Trial of Digital Filter Photography for Alteration Mineral Detection in the Hachimantai Area, NE JAPAN

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Introduction

- This study focuses on hydrothermally altered materials using satellite image (ASTER data) and trial new digital filter photography remote sensing method in the Hachimantai area, Northern JAPAN.
- Most satellite images are good quality and georeferenced so they can be loaded directly into GIS software.
- Unfortunately, most satellite systems have limited resolution, limited orbital periods. Cloud cover adversely affects them at the time of image acquisition.
- Alteration zones can guide exploration geologists to hidden systems or to ancient spring activity and important in geothermal resource exploration over the Hachimantai area.

Objective

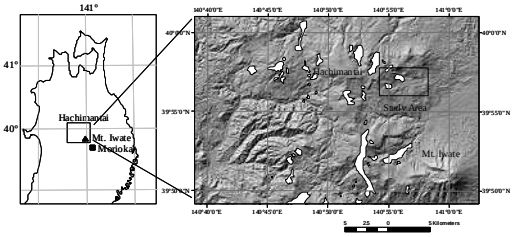
- To develop a flexible, low cost remote sensing system that can be applied in the detection of alteration minerals.
- The aim will be met through the following specific objectives:

  (1) Develop a lightweight digital imaging system capable obtain high-resolution images.

  (2) Demonstrate the usefulness of the filter camera system for alteration detection.

  (3) Demonstrate the utility of the filter camera system for pre-scouting fields.

The Study Area



- Hachimantai volcanic region is one of the largest geothermal provinces in JAPAN, is located 50 km northwest of Morioka city Prefecture.
- Hydrothermally altered rocks are exposed by landslide on the hill.
- The Geological Survey of Japan considers mapping hydrothermal alteration zones as an extremely important element in geothermal exploration.
- The white polygons are alteration zones mapped by geological survey of JAPAN.

Hydrothermal alteration

- The acidic hydrothermal alteration zones elongated along ENE striking fractures (Sumi, 1968).
- The acidic stage has been divided into three alteration subzones based on the distribution of kaolinite, alunite and pyrophyllite (Nakamura and Sumi 1981)

  (1) Silicic subzone – siliceous rocks, alunite and sulphur.

  (2) Silicification subzones – silicified rock, clays, sericite, alunite, gypsum, calcite, rutile, diaspore and andalusite.

  (3) Argillization subzone – clay, montmorillonite, kaolin and alunite.

Red = suitable spectral signature in Remote Sensing

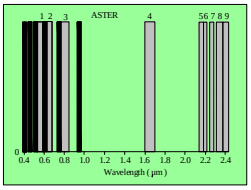
Methodology

(1) Processing of ASTER data Image analysis
- DN image to Radiance Image calibration
- Radiance Image to Reflectance Image calibration
- Reflectance band ratio method
- Principal Component Analysis (PCA) method
- Band Math Method

(2) New digital filter photography method.

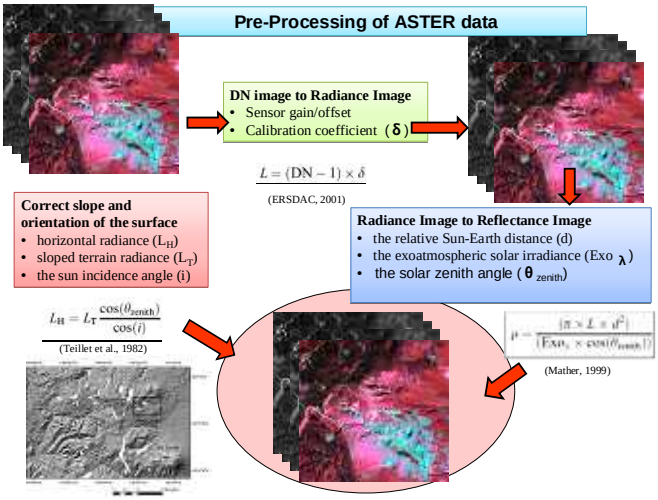
(3) X-ray diffraction (XRD) analysis

IMAGE DATA



- This study used the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data level AST3A01.
- It has been acquired on September 16, 2004 with a soloar incidence angle of 50.0º and azimuth angle of 156.10º .
- Another one is digital camera filter photography image. filtered through;
  - visible wavelength filters - 400 nm, 450 nm, 500 nm, 550 nm and 600nm.
  - infrared wavelength filters – 750 nm and 950 nm.

