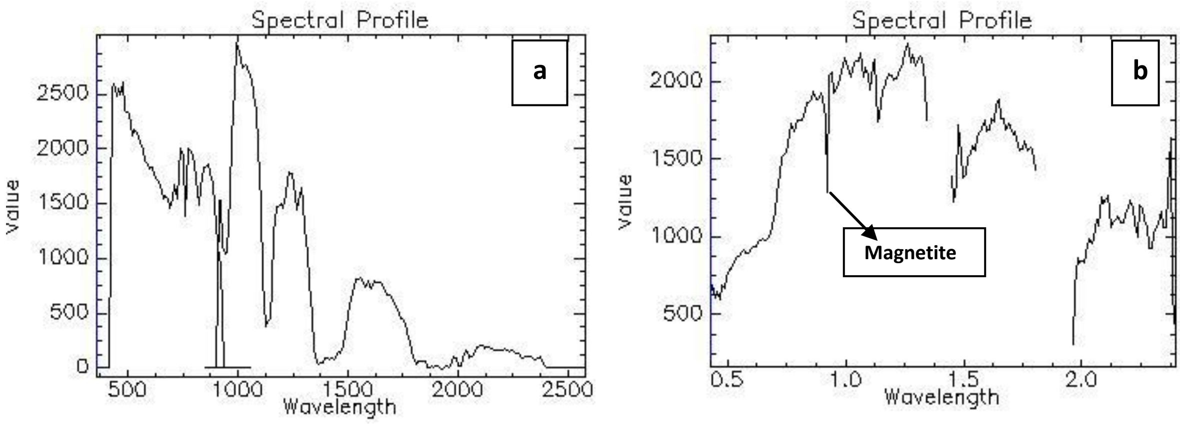


Figure 3.1: *Spectral Profile (Z-profile) Magnetite pixel **a)** before Atmospheric Corrections and **b)** after Atmospheric Corrections with FLAASH*

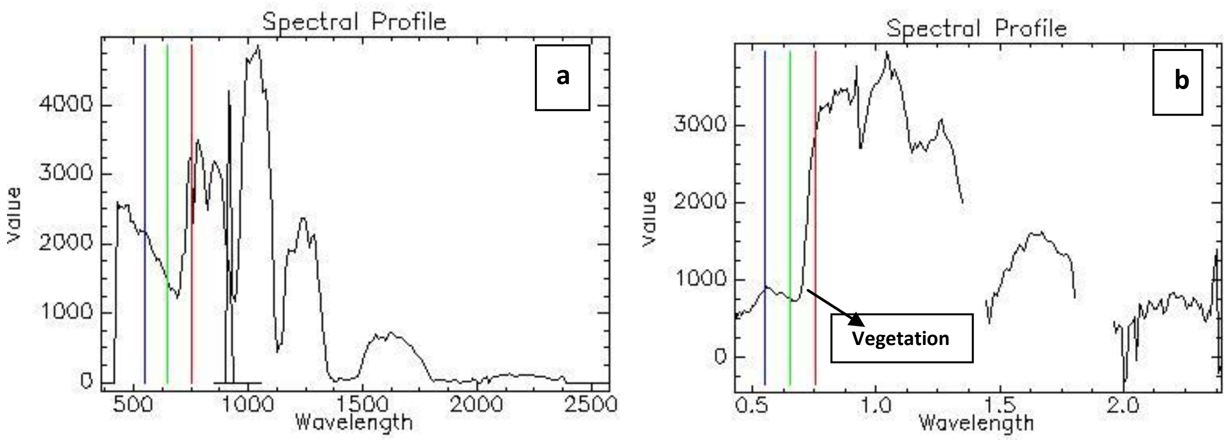


Figure 3.2: *Spectral Profile (Z-profile) Vegetation Pixels, **a)** Before Atmospheric Corrections and **b)** After Atmospheric Corrections with FLAASH*

In general the spectral absorption peak for the magnetite is 0.9 to 1.1 µm and fall, in VNIR bands in 0.48 to 0.52 µm region. The Hyperion image after FLASSH atmospheric correction has clearly showed the absorption peak at 0.49 and 0.9 µm (Poovalinga Ganesh et al., 2012). In order to cross check as well as to understand the vegetation influences in the retrieved spectral absorption. The vegetation spectra were separately identified and taken into account highly in following classification procedures.

2.1. Hyperspectral Analysis

For this research, minimum noise fraction transformation (for Reduction of spectral data), pixel purity index (to retrieve the spectrally pure pixel values), and subsequently n-dimensional visualizer (to determine the end member) were applied to hyper spectral satellite datasets to map the magnetite mineral deposits. Details about these techniques are discussed as follows.

The approach of SAM was employed to identify the magnetite deposits. Finally, the Matched filtering technique was used to target the magnetite deposits.

