



# Remote Sensing & Mineral Resources

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GeMMe – Georesources & Geoimaging - PhD's & PostDocs

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# Sensing Resources

*To support the spherical economy*

# Spherical Economy

Atmosphere

Biosphere  
*Bioresources*  
*Organic matter*



Anthroposphere  
*Manufactured goods*  
*Waste*

Geosphere  
*Georesources*  
*Mineral materials*

*If you can't grow it, you'll have to dig it*

# A world of resources

## Georesources ?



- Energetic resources
    - Oil, Gas, Coal, Lignite,...
    - Uranium
  - Water resources
  - Industrial Minerals
    - Sand, aggregates, gypsum, ...
    - Kaolin, talc, diatomea,...
    - Gems,...
  - Metallic resources
    - Base metals
    - Precious metals
- *Non-renewable*
  - *Vital, Purifiable*
  - *Non-renewable, Synthesizable*
  - *"Recyclable"*

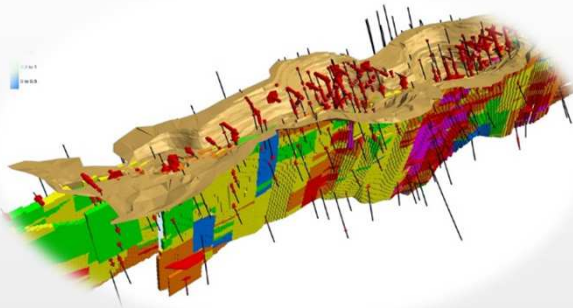
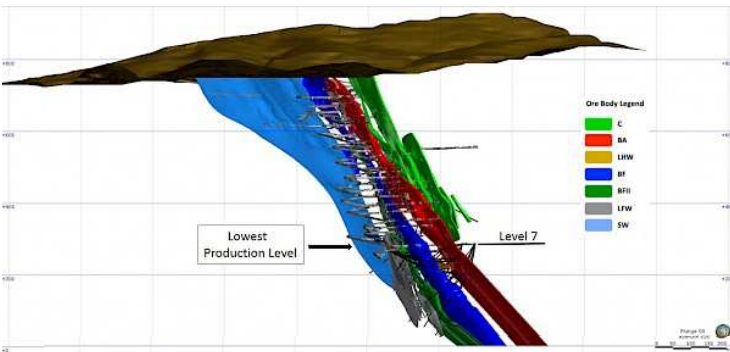
# A world of resources

## Deposits

- 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



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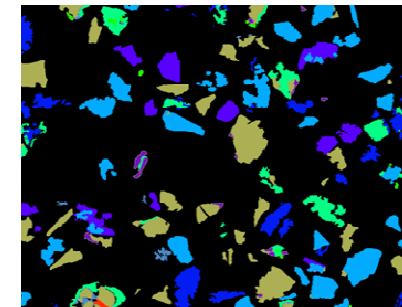
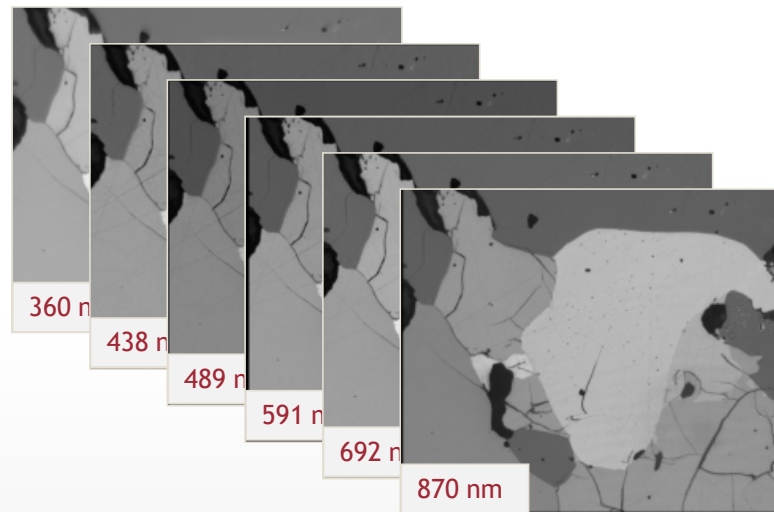
# Mapping Minerals

*From microns to kilometers*

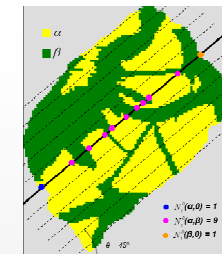
# Mapping Minerals

## Microscopy

- AMCO

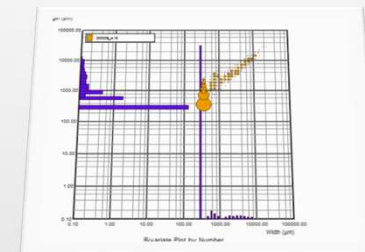


- Chalcopyrite (A)
- Chalcopyrite (B)
- Copper
- Cuprite
- Digenite
- Malachite
- Chalcosite
- Rutile
- Molybdenite
- Pyrite



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

**AMCO**  
 Automated Microscopic Characterization of Ores



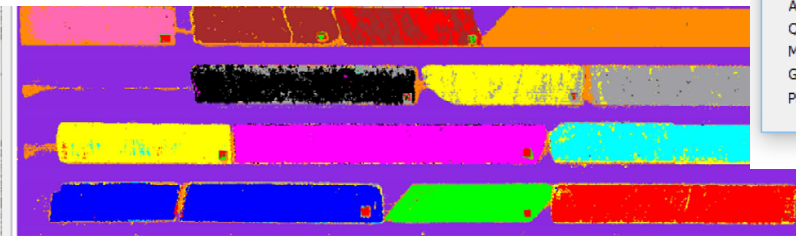
# Mapping Minerals

## Core-scanning

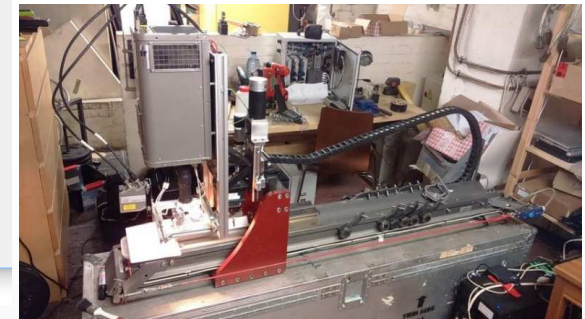
- ANCORELOG



© DMT



Legend	
Magnetite Amphibolite	Red
Amphibolite	Green
Barite Quartzite	Blue
Magnetite Barite	Cyan
Leptite	Magenta
Magnetite Quartzite	Yellow
Garnet Magnetite	Grey
Aluminous schists	Black
Quartzitic Schists	Orange
Massive Magnetite	Brown
Garnet Quartzites	Pink
Plastic	Purple



DMT, leader  
ULiege – GemMe  
Fraunhofer EZRT; BGR; GTK  
LTB; Bachmann; ; U Paris Sud; Eramet; MATSA

**AncoreLog** – Analytical Core Logging System

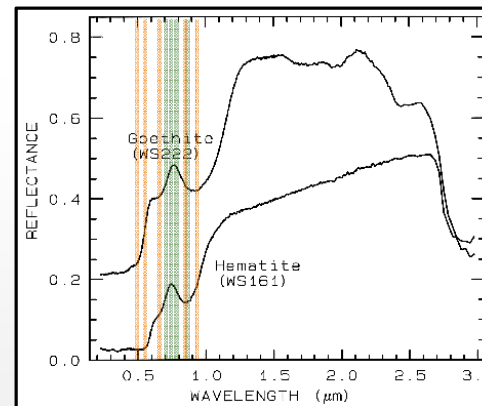
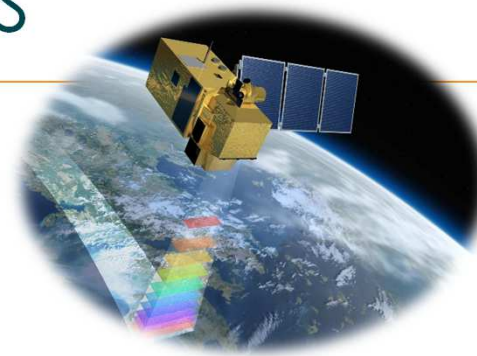
A mobile drill core logging system that measures chemical, physical and structural rock properties with high accuracy and classifies into geological, geotechnical and geometallurgical domains



