Processing of AVIRIS-NG data for geological applications in southeastern parts of Aravalli fold belt, Rajasthan

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Abstract

Advanced techniques using high resolution hyperspectral remote sensing data has recently evolved as an emerging tool having potential to aid mineral exploration. In this study, pertinently, five mosaicked scenes of Airborne Visible InfraRed Imaging Spectrometer-Next Generation (AVIRIS-NG) hyperspectral data of southeastern parts of Aravalli Fold belt in Jahazpur area, Rajasthan have been processed. The exposed Proterozoic rocks in this area is of immense economic and scientific interest because of richness of poly-metallic mineral resources and their unique metallogenesis. Analysis of high resolution multispectral satellite image reveals that there are many prominent lineaments which acted as potential conduits of hydrothermal fluid emanation, some of which resulted in altering the country rock. This study takes cues from studying those altered minerals to enrich our knowledge base on mineralized zones. In this imaging spectroscopic study, we have, thus, identified different hydrothermally altered minerals consisting of hydroxyl, carbonate and iron-bearing species. Spectral signatures (image based) of minerals such as Kaosmec, Talc, Kaolinite, Dolomite and Montmorillonite were derived in SWIR (Short wave infrared) region while Iron bearing minerals such as Goethite and Limonite were identified in VNIR (Visible and Near Infrared) region of electromagnetic spectrum. Validation of the target minerals were done by subsequent ground truthing and XRD analysis. The altered end members are further mapped by Spectral Angle Mapper (SAM) and Adaptive Coherence Estimator (ACE) techniques to detect target minerals. Accuracy assessment is reported to be 86.82% and 77.75% for SAM and ACE respectively. This study, hence, confirms that the AVIRIS-NG hyperspectral data provides better solution for identification of endmember minerals.

Keywords: AVIRIS-NG, hyperspectral data, SAM, ACE, mineral mapping, accuracy.

Introduction:

Remote sensing techniques have significantly enhanced and eased mapping of structural controls like faults, fracture systems, host rocks and alteration/ weathered zones indicative of mineral deposits (Hunt, 1977, Hunt and Salisbury, 1970, Hunt, 1982, Goetz et al., 1985, Thompson et al., 1999). Pertinently, high spectral resolution of hyperspectral data goes in tandem with multispectral and field based methods to aid mineral exploration. Hence, image and field based reflectance and emission spectroscopy in visible to near infrared and short/mid infra-red have been employed universally as an aid in mineral characterisation and exploration (Cloutis, 1996, Sabins, 1999, Kruse, 1996). Data collected by hyperspectral sensors with contiguous and coherent band parameters provide crucial help in quantitative and qualitative identification and mapping. This allows a vivid characterisation of the spatially distributed heterogeneous mineralogical paragenesis taking cues from different advanced image processing techniques (van der Meer and Jong, 2001, van der Meer et al., 2012, van der Meer, 1999, 2012, Kruse et al., 2003, 2012,). Thus, with the evolution of spectrometry being more sophisticated and greater signal to noise ratio, the arena of space-borne, field or lab-based imaging spectroscopy has alleviated role of remote sensing in the technical capability and application potential for geological mapping and mineral exploration (Goetz et al., 2001, 2009, Sun et al., 2001, Ramakrishnan and Kusuma, 2008, Ramakrishnan et al., 2013, Kodikara et al., 2016, Pour and Hashim, 2012).

Though hyperspectral remote sensing techniques for mineralogical targeting and abundance mapping are in operation since 1980s, application of same in Indian sub-continent is in budding stage, albeit. It is mainly because of lack of space or air borne hyperspectral coverage. A joint airborne hyperspectral imaging campaign was conducted by Indian Space Research Organization (ISRO) and National Aeronautics and Space Administration (NASA) as AVIRIS-NG over the different part of INDIA since 2016. AVIRIS-NG measures 380-2510 nm spectral range, high spectral and spatial uniformity with high SNR (>2000 @ 600 nm and >1000 @ 2200 nm) having an accuracy of 95% (Bhattacharya et al., 2019). This study has thus been benefitted by AVIRIS-NG hyperspectral data, used to identify, characterize and classify the alteration zones based on abundance of diagnostic mineral assemblages and therefore holds promise for their application in potentially mineralized areas, so far unexplored or inadequately explored.

