RAPID CLASSIFICATION OF INFRA-RED HYPERSONTRAL IMAGERY OF ROCKS WITH DECISION TREES AND WAVELENGTH IMAGES

INTRODUCTION

- Specim hyperspectral camera, sisuchema setup
- Wavelength range: 1000-2500 nm (short-wavelength infrared)
- # pixels across: 384
- Spatial resolution: 26 µm
INFRA-RED HYPERSPECTRAL IMAGE ACQUIRED WITH SISUCHEMA

Silicified, sericitized dacite-andesite

Pixel size: 26 µm
USE OF HIGH SPATIAL RESOLUTION IR IMAGERY

- Provides detailed information on mineralogical composition and microstructure of rocks
- Enables characterization of rock type and rock forming processes
- Spatial scale comparable to “traditional” thin section
- Input in predictive modeling of rock chemistry, e.g. ore grade, and other physical-chemical parameters
PROBLEM

- Image-sizes are typically large (> 1 GB per raw image)
- Images contain many pixels (~ 1 million per image) and bands (288)
- Easy generation of large volumes of image data (1 image acquired in ~5 minutes, incl. sample preparation)
- Interpretation of imagery is labor intensive and time consuming (and often subjective)

Methods are needed for rapid assessment of mineralogical composition

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SISUCHEMA VERSUS HYMAP

Hymap (airborne sensor)

SisuChema

Atmospheric interference

~3.4, 1.40μm

~1.8, 1.95μm

~512 pixels
384 pixels
126 bands
288 bands
1000-2500nm
450-2500nm
450-2500nm
SISUCHEMA VERSUS ASD

ASD

1 point spectrum
2151 bands
350-2500nm

SisuChema

384 pixels
288 bands
1000-2500nm

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Many strategies involve spectral matching of image and reference spectra and thresholding, e.g. Spectral Angle Mapper.

Limitations of these methods:

- A priori knowledge of scene is required for the selection of reference spectra.
- Matching statistics doesn’t show which parts of the spectrum match best (hull shape vs. absorption feature) and which do not.
- Selection of threshold for a “match” is rather subjective.

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MATCHING OF IMAGE AND REFERENCE SPECTRA

Is this a good match?

Molecular bond
Wavelength position of absorption features is used as the dominant spectral characteristic in the interpretation of reflectance spectra.

It is directly related to molecular bond in crystal lattice and often specific to (groups) of minerals.

This information is extracted from wavelength images calculated from the IR imagery.

A decision tree is used for classification of the wavelength imagery.
CALCULATION OF WAVELENGTH POSITION

\[ w(x) = ax^2 + bx + c, \]

where \( w(x) \) is the interpolated reflectance value at position \( x \); \( x \) is the wavelength position in \( \mu \text{m} \); \( a, b, c \) are the coefficients of the parabola function.

\[ w_{\text{min}} = \frac{-b}{2a} \]

where \( w_{\text{min}} \) is the interpolated wavelength position at minimum reflectance; \( a, b \) is the coefficients of the parabola function.

\[ \text{depth} = 1 - f(w_{\text{min}}) \]

where depth is the interpolated depth of absorption feature.
W1, D1: Wavelength and depth of deepest feature
W2, D2: Wavelength and depth of 2nd feature
W3, D3: Wavelength and depth of 3rd feature
LIMITATION OF WAVELENGTH MAPPING

- Only for exploratory analysis -> no classified mineral map
- Small variation in wavelength positions often not visible
- Deep absorption features dominate over shallow features
classification using decision trees

Scatter plot of wavelength image

Wavelength image

Classified map

\[
\text{Silicified, chloritised amygdaloidal (dacite)-andesite}
\]
DESIGN OF DECISION TREE

- Based on analysis absorption features in spectra of USGS spectral library and other spectra (total of 400+ spectra)

Decision tree 2100-2400nm (Al-OH, Fe-OH, Mg-OH & carbonate features):
CLASSIFICATION WITH DECISION TREE

Short-list of candidate spectra

Rock sample: Silicified, sericitised amydaloidal andesite
CLASSIFICATION WITH DECISION TREE

Rock sample: Silicified, sericitised amygdaloidal andesite

Short-list of candidate spectra

dickite_nnmh46967.6913.asc
derellite_gds16.7379.asc
halloysite_cm13.8921.asc
kaolinite_cm3.11788.asc
kaolinite_cm5.11846.asc
kaolinite_cm7.11904.asc
kaolinite_cm9.11962.asc
kaolinite_gds11.12060.asc
kaolinite_kga1.12117.asc
kaolinite_kl502.12272.asc
kaolinite_pfn1_kga2.12176.asc
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CASE STUDY

- Hydrothermally altered rocks
- Associated with VMS Cu-Zn deposits
- Pervasive alteration of volcanic rock
- Archean (3.2 Ga) submarine setting
Albedo – reflectance at 1650nm

- Weakly sericite altered and silicified muddy chert
- Silicified, sericitized xenocrystic-phenocrystic (dacite)-andesite
- Silicified, sericitized phenocrystic (dacite)-andesite
- Silicified, sericitized weakly phenocrystic dacite
- Silicified, sericitized weakly phenocrystic quenched dacite
- Silicified, sericitized weakly phenocrystic dacite
- Silicified, sericitized weakly amygdaloidal andesite
- Silicified, sericitized weakly amygdaloidal titanium-rich andesite
- Ferruginous, chloritised basalt
- Ferruginous, chloritised (pyroxene-bearing) andesite
- Silicified, and chloritised amygdaloidal (dacite)-andesite

Micrograph thin section

[Map with geological features]
Interpreted mineralogy:

- **Albedo** – reflectance at 1650nm
- **Classification** – general decision tree

Zonation:
- **Al-rich illite-muscovite**
- **Al-poor illite-muscovite**
- **Chlorite +/- illite-muscovite**

Pervasive alteration:
- **Kaolinite filled amygdales**
- **Illite-musc rich amygdales**

**Illite-muscovite alteration**
- **Al-rich illite-muscovite < 2203nm – chert**
- **Al-rich illite-muscovite > 2210nm**
- **Al-poor illite-muscovite > 2210nm**
- **Kaolinite**
- **Shallow Fe-OH feature 2260-2300nm**
- **Fe-chlorite**
- **Chlorite**
- **Mg-Fe chlorite**
SUMMARY AND CONCLUSIONS

- Classification of wavelength images with decision trees provides method for rapid assessment of mineral composition
- No a priori information on mineralogy of rock sample is required
- Focus on mineral absorption features (diagnostic for many minerals, unlike hull-shapes)
- Objective and reproducible result
FURTHER WORK

- Scene-specific optimization of decision tree
- Automation of processing steps
- Extraction of microstructural / textural information
Spare slides:
STEP 2 – DETAILED IMAGE ANALYSIS

Objective: To optimize decision tree for specific scene – sample set

- Enhancement of spectral variation in wavelength images
- Calculation of summary products, such as illite and kaolinite crystallinity, ferrous drop, etc
- Visual-spatial analysis of contrast enhanced images and selection of additional end member ROIs
- Analysis of ROIs: Spectra and scatter plots of wavelength positions and depth of absorption features and summary products
- Improvement of slicing intervals and update of decision tree

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Albedo: Reflectance at 1650nm

Classified with decision tree

CC of W1, W2, W3 between 1850-2100nm

Illite-musc crystallinity

Summary product:
Illite-musc crystallinity = Depth $H_2O$ / Depth $Al-OH$

[Image of depth measurement graphs]
Illite-musc crystallinity

Albedo: Reflectance at 1650nm

**ROIs**

<table>
<thead>
<tr>
<th>Phenocyst</th>
<th>Color</th>
<th>Reflectance</th>
</tr>
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<tbody>
<tr>
<td>Xenocryst 1a</td>
<td>Green</td>
<td>5.471</td>
</tr>
<tr>
<td>Xenocryst 1b</td>
<td>Blue</td>
<td>922</td>
</tr>
<tr>
<td>Matrix 1</td>
<td>Yellow</td>
<td>1.674</td>
</tr>
<tr>
<td>Matrix 2</td>
<td>Cyan</td>
<td>2.040</td>
</tr>
</tbody>
</table>

**Graph:**

- Phenocryst (red) 1235 points
- Xenocryst 1a (green) 5471 points
- Xenocryst 1b (blue) 922 points
- Matrix 1 (yellow) 5074 points
- Matrix 2 (cyan) 2040 points

**Wavelength (Nanometers):**

800 1000 1200 1400 1600 1800 2000 2200 2400 2600
Illite-musc crystallinity

Classified with decision tree

Update decision tree with crystallinity data

Interpretation:
- Illite/muscovite matrix
- Well-ordered illite/muscovite phenocryst
- Poorly-ordered illite/muscovite

Phenocryst Length: 1.4 mm

Xenocryst Length: 2 mm
Albedo – reflectance at 1650nm

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- Al-rich illite-muscovite > 2210nm
- Al-poor illite-muscovite
- Chorite +/- illite-muscovite
- Ordered illite/muscovite
- Disordered illite/muscovite
- Ordered illite/muscovite
- Disordered illite/muscovite
- kaolinite
- “Ordered” kaolinite
- Shallow Fe-OH feature 2260-2300nm
- Fe-chlorite
- Chlorite
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- Albedo – reflectance at 1650nm
Albedo – reflectance at 1650nm

Classification – general decision tree

Classification – decision tree - sample specific

Interpreted mineralogy:

Phenocrysts
Xenocrysts
Amygdales

Volcanic texture!