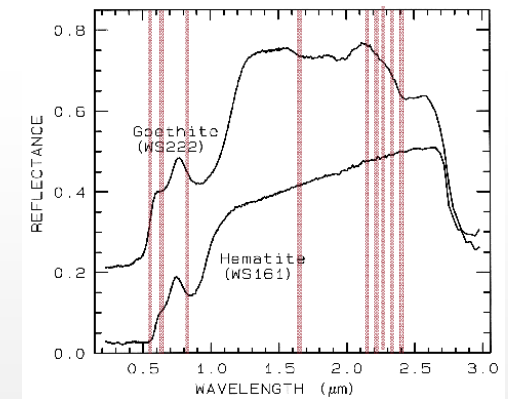
# Mapping Minerals

## Remote Sensing

- Airborne / UAV
  - LIDAR
  - Hyperspectral Instruments
- Spaceborne
  - Landsat ETM - 8
  - Aster
  - Sentinel



Sentinel 2 bands 2-3-4-8  
bands 5-6-7-8A



Aster bands 1-2-3 (VNIR)  
& 4 to 9 (SWIR)



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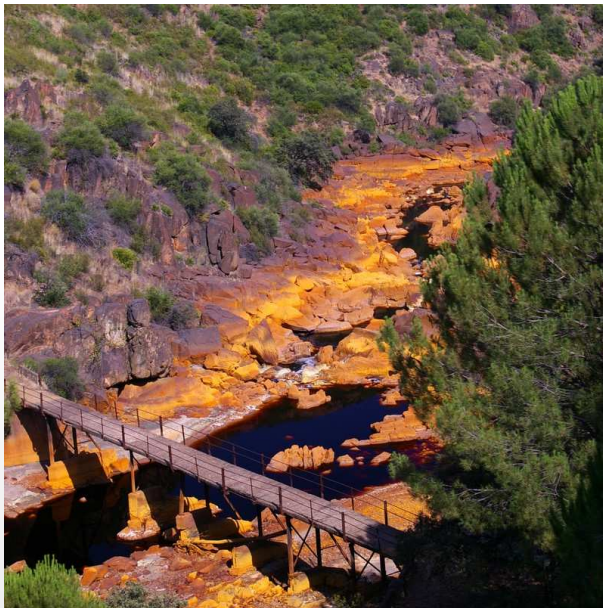
# Exploring Remote Regions

*The Space Shepherd*

# Exploring remote regions

## Unaided eye

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



Rio Tinto

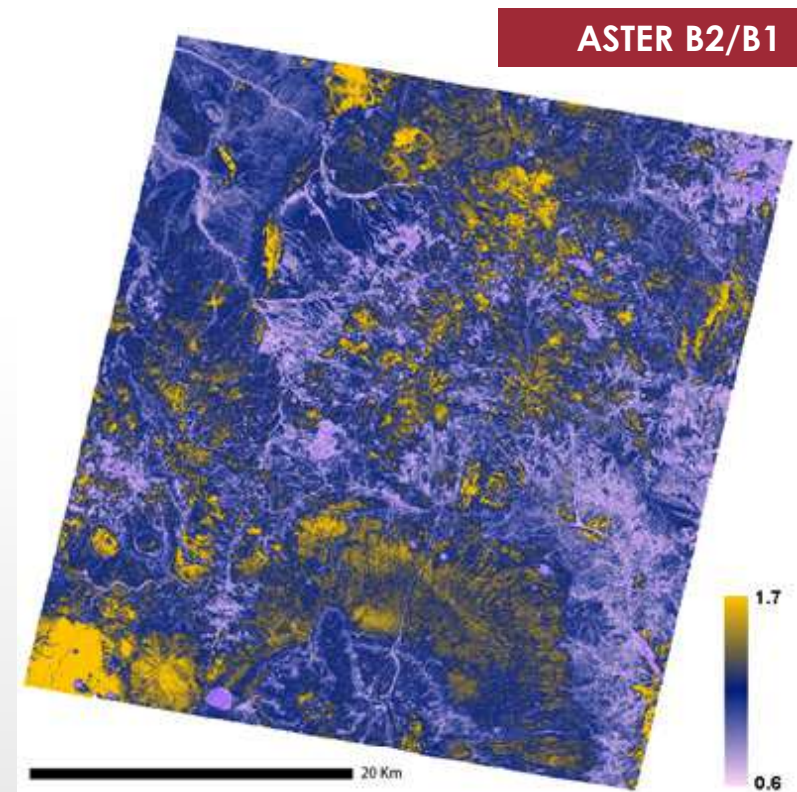
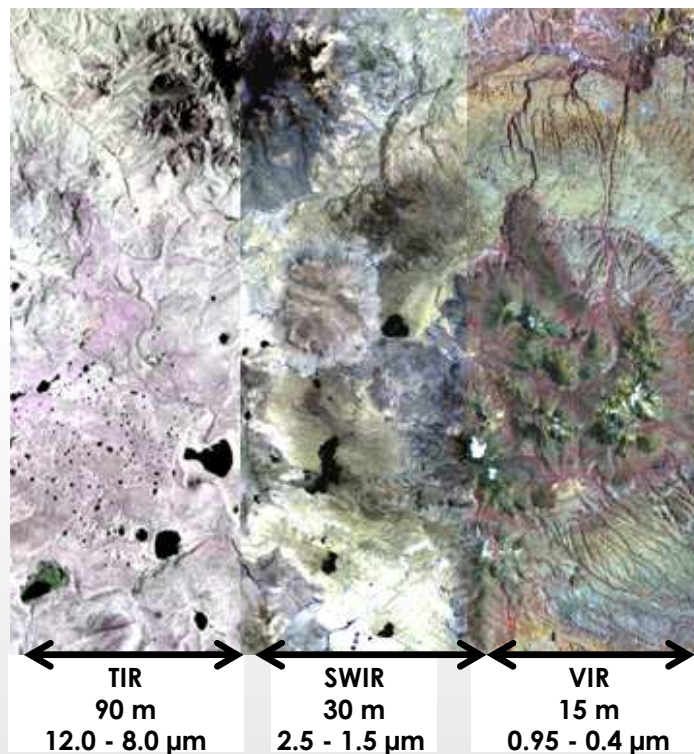