Materials and Methods:

In this study, 364 VNIR & SWIR channels out of 425 ranging from 376 to 2500 nm were analyzed for identification of hydroxyl, carbonate and iron-bearing mineral phases and to map on the basis of the nature

& shape of diagnostic absorption feature of mineral. Figure 1 describes the methodology/algorithm adopted for this study through a flow diagram. The apparent reflectance product (L2) is linearly transformed through minimum noise fraction (MNF) transform which is a doubly cascaded principal com-

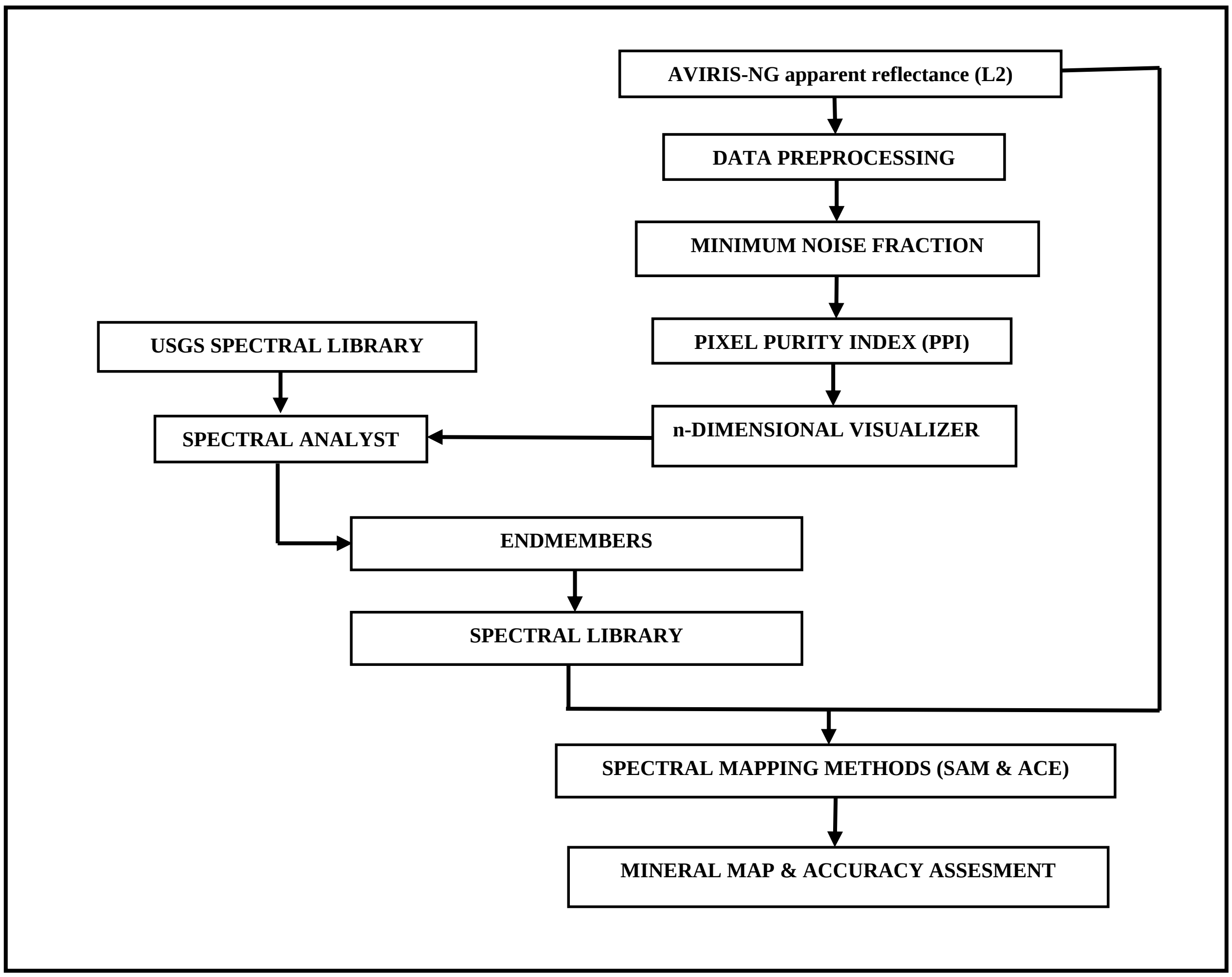

Figure 1. Flow diagram showing the methodology/algorithm adopted (Courtesy: ENVI 4.7 User's guide 2009).

