# Application of EO-1 HYPERION Data to Classifying Geological Materials

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**Abstract:** Hyperspectral image divides VNIR region to over 200 bands which can show continuous spectrum with 10 nm spectral resolution. This property is useful in geology where a spectral feature which is decided by chemical compositions and crystalline structures is recorded well. While this field has been studied variously in foreign countries, the studies are in the early stage in Korea. In this study, characteristic materials associated with AMD were classified by using EO-1 HYPERION data which is a spaceborne hyperspectral image and topographical map and DEM and geochemical map were analyzed in conjunction with the image in order to examine that classified minerals are secondary minerals by AMD.
**Keywords:** EO-1 HYPERION, AMD, secondary minerals.

## 1. Introduction

AMD[1] is able to be caused by mining activities and the environmental impact of AMD from mine areas can be diffused widely to near soil and water system. Iron hydroxides minerals of yellowish brown precipitate materials and amorphous white precipitate materials are collected in the water system from AMD and then sulfate, Fe(Ⅱ), and Fe(Ⅲ) ion of precipitate materials compose a variety of secondary minerals in accordance with pH and iron ion's concentration [5].

The geological and mineralogical assessment and analysis of areas around mine site have been traditionally conducted through geochemical, hydrologic, and geophysical surveys at ground level up to date. Recently remote sensing has been successfully used to aid in this process [1]. The high quality hyperspectral data provided by systems such as AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) and HYPERION enable a higher level of results in assessment of the impact of mining activities.

In this study, geological characters of areas around Naju lake beside Honam coal mine site are analyzed and the impact of AMD is assessed by classifying the EO-1 HYPERION image, topographical conditions, and geochemical information.

## 2. Characteristic Materials Associated with AMD

Sediments are enriched in the water system of Hancheon stream, Youngsan river, and Naju lake in trace materials such as Ba, Fe, Mn, Zn, Na, $SO_4$, and $NO_3$ due to AMD. These elements are exchanged for organics, clays, iron oxides, and oxy-hydroxides minerals and then aggregated in stable secondary minerals under suitable pH range or reactive ions [1]. Fe(Ⅱ) and sulfate ions are dissociated from pyrite [$FeS_2$] in coal seams and minerals under the oxidation condition with water such as mining activities. Al and Mn are corroded from metals of near rocks by this acid water and occur red precipitate [$Fe(OH)_3$] with ferrous ion and yellow or white precipitate [$Al(OH)_3$] with Al [3]. In general, these secondary minerals formed by AMD are iron oxides or oxyhydroxides mineral such as goethite [α-FeOOH], hematite [$Fe_2O_3$], and ferrihydrite [$Fe_5HO_8 \cdot 4H_2O$]. Ferrous ion first precipitates in soil as amorphous iron hydroxides and forms insoluble goethite increasingly after getting through various forms of oxides. Then most of the heavy metals concentrate on goethite because of exchange and

[1] AMD (Acid Mine Drainage)

concentration of them in this process.

## 3. Data and Image Processing

### 1) Data

The EO-1 HYPERION, which is a spaceborne hyperspectral data, for this study was acquired at November 22, 2002 and covers some parts of Gwangju, Naju, and Hwasun in Jeonnam. The instrument has 220 spectral bands covering the 0.4 to 2.5 ㎛ range with approximately 10 nm spectral resolution and 30 m spatial resolution. Ground coverage is approximately 7.5 km by 180 km per image.

### 2) Image Processing

Objects to be identified are ferrihydrite, hematite, and goethite of minerals that are possible to be a secondary mineral and granite and rhyolite of bed rocks in the study area.

**Calibration:** Although instruments measure radiance rather than reflectance, reflectance is a surface property, while reflected radiance depends also on the strength and geometry of the illumination and on sensor view angle. So, one of the most critical steps in most imaging spectrometer data analysis strategies is to convert the data to reflectance, principally so that individual spectra can be compared directly with spectral library data for identification [4]. In this study, IARR (Internal Average Relative Reflectance) technique was used to normalize images to a scene average spectrum because this tech-nique is particularly effective in an area where no ground measurements exist and little is known about the scene.

**Band Selection:** In order to operate hyperspectral image with over 200 bands effectively, 185-235 bands of SWIR region (2.0-2.5 ㎛) where the spectrum feature of rocks and minerals is remarkable was separated (Fig. 1).

**MNF Transform:** The MNF (minimum noise fraction) transformation is a linear transformation related to principal components that orders the data according to S/N ratio. The MNF transformation is used to partition the data space into two parts: one associated with large eigenvalues and coherent eigenimages, and a second with near-unity eigenvalues and noise-dominated images. In general, the higher numbered MNF bands contain progressively lower signal-to-noise [4].

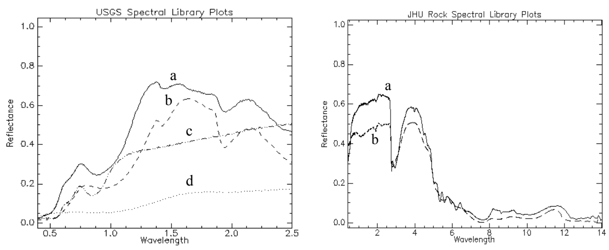
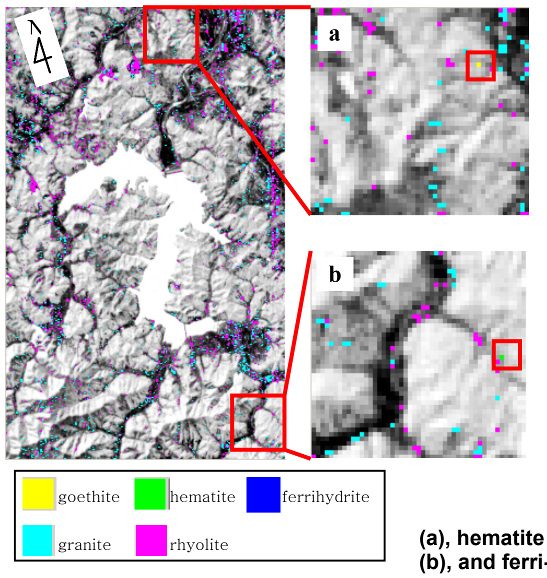