Sensor Product	Sub-System	Number of bands	Spectral range (μm)	Spatial resolution (m)
Aster L1B	VNIR	3 (+ 1 backward)	0.52 up to 0.86	15x15
	SWIR	6	1.60 up to 2.43	30x30
	TIR	5	8.125 up to 11.65	90x90

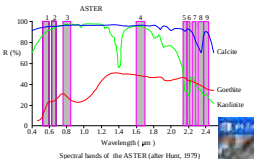


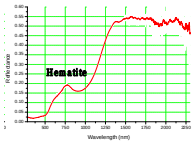
Band Ratio Method

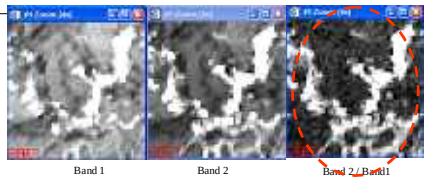
- The mineral or rock unit may have high reflectance in some spectral portion, however, it may absorb in another spectral region (Bannari et.al., 1995).
- Band ratio method used this reflectance and absorption bands characteristic.

The most appropriate index used to extract the laterite area is the ratio of band 2 to band 1 in ASTER data.

Band 2 / Band 1 = New band (iron oxide image)



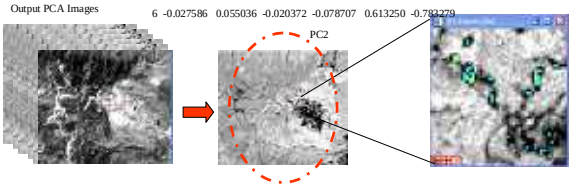




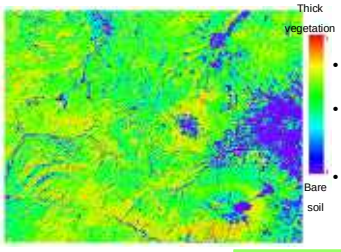
Principal Component Analysis Method (PCA)

- The principal component transformation is a multivariate statistical technique.
- This technique indicates whether the materials are represented bright or dark pixels in the principal components according with the magnitude and sign of the eigenvectors loading.
- As we know that the iron oxide give high reflectance values in ASTER band 2 and low in band1, we look for the principal component in which *the difference of reflectance is large at table.*

PC	Band 4	Band 5	Band 6	Band 7	Band 8	Band 9
1	0.774759	0.301401	0.372717	0.315822	0.229668	0.132276
2	*0.610152*	*-0.363007*	*-0.299115*	-0.361144	-0.412267	-0.325701
3	0.053647	-0.650366	-0.311138	0.638889	0.247169	0.089823
4	-0.077688	-0.573204	0.792854	-0.188634	0.006616	-0.034026
5	-0.133375	0.151050	0.213947	0.565574	-0.583161	-0.503657
6	-0.027586	0.055036	-0.020372	-0.078707	0.613250	-0.782279



Vegetation Indices



-1<NDVI<1

- The most commonly used NDVI for estimating green vegetation cover in Remote Sensing.
- Normalized Difference Vegetation Index (NDVI)
- ASTER bands 3N (NIR) and 2 (R) were then converted into apparent reflectance values.
- Using apparent reflectance images in Red and NIR bands, the NDVI index was computed by the standard formula:

ρ_{red} = Reflectance in red channel

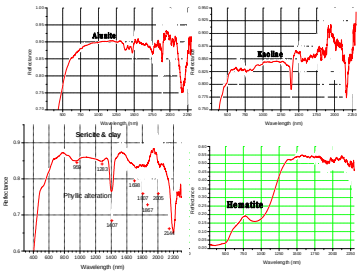
ρ_{NIR} = Reflectance in NIR channel

$$NDVI = \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red}}$$

(Rouse et al., 1974)

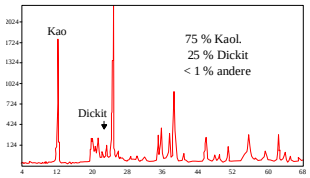
MSR7000 Multispectro Radiometer each mineral powder sample measurement

- The reflectance spectra were measured using MSR7000 Multispectro Radiometer (covers the 280 nm to 2500 nm wavelength).
- Laboratory reflectance spectroscopy, MSR 7000 can be a definitive test of the presence of hematite and kaolinite, if the absorptions appear strong.
- Mixtures of minerals with overlapping absorption bands can be difficult to interpret with spectroscopy .



X-ray diffraction (XRD) analysis

- Spectral measurement methods are sensitive to different abundances of materials especially clay minerals.
- However, the minerals quartz and low iron feldspars have no diagnostic absorption in Visible-NIR wavelength range but XRD is very sensitive to them.
- X-ray diffraction analyses confirmed that much of the silica is the dominant mineral in the alteration area.
- According to XRD analyses of samples contains iron oxide (goethite, hematite), a variety of clay minerals including kaolinite, montmorillonite, illite and siliceous minerals.