ponent analysis (Green et al. 1988). The first step segregates the data in terms of noise & the second step is a standard PC transformation applied on the noise-whitened data. The MNF transformation calculates noise statistics in terms of eigenvalues from the input data. Eigenvalues were then used to understand the data dimensionality, which allows one to choose the maximum suitable MNF bands for further processing (Green et al. 1988). Subsequent to data dimensionality reduction, PPI image was generated to identify the spectrally pure pixels within the area. In PPI image each pixel value corresponds to the number of times that pixel was recorded as extreme. The n-dimensional visualizer is used to locate, identify and cluster the purest pixels & the most extreme spectral responses in a dataset. The spectra collected by n-dimensional visualizer were used as endmembers to run the SAM & ACE classifier. Before running the SAM classifier, the identification of endmember spectra was obtained by comparing with the available predefined mineral spectra of the United States Geological Survey (USGS) spectral library, using the spectral analyst tool of ENVI 5.0 (Research Systems, Inc., Boulder, CO, USA). Two well established mapping methods namely SAM & Spectral feature fitting (SFF), were used for the identification of the collected endmember spectra. SAM is a physical based spectral classification method that uses an n-D angle to match pixels to reference spectra. The algorithm determines the spectral similarity between two spectra by calculating the angle between the spectra and treating them as vectors in space with dimensionality equal to the number of bands (kruse et al. 1993). In this study, a single value threshold of 0.1 rad was used as the maximum angle threshold. SFF is an absorption feature-based methodology. The reference spectral and the image spectra were scaled to match after the continuum was removed from both datasets. In this study, our aim was to map the hydroxyl, carbonate and iron-bearing minerals that have characteristic absorption features in VNIR as well as SWIR region. This is the reason why we have given the same weights to SAM and SFF as 0.5. Also in many cases, the spectral analyst lists multiple identical scores for different materials in the rule base. This indicates that spectral analyst cannot discriminate the two materials under the identification conditions. In this case, different weighted methods should be used to produce a unique result. The SAM and ACE technique was then applied to the all five AVIRIS-NG scenes to classify the same in terms of hydroxyl, carbonate and iron-bearing minerals. As accuracy assessment is an important part of any classification technique. It helps to find how well the classification is performed. Mineral maps further undergo accuracy assessment for determining the better method.

Results and Discussion:

The apparent reflectance data (L2), before doing processing, were preprocessed by removing the bad bands, 374 bands are remained out of 425. Then data were first linearly transformed (MNF transformation) to generate 374 MNF bands. Out of 374 MNF bands, the first 20 bands were chosen on the basis of eigenvalues which contain most of the spectral information. Minerals endmember extracted after processing PPI calculation and N-dimensional visualization analysis.