Cerro Colorado

# Exploring remote regions

ASTER

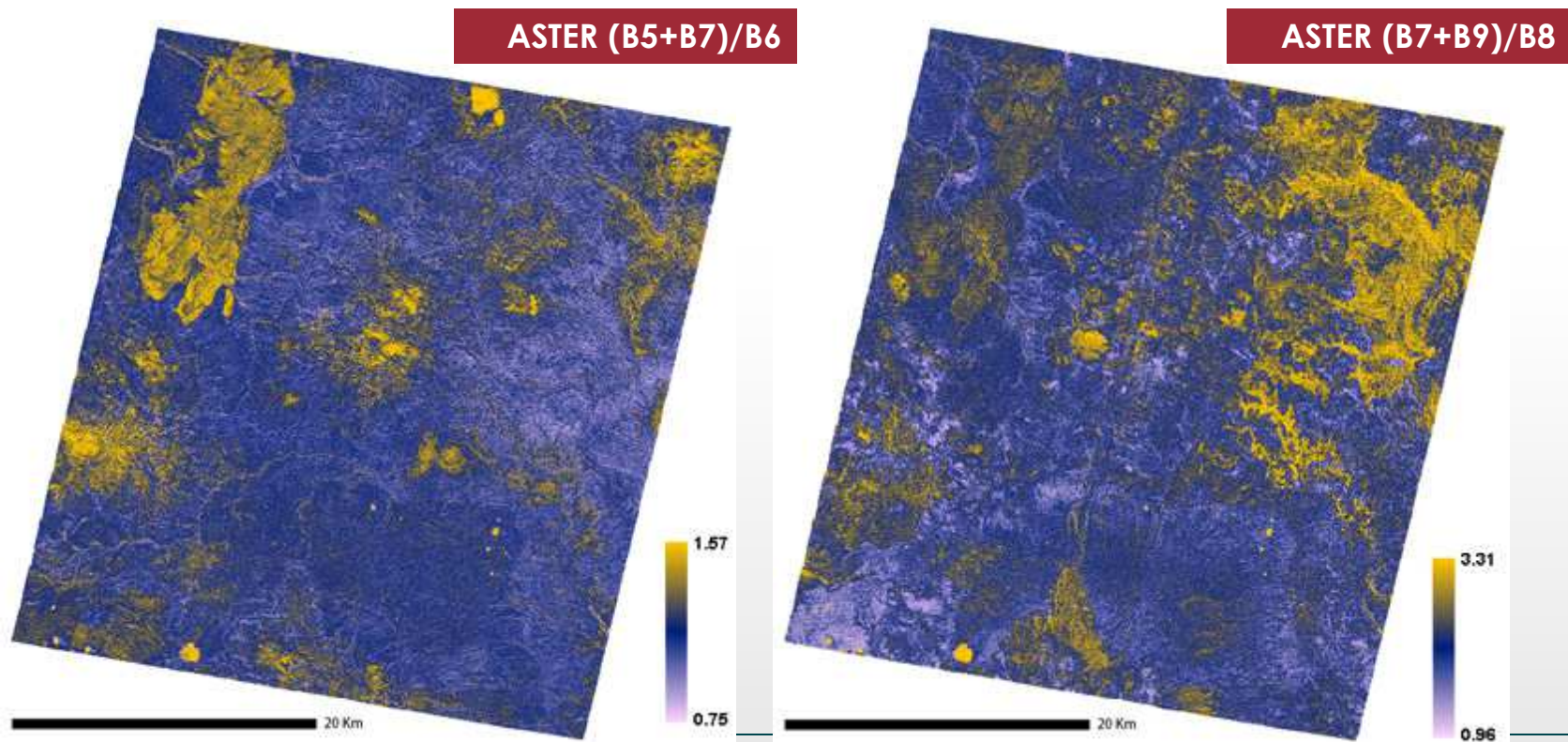
- Modern shepherds use band ratios to reveal « gossans »



# Exploring remote regions

ASTER

- Modern shepherds use band ratios to reveal « **clays** » and « **carbonates** »



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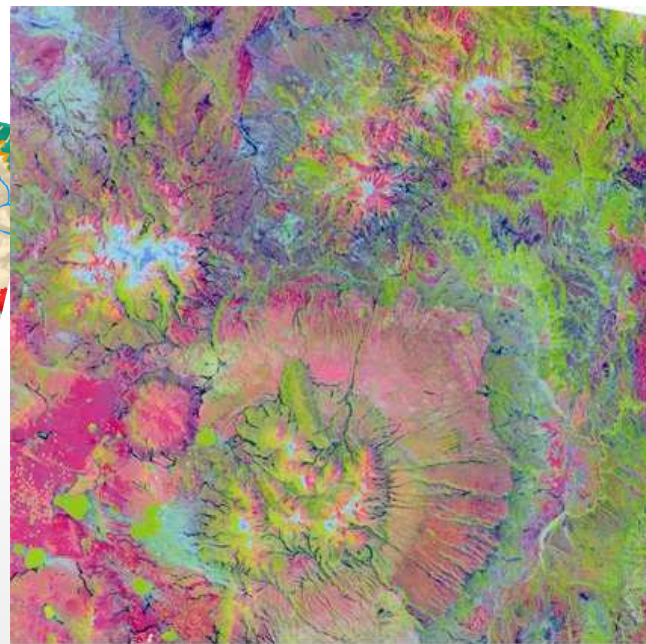
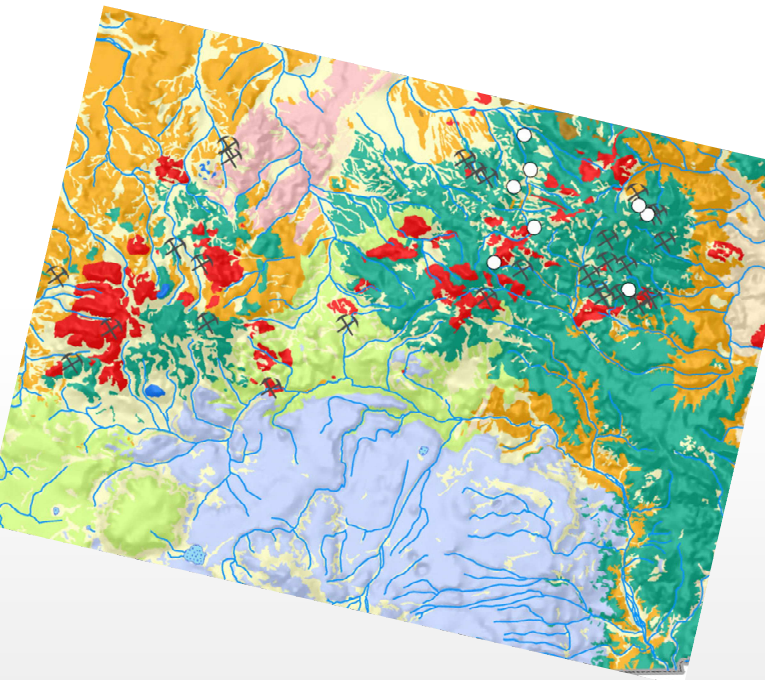
# Supporting Field Geology

