ALTERATION MINERAL MAPPING FROM HYPERSPECTRAL DATA USING PIXEL BY PIXEL SPECTRAL IDENTIFICATION - IRIKI KAOLINITE MINE, KAGOSHIMA, JAPAN –

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ABSTRACT: Airborne hyperspectral data of the Iriki kaolinite mine, located at southwest Japan was obtained on 2010, November 17th. AISA hawk sensor (1,000 - 2,400 nm) was used for the data acquisition and two lines of airborne hyperspectral data were obtained covering the open pit mine. Pixel resolution at ground is 1.5 m and 127 bands of data were obtained at the short wave infrared (SWIR) region.
We have created an IDL program to conduct mineral identification on each pixel of the hyperspectral image to provide mineral maps. This “pixel by pixel spectral identification” method is similar to a spectral identification using a spectrometer on to each pixel. There are 59 minerals or mineral groups in the database for spectral identification. Spectral enhancement is applied to the spectral data before the identification of minerals to clarify the absorption pattern in the spectral data.
Mineral distribution maps for kaolinite, montmorillonite, alunite and dickite were obtained from hyperspectral data of the Iriki kaolinite mine. The identification result matches very well with the X-ray diffraction analysis results of the samples collected from the ground truth survey. The “pixel by pixel” spectral identification is effective and able to provide accurate alteration mineral maps. It is a stable method to process hyperspectral data for alteration mineral mapping compared to the conventional methods.

1. INTRODUCTION

In general hyperspectral data processing methods, a number of pure end member spectra are obtained from the hyperspectral data using multivariate data analysis. The pure end member spectra need to be identified and then mapped by spectral matching within the whole data. The difficulty for this method is to identify the end member spectra with accuracy. Skills are needed for interpreting the spectral data. Identification of the end member spectra may be subjective and mistakes may occur.
Since each pixel in the hyperspectral data possesses continuous spectral data, it is possible to apply mineral identification on each pixel by applying spectral feature enhancement. We used an in house IDL program for the remote sensing data processing in order to identify the alteration minerals for each pixel.

2. IRIKI KAOLINITE DEPOSIT

The Iriki kaolinite deposit is located in the Kagoshima prefecture, southwest Japan. There are many hydrothermal activities in this area and famous for occurrences of many low sulfidation type gold deposits and kaolinite deposits. The Hishkari gold deposit that is the largest gold deposit in Japan is also present in this area. The geology of this area consists of Cretaceous marine sediments called the “Shimanto supergroup” forming the basement and Pleistocene volcanic rocks and volcaniclastic rocks covering the basement inconsistently. The Iriki kaolinite mine is located at the western flank of the Imuta volcano which consists of quartz andesite. The host rock of the kaolinite deposit are pyroxene andesite and its clastic rocks. Alteration zonation is classified into four zones. Stronger to weaker alteration, zone I; kaolinite, zone II; kaolinite+montmorillonite, zone III; montmorillonite and zone IV; halloysite. Also, minor amount of cristobalite, tridymite, dickite, alunite, jarosite, pyrite are accompanied [1].

3. AIRBORNE HYPERSPECTRAL DATA

Airborne hyperspectral sensor AISA Hawk of Specim made in Finland was used for the hyperspectral data acquisition. AISA Hawk obtains 127 bands of data in the shortwave infrared region (1,000 - 2,400 nm). The spectral resolution was set to 11.36 - 11.46 nm. The spatial resolution at ground is 1.5 meters. The aircraft flew at altitude approximately 1,142 m and velocity at 120 knots. The frame rate for data acquisition was 41 frames / sec and the overlap with the adjacent flight line was 50%. The specification of the AISA Hawk sensor and data are shown in Table 1 and the spectral data of the AISA Hawk sensor are shown in Figure 2. Two lines of airborne hyperspectral data were obtained to cover the open pit mine.

Figure 1 Location of the Iriki kaolinite mine.

Table 1 Specfications of the AISA Hawk sensor.

