European Commission

Raw Materials Week

12-16 November 2018

Earth Observation in support of sustainable mining by the Geological Surveys of Europe

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Keywords: Remote Sensing, mining, raw materials, Earth Observation

Presentation abstract

Current and emerging Earth Observation (EO) technologies have the potential to provide regular top- surface compositional information with a high temporal rate and at high spatial resolution. Earth Observation working group (EOEG) under the EuroGeoSurveys (EGS) has been working on a topic how different type of EO data can be utilized to assess mineral resources as well as to monitor mining impacts and other anthropogenic hazards. Since 2016 the group has been contributing to the global GEO network with the GEO Community Activity (CA) entitled as "Earth Observations for Geohazards, Land Degradation and Environmental monitoring" investigating the feasibility to develop new applications or monitoring systems. Diverse Earth Observation data integration and utilization of the new generation satellite data (e.g., Copernicus data, EnMap) belongs to key topics the expert group has been working on. In addition, through this Community of Activity EOEG is sharing software tools, capacities and knowledge on the exploitation of Copernicus data for geological and anthropogenic hazard assessment and for environmental/mineral mapping.

In our presentation diverse case studies will be presented showing how high spectral resolution Earth Observation data can be employed for mineral mapping and assessing environmental impacts of mining including vegetation stress. Moreover, the free toolbox – QUANTools – will be presented allowing to process hyperspectral data for mineral mapping and classification. One of the biggest advantages when using this toolbox is the fact that no prior definition of the endmembers is required, this is a requested routine used for all widely-used spectral mapping techniques. This is indeed a big advantage. As a result, it can increase time/cost efficiency as the validation samples can be collected after image classification targeting, specifically, the identified surface variability (e.g., mapped classes).

In the context of new state-of-art satellite sensors and the COPERNICUS program we will also demonstrate how Sentinel-1, Sentinel-2 and WorldView3 data can be used for monitoring of mining impacts (e.g., mine stability, Acid Mine Drainage mapping).

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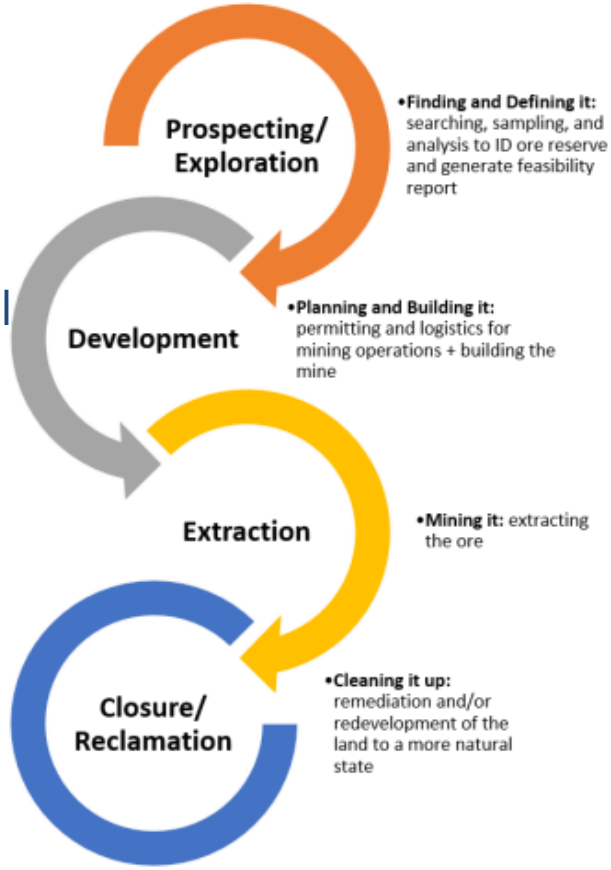
40 Years Listening to the Beat of the Earth

outlines

1. **Earth Observation and Geohazards Expert Group** (**EOEG**) from EuroGeoSurveys, activities, free SW
2. **EO** applications for the **Exploration phase (**geological and mineral mapping)
3. **EO** applications for the **Extraction/Closure/Reclamation/Mine Monitoring**
4. Summary, list of our future research and development



Earth Observation and Geohazards Expert Group

Members: 28 Geological Surveys and 80 scientists

Mission and Vision:

- Assessment of geohazards
- Application of Earth Observation for raw materials

Chairman: Gerardo Herrera (IGME, Spain)

Deputy chairs:

- Veronika Kopackova (CZ): responsible for Raw materials EO
- Eleftheria Poyiadji (IGME GR): responsible for H2020 Geo-Cradle project
- Maria Przyłucka (PGI): responsible for H2020 Geo-Cradle pilots

Earth Observation and Geohazards Expert Group

GEO CA: Earth Observations for Geohazards, Land Degradation and Environmental monitoring

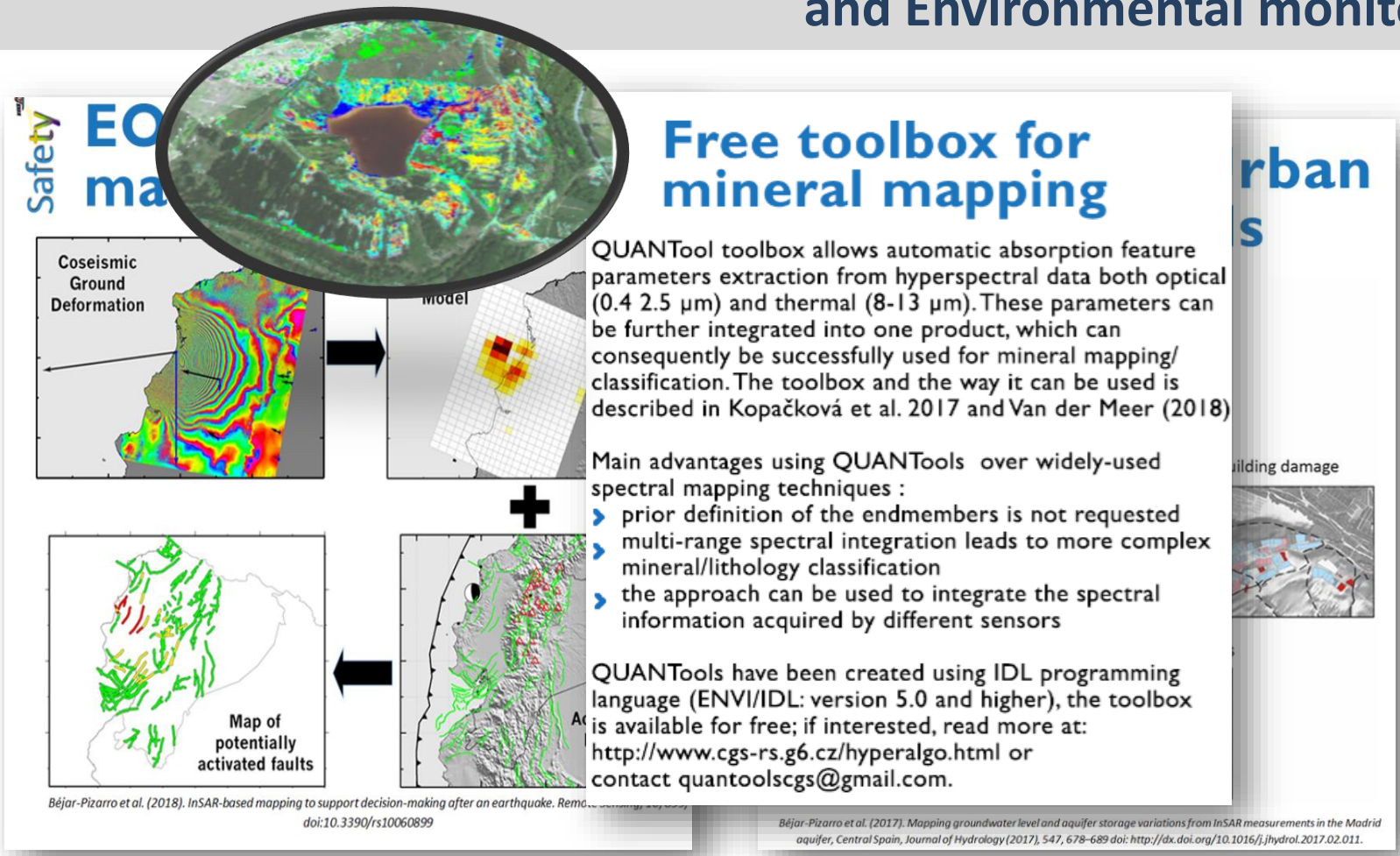
- Earth Observation working group (**EOEG**) under the **GEO CA** has been working on a topic how **different type of EO data** can be utilized to **assess mineral resources** as well as to **monitor mining impacts** and other **anthropogenic hazards**.
- Aiming at **developing new applications** or **monitoring systems**. **Diverse** Earth Observation **(EO) data integration** and **utilization** of the **new generation satellite data** (e.g., Copernicus data, EnMap)
- EOEG is **sharing software tools** and knowledge on the exploitation of Copernicus data for geological and anthropogenic hazard assessment and for environmental/mineral mapping.