## *Remote Mapping*

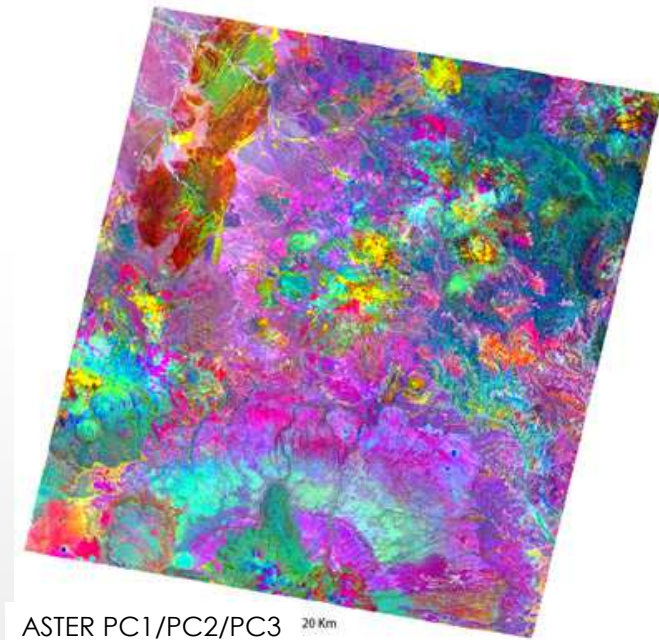
# Supporting Field Geology

## LANDSAT - ASTER

- Remote geological mapping



Landsat TM PC1/PC2/PC3 40Km

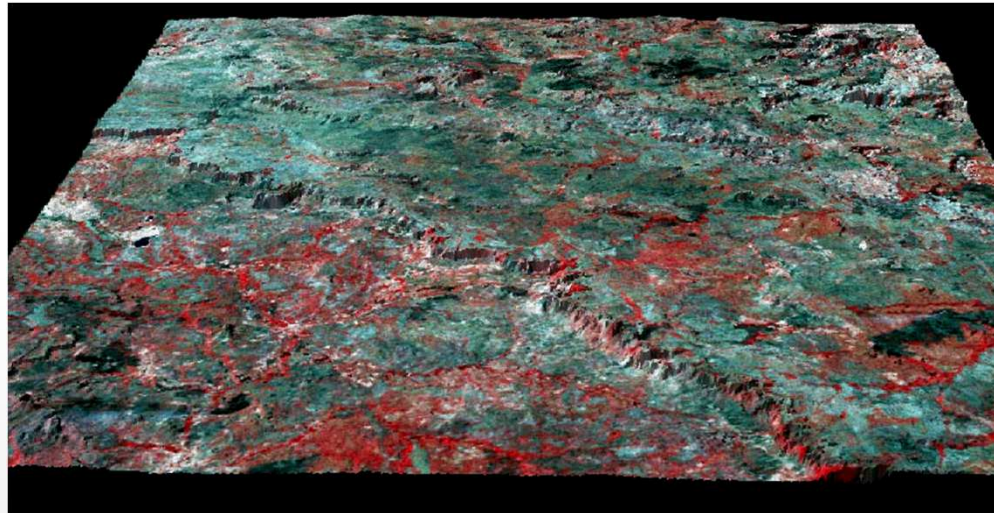


ASTER PC1/PC2/PC3 20 Km

# 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

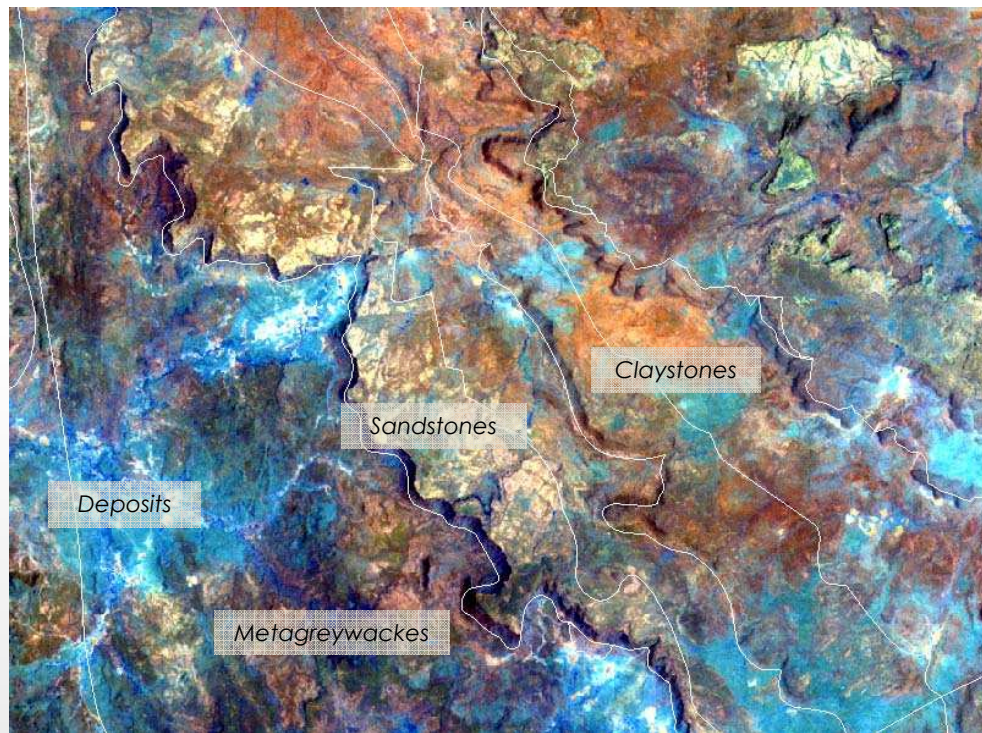




# Supporting Field Geology

## Discovering orebodies

- False colour imaging vs. geological boundaries

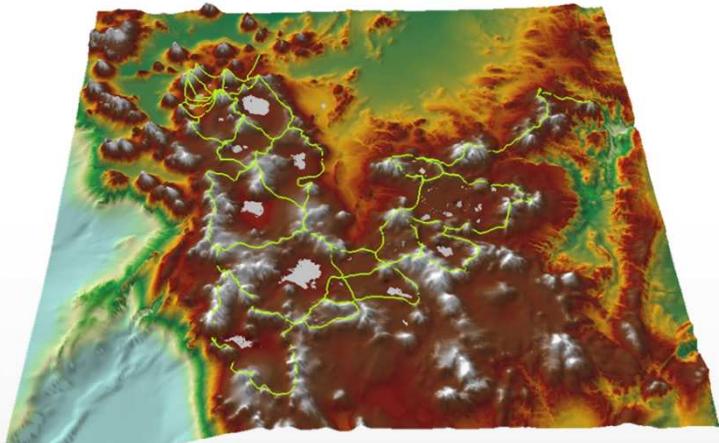


Visualisation of lithological information from colour-composite image (bands 7-5-4).  
Bonino et al., 2001, GIROS project