AISA Hawk sensor	Specification
Wave length range	1,000 - 2,400 nm
Band number	127 bands
Band width	11.36 - 11.46 nm
Instantaneous field of view	1.3 mrad
Field of view	22 degrees
Focal length	22.8 mm
Dynamic range	14 bits

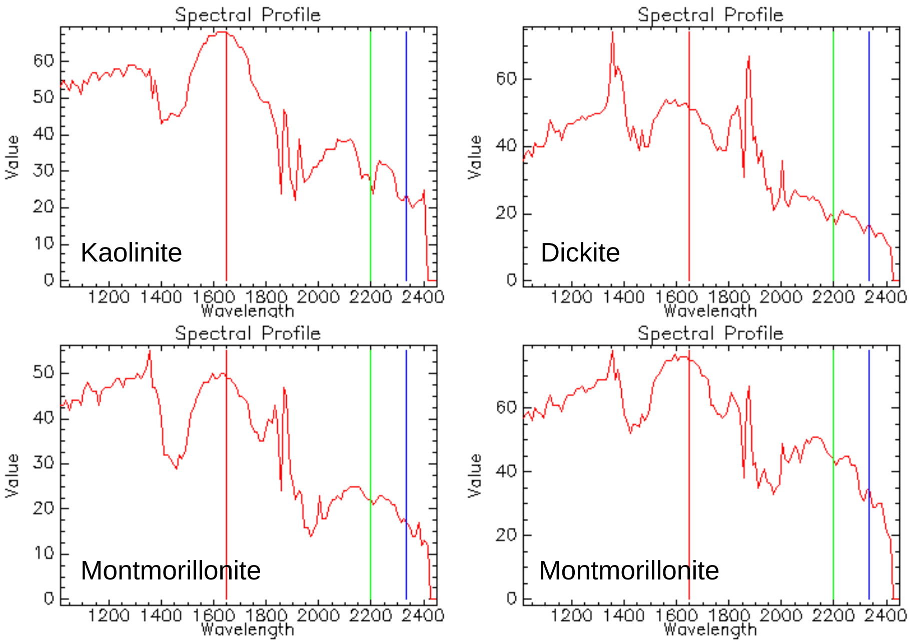

Figure 2 Spectral data obtained from the airborne AISA Hawk sensor.

4. DESCRIPTION OF THE PROCESSING METHOD

4.1 Processing

An alteration mineral identification equipment named POSAM (Portable Spectroradiometer for Mineral identification) has been developed by the Metal Mining Agency of Japan (former organization of JOGMEC) in 1993 [2], [3]. POSAM consists of a spectrometer that measures the reflectance spectra in the short wave infrared (1300 - 2500 nm) and software to identify alteration minerals (Figure 3).

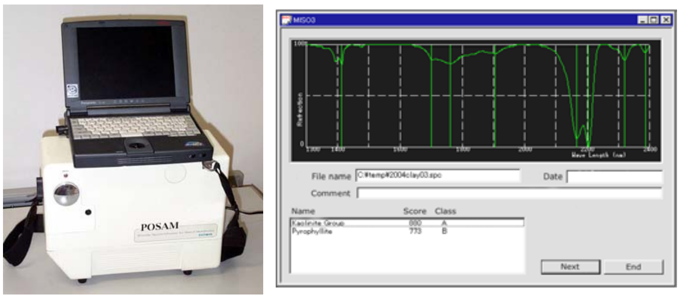

Figure 3 POSAM and its mineral identification software.
(POSAM can identify over 40 minerals at over 80 % of accuracy.)

The alteration mineral identification software for POSAM was applied on each pixel in the hyperspectral data to create an alteration mineral map. The processing steps are as follows.

1) Obtaining spectral data from pixel (1,300 - 2,400 nm).
2) Spectral correction.
   ･Normalize (spectral enhancement)
   ･Hull (base line correction)
3) Peak position finding
4) Scoring
   POSAM has a data file of approximately 59 alteration minerals. The pixel spectrum is compared with the alteration minerals in the data file and scoring is conducted. Score is added if absorption matches for an alteration mineral and subtracted if there is no match for an important absorption feature.
5) Display
   Pixels with high scores will be shown in brighter tone and low scores will be shown in darker tone. Low scored pixels under the threshold will not be shown.