- https://www.earthobservations.org/activity.php?id=88

GEO GROUP ON EARTH OBSERVATIONS

Copernicus esa

GEO CA: Earth Observations for Geohazards, Land Degradation and Environmental monitoring

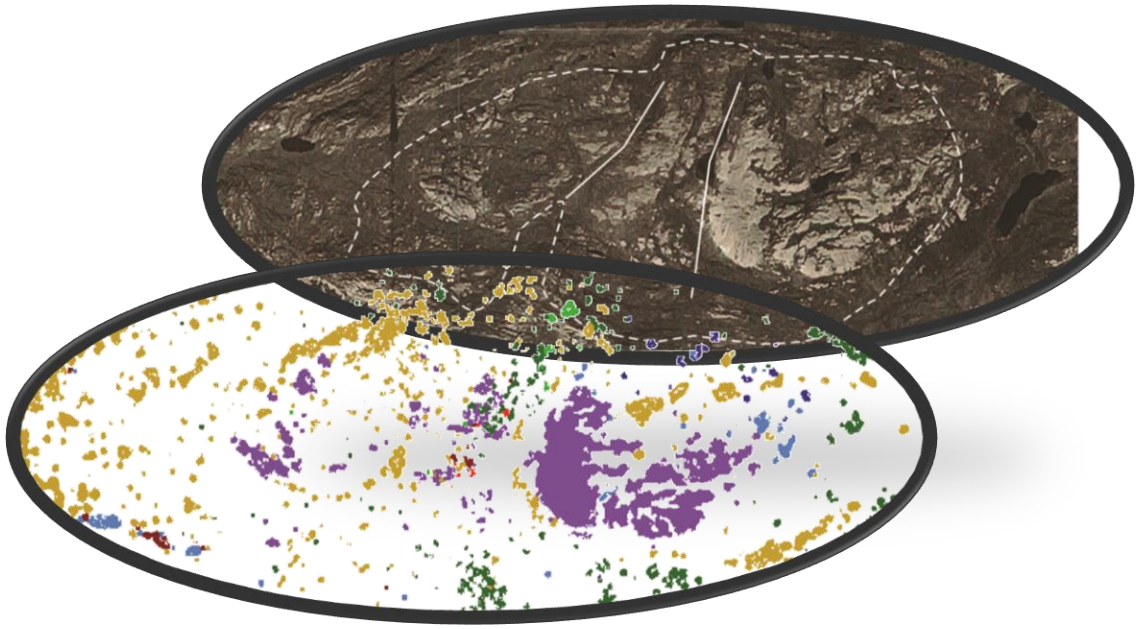


Copernicus esa GEO GROUP ON EARTH OBSERVATIONS

EuroGeoSurveys - The Geological Surveys of Europe

EUROGEOSURVEYS European Geoscience for Society
The Geological Surveys of Europe

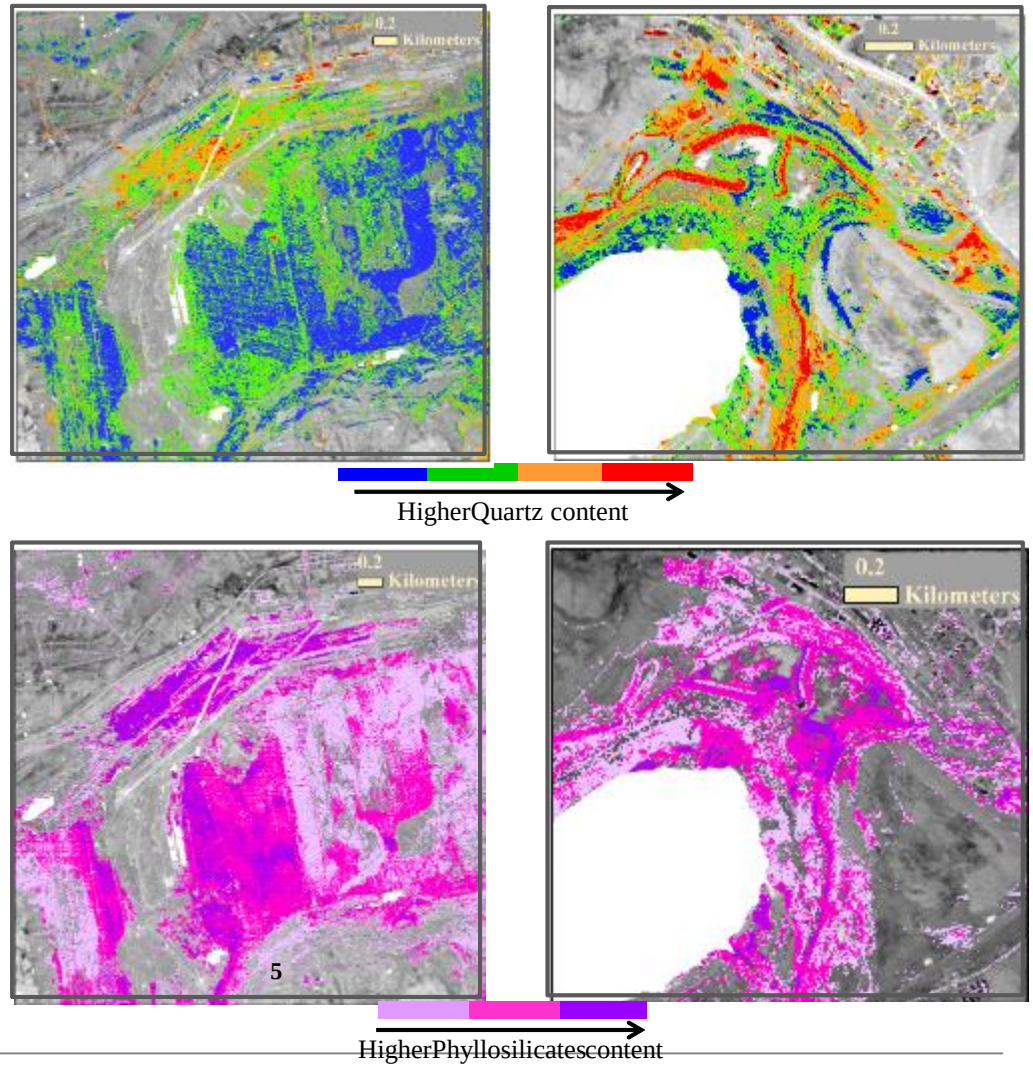
Exploration phase: geological and mineral mapping