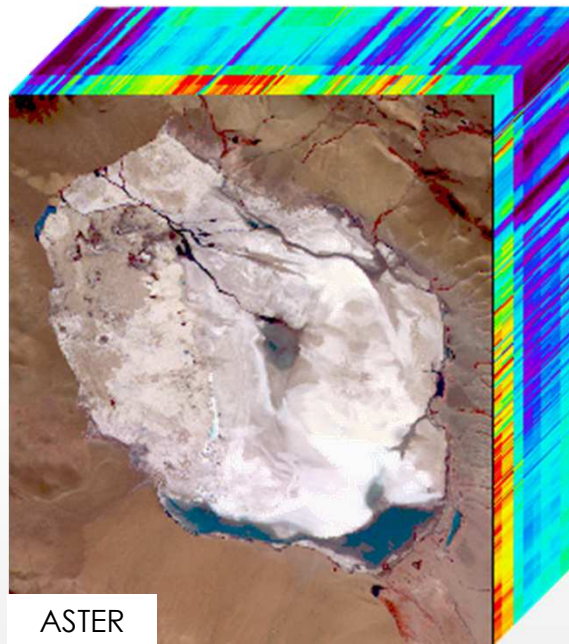


# Supporting Field Geology

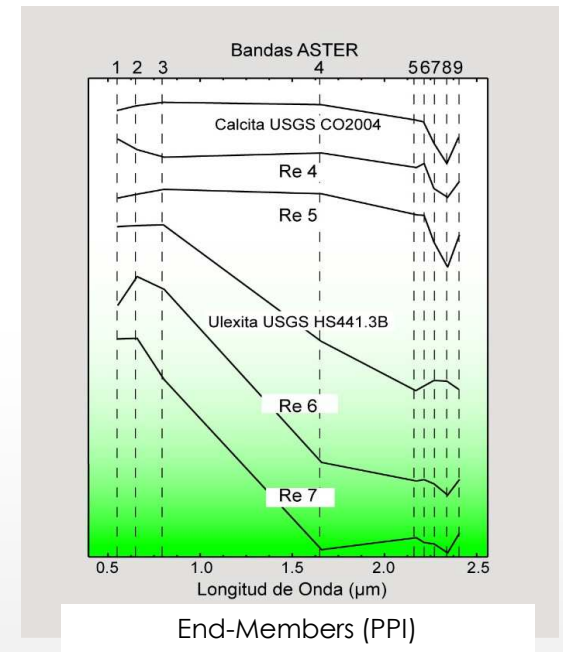
## Advanced Mineralogical Mapping



SRTM 90m

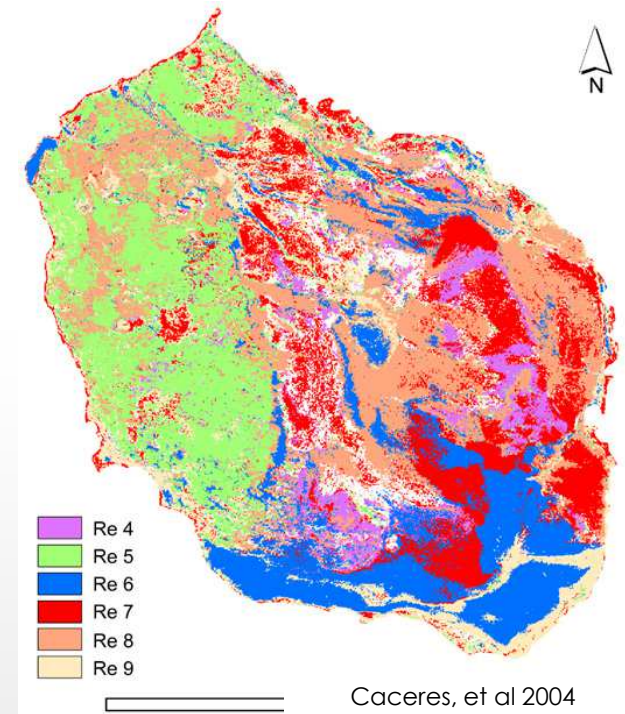
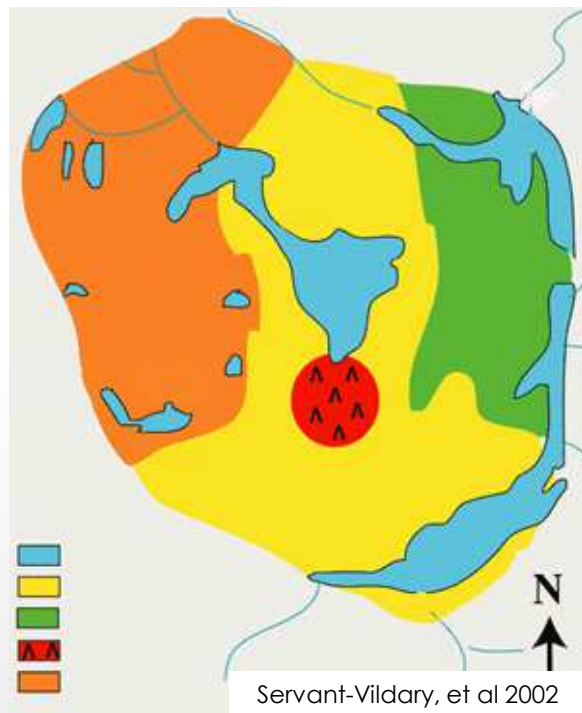


ASTER



# Supporting Field Geology

## Advanced Mineralogical Mapping



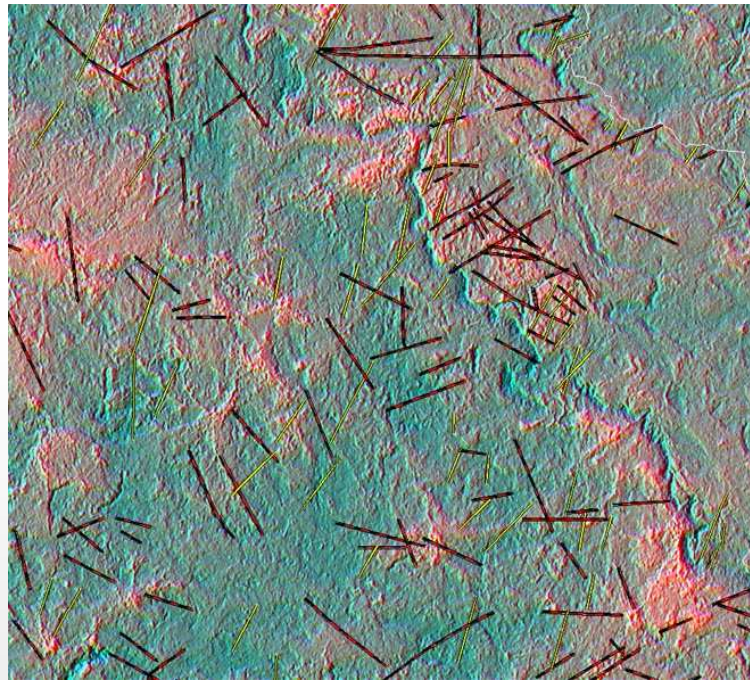
Caceres, F., Ali-Ammar, H., & Pirard, E. (2008). Mapping evaporitic minerals in Sud Lipez salt lakes (Bolivia) using remote sensing. *Reviews in Economic Geology*, 16.

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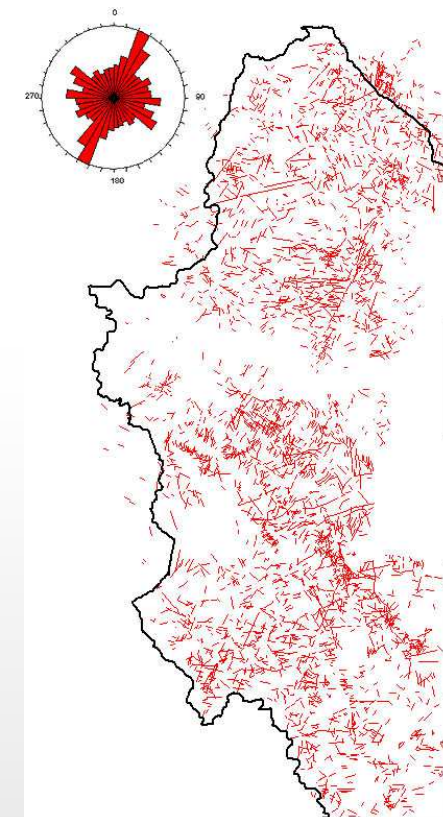
# Revealing Metallogenical Targets