The steps will be repeated until all the pixels are identified.

4.2 Interface

The interface of the program is shown on Figure 4. The user is able to customize the processing.

1) Expected minerals can be chosen for mapping. Mineral maps will be created for each chosen mineral.
2) Spectral corrections can be chosen ("normalize" and "hull"). Normalization will emphasize the absorption. Hull quotient will conduct base line correction (Figure 5).
3) Correlation of the absorption dips can be considered for scoring. The total shape of the spectra will be considered.
4) Threshold depth of the absorbance for the identification can be defined (default is 93 % from 100 % reflectance).
5) Threshold of the calculated scores for mineral mapping can be defined.
6) Output absorption list can be obtained.

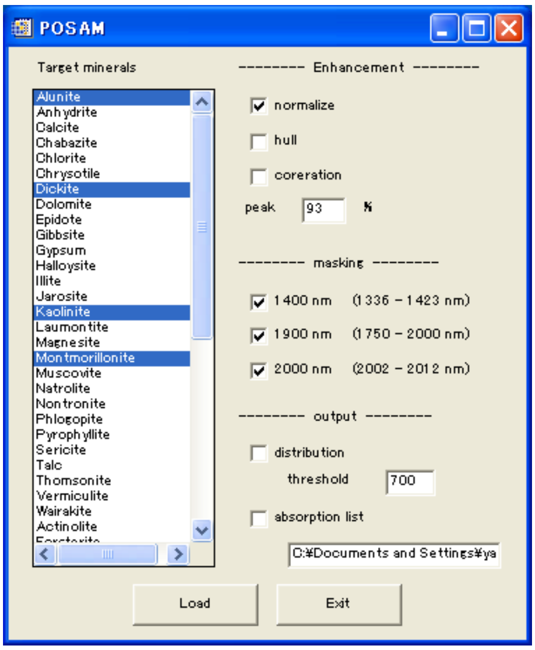

Figure 4 Interface of the in house IDL program.

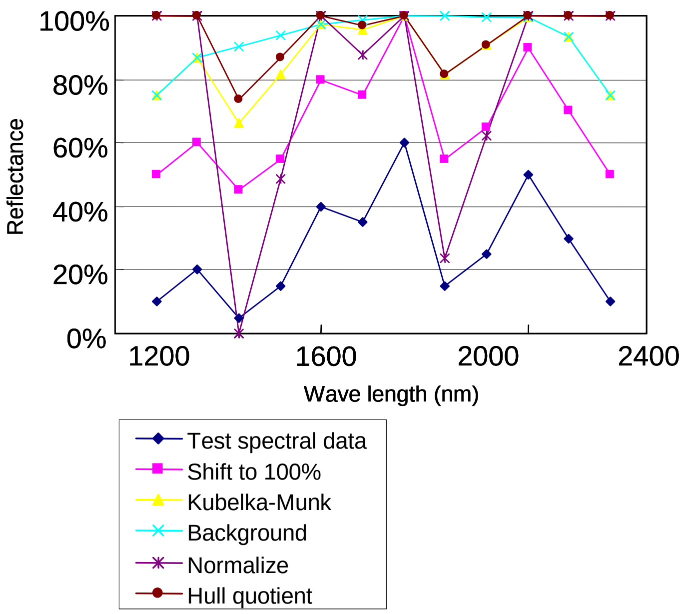

Figure 5 Enhancement of spectral data for data processing.

5. RESULTS

Processing using the in house software was conducted on the two lines of hyperspectral data separately. Both data were atmospheric corrected before processing by the empirical line method using the spectral measurement data obtained at ground (blue plastic sheets). Since "normalize" (Figure 4) is selected for processing the hyperspectral data, subtle absorption features are enhanced (Figure 5) and detail mineral identification is enabled. Brightness of the pixels displays the abundance of the alteration mineral present in the pixel. Mineral maps of kaolinite, dickite and monmorillonite are shown in Figure 6.