Exploration phase: geological and mineral mapping

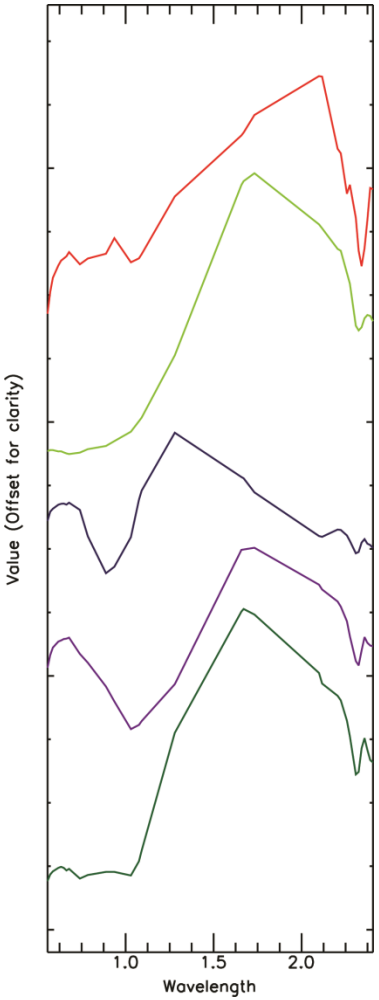
Mineral thematic map showing surface geological materials from airborne multispectral and hyperspectral data

Sokolov Lignite Open-Pit Mines, Czech Republic

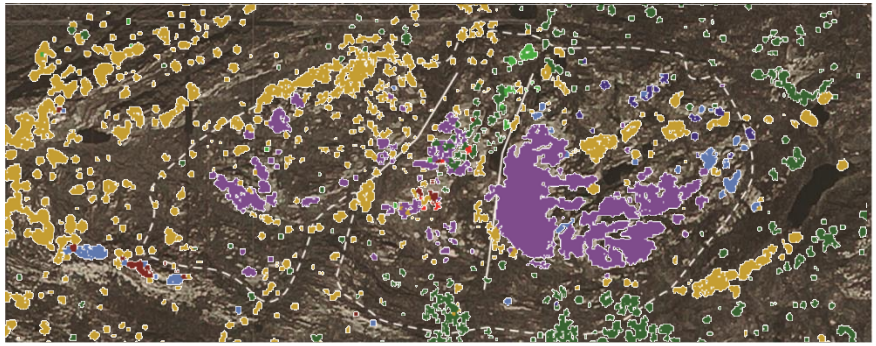


Notesco, G. – Kopačková V. – Rojík, P. – Schwartz, G. – Livne, I. – Ben-Dor, E. (2014): Mineral Classification of Land Surface Using Multispectral LWIR and Hyperspectral SWIR Remote-Sensing Data. A Case Study over the Sokolov Lignite Open-Pit Mines, the Czech Republic. – Remote Sensing 6, 8, 7005-7025. ISSN 2072-4292 (on line). DOI 10.3390/rs6087005.

Exploration phase: geological and mineral mapping

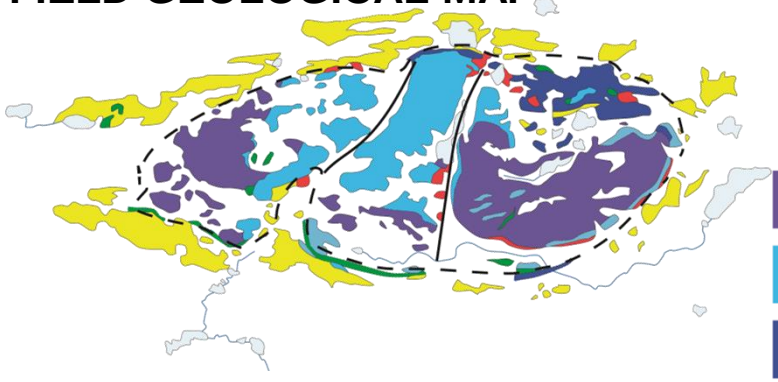


HYPERSPECTRAL MINERAL MAP



- Mafic-hornblende/amphibole
- Ultramafic-antigorite+olivine/diopside
- Ultramafic-antigorite+enstatite/hypersthene
- hornblende/amphibole
- Mica
- epidote/chlorite/clinoclore
- Granite/Pegmatite
- Gneiss (basement)

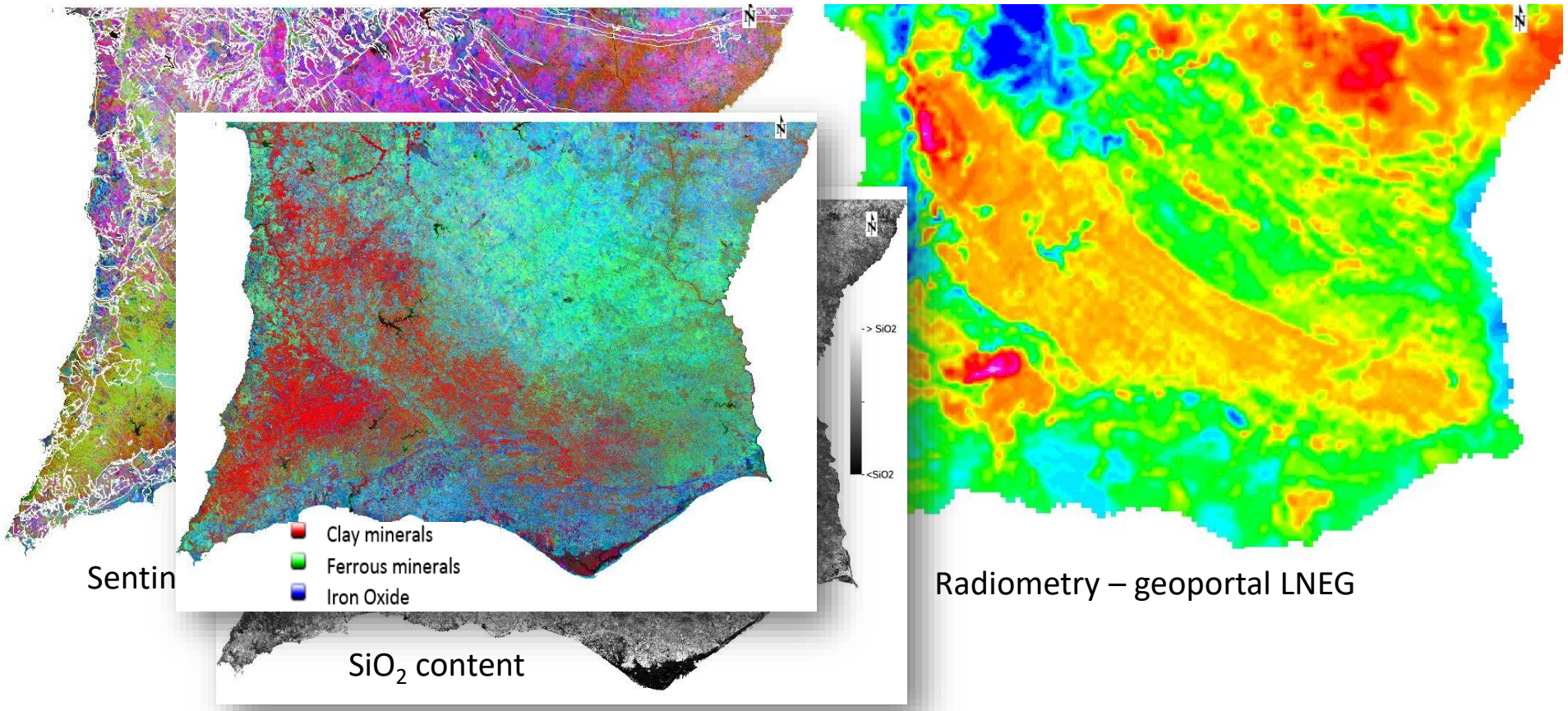
FIELD GEOLOGICAL MAP



- Dunite
- Olivine-peridotite
- Pyroxenite
- Gabbro
- Granite/Pegmatite
- Gneiss (basement)

