INCO-Piles
International Consortium to recover CRMs from stockpiles/tailings targeting RIS

Deliverable code: EITRM109341

Deliverable number: D4.2

Deliverable name: An exhaustive map, with the optimised sample grid

Deliverable description: Activities of Earth Observation analysis, together with geostatistical technique, on the case study, have led to realise a map of the stockpile/tailing, with the definition of the optimised sample grid.

Confidentiality level: Confidential
Related Task: T4.2

Deliverable realized by: Alma Mater Studiorum – Università di Bologna (UNIBO): S. Kasmaeeyazdi, F. Tinti

With the collaboration of: ORANO (WP4 Leader), MYT, NTUA, BRGM, UL and DELFT

INCO-Piles 2020

International consortium to recover CRMs from stockpiles/tailings targeting RIS

Definition of the sampling grid

Table 1: time schedule of meetings

Meeting	Date	Participants	Topic of discussion
1	27/04/2021	ORANO, UNIBO, NTUA, BRGM, DELFT, UL	Definition of the sampling grid

Table 2: time schedule of Deliverable preparation and revision

Version	Date	Authors	Description
1	26/04/2021	UNIBO	First draft of the document with a possible sampling grid based on the past experience on pilot site.
2	30/04/2021	ORANO, UNIBO, NTUA, BRGM, DELFT, UL	Updated version of the document based on the meeting with the Partners
3	4/05/2021	UNIBO, all	Final version of the sampling strategy, presented to MYT

Case study

Bauxite residues from AoG

INCO-Piles Sampling – Definition of the sampling grid

Definition of piling areas: Figures 1, 2 and 3

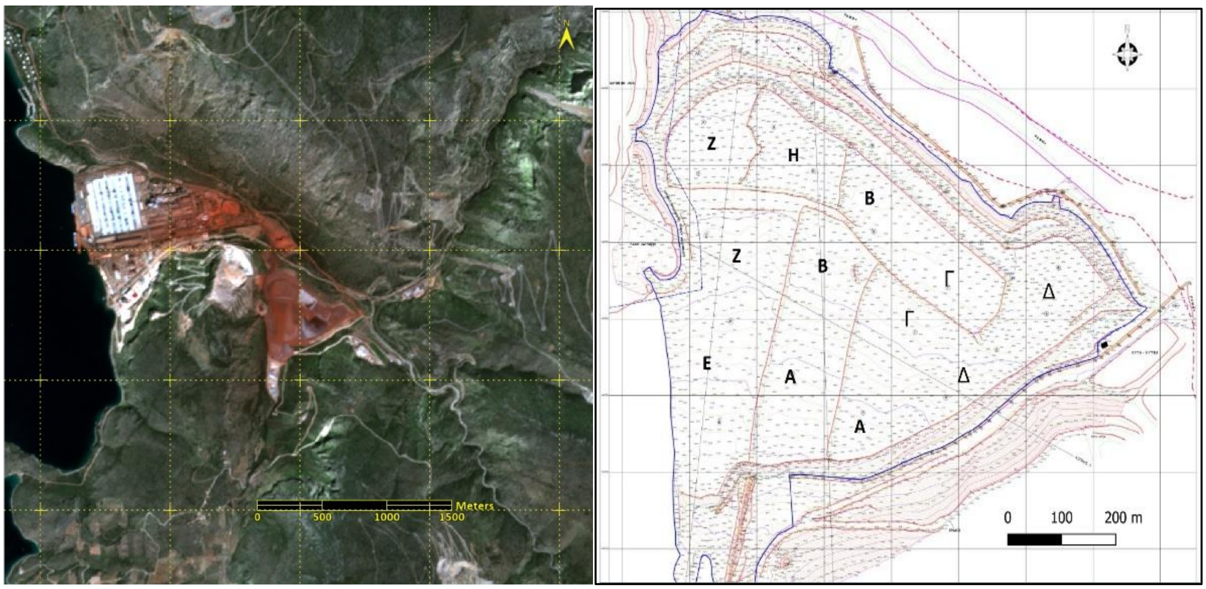

Figure 1. Sentinel-2 image true color (RGB), sensing date: 15-04-2021 (Left) and Topography map of piling area (Right)