2.2. MNF Transformation

MNF transformations determine the inherent dimensionality of image data to disintegrate noise in the data and to diminish the computational requirements for further process. This MNF take place in two-step process. The results of first step is to transform the spatial data in which the noise has unit variance and without band-to-band correlations. The second step result is the standard principal components transformation of the noise-whitened data.

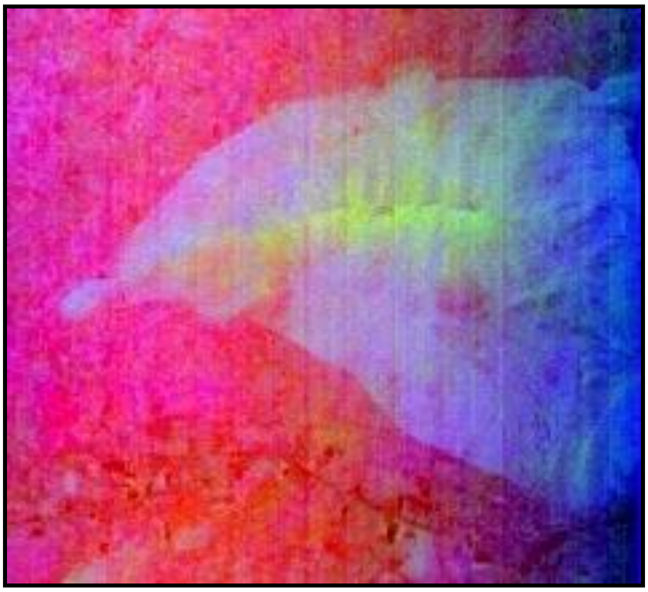


Figure 4: *MNF Hyperion Pseudo Color Image of Godumalai Hill*

2.3. Pixel Purity Index

Pixel purity index (PPI) is a means to determine automatically the relative purity of the pixels from the higher order. A MNF Eigen image uses the convex geometry argument (Boardman, 1993). A PPI image was created by repeatedly projected MNF images into random unit vector in a dimensional scatter plots in which the digital number (DN) of each pixel corresponded to the total number of times that the pixel was judged as extreme in all projections.

2.4. N-Dimensional Visualizer

Further step is to refine the most spectrally pure end members derived from the two- dimensional PPI image and more importantly to label them with specific end member types. Thus each end members had assigned with specific mineral type by examined visually the selected pixels and grouped (Boardman et al., 1994). This could be achieved through the field knowledge about the study area.

2.5. Spectral Angle Mapping

Spectral angle mapper (SAM) is a procedure that determines the similarity between a pixel and each of the reference spectra based on the calculation of the "spectral angle" between them (Boardman et al., 1994). It had been treating both the known and unknown spectra as vectors and calculated the spectral angle between them. A smaller angle differences between the two spectra and the pixels were identified as the fixed class else as a separate class. This classification carried following equation (ENVI Tutorials, 2002) and easily achieved through the ENVI software.

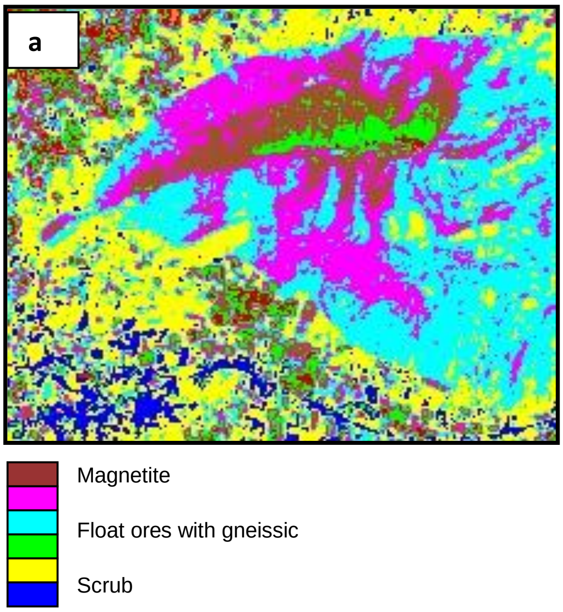
$$\alpha = \cos^{-1}\left[\frac{\vec{t} \quad * \quad \vec{r}}{\|\vec{t}\| \quad * \quad \|\vec{r}\|}\right] \qquad \text{Eq. 1}$$

2.6. Matched Filtering

Matched Filtering (MF) is a mapping technique to find the abundances of user-defined end member using a partial immixing (ENVI User's Guide, 2008). Matching filtering techniques maximize the response of known spectra and suppress the response of the composite unknown spectra, thus matching with known signature. Matched filtering assists us to detect known minerals easily from the study area and it does not require more knowledge about the field while there will be a chances of false minerals mapping for the presence of ambiguity spectral values. This attempt also tries to validate the earlier approach of SAM analysis and delineate the magnetite deposits as exact as possible.