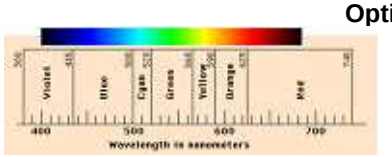


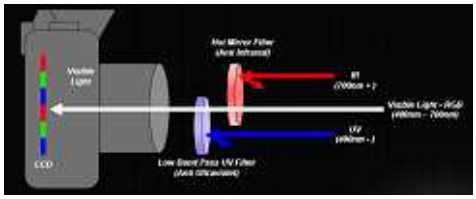
Trial of Digital Filter Photography

Equipment Required

- The basic elements of digital filter photography include the charge coupled devices (CCD) digital camera, filter, filter holder and ball head tripod in this method.
- The camera can store images as uncompressed TIFF format or RAW files.
- One of the highlights of the Dimage 7 is that F 2.8, 7X optical zoom Minolta GT lens. The focal range is 7.2 – 50.8 mm.
- A conventional 5 mega pixel camera actually may output 2560×1920 pixel images (4915200 pixels) because some of the pixels in the camera are used for various measurements in image processing.

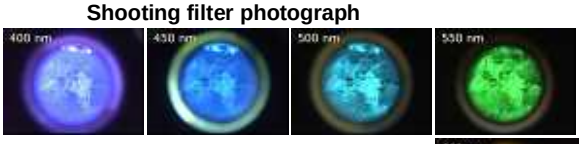
Optical Filter





- CCD camera filtered through visible wavelength filters – 400 nm, 450 nm, 500 nm, 600 nm (visible wavelength) and Infrared filter 750 nm and 950 nm.
- CORION [(Holliston, MA) S25-F0470-4M229] filter with an optical bandwidth of ± 25 nm.

Shooting filter photograph

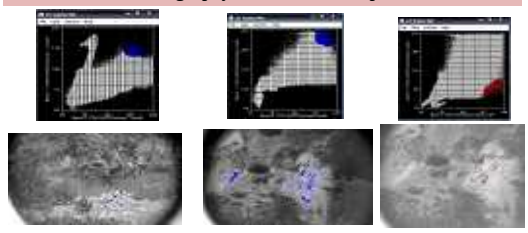


- Shooting filter photographs is simple, by placing various filters in front of the main lens of digital camera.
- But there are a few things to get good photos in field work.

- First, make sure no light can leak through the filter attachment mechanism and turn off automatic flash.
- Second, set the camera to the highest ISO rating and remember to use the tripod for image registration.
- Focusing was a problem because the infrared is so dark, it was going to take some work before.

Digital filter photo station

Filter Photography Results and Interpretation



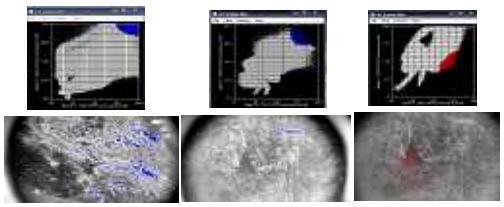
Outcrop-1
Hydroxyl mineral with sub silicification

Outcrop-2
Hydroxyl mineral with sub silicification

Outcrop-2
Iron oxide (hematite, goethite)

- This study examined filter image processing based on alteration outcrops and non-alteration outcrops in fieldwork.
- Shoot filter photos and create to image cube or one packet image file.
- The purest pixels selected from filter photographs using the 2D scatter plot method.
- Scatter plots provides a good way to show the relationship between spectral and image space.

Recognizing hydrothermal alteration on Filter Photography



Outcrop-3
silicification and argillization

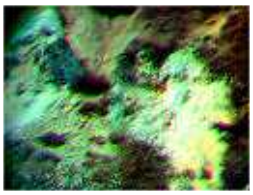
Outcrop-4
silicification and argillization

Outcrop-2
Iron oxide (hematite, goethite)

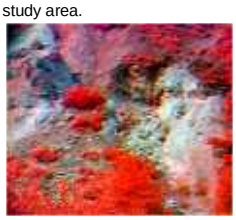
- The purest pixels showed 2D scatter plot of 750 nm and 450 nm sensitive for Hydroxyl minerals and 600 nm and 500 nm for iron oxide minerals.
- Blue pixels represent hydroxyl minerals and red color pixels represent iron oxide minerals.

Filter Photography False Color Composite

- The color composite of filter image 600:500:450 assigned to RGB channels respectively, with histogram equalization, clearly displayed the distribution of iron oxide pixels (pink color pixels).
- 750:450:400 assigned to RGB channels respectively, displayed the distribution of highly altered pixels)light color pixels.
- This result was coincided and recognized with other alteration outcrops filter photos image processing results of study area.