# 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°  
B = Landsat image (band 5) + directional filter 45°

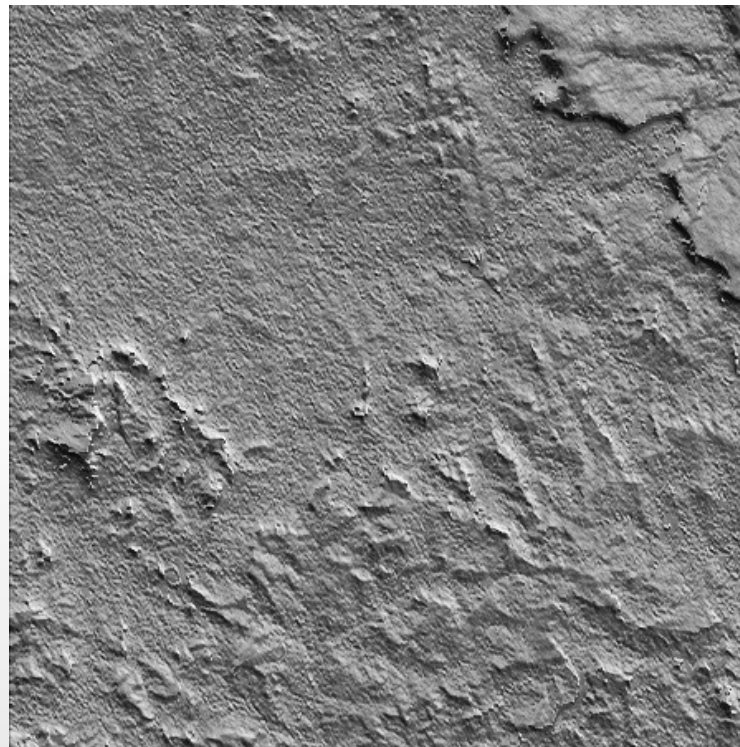


Kayes-Kenieba region, Western Mali

# Revealing Metallogenical Targets

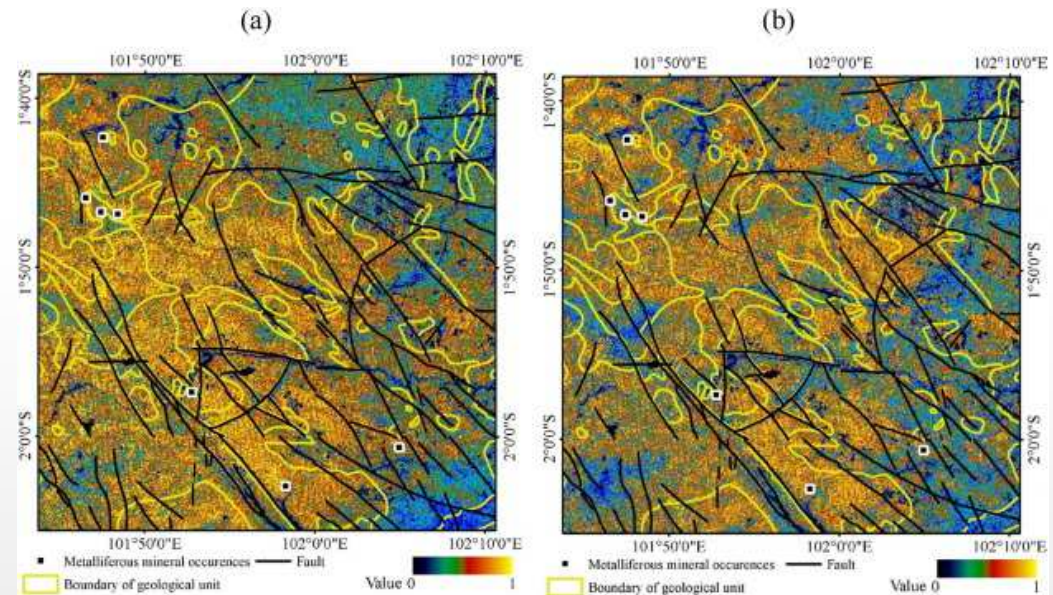
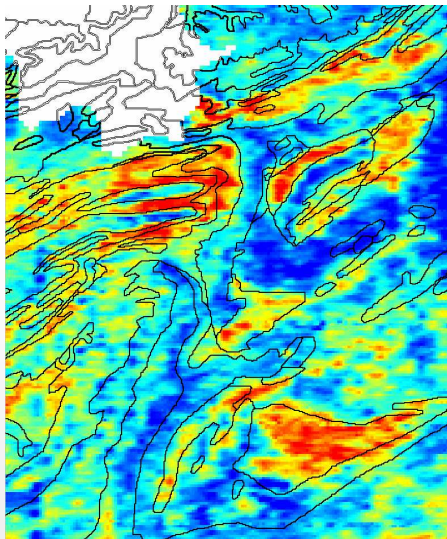
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- Mapping of lineaments and possible « shear zones »



# 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.*

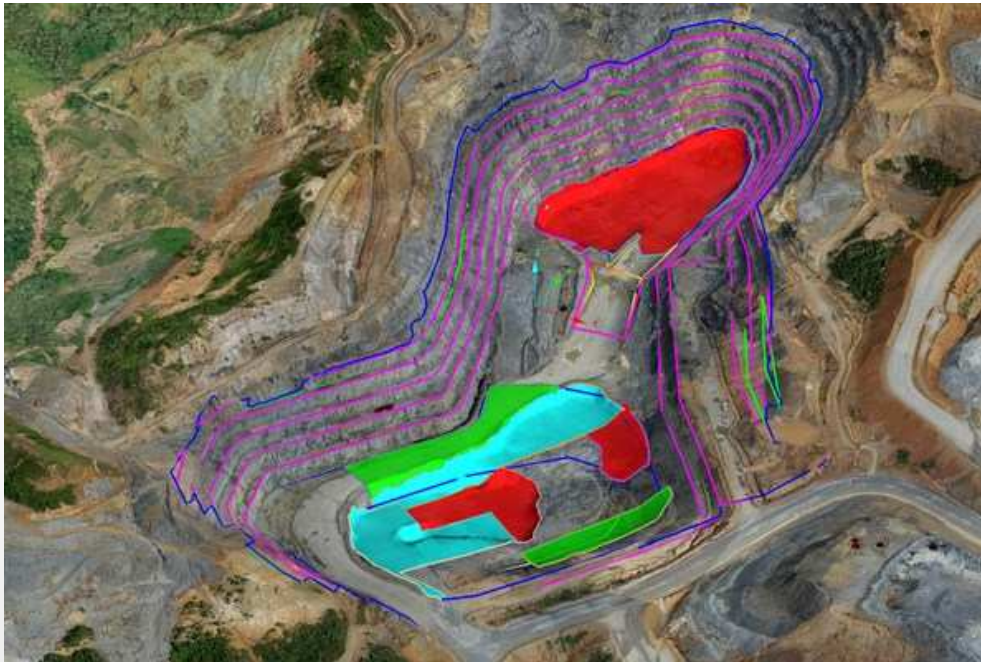
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# Mine Site Monitoring

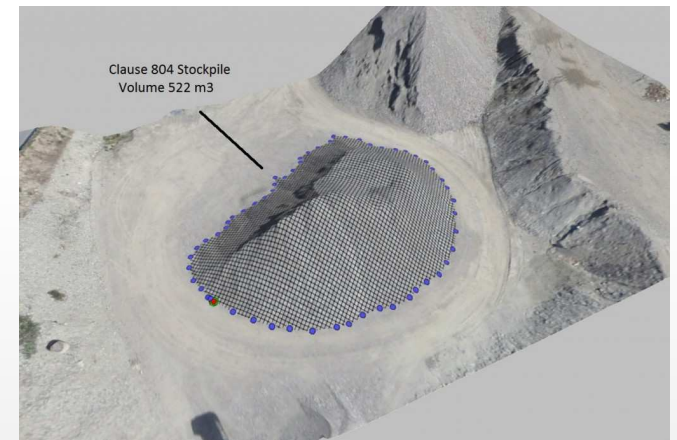


# Mine Site Monitoring

- 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)