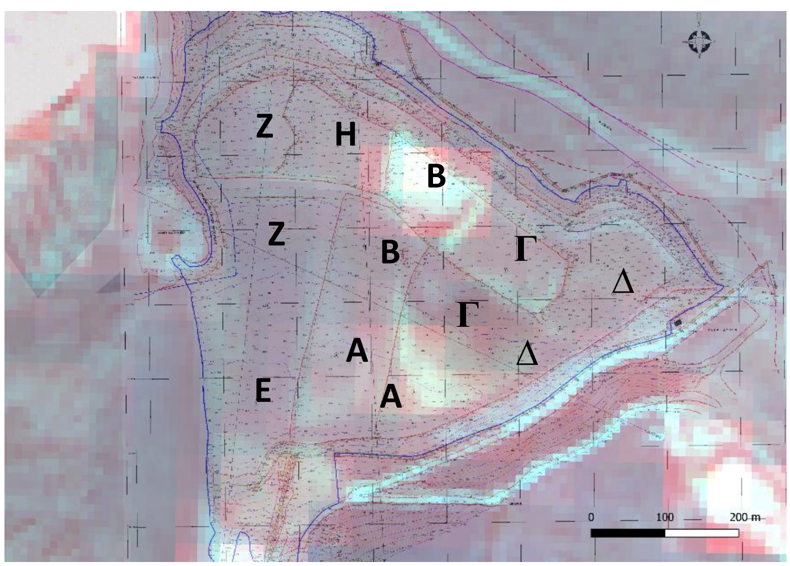

Figure 3. Sentinel-2 image plus topography map of piling area in QGIS

Sampling strategies:

- Taking maximum sample from the active layers;
- No sample is needed from geofabric layer (for example area B in April);
- Samples are homogenous with grain sizes almost equal to 5 microns;
- Sample grid should be updated due to the exact day of sampling: a dense grid from a specific area and large distanced-samples from the whole area.

Proposal of sampling: Figure 4

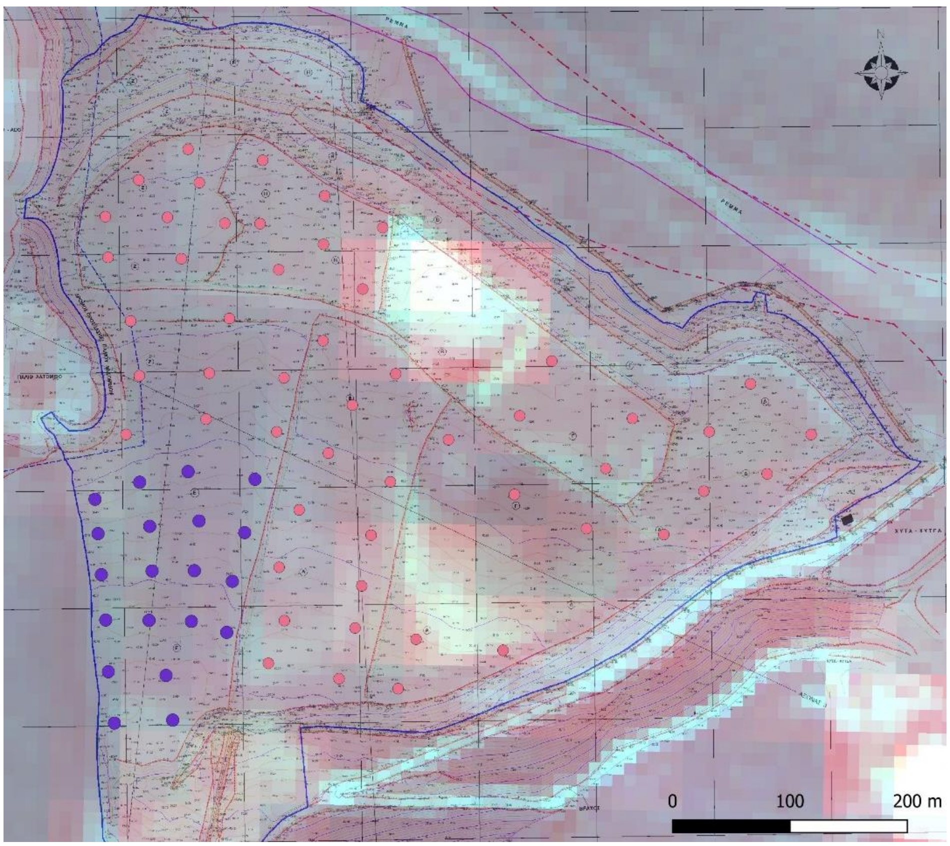

Figure 4. Regular sampling grid on Sentinel-2 image plus topography map of piling area in QGIS (purple samples is selected area)

Time period needed for data collection to find the correlation between infield samples and the exit of processing plant: minimum 4 months to 8 months.

Proposed time for sampling: approximately one day between 26 May and 7 June.

Extra information: how long it takes to complete a geofabric layer?