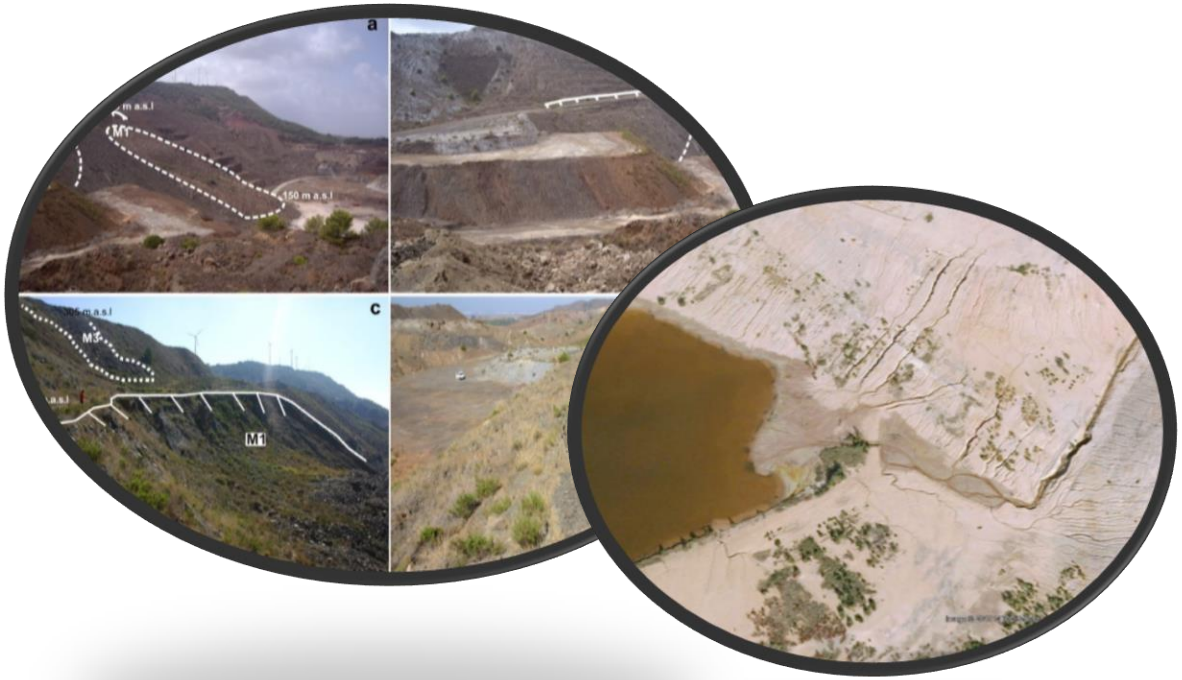
Salehi et al. (GEUS): AIRBORNE HYMAP DATA VS. TRADITIONAL GEOLOGICAL MAPPING IN THE ARCTIC (CASE STUDY: SOUTH-WEST GREENLAND)

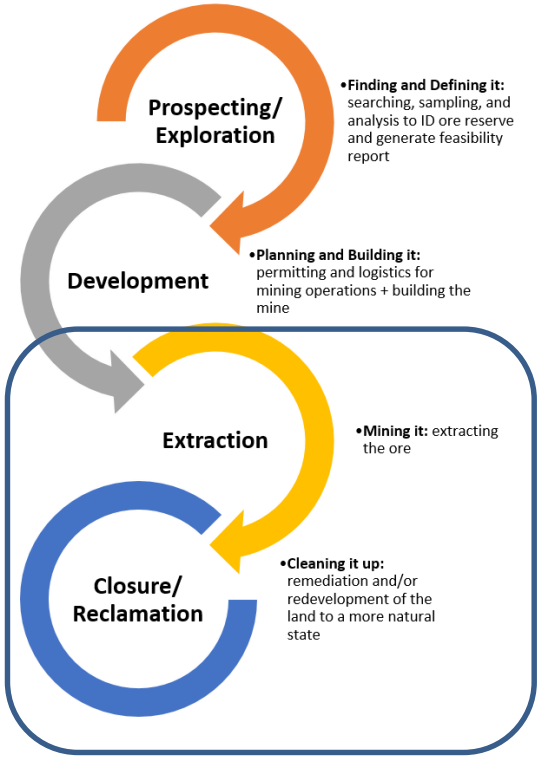
Exploration phase: geological and mineral mapping

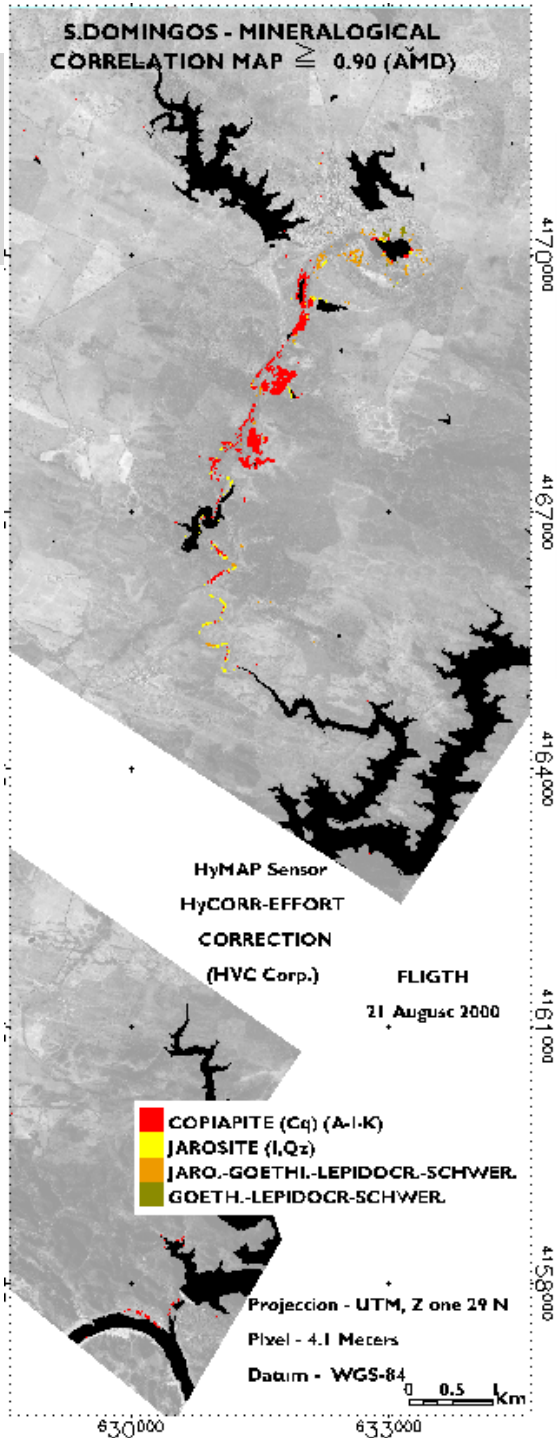


L.Quental, M.J. Batista, D. Oliveira, J.X. Matos, R. Dias, P. Gonçalves (2018). Sentinel 2 and radiometric data as geological and mineral exploration characterization tools in southern Portugal). *Vulcânica* (2018) Vol. II, ISSN 1646-3269, pp167-168.