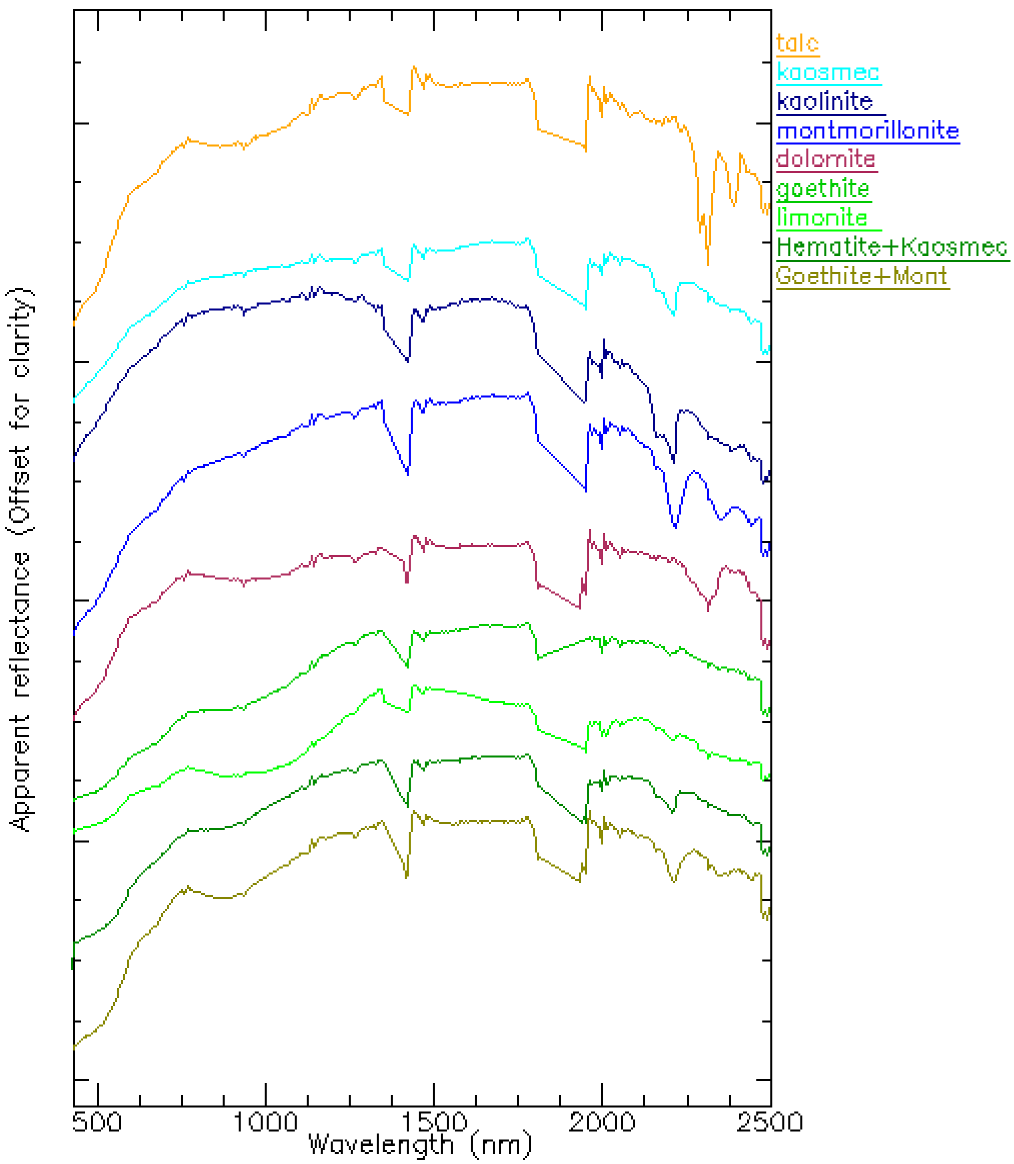

Figure 2. Endmember Collection Spectra.

A total of nine endmembers (Figure 2) representative of different hydroxyl, carbonate and iron bearing mineral selected from the image on the basis of shape, size and position of spectral absorption features. A higher total score will give more proximity of an endmember to the designated mineral chosen from the USGS spectral library. The known versus unknown analysis revealed that the nine endmembers are talc, Kaosmec, montmorillonite, kaolinite, dolomite, goethite, limonite, goethite+montmorillonite, hematite+Koasmec.