**Fig. 1. USGS Spectral Library Plots: a. goethite b. ferrihydrite c. hematite d. pyrite (left), JHU Rock Spectral Library Plots: a. granite b. rhyolite (right).**

**Endmember Collection:** A PPI (pixel purity index) was applied to the MNF image bands that contained any information. This algorithm examines the n-D data cloud in a series of projections to find the most spectrally extreme pixels. Vertices in the n-D data cloud were extracted. The surface materials on the ground covered by these pixels could then be identified based on their VNIR reflectance spectra [2]. After this analysis, 5 endmembers were identified, ferrihydrite, hematite, goethite, granite, and rhyolite.

**SAM Classification:** The location and relative concentration of secondary minerals and exposed bed rocks were mapped using a spectral matching program called the SAM (spectral angle mapper). The SAM matches pixel spectra to reference spectra using a measure of spectral similarity based on the angle between the spectra treated as vectors in an n-dimensional space with dimensionality, n, equal to the number of image bands.

**Fig. 2. SAM result images about granite, rhyolite, goethite**




**(a), hematite (b), and ferrihydrite.**

## 4. Qualitative Analysis and Results

The result of classifying and mapping rocks and minerals based on the continuous spectrum feature of HYPERION image showed that granite and rhyolite as a bed rocks were widely distributed visibly, but in case of secondary minerals, ferrihydrite wasn't appeared and though goethite (Fig. 2. a) and hematite (Fig. 2. b) were sparsely distributed, they were confirmed when the mapped image was zoomed in (Fig. 2). DEM and topographical map for topographical conditions and geochemical map were analyzed in conjunction with HYPERION data in order to examine that classified minerals are secondary minerals by AMD.

DEM in 2D was overlaid by the locations of mines and classified minerals and the watershed because AMD is able to be diffused to water system such as Naju lake, Hancheon stream, and Youngsan river and near cultivated land through a branch stream (Fig. 3). Figure 4 shows pixels of goethite and hematite classified as minerals are appeared near a river in the colline zone.

Also, in order to look into the possibility of secondary minerals' formation, Fe which participates mechanism of forming secondary minerals which are able to from AMD was examined from pH map that is able to show impact of acid mine water by alteration of pH, $Fe_2O_3$ map which can appear how amount of Fe there is, and the report included in the Jeonnam geochemical map [6]. According to geochemical map [6], $Fe_2O_3$ didn't present remarkably high values on the study area. But according to the geochemical map and report [6], the low pH value (5.9-6.3) in Hwasun area around the coal mine site was affected by acid mine water. As these results of, minerals classified in the HYPERION image could be considered as the secondary mineral formed by AMD.

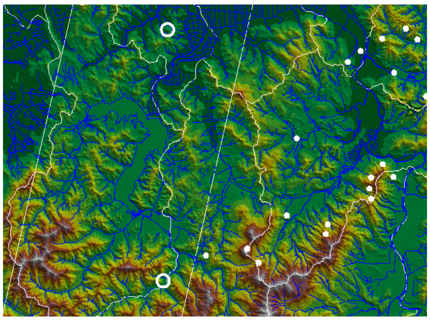


**Fig. 3. 2D DEM image overlaid by the boundary of HYPERION image, points for the locations of mines and circles for classified minerals.**

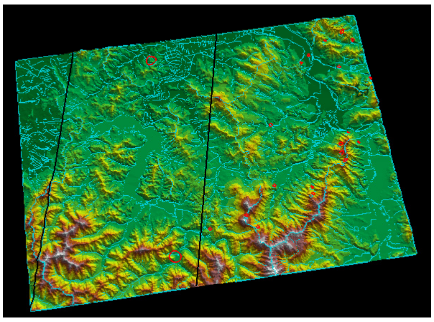


**Fig. 4. A 3D view of Figure 3 as seen form the west.**

## 5. Conclusions

Using the EO-1 HYPERION data, granite and rhyolite which are main rocks and goethite, hematite, and ferrihydrite which are the secondary mineral were attempted to be classified and as the result, main rocks were distributed visibly and distribution of secondary minerals were sparsely confirmed when the mapped image is zoomed in. Through the analysis of the topo-graphical map and DEM, classified minerals from HYPERION data usually appeared near a river in the colline zone so there was a possibility that the AMD form a mine could form the secondary minerals.

From these results, it was presented that the hyperspectral data is identified in further detail since its continuous spectral feature makes it possible to directly compare to spectral library and is able to offer further detail information to geological survey, although there is the weak point that it's difficult to analyze a small area such as areas around mine site in detail with 30m spatial resolution of HYPERION image.

This study conducted only qualitative analysis indoor, but for more precise analysis, comparison, and examination, rock and mineral samples and field spectrum data need to be collected from around the mining area and their reflectance spectra has to be quantitatively analyzed in conjunction with information stated in this study.

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