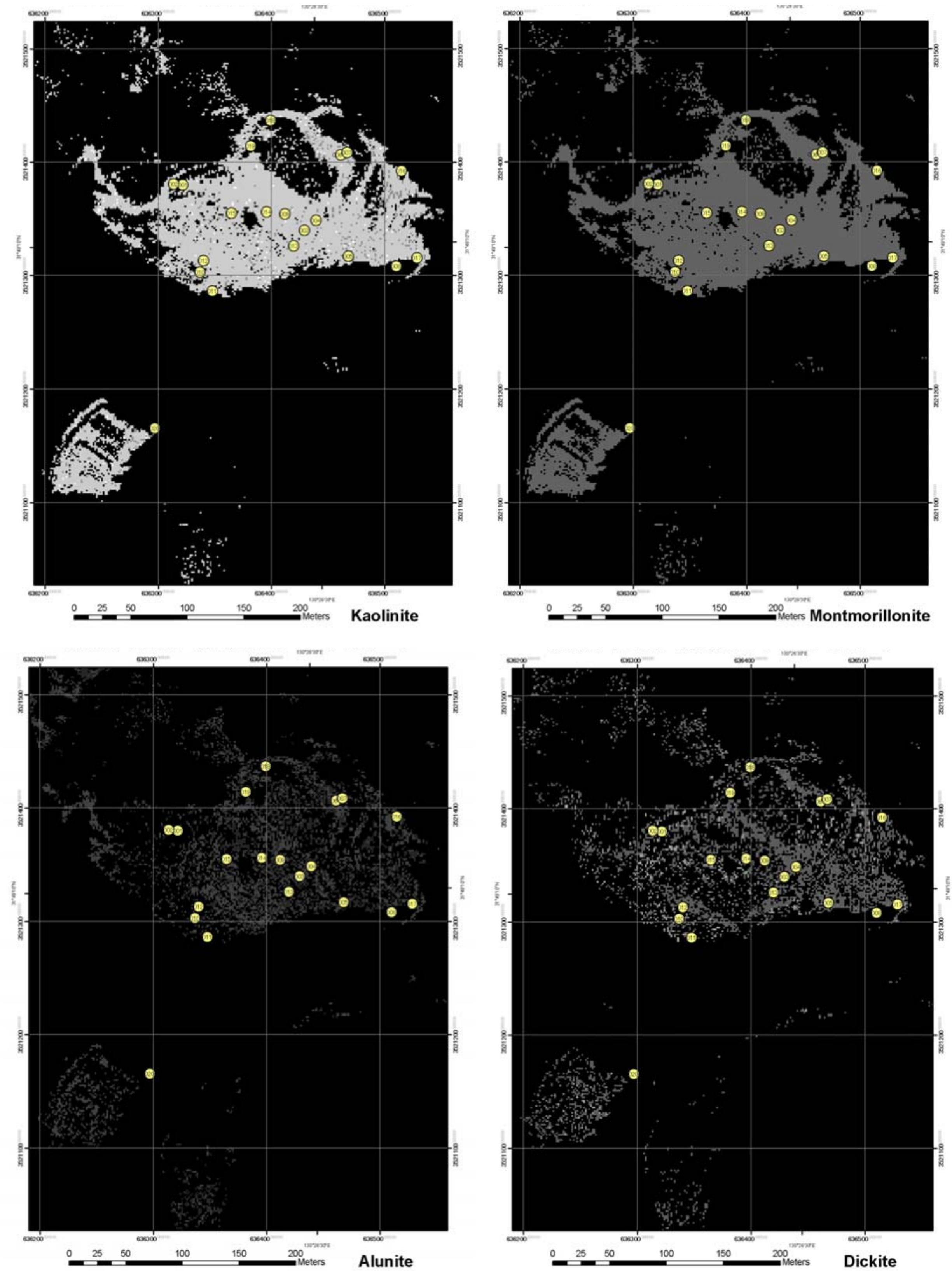

Figure 6 Alteration mineral maps obtained from processing of the hyperspectral data.
Brightness of the pixels display the abundance of the alteration mineral present in the pixel.
The sampling location and sample numbers are shown in yellow circles.