RGB = 600:500:450
Iron oxide image
Pink color pixels

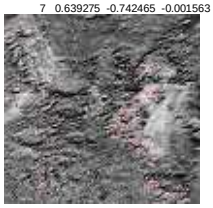


RGB = 750:450:400
Alteration image
Light color pixels

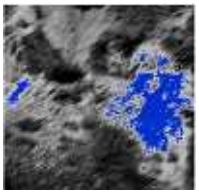
Filter Photography and Principal Component Analysis

- The examination of PCA eigenvector loadings decided which of the principal component extracted information directly related to the target.
- Iron oxide image was correlation with the PC image of 500 nm and 600 nm eigenvector loading and alteration image coincided with PC 1 image.

	400 nm	450 nm	500 nm	550 nm	600 nm	750 nm	900 nm
PC	Band 1	Band 2	Band 3	Band 4	Band 5	Band 6	Band 7
1	0.303378	0.306451	0.602092	0.521392	0.415650	0.064133	0.052970
2	0.169661	0.047326	0.548430	-0.463789	-0.247157	-0.530721	-0.332187
3	-0.212583	-0.046964	0.464213	-0.460632	-0.048967	0.516112	0.506120
4	0.612482	0.575002	-0.326311	-0.386089	0.048430	0.165799	0.094130
5	0.193584	-0.021586	*0.121346*	0.224672	*-0.611067*	0.560183	-0.457874
6	0.112707	0.138909	0.003044	0.316755	-0.614961	-0.326242	0.618909
7	0.639275	-0.742465	-0.001563	-0.031498	0.099120	0.011076	0.170678



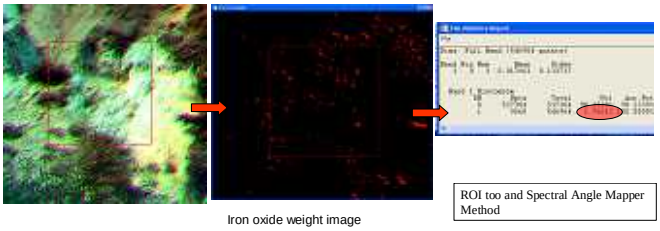
PC 5 for iron oxide image



PC 1 for alteration image

Rechecking Field work

Estimate weight percent from outcrop

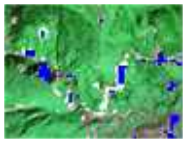


Iron oxide weight image

ROI too and Spectral Angle Mapper Method

Alteration (silica, kaolinite) weight image

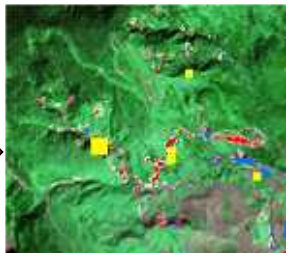
Iron oxide image
VNIR band 2 / band 1 (15m)



Hydroxyl minerals (30 m)
Principal Conponet Analysis

Silica minerals (90 m)
B 13 / B 12

Recognizing hydrothermal alteration on ASTER Images



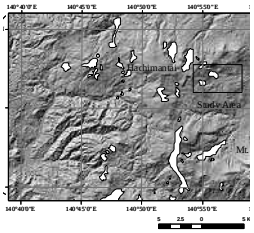
Iron oxide

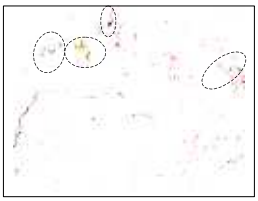
Kaolinite, alunite, montmorillonite

Silica mineral

- The best results for alteration mapping obtained little vegetation cover outcrops and landslide.
- The new filter photo method can be used in this hilly and landslide outcrop as field spectrometer and can be detected up to data of outcrop.

Summary





- The most appropriate index used to extract the iron oxide areas is the ratio of band 2 to band 1 of ASTER data.
- The vegetation mapping based on NDVI has shown no or sparse vegetation cover in the areas.
- Principal Component Analysis selection is based on the examination for PCA eigenvector loading to the for hydroxyl mineral, kaolinite, alunite and illite etc..
- Silica rich areas were mapped with TIR ASTER emissivity band 13 / band 12.

Summary

- New digital filter photography remote sensing method is a good trial tool for detecting signs of alteration. Because
  - can be detected by high resolution (miga pixel).
  - could be used ground truth field checking like mobile field spectrometer.
- This method could be used to discriminate mainly the iron oxide and among hydroxyl mineral sub silicification sub zone.
- Iron oxide sensitivity at 500 nm and 600 nm filter photography and hydroxyl mineral sub silicificication image coincided with the high albedo principal component analysis image (PC1).
- Can be estimated the weight of alteration mineral percent of each outcrop.