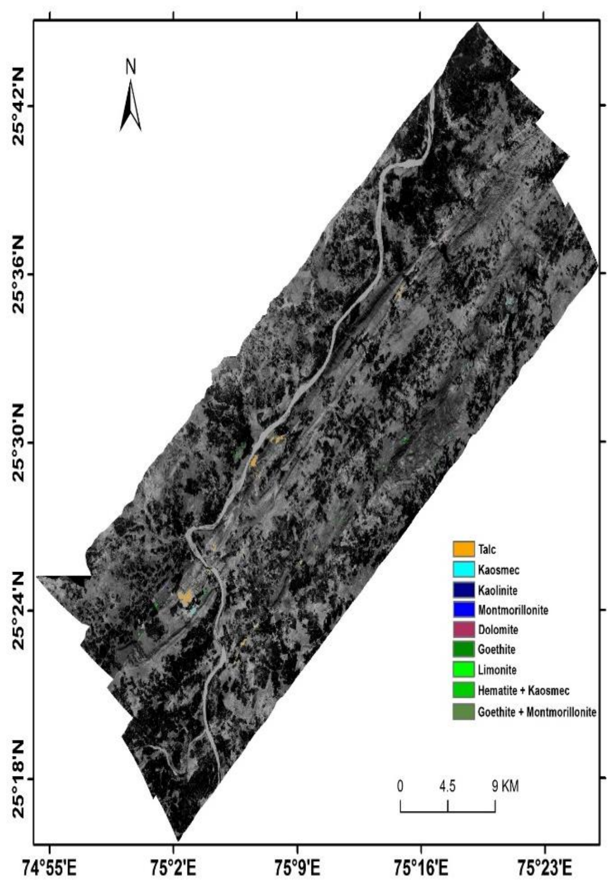

Figure 3. SAM-classified mineral map

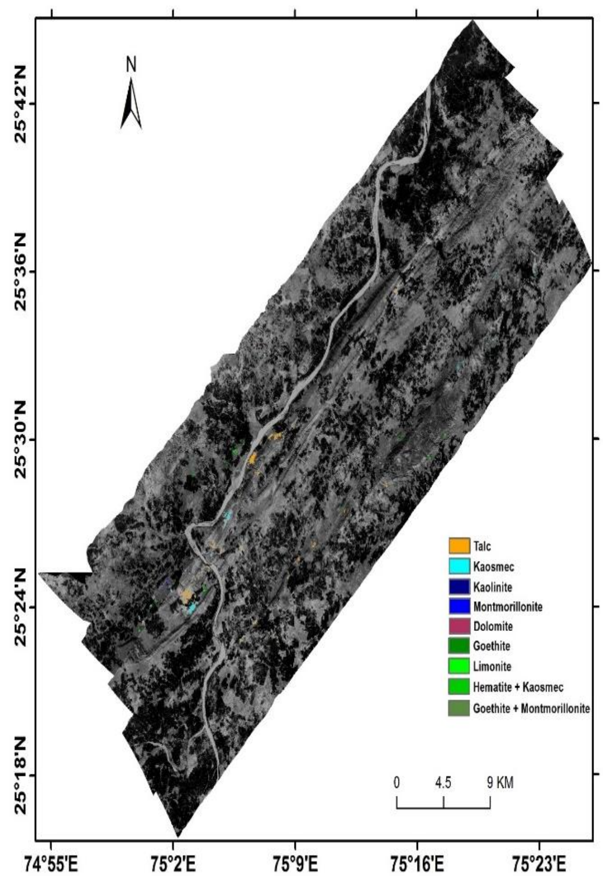

Figure 4. ACE-classified mineral map

Endmembers were used to classify these 5 AVIRIS-NG scenes using SAM & ACE (figure 3 & figure 4) respectively. The mineral map obtained by applying SAM & ACE classifier were further subjected to accuracy assessment. The overall accuracy for both SAM & ACE as obtained is shown in table 2. This shows that SAM is better technique than ACE to produce mineral map.

Scenes / Mapping Method	Scene1 (%)	Scene2 (%)	Scene3 (%)	Scene4 (%)	Scene5 (%)	Overall Accuracy
Spectral Angle Mapper	85.714	87.500	87.804	85.589	87.500	86.821
Adaptive Coherence Estimator	71.428	79.166	77.235	77.611	83.333	77.754

Conclusions:

- In present study, mineral endmembers are identified from AVIRIS-NG hyperspectral images by using spectral and spatial data dimensionality reduction techniques.
- Because of contiguous nature of AVIRIS-NG data, it has become possible to study the shape, size, and accurate location of spectral feature, which in turn help in identifying and discriminating various minerals in particular phyllosilicate, carbonate and iron bearing minerals.
- Thus it can be calculated that AVIRIS-NG data with high spectral and spatial resolution can be very efficiently used for the identification and mapping of altered and clay components.
- Accuracy assessment of mineral map, by using SAM and ACE technique, reveals the result that SAM produces better result.

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