Abundance of kaolinite is very high, alunite and dickite are distributed sparsely with low amount and montmorillonite is accompanied widely in the mine.
Ground truth survey was conducted and kaolinite, montmorillonite and silicified alteration are noticed in the open pit. The central part of the mine consists of kaolinite and silicification alteration and the peripheral area is dominated by kaolinite + montmorillonite alteration. Sampling and X-ray diffraction (XRD) analysis was conducted. The XRD analysis results are shown in Table 2.

Table 2 XRD analysis results of rock samples.

		Silicate														Sulfate				Others					
		Silica			Feldspar			Clay																	
		Quartz	Cristobalite	Tridymite	Plagioclase	Orthoclase	Albite	Chlorite	Kaolinite	Montmorillonite	Illite	Pyrophyllite	Halloysite	Sericite/Mont	Mont/Illite	Alunite	Jarosite	Gypsum	Barite	Pyrite	Hematite	Anatase	Rutile	Native sulfur	
1	001	◎							○						◎										Iriki kaolinite mine
2	002	◎	・						○	○						・									Iriki kaolinite mine
3	003	△	△						◎	△						・		△							Iriki kaolinite mine
4	004	◎	○						◎							・									Iriki kaolinite mine
5	005	◎							◎							・									Iriki kaolinite mine
6	006	◎	○						◎	△						・									Iriki kaolinite mine
7	007	◎	○						◎	・						・									Iriki kaolinite mine
8	008	◎							◎							△									Iriki kaolinite mine
9	010	◎	・						◎							△									Iriki kaolinite mine
10	012	○	△						◎	△						・									Iriki kaolinite mine
11	014	◎	・						◎	△						・									Iriki kaolinite mine
12	015	○	△						◎	△						・									Iriki kaolinite mine
13	016	・	・						・																Iriki kaolinite mine
14	017		○						◎							○									Iriki kaolinite mine
15	018	◎							◎							△						△			Dickite?
16	019	○	◎						◎							・									Iriki kaolinite mine
17	020	・	○						◎							△									Iriki kaolinite mine

The XRD analysis results show that quartz and kaolinite are highly abundant and montmorillonite is abundant. Alunite is present but only minor amount. Chemical composition of alunite is Na-alunite.

6. DISCUSSIONS

The alteration zoning in previous study are described from the central to periphery as follows, 1) kaolinite, 2) kaolinite + montmorillonite, 3) montmorillonite, 4) halloysite. Also the previous study show that halloysite that is a low temperature phase mineral of kaolinite and dickite that is a high temperature phase mineral of kaolinite are present in the Iriki kaolinite mine [1]. This shows that there is a difference of the temperature of the hydrothermal fluid that created the kaolinite alteration. The areas identified as dickite could be hydrothermal feeders and central areas that created the kaolinite alteration.

7. CONCLUSIONS

The AISA Hawk data obtained in low altitude has high resolution and continuous spectral data. In order to avoid the effect of topography and surface roughness to create different reflectance intensity, it is important to normalize the hyperspectral data so that the single alteration zone is not differentiated into separate alteration zones. This method could show a number of minerals in each pixel as a result and matched very well with the XRD analysis results.

ACKNOWLEDGEMENT

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REFERENCES

[1] Fujii, N., Tsukimura, K. and Julio, J. M. (1989) Mode of occurrence and genetic processes of the Iriki kaolin deposit, southern Kyushu. Bull. Geol. Surv. Japan, vol. 40(6), p. 299 – 322.

[2] http://www.geotechnos.co.jp/service_products_hard.html

[3] S. Huzikawa, K. Ohkawa, and S. Tanaka, “Automatic Identification of Alteration Mineral Using a Portable Infrared Spectrometer, Jour. Rem. Sen. Soc. Japan, vol. 21, pp. 206–209.