Extraction/Closure/Reclamation/Mine Monitoring

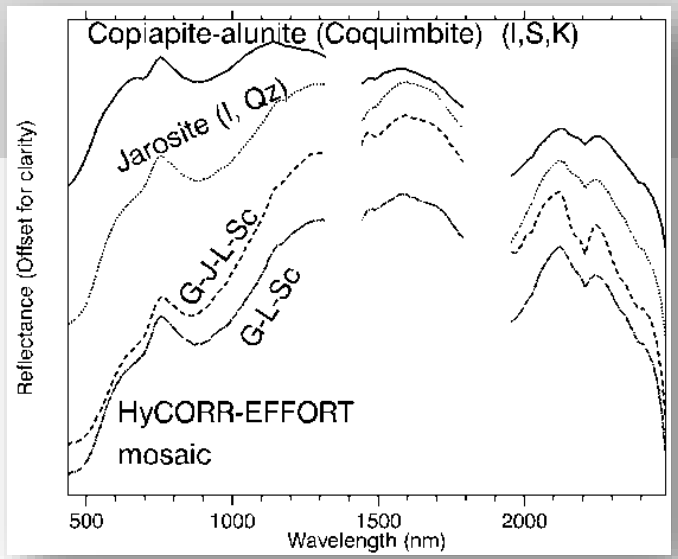




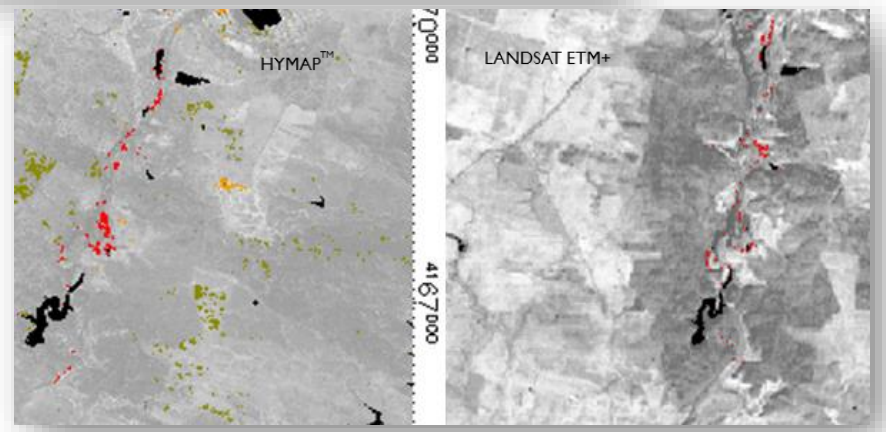


Closure/Reclamation/

Mine monitoring



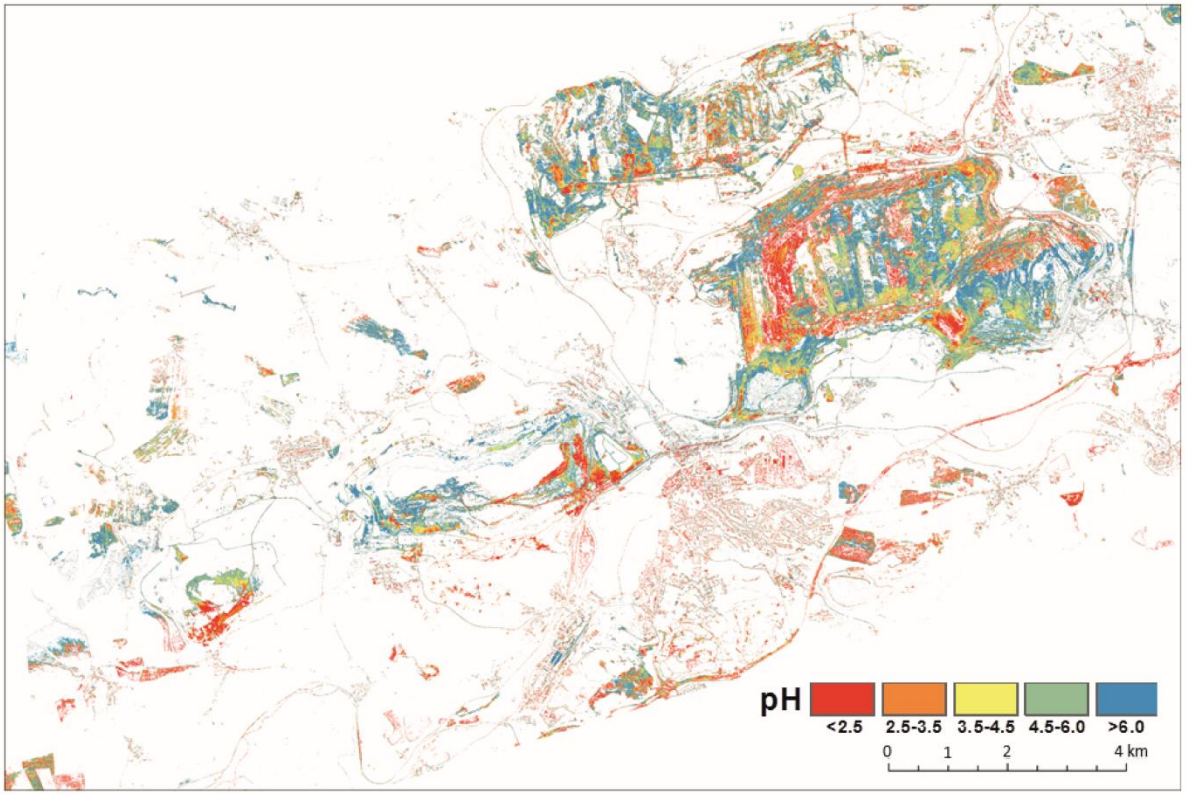
COPIAPITE-COQUIMBITE-ALUNITE
(exclusive signature) pH < 3



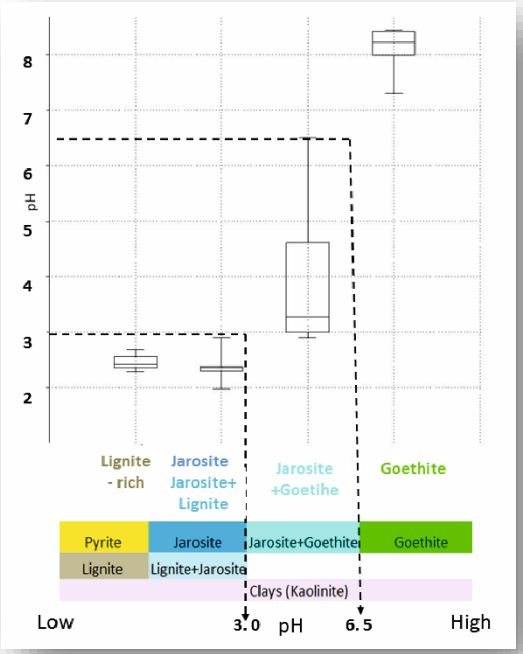
J- jarosite
G- goethite
L- lepidocrocite
Sc- schertmannite
Qz- quartz
I- illite
S- smectite
K- kaolinite