Table 1: localisation of sampling, according to Figure 4 (selected area)

id	X	Y	Area
1	22.70245	38.35391	E
2	22.70289	38.35404	E
3	22.70336	38.35412	E
4	22.70402	38.35407	E
5	22.70248	38.35365	E
6	22.70299	38.35371	E
7	22.70347	38.35375	E
8	22.70391	38.35366	E
9	22.70252	38.35334	E
10	22.70301	38.35337	E
11	22.70342	38.35337	E
12	22.70379	38.35329	E
13	22.70256	38.35299	E
14	22.70298	38.35299	E
15	22.70339	38.35298	E
16	22.70374	38.3529	E
17	22.70258	38.3526	E
18	22.70315	38.35257	E
19	22.70264	38.3522	E
20	22.70321	38.35223	E

Table 2: localisation of sampling, according to Figure 4 (other areas)

id	X	Y	Area
21	22.70336	38.35659	Z
22	22.70288	38.35635	Z
23	22.70347	38.35633	Z
24	22.70256	38.35607	Z
25	22.70316	38.35607	Z
26	22.70372	38.35602	Z
27	22.70258	38.35576	Z
28	22.7033	38.35575	Z
29	22.7028	38.35527	Z
30	22.70376	38.3553	Z
31	22.70289	38.35486	Z
32	22.70357	38.35488	Z
33	22.7043	38.35484	Z

34	22.70276	38.35441	Z
35	22.70354	38.35453	Z
36	22.70423	38.35443	Z
37	22.70409	38.3565	H
38	22.70469	38.35623	H
39	22.70526	38.35599	H
40	22.70406	38.35602	H
41	22.70468	38.35586	H
42	22.70506	38.35552	H
43	22.70425	38.35567	H
44	22.70468	38.35512	B
45	22.70539	38.35487	B
46	22.70496	38.35463	B
47	22.70473	38.35427	B
48	22.70533	38.35405	B
49	22.70444	38.35383	B
50	22.70515	38.35364	B
51	22.70425	38.35339	A
52	22.70506	38.35325	A
53	22.7043	38.35299	A
54	22.70499	38.35293	A
55	22.70415	38.35266	A
56	22.70483	38.35254	A
57	22.70541	38.35247	A
58	22.70559	38.35284	A
59	22.70643	38.35276	A
60	22.70691	38.35497	Γ
61	22.70769	38.35453	Γ
62	22.7066	38.35455	Γ
63	22.70743	38.35415	Γ
64	22.7059	38.35437	Γ
65	22.70654	38.35395	Γ
66	22.70725	38.35369	Γ
67	22.70885	38.3548	Δ
68	22.70944	38.35441	Δ
69	22.70844	38.35443	Δ
70	22.70901	38.35411	Δ
71	22.70839	38.35398	Δ
72	22.708	38.35364	Δ

Sampling (NTUA and Mytilineos):

- before sampling, picture of location
- Grab sampling: not from the surface but with the depth of less than 0.5 m. After removing the weathered surface, samples can be taken. It should be representative of materials which we have their daily information.
- mass of each samples ≈ 300 g
- samples in a closed plastic bag with id number
- shipping of all samples to Orano (middle of June)

After sampling (Orano):

- laser particle size analyser on some samples
- samples preparation:
  - Drying at 105°C
  - homogenizing, separation, mixture of some individual samples (composite)
  - appropriate weight for analyses
- shipping of samples to BRGM and DELFT

Analyses (Orano, BRGM and Delft)

Table 3: List of analyses

id	Area	Orano	BRGM		DELFT
1	E	ICP A	ICP A	ICP-B	XRF
2	E	ICP A			XRF
3	E	ICP A			XRF
4	E	ICP A			XRF
5	E	ICP A			XRF
6	E	ICP A	ICP A	ICP-B	XRF
7	E	ICP A			XRF
8	E	ICP A			XRF
9	E	ICP A			XRF
10	E	ICP A			XRF

11	E		ICP A	ICP-B	XRF
12	E		ICP A		XRF
13	E		ICP A		XRF
14	E	ICP A	ICP A	ICP-B	XRF
15	E		ICP A		XRF
16	E		ICP A		XRF
17	E		ICP A		XRF
18	E		ICP A		XRF
19	E		ICP A		XRF
20	E	ICP A	ICP A	ICP-B	XRF
21	Z	ICP-A		ICP-B	XRF
22	Z				XRF
23	Z				XRF
24	Z				XRF
25	Z	ICP-A			XRF
26	Z				XRF
27	Z				XRF
28	Z				XRF
29	Z	ICP-A			XRF
30	Z				XRF
31	Z				XRF
32	Z				XRF
33	Z	ICP-A			XRF
34	Z				XRF
35	Z				XRF
36	Z				XRF
37	H	ICP-A		ICP-B	XRF
38	H				XRF
39	H				XRF
40	H				XRF
41	H	ICP-A			XRF
42	H				XRF
43	H				XRF
44	B		ICP-A	ICP-B	XRF
45	B				XRF
46	B				XRF
47	B				XRF
48	B		ICP-A		XRF
49	B				XRF