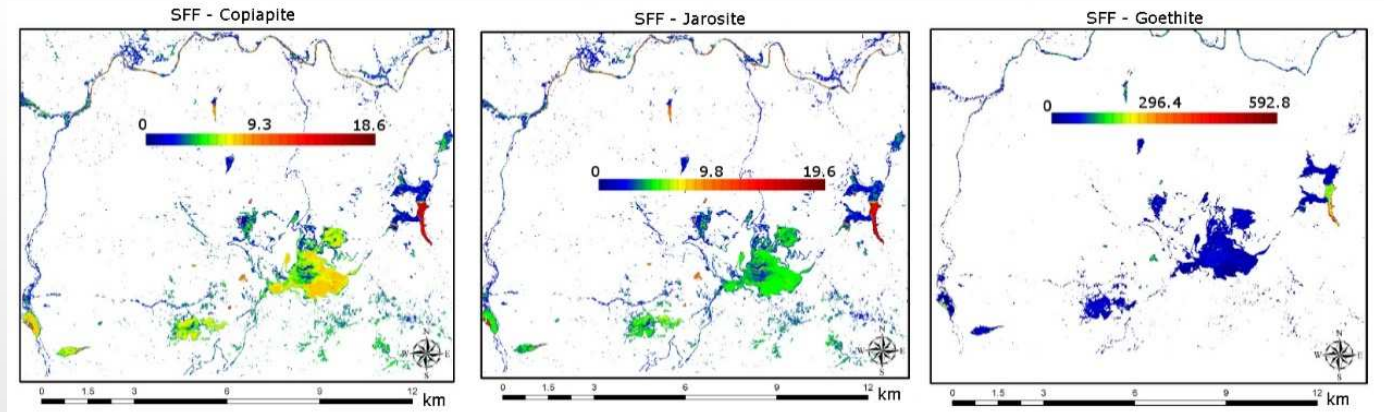
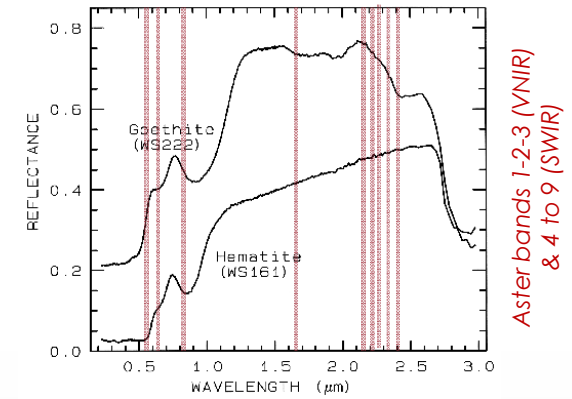
Stockpile measurement  
<http://asmireland.ie/>

# Mine Site Monitoring

- Acid Mine Drainage



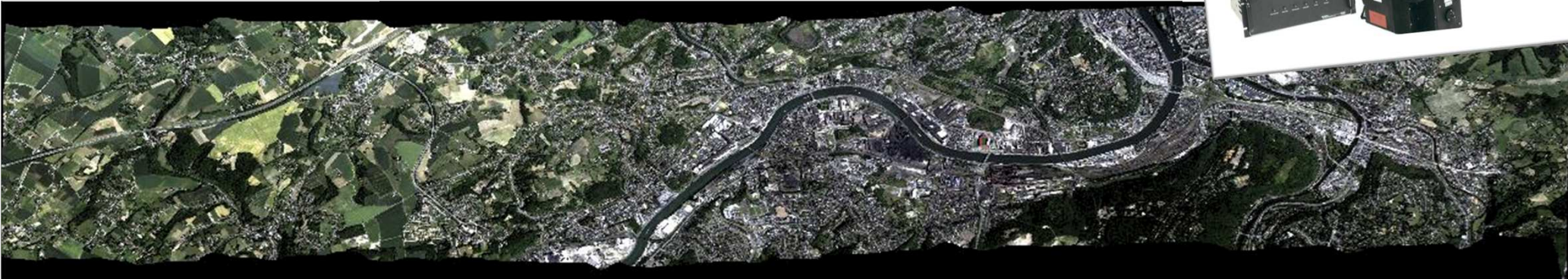
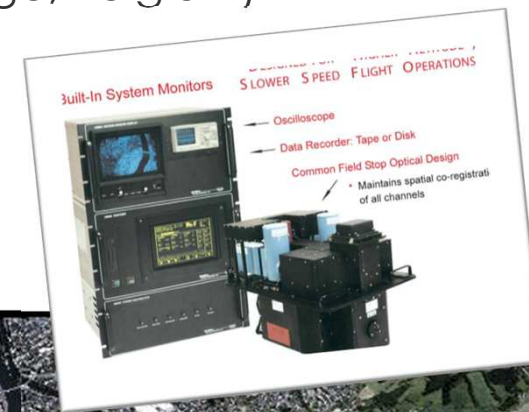
Aster scene of Rosia Poieni mine site



# Industrial Site Monitoring

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

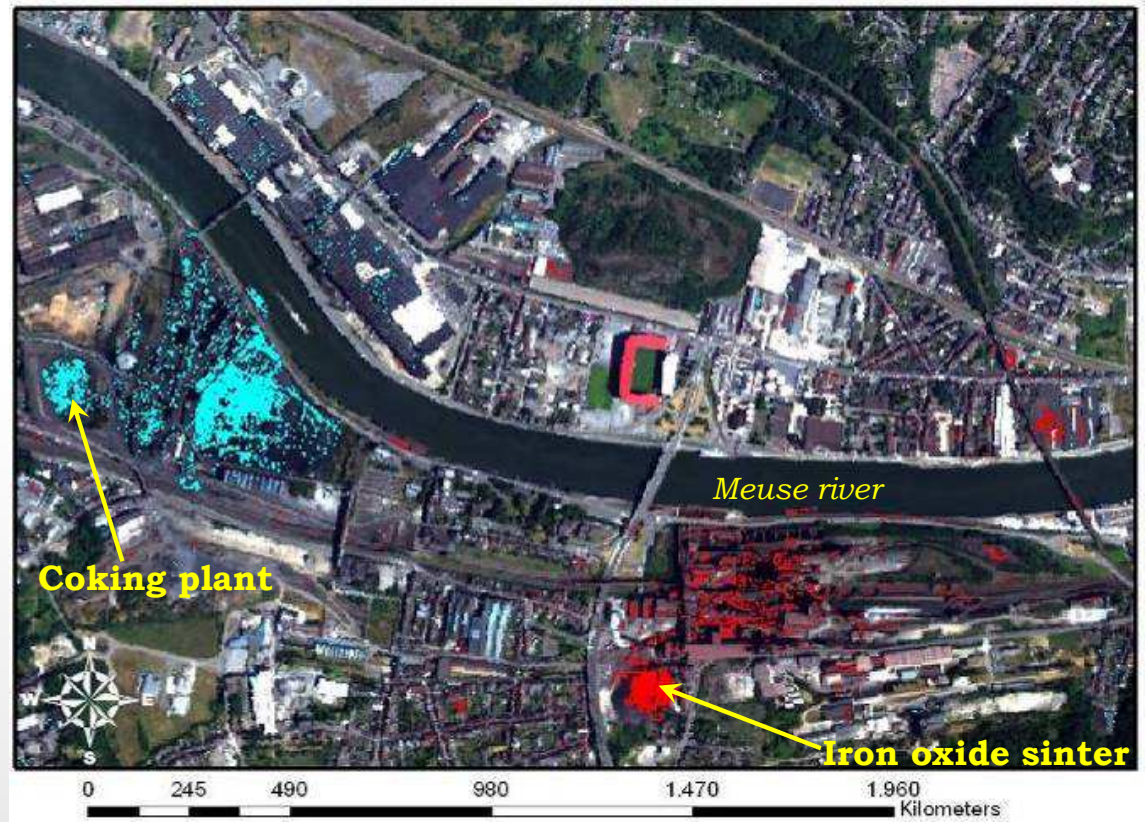
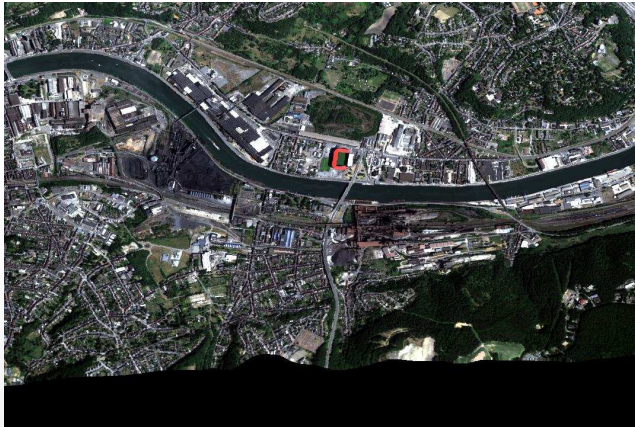
R: 0.630  $\mu\text{m}$ , G: 0.571  $\mu\text{m}$ , B: 0.513  $\mu\text{m}$