Quental, L. Sousa, A.J, Marsh, S., Brito, G. Abreu, M.M. (2011) Imaging spectroscopy answers to acid mine drainage detection, **Iberian Pyrite Belt, *Portugal.*** *Comunicações Geológicas, 98, 61-71.*

Soil pH map derived from mineral association using hyperspectral imagery

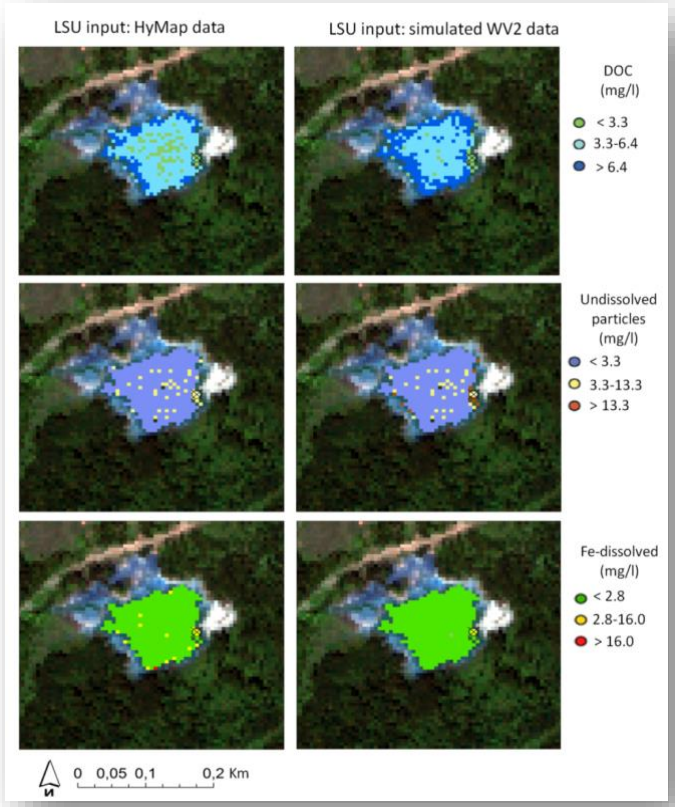


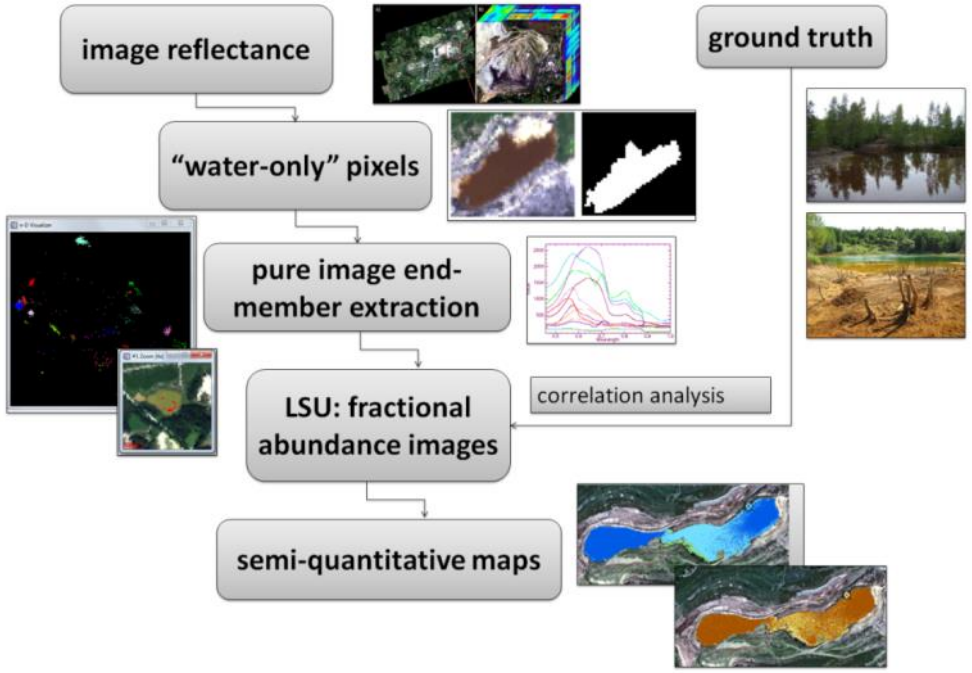
Conceptual mineral model



Kopačková, V. (2014). Using multiple spectral feature analysis for quantitative pH mapping in a mining environment. *International Journal of Applied Earth Observation and Geoinformation*, *28*, 28-42.

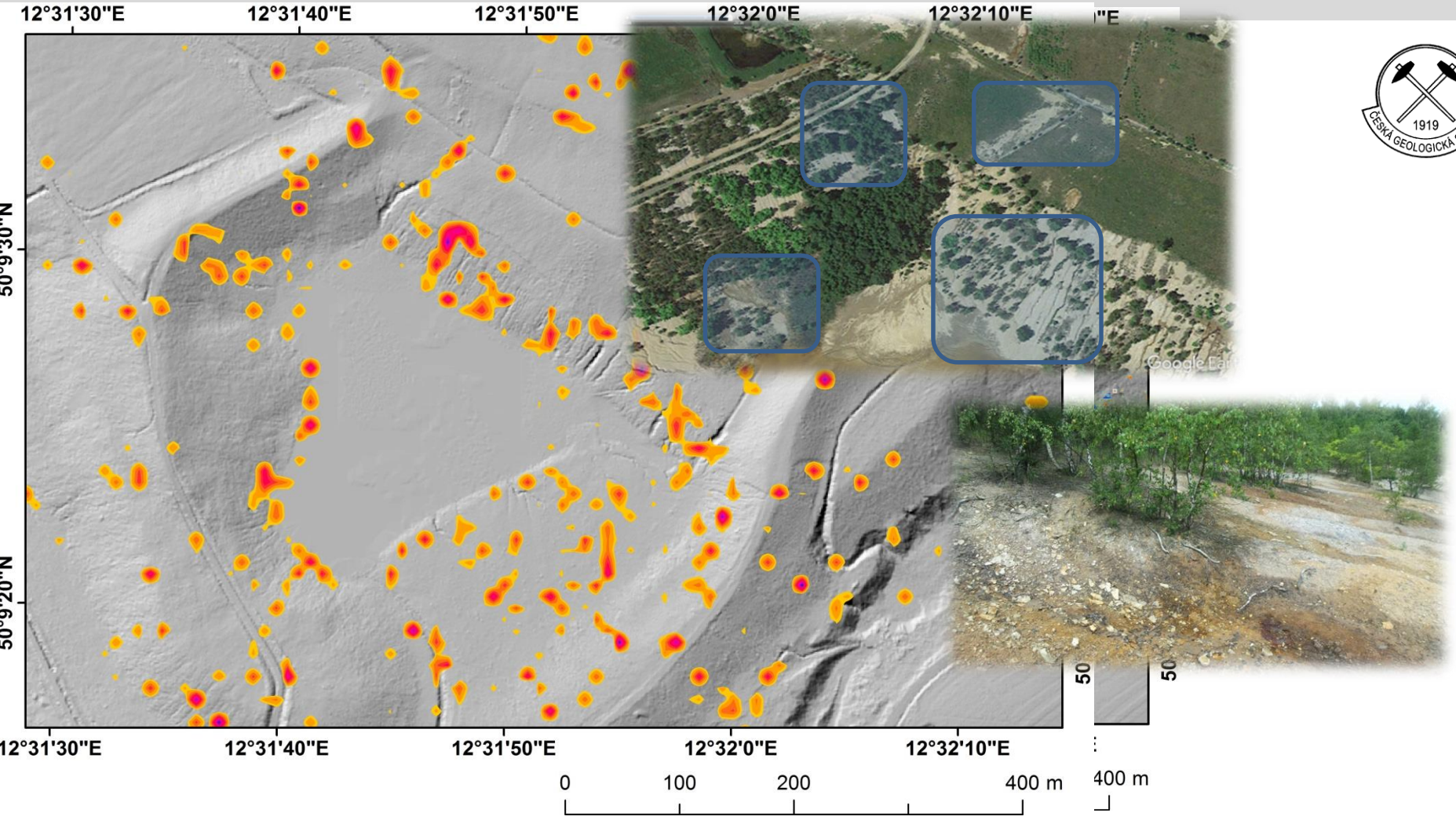
Mapping mineral content of surface water from hyperspectral and HR optical satellite (Worldview 2)





Kopačková V. – Hladíková, L. (2014): Applying Spectral Unmixing to Determine Surface Water Parameters in a Mining Environment. – Remote Sensing 6, 11, 11204-11224. ISSN 2072-4292. DOI 10.3390/rs61111204.