3. Results and Discussion

The atmospherically corrected reflectance image was transformed linearly by using MNF transformation. There were first 10 MNF bands contains most of the spectral information. Then, pixel purity index techniques employed to determine the pure pixels in the hyperion satellite image. The spectra of pure pixels were plotted on the n-dimensional scatter plot to retrieve the end members. The end member is analyzed using spectral angle mapper and matched filtering technique is used to identify the magnetite minerals. SAM identifies most of the magnetite and float ores deposits used as end members accurately. The advantage of SAM was attributed to the fact that SAM determines the similarity of two spectra based on calculating the "spectral angle" between them. The angle or direction of the spectral vectors where determined by the "color" of the material. If color increases, SAM can identify them. The spectral angle used for magnetite mapping for the study is 0.10radian. The matched filtering technique maximized the magnetite abundances and suppresses the background features. Here, the SAM & MF ratio image (Figure 5a and 5b) identified most accurately the magnetite abundances within the study area. The MTMF image showing exposed magnetite quartzite deposits in the presence of top of the hill in red color and floats ores abundance near to gneissic rocks and foot hill region in yellow color. Rest of the other classified features such as scrub, vegetation, harvested land and settlement are mapped for the purpose to differentiate the features and enhance the magnetite deposits from the other interferences.



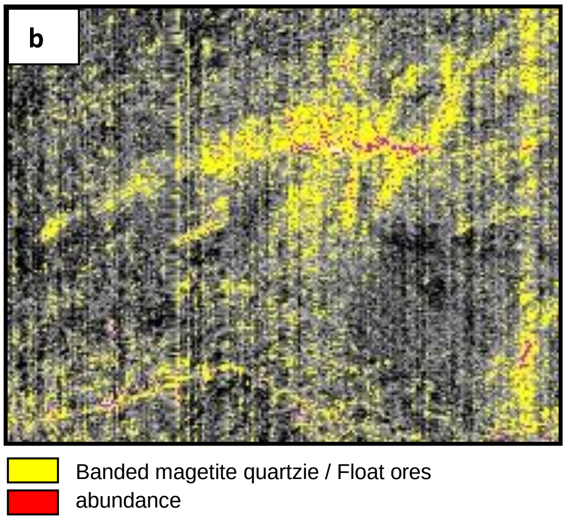


Figure 5a: *SAM Classified Image Showing the Magnetite Deposits and Other Features*
Figure 5b: *MTMF Image Showing Magnetite Mineral Abundance in Red Color and Gneissic Mixed with Iron Ores / Float Ores Abundance in Yellow Color*

In order to improve the classification accuracy and make the result reliable, the results of SAM classification was implemented in confusion matrix with reference to user ROI end members where known pixel locations are found in the image, cross checked with published geology map and field check. Accuracy of the classification in percentage is given in Table 2.

Table 2: *Result of Confusion Matrix in % for SAM Classified Features with User ROI end Member's Datasets*

Class	Production Accuracy (%)	User Accuracy (%)
Magnetite	28.57	40
Vegetation	92.42	100
Harvested Land	82.84	77.78
Settlement	75	99.71
Hill Gneiss	84.89	92.84
Scrub	96.16	91.04
Overall Accuracy	0.84507	84.51%
Kappa Coefficient	0.8045	

Result of Confusion matrix in % for SAM Classified features with user ROI end member's datasets Class Production. Accuracy (%) of Magnetite is 28.57/40, Vegetation - 92.42 / 100, Harvested Land - 82.84 / 77.78, Settlement - 75 / 99.71, Hill & Gneisses - 84.89 / 92.84, Scrub - 96.16 / 91.04, Overall Accuracy level are 0.84507 / 84.51%, Kappa Coefficient is 0.8045, Iron ore (Magnetite) was mapped to 40% accuracy and remaining features were mapped with more than 75% accuracy. This is due to the iron ore pixels which are unable to discriminate well from associated geological features and other land use / land cover features in the satellite image due to presence of overlapping pixels and less spatial resolution of satellite data. The overall accuracy percentage was 84.51%. Thus the highly discriminating features or non-overlapped pixel features which can be easily mapped with high accuracy due to its high spectral resolution.

4. Conclusion

Comparing the results with the field check and geology map of the study area, it illustrates usefulness of Hyperion data for identifying mineral abundances and mapping the geology of natural features.

Hyperion data covering the study area were analyzed using several hyper spectral image analysis techniques, which have demonstrated their potentiality in identifying magnetite deposits since spectral absorption peak has clearly showed magnetite regions after FLAASH correction and pure end members were able to be retrieved from the satellite data without any ambiguity. Limitations of the hyperion imagery is apparent strips could be view in the several important absorption bands and low signal-to-noise ratio. Within the 242 spectral bands, only 158 bands were used because of overlap between the VNIR and SWIR focal planes and FLASSH atmospheric correction model was performed well within those spectral bands. The SAM and MF techniques have proved that magnetite can be mapped through these techniques with high precaution of Hyperion preprocessing adoption methods. The classification accuracy can be increased further in the study area by refining the procedure in pure pixel selection process or by employing spectral end members from field spectral data or from spectral library as satellite data has high spectral resolution.

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