*Dardenne V., Caceres F., Hansen H., Bonino E., Pirard E. (2006) GRSG Annual Meeting London – Dec 2006*

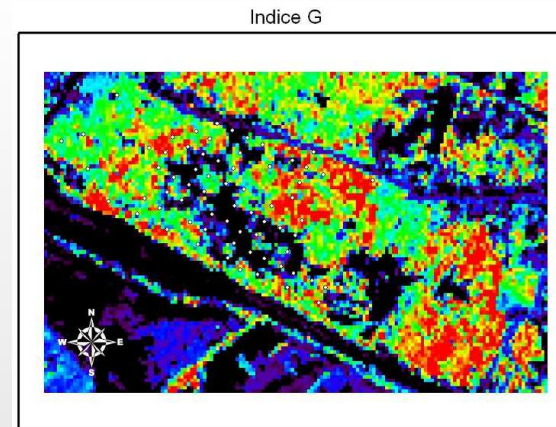
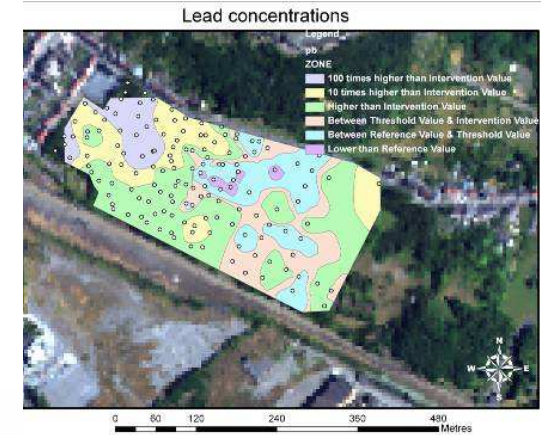
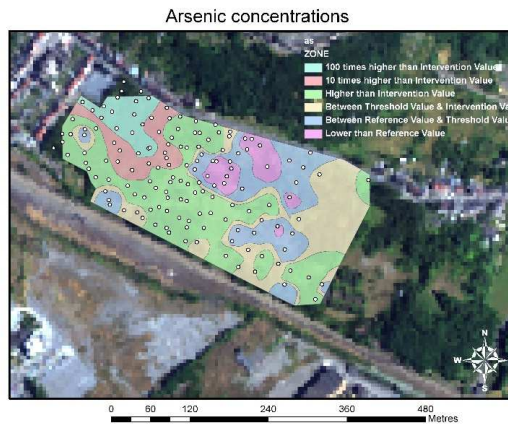
# Industrial Site Monitoring

- Dust Dispersion
  - Spectral Feature Matching
    - Coking coal
    - Iron sinter



# Industrial Site Monitoring

- Vegetation Stress
  - Geochemical mapping
  - Vegetation indices

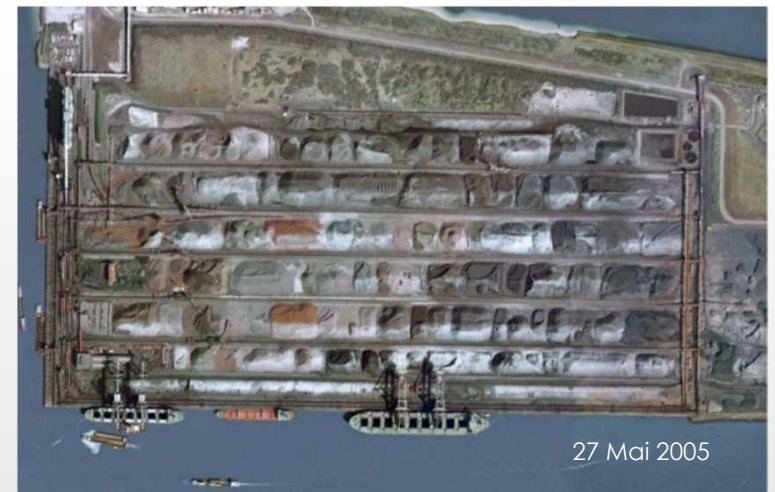
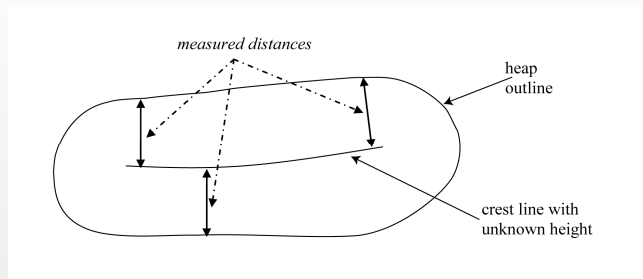


High As & Pb concentrations potentially linked to unhealthy vegetation

# Processing and Handling

- Volume estimation of stocks

Product	Size	Angle of Repose (degrees)		Bulk Density (t/m <sup>3</sup> )	
		Average	Std. Dev.	Average	Std. Dev.
Ultra-fines (pellet feed)	< 0.15 mm = 92%	38	4	2.32	0.11
Fines (Sinter Feed (+concentrates))	[1-9.5 mm] = 58% < 1mm = 42%	36	2	2.59	0.15
Pellet	[8-18mm]= 96%	28	4	2.16	0.10
Lump	[12.5-31.5 mm]=65%	31	0	2.56	0.00



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# Regional Monitoring

# Regional Monitoring

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

**mapx** ABOUT CONTACT ARTICLES PROJECTS APPLICATIONS TRAINING ACCESS DATA

## DR Congo Support To The Extractive Industries Transparency Initiative

Data catalog: <https://app.mapx.org/?country=COD>

### 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

**Scale**  
National

**Completed**  
December 2017

### Data catalog of EITI thematic maps



# Regional Monitoring

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

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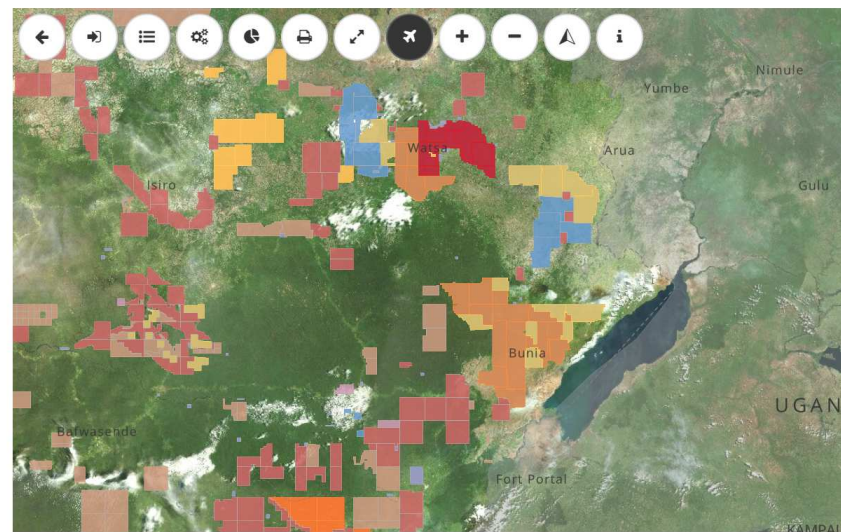
### Completed

December 2017



English

## Data catalog of EITI thematic maps



DR Congo English Filter views ...

Differences between declaration and payments by mining company (EITI/2015)

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What's next ?  
*Imagination...*