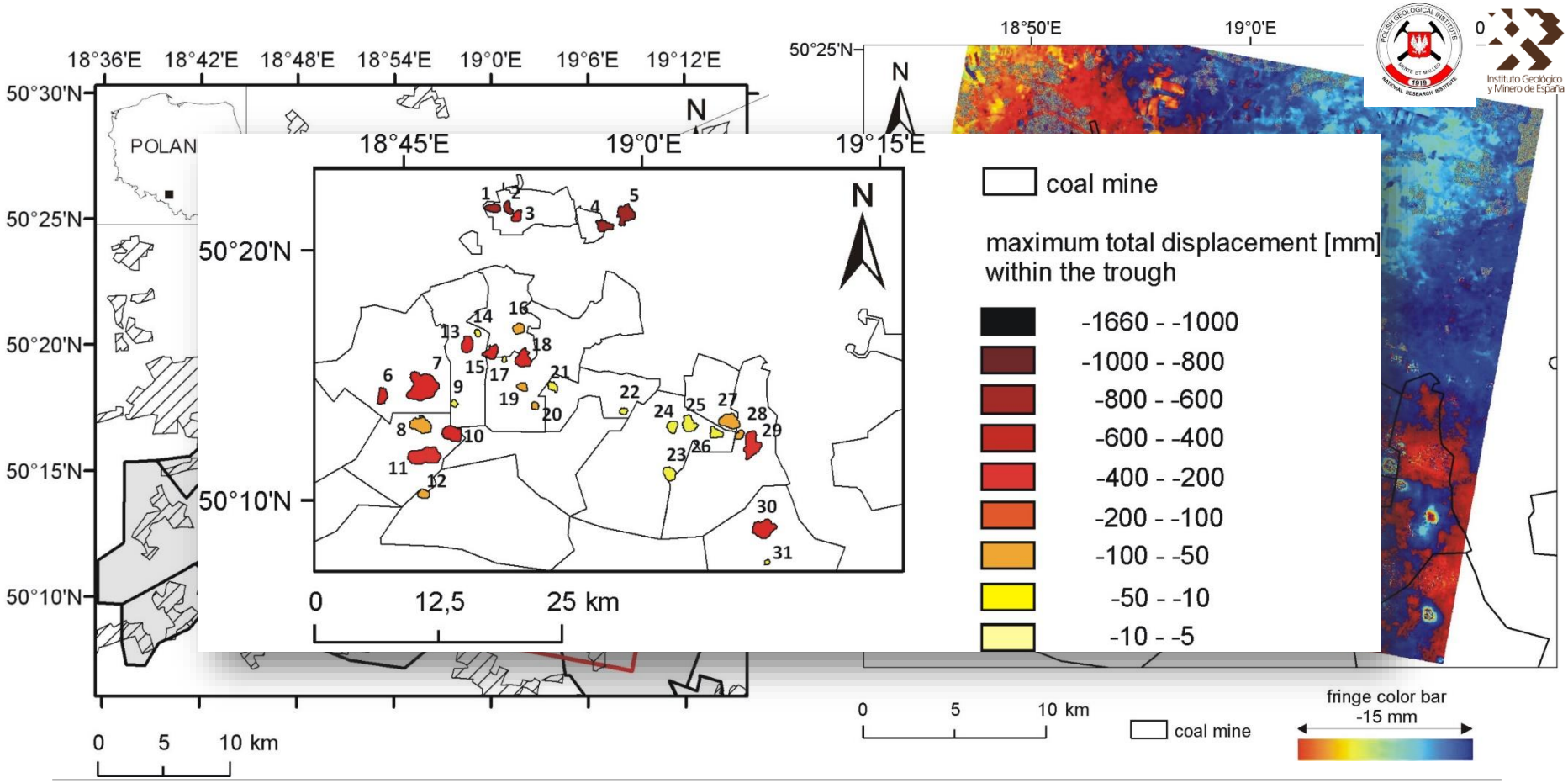
Closure/Reclamation/Mine Monitoring



Kopačková V. : Using Sentinel-2 time series to monitor Acid Mine Dranaige

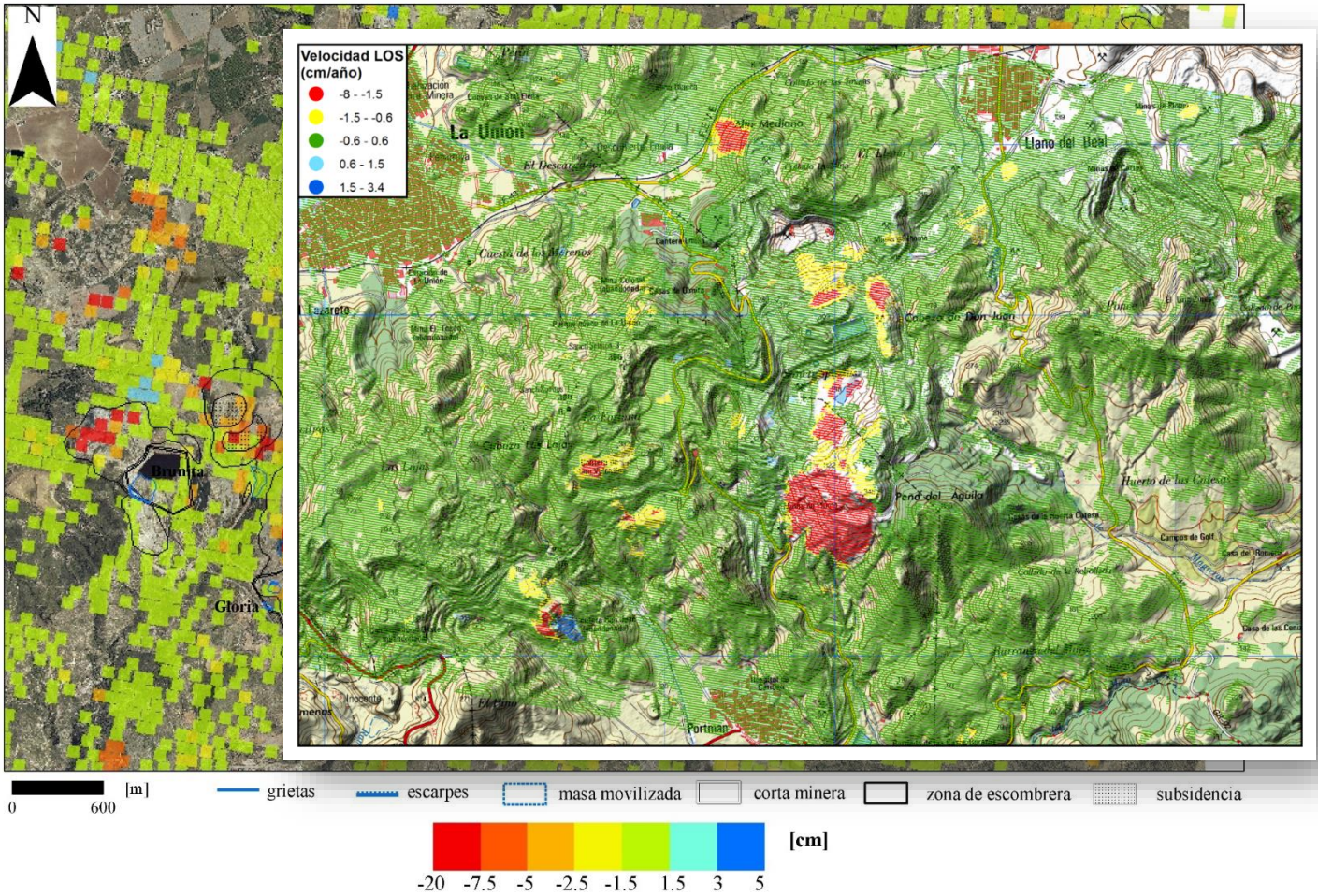
Orthophoto, 2016

Monitoring mining subsidence: Upper Silesia Coal basin (Poland) using TerraSAR-X



Przyłucka, M., Herrera, G., Graniczny, M., Colombo, D., & Béjar-Pizarro, M. (2015). Combination of conventional and advanced DInSAR to monitor very fast mining subsidence with TerraSAR-X Data: Bytom City (Poland). Remote Sensing, 7(5), 5300-5328.

Ground deformation maps derived from Envisat satellite 2008-2010

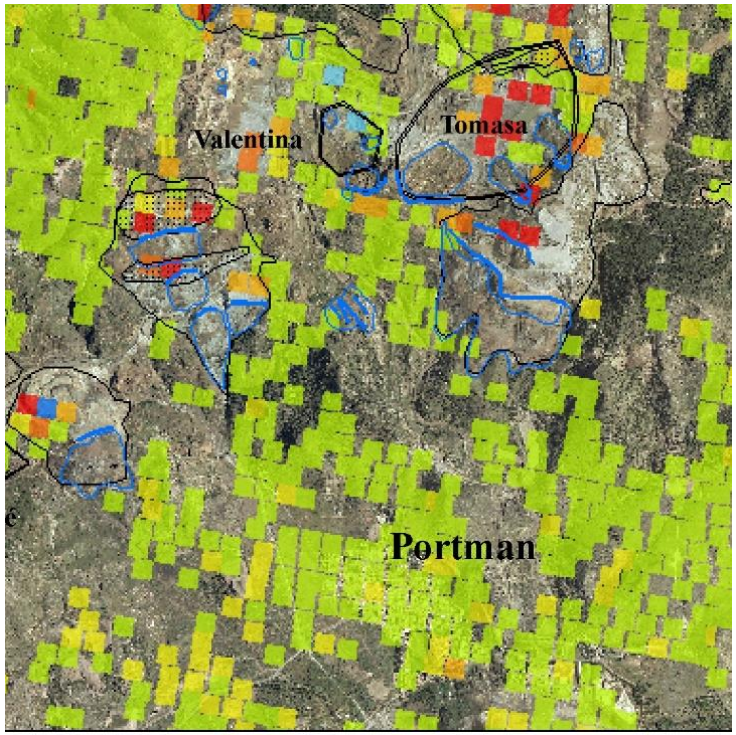


Instituto Geológico y Minero de España

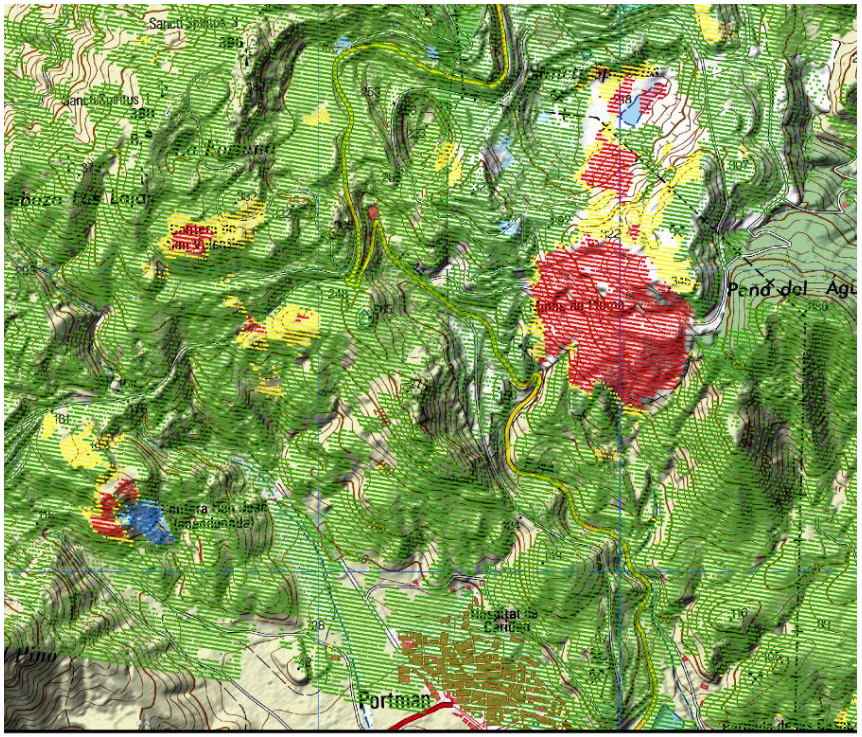
Herrera et al. Mapping ground movements in open pit mining areas using differential SAR interferometry. International Journal of Rock Mechanics and Mining Sciences, 2010, vol. 47, no 7, p. 1114-1125.

Closure/Reclamation/Mine Monitoring

Envisat



Sentinel



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Future perspectives

- Developping models for quantitative assessment of physical and chemical surface properties (mines, post-mining areas, remediation's) using hyperspectral data as well as satellite data (e.g.,Sentinel-2 and EnMap)

- Building a world-wide mineral/rock/soil reflectance and emissivity libraries:
  - Mine waste spectral libraries
  - Other minerals of the interest
  - Soil spectral libraries
  - Drill core scanning

- Detection and monitoring of ground instabilities related to active and abandoned mining areas with radar satellite data (Sentinel-1), assessing the vulnerability of exposed urban areas and infrastructures.

Summary

- EOEG shows how **diverse EO datasets** as **well as Sentinel missions** (1 and 2) **provide quantitative data to develop, support and validate studies**/geological models for exploration, extraction, closure and post-closure, with relevant impact in economic, societal and environmental sustainability pillars.

- **Copernicus data can also be used to implement tools related to legal aspects of mining** activity, **as well as to support EU Directives and policies**, e.g. Waste, Raw materials Initiative (RMI), European Innovation Platform on Raw Materials (EIP-RM) and *Establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe* (**GeoERA**)

PanAfGeo, Bishoftu, Ethiopia (Dec 2017)

Dissemination activities: training in Ethiopia

- Radar theory and data processing
- INSAR geological applications
- Optical and thermal remote sensing
- Mineral mapping using free satellite data and free ware (e.g., QGIS, SNAP)

EuroGeoSurveys
European Geoscience for Society
The Geological Surveys of Europe

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40 Years Listening to the Beat of the Earth