50	B				XRF
51	A		ICP-A	ICP-B	XRF
52	A				XRF
53	A				XRF
54	A				XRF
55	A		ICP-A		XRF
56	A				XRF
57	A				XRF
58	A				XRF
59	A				XRF
60	Γ		ICP-A	ICP-B	XRF
61	Γ				XRF
62	Γ				XRF
63	Γ				XRF
64	Γ		ICP-A		XRF
65	Γ				XRF
66	Γ				XRF
67	Δ		ICP A	ICP-B	XRF
68	Δ				XRF
69	Δ				XRF
70	Δ		ICP-A		XRF
71	Δ				XRF
72	Δ				XRF

- ICP A : Sc, Nd, Y, Sc Li
- ICP B : La, Ce, Pr, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Tu

TEM analysis: to be determined

Additional information about the origin of processing plant feeds will be asked:

- Possible information about the mine of rocks;
- The geological type of ore-bodies;
- The name of mines (if possible).

Timeline

Tasks	Week number															
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	May				June				July				August			
Validation of sampling procedure	■															
Sampling on site					■											
Samples shipping MYT → Orano						■	■									
Samples preparation								■	■							
Samples shipping Orano → DELFT and BRGM										■						
analyses											■	■	■	■	■	■

Annex 1: Meeting WP4 – T4.2 Sampling

27 April 2021, 11.00 - 12.00 CET

Participants

- F. Tinti, S. Kasmaee UNIBO
- F. Bodenan BRGM
- O. Chernoburova UL
- D. Sparis NTUA
- A. Guatame Garcia DELFT
- J. Schick ORANO

Main issues and questions

- There is not large information about the origin of the bauxite. Similarity inside the processing plant is for main element, not the trace ones. It is possible that MYT will say qualitatively the mix of materials (Greek and Brasil) but not the mix. In any case, having the names of deposits would allow to make a literature research over them. We should has them. In any case it is very hard to correlate the raw material with the bauxite residue.
- Our target would be to sample in May. It is better to focus on the piling area (where performing ICP, in dense samples), while in the rest the sampling will be sparser and where will be performed XRF. Regarding samples, there will be around 20 in the sampling area (ICP) and around 100 sparse around (XRF).
- It would be important to know if MYT record some information about plants in the 5-6 months before sampling. Also, information over the geo-fabric would be very much useful. If laying of the geo-fabric is constant in time or not.
- All samples will be sent to ORANO, which will prepare them in their labs. They will perform also some XRF and ICP. Afterwards, the samples will be sent to BRGM for ICP (20) and to DELFT for XRF (100). The few samples measured in ORANO will be repeated over the same samples in BRGM and DELFT, to check any differences in the labs.
- NTUA will support MYT for taking samples. There will be need of authorization. It is possible it will be a 1-2 days campaign.
- In the final grid, the identification of samples for ICP and the ones for XRF will be done.
- Each sample will have the same quantity (some grams). No need of big quantities because there will not be leaching tests at the moment.
- Regarding processing, according to the results, it should be theoretically hypothesized a zero waste processing, with extraction of target elements, and a way to reuse the rest.
- The target elements will be: scandium, lithium, yttrium, neodymium. ICP will be performed over these four for the 20 target samples. A broader ICP for other materials will be done on few samples.
- It is possible there will be mixing of samples before analysis. However, the coordinates should be kept because they are useful for correlation with remote sensing.

Annex 2: Remote sensing and geostatistical preliminary analyses over the case study

Front page, abstract and funding details of the open access paper over the preliminary analyses of remote sensing and geostatistics on the case study, realised by the Responsible of T4.2 and the owner of the case study and published in late May 2021

minerals MDPI

Article

Spatial Component Analysis to Improve Mineral Estimation Using Sentinel-2 Band Ratio: Application to a Greek Bauxite Residue

Roberto Bruno [1,*], Sara Kasmaeeyazdi [1,*], Francesco Tinti [1], Emanuele Mandanici [1] and Efthymios Balomenos [2]

1 Department of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, 40136 Bologna, Italy; francesco.tinti@unibo.it (F.T.); emanuele.mandanici@unibo.it (E.M.)
2 Metallurgy Business Unit, MYTILINEOS S.A., Ag. Nikolaos, 320 03 Viotia, Greece; efