Application of geostatistical analysis with the Earth Observation data for recovery of raw materials from mining residuals

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Summary

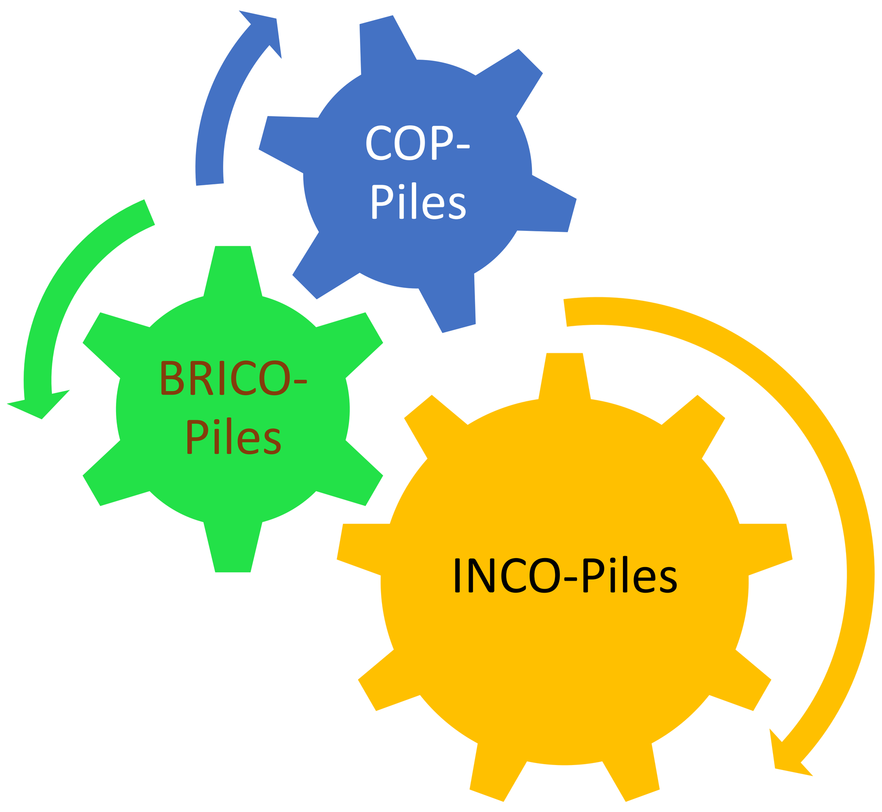
The poster presents an overview of the ongoing research projects at University of Bologna – DICAM Department, applying geostatistical methods to mining stockpiles and tailings with the purpose of metal recovery. The educational program RawMatCop of EIT Raw Materials is the main supporter of the research.

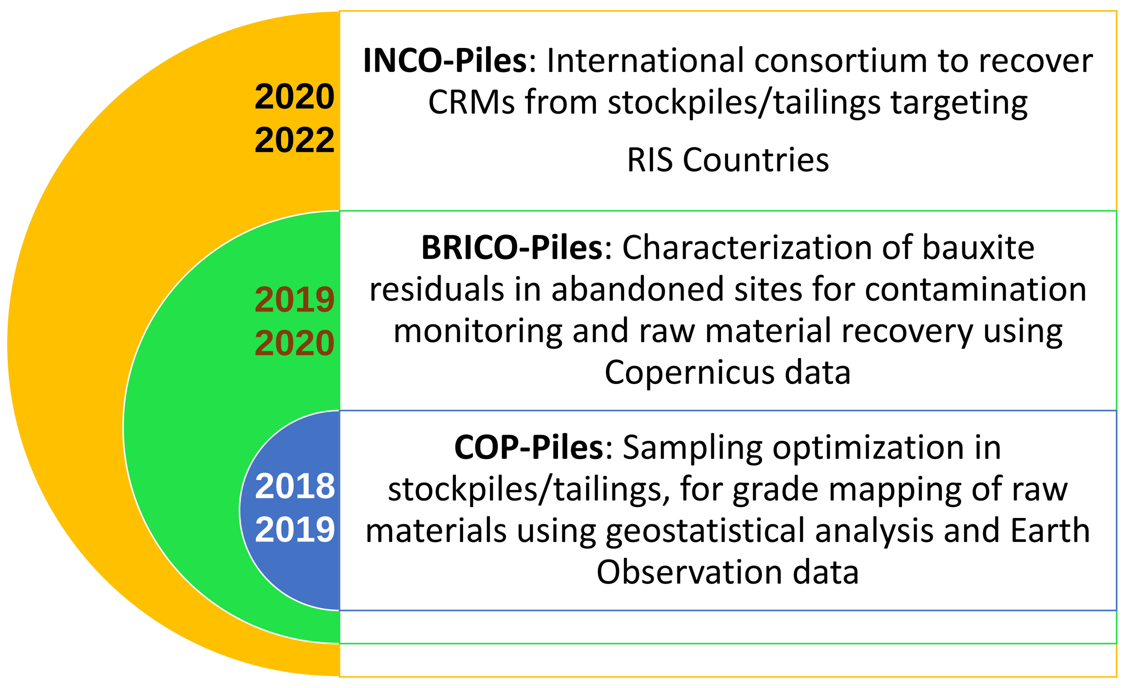
The work takes advantage of the use of Earth Observation (EO) data for sampling optimization in mining residuals from abandoned and active mines. Purposes are both recovery of raw materials and environmental rehabilitation spatial resolution, Copernicus data can improve the characterization of tailing dams and landfills.

EO can play an important role in accounting the raw material resources of a territory, since current satellites, such as the Copernicus constellation (Sentinels), provide continuous spatial and temporal coverage of the global at no cost. Thanks to the on (quantification and evaluation) of a resource, together with the assessment of the associated risks. Moreover, EO can be used for continuous monitoring of the target areas, conditioned by mining activities.

On the other hand, geostatistical analysis, using in situ sampling and EO images, exploit innovative methods to improve accuracy of grade and pollution maps, thus reducing the number of samples, with evident cost reduction.

Test sites are bauxite residuals, located in Mediterranean Region: Greece and Montenegro (COP-Piles Project, completed in 2019), Sardinia and Apulia (BRICO-Piles Project, currently ongoing). Finally, a new international Cooperation Project, INCO-Piles, starting in early 2020 and led by the research group, has the scope to identify the most promising mining residuals of Southern Europe for recovery of critical raw materials.





Materials and Methods

In many European countries, there is an important growing trend of demands for raw materials. The European Commission (EC/2008/699) highlighted the importance of a secure and sustainable supply of raw materials from local sources, international markets, and from secondary raw materials sources. Hence, the depletion of the in-situ reserves, the increasing needs of using lower grade materials, advances in recovery and processing technologies are the main reasons recently all types of mining residuals, stockpiles and tailings, are considered as recoverable resources.

Therefore, these aboveground tailings/stockpiles have to be quantified and classified and a reliable expected revenue model should be developed to assess the feasibility of production. To perform a comprehensive study on stockpiles and tailings, there is a need of in situ samples. To implement the methodology, the remote sensing multispectral images (and some derived band ratios) including those provided by the Copernicus services (especially Sentinel-2 data or higher resolution data in local scale) can be joined. The in-situ monitoring samples can be considered as an added value to improve the concentration maps of stockpiles/tailings. Hence, by merging the sample information from stockpiles/tailing and the remote sensing and the Copernicus information (including their in-situ data), the final maps of mineral grade (metals, non-metals or critical raw material: CRMs) can be achieved.

Case study – COP-Piles Project

Bauxite residue (BR) or filtered red mud, is the major solid waste generated by the process of alumina extraction from the bauxite ores. It is estimated that 1 to 2 tons of BR is generated per ton of alumina produced. The selected case study is a BR from the alumina refinery of Mytilineos-Aluminium of Greece-AoG in Greece. It is located on the Gulf of Corinth, 136 km from Athens (Fig.1-a).

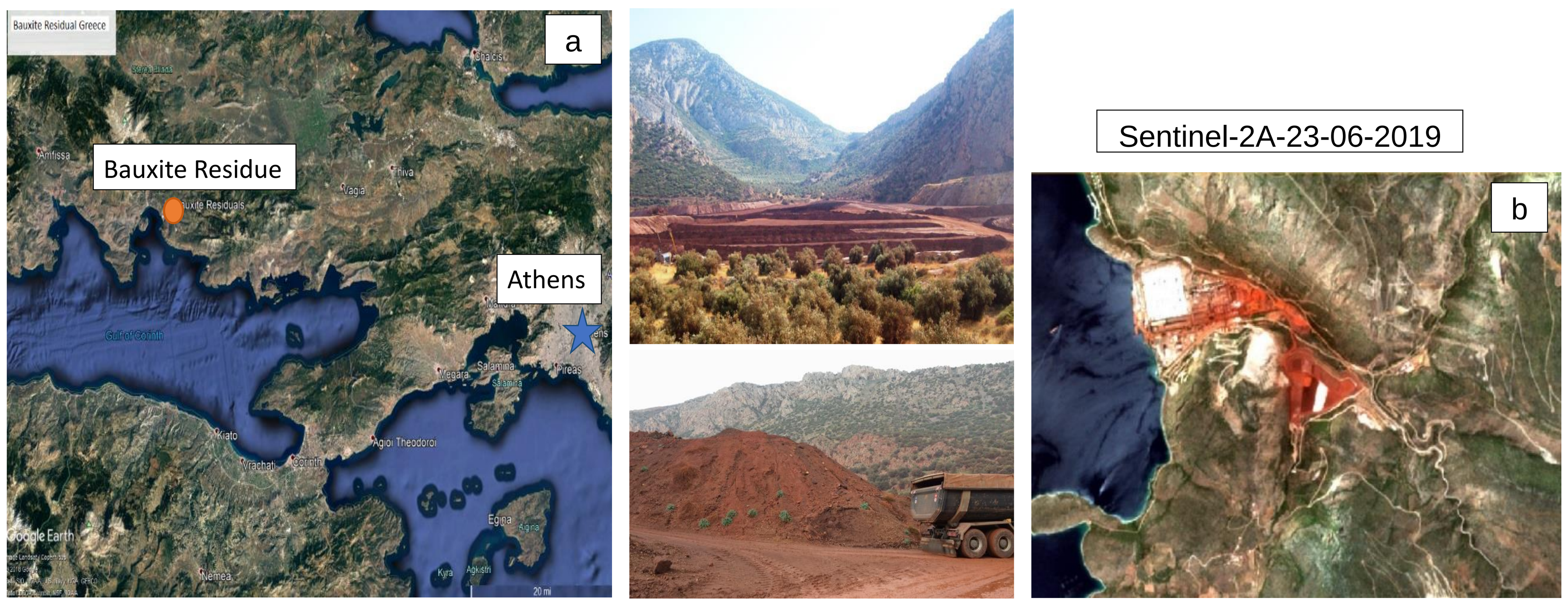


Fig.1 Bauxite Residuals location in Greece (a) and the Sentinel-2A image (with atmospheric correction) obtained in 23th June 2019 (b)

Data Analysis

For remote sensing analysis, the Sentinel-2 Images were used.

In the first step, for image analysis, the spectrum views of both images are shown in Fig. 2-a Pins (six pins), identified in Fig.8, show the possible different types of materials piled for two months. The colors of pixels can help to identified different types of materials. The selected six pins have shown different band reflectance in the spectrum view. Graphs of the spectrum views, as shown in Fig.2-b, can help for image classifications and for identifying the appropriate bands and ratio band analysis (Ducart et al. 2016). According to the selected points for the spectrum view, the un-supervised classifications have been performed using the K-mean method. The results of unsupervised classification are shown in Fig.2-c.

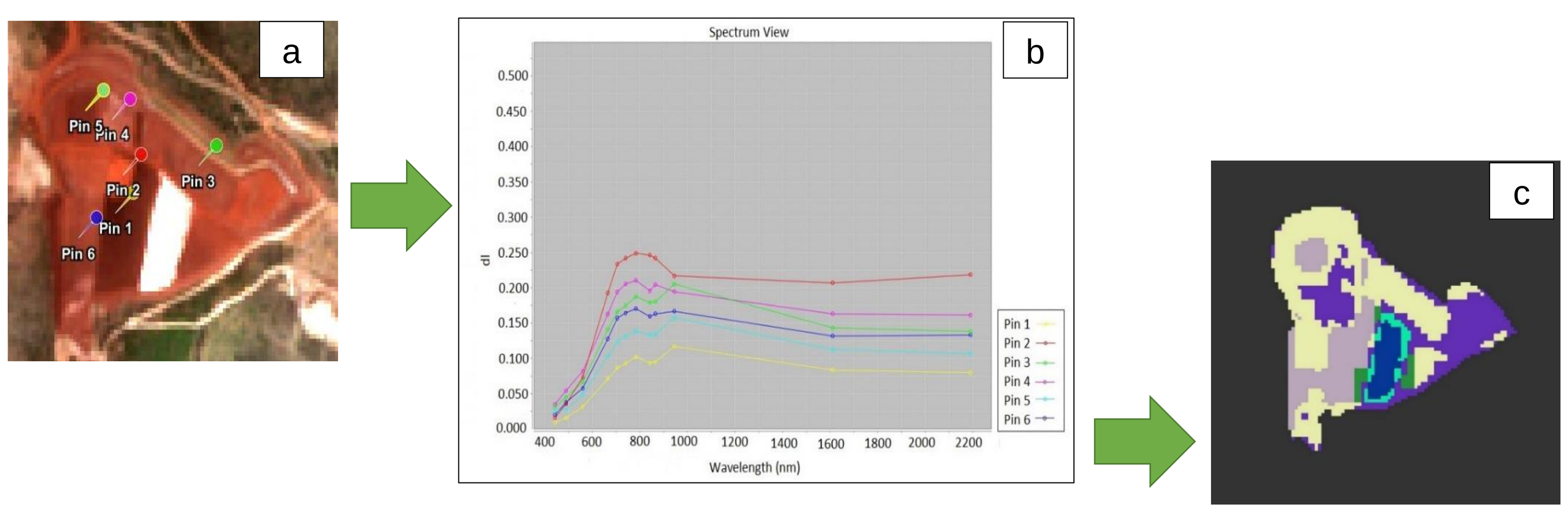


Fig.2 Sentinel-2A-Images of Greece BR with the selected points (a) and the spectrum view (b) and as the results the unsupervised classification of images using K-Mean Cluster Analysis (c)

Table 1. Direct and cross-variogram models between Al_2O_3 and Laterite band ratio (11/12) from image Sentinel-2A-23-06-2019

Variogram models	Nugget effect	Structure 2 : Spherical		Structure 3 : Spherical	
		Range	Sill	Range	Sill
Al_2O_3	0.05	85	0.70	180	0.100
Laterite-bands	0.05	85	0.30	180	0.660
Cross-variogram	0.00	85	-0.15	180	-0.004

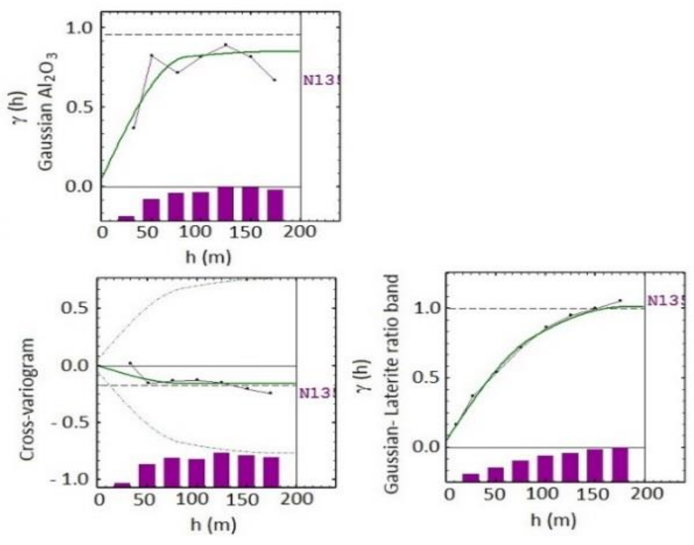


Fig.3 Direct and cross-variograms between Al_2O_3 and Laterite band ratio (11/12)

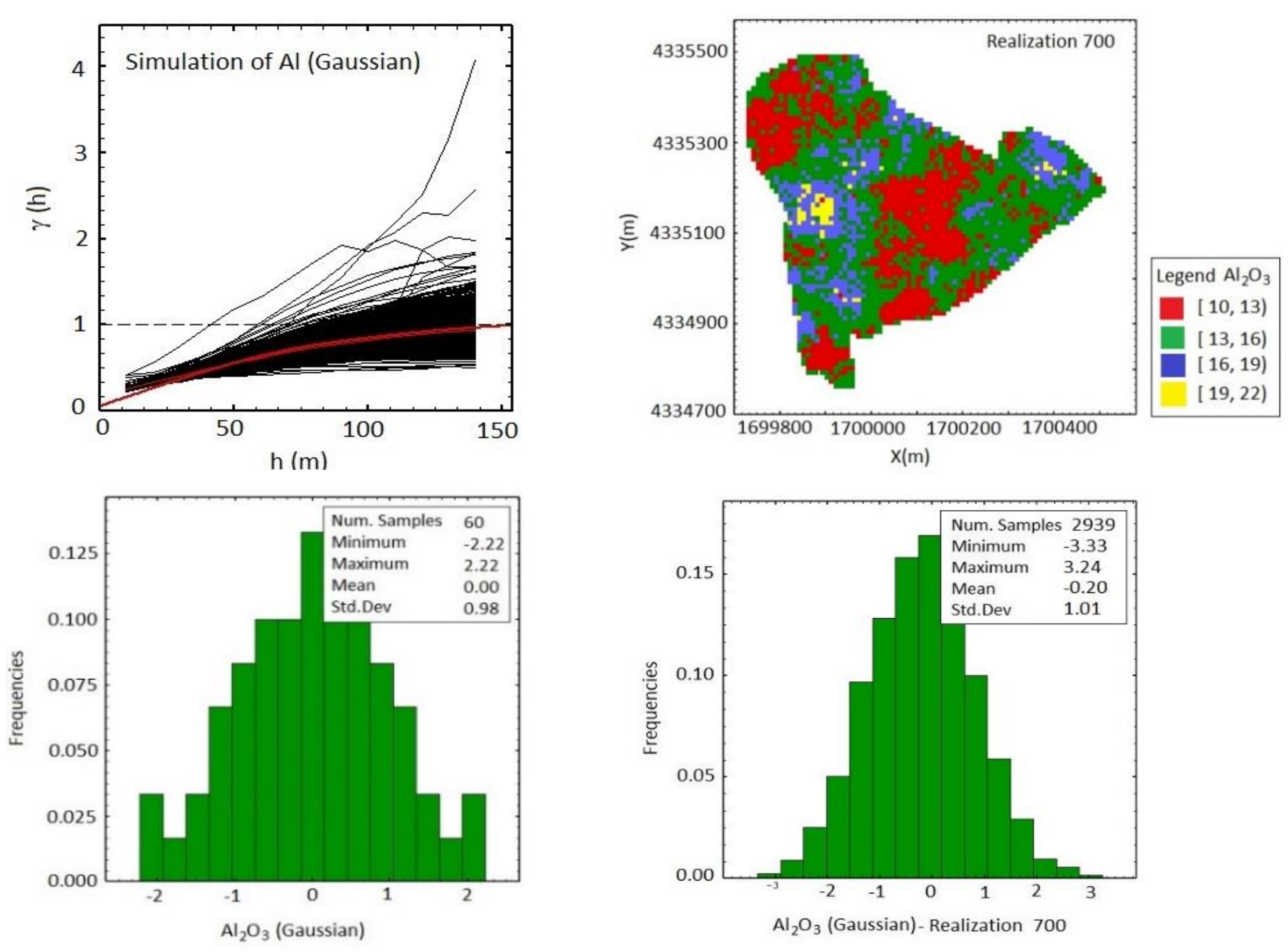


Fig.4 Comparison among the variogram reproduction from 1000 realizations of geostatistical simulation (black lines), its average (cyan line) and the variogram model of the main variable (red line); and Co-Simulation map results of Al_2O_3

Mapping metals concentrations

To compute the metal grade maps, the remote sensing imagery (Sent-2A-29-04-2019 image) was used with the in-situ samples. The Turning Bands simulation has been performed for 1000 realizations, using the 60 samples and the related ratio bands information as collocated variable. To check the simulation results, the reproduction of the variogram model by the simulation results is compared with the experimental variograms of the realizations with the selected variogram model of the metal concentration.

Results and Conclusion

A collection of information (in-situ samples and remote sensing data) was used to analyse the case study: the Bauxite Residue Landfill (from Aluminum of Greece: AoG).
Statistical studies of samples and band ratio calculations were used for characterization of aluminum grade variability within the bauxite residuals.
Advanced geostatistical methods (Co-simulation conditioned by in-situ samples and using the band ratio information as auxiliary variable) were performed to achieve the grade variability maps.
The results were shown the appropriate methodology to combine the geostatistical analysis and the Earth Observation data for mapping the grade variability for aluminum.

References

Ducart, D. F., Silva, A.M., Bemfica, C. L., de Assis, L.M., 2016. Mapping iron oxides with Landsat-8/OLI and EO-1/Hyperion imagery from the Serra Norte iron deposits in the Carajás, Mineral Province, Brazil, Brazilian Journal of Geology, 46(3): 331-349, DOI: 10.1590/2317-4889201620160023;

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