Mineral Deposit Characterization from Airborne and Spaceborne Imaging Spectroscopy Data, Applications to the EnMAP Mission

Ch.Mielke, N.K. Boesche, C.Rogass and H. Kaufmann
1. Mineral Deposit Types
2. Expert Systems
3. Hydrothermal Gold (Rodalquilar, Spain)
4. Porphyrry Cu/Mo (Haib River, Namibia)
5. Conclusions
Why Spectroscopy in Geology?

1. Identification of mineral mixtures, groups and phases
2. Reduction of exploration costs
3. Full mining lifecycle monitoring (ground based, airborne, spaceborne) for management and mitigation operations.
4. Areal extensive mapping

Hyperion CIR Composite: R: 2.2μm, G: 0.75 μm, B: 0.4 μm
Questions to be answered

1. How do sensor characteristics influence performance of mapping algorithms (e.g.) expert systems?
2. What processing steps are necessary to achieve a robust mapping result?

Hyperion CIR Composite: R: 2.2μm, G: 0.75 μm, B: 0.4 μm
Mineral deposit types
Acid sulphate gold
(Cerro Cinto)

Cerro Cinto Mine Face

<table>
<thead>
<tr>
<th>Mineral Assemblage</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vuggy quartz and alunite</td>
<td>mineralized Zone</td>
</tr>
<tr>
<td>Quartz, Alunite, Jarosite</td>
<td>Adv. Argillic Zone</td>
</tr>
<tr>
<td>Kaolinite, Illite</td>
<td>Argillic Zone</td>
</tr>
<tr>
<td>Epidote, Chlorite</td>
<td>Propylitic Zone</td>
</tr>
</tbody>
</table>
Porphyry Cu/Mo
(Haib River)

<table>
<thead>
<tr>
<th>Mineral Assemblage</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrite, Chalcopyrite, Malachite, Chrysocolla, Sericite</td>
<td>mineralized Zone</td>
</tr>
<tr>
<td>Qz, Sericite, Pyrite</td>
<td>Sericitic Zone</td>
</tr>
<tr>
<td>Epidote, Chlorite</td>
<td>Propylitic Zone</td>
</tr>
</tbody>
</table>
Image spectra (unknown) \[ \rightarrow \] Cont. Removal \[ \rightarrow \] Matching according to char. Features \[ \rightarrow \] Results

Reference spectra (well known)
How to isolate important feature information from an unknown spectrum?
Haib-Cu/Mo modified vs. simple convex hull

mineral index convex hull

chlorite

mineral index local hull

sericite jarosite
Hydrothermal Gold Deposits
Remote Sensing section – test sites
Rodalquilar Hydrothermal Au

<table>
<thead>
<tr>
<th>Mineral Assemblage</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vuggy quartz and alunite</td>
<td>mineralized Zone</td>
</tr>
<tr>
<td>Quartz, Alunite, Jarosite</td>
<td>Adv. Argillic</td>
</tr>
<tr>
<td>Kaolinite, Illite</td>
<td>Argillic Zone</td>
</tr>
<tr>
<td>Epidote, Chlorite</td>
<td>Propylitic Zone</td>
</tr>
</tbody>
</table>

Cerro Cinto Mine Face

Kaolinite/Alunite

Adv. Argillic Alteration
Pure Oz, Alunite+Jarosite

0m

12m
Rodalquilar
(Clay minerals, etc.) Hydrothermal Au

Hyperion CIR Composite:
R: 2.2μm, G: 0.75μm, B: 0.4μm

Legende

mica_gp2
- no_data
- calcite_abundant
- calcite.8+montmorillonite_Na.2
- dolomite.5+montmorillonite_Na.5
- dolomite.25+calcite.25+mont_Na.5
- epidote
- chlorite+muscovite
- muscovite_lowAl
- illite
- kaolinite_wxl
- kaolin.5+muscovite_medhighAl
- montmorillonite_Ca
- alunite_K_250c
- jarosite_Na
- kaol_possible_alunite_or_dickite
- buddingtonite
- buddingtonite+montmorillonite
- chalcedony
- gypsum

Main Alteration Centers
Rodalquilar
Hydrothermal Au
What about Sensors (Hyperion)

Hyperion CIR Composite:
R: 2.2 μm, G: 0.75 μm, B: 0.4 μm

mineral index

illite

alunite/pyroph.

kaolinite
Rodalquilar
Hydrothermal Au
What about Sensors (EnMAP)

Simulated EnMAP CIR Composite:
R: 2.2\,\mu m, G : 0.75 \,\mu m, B: 0.4 \,\mu m

mineral index

illite

alunite/pyroph.

kaolinite
Rodalquilar
Hydrothermal Au
What about Sensors (EnMAP)

chlorite

alunite/pyrophyllite
kaolinite
Porphyry Cu/Mo Deposits
Mineral Deposits in southern Africa
Geological Mapping, Expert Systems

Landsat 7 CIR Composite: R: 2.2μm, G: 0.8 μm, B: 0.5 μm

- Haib River (Cu, Mo)
- Tantalite Valley (REE)
- Henkries (Li, U)
- Aggeneys Cu, Pb, Zn

mineral deposit sites
55 km
Haib-Cu/Mo and modified convex hull as detection tool

simulated EnMAP composite:
R: 2.2\(\mu m\), G: 0.75\(\mu m\), B: 0.4\(\mu m\)

chlorite

sericite

jarosite

mineral index
Haib-Cu/Mo
Geological mapping, Hyperion Data

Box outlining roughly the main ore zone

Hyperion CIR Composite:
R: 2.2μm, G: 0.75 μm, B: 0.4 μm

chlorite
sericite
jarosite
Haib-Cu/Mo
Geological mapping, expert systems (USGS MICA)

Box outlining roughly the main ore zone
Via secondary iron minerals from sulphide ore oxidation

Hyperion CIR Composite:
R: 2.2μm, G: 0.75μm, B: 0.4μm

Legende

mica_gp1
- no_data
- hematite.thincoat
- hematite/lg.gr.br34c
- hematite/lg.gr.br25c
- Fe-Hydroxide
- goethite.thincoat
- goethite/coarsergr
- goeth+jarosite
- jarosite_br34a2
- ferrirhydrite
- Schwertmannite
- Acid Mine Dr.
- Desert Varnish
- Hypersthene
- Diopside
- Chlorite Muscovite
Haib-Cu/Mo
Geological mapping, expert systems (USGS MICA)

Hyperion CIR Composite:
R: 2.2μm, G: 0.75 μm, B: 0.4 μm

Zones of past hydrothermal activity?
Conclusions

- Advanced spaceborne imaging spectrometers, with superior SNR (especially in the short-wave infrared), needed for geological applications -> EnMAP

- Expert Systems need further development (e.g. feature isolation, matching, unmixing)

- First steps of an exploration program can benefit from first order spaceborne sensors, on a localized scale airborne instruments can provide further spatial detail
Thank you!

Contact: Christian Mielke PhD candidate
chmielke@gfz-potsdam.de
+493312881763

Special Thanks to:
- USGS and NASA for Hyperion Data and Tetracorder/Mica
- GFZ Potsdam and EnMAP program