Remote Sensing & Mineral Resources

Prof. Eric PIRARD

GeMMe – Georesources & Geoimaging - PhD’s & PostDocs
Sensing Resources
To support the spherical economy
Spherical Economy

Atmosphere

Biosphere
  Bioresources
  Organic matter

Geosphere
  Georesources
  Mineral materials

Anthroposphere
  Manufactured goods
  Waste

If you can’t grow it, you’ll have to dig it
A world of resources

- Energetic resources
  - Oil, Gas, Coal, Lignite,…
  - Uranium

- Water resources

- Industrial Minerals
  - Sand, aggregates, gypsum, …
  - Kaolin, talc, diatomea,…
  - Gems,…

- Metallic resources
  - Base metals
  - Precious metals

Georesources?

- Non-renewable
- Vital, Purifiable
- Non-renewable, Synthesizable
- “Recyclable”
A world of resources

A mineral deposit is

- A mineral occurrence of sufficient **SIZE** and **GRADE** that it might, under the most favorable of circumstances, be considered to have economic potential.

**Discovery**

- Prospectivity mapping (GIS-based)
  - Remote sensing
  - Geological mapping
  - Geochemical
  - Geophysical (magnetic, gravimetric, seismic, ...)

- Orebody evaluation
  - Drilling and sampling
  - Geostatistics for grade and volume estimation
  - Geometallurgy
Mapping Minerals

*From microns to kilometers*
Mapping Minerals

- AMCO

Automated Microscopic Characterization of Ores

UPM Politecnica de Madrid - GeMMe
TSL Labs
First Quantum (CLC) - KGHM

Microscopy

Chalcopyrite [A]
Chalcopyrite [B]
Copper
Cuprite
Digenite
Molybdenite
Chalcocite
Rutile
Molybdenite
Pyrite
Mapping Minerals

• **ANCORELOG**

**AncoreLog** – Analytical Core Logging System
A mobile drill core logging system that measures chemical, physical and structural rock properties with high accuracy and classifies into geological, geotechnical and geometallurgical domains.
Mapping Minerals

- Airborne / UAV
  - LIDAR
  - Hyperspectral Instruments

- Spaceborne
  - Landsat ETM - 8
  - Aster
  - Sentinel

Copernicus Spaceborne Data for Exploration, Mining and Landfill Mining Applications

MinEODust – Mapping Dust Dispersion around Mining / Ore Handling sites
Exploring Remote Regions
The Space Shepherd
Exploring remote regions

- Many deposits were discovered by... shepherds!
  - Colourful alterations

Rio Tinto

Cerro Colorado
Exploring remote regions

- Modern shepherds use band ratios to reveal « gossans »

ASTER

ASTER B2/B1
Exploring remote regions

- Modern shepherds use band ratios to reveal «clays» and «carbonates»
Supporting Field Geology
Remote Mapping
Supporting Field Geology

- Remote geological mapping
Supporting Field Geology

Discovering orebodies

- False colour imaging on shaded relief

3D visualisation of an ASTER image wrapped over an InSAR DEM. The cliff separates sedimentary (upper-right part) and metamorphic - volcanic (lower-left part) zones. Bonino et al., 2001, GIROS project
Supporting Field Geology

Discovering orebodies

- False colour imaging vs. geological boundaries

Visualisation of lithological information from colour-composite image (bands 7-5-4).
Bonino et al., 2001, GIROS project
Supporting Field Geology

Advanced Mineralogical Mapping

SRTM 90m

ASTER

End-Members (PPI)
Supporting Field Geology

Advanced Mineralogical Mapping

Revealing Metallogenical Targets
Revealing Metallogenical Targets

• Mapping of lineaments and possible « shear zones »

Extraction of lineaments from LANDSAT colour-composite image

- $R =$ First principal component
- $G =$ Landsat image (band 5) + directional filter $0^\circ$
- $B =$ Landsat image (band 5) + directional filter $45^\circ$

Kayes-Kenieba region, Western Mali
Revealing Metallogenical Targets

- Mapping of lineaments and possible « shear zones »
Revealing Metallogenical Targets

- More powerful technologies are needed to
  - Penetrate below the surface
  - Reveal anomalies through vegetation

A N Hawu Hede et al., 2015, A new vegetation index for detecting vegetation anomalies due to mineral deposits with application to a tropical forest area, Remote Sensing of Environment, V 171.
Mine Site Monitoring
Mine Site Monitoring

- Orthophotos and DEMs of quarries
  - UAV imaging

An orthophoto of one of the pits at the Pueblo Viejo gold mine (Barrick) generated by an eBee (© FlySense)

Stockpile measurement
http://asmireland.ie/
Mine Site Monitoring

- Acid Mine Drainage

Detection of acid drainage effects around Rosia Poieni mine in Romania using ASTER images. – 5th EARSeL SIGIS workshop
Industrial Site Monitoring

- Hyperspectral monitoring of industrial sites in the Meuse valley (Liège, Belgium)
  - AHS-160 Hyperspectral Instrument

Industrial Site Monitoring

- Dust Dispersion
  - Spectral Feature Matching
    - Coking coal
    - Iron sinter
Industrial Site Monitoring

- Vegetation Stress
  - Geochemical mapping
  - Vegetation indices

High As & Pb concentrations potentially linked to unhealthy vegetation
### Processing and Handling

- **Volume estimation of stocks**

<table>
<thead>
<tr>
<th>Product</th>
<th>Size</th>
<th>Angle of Repose (degrees)</th>
<th>Bulk Density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average</td>
<td>Std. Dev.</td>
</tr>
<tr>
<td>Ultra-fines (pellet feed)</td>
<td>&lt; 0.15 mm = 92%</td>
<td>38</td>
<td>4</td>
</tr>
<tr>
<td>Fines (Sinter Feed (+concentrates))</td>
<td>[1-9.5 mm] = 58% &lt; 1mm = 42%</td>
<td>36</td>
<td>2</td>
</tr>
<tr>
<td>Pellet</td>
<td>[8-18mm] = 76%</td>
<td>28</td>
<td>4</td>
</tr>
<tr>
<td>Lump</td>
<td>[12.5-31.5 mm] = 65%</td>
<td>31</td>
<td>0</td>
</tr>
</tbody>
</table>

**Measured distances**

- heap outline
- crest line with unknown height
Regional Monitoring
Regional Monitoring

- Map-X and the EITI
  - Transparency of supply chains
Regional Monitoring

• Map-X and the EITI
  o Transparency of supply chains

**Objectives**
To support the multi-stakeholder group of the Extractive Industries Transparency Initiative (EITI) to map payment information at the project level and to contextualize relative socio-economic and environmental data.

**Clients**
- Extractive Industry Transparency Initiative
- World Bank
- Ministry of Planning

**Goals**
- National

**Completed**
December 2017
What’s next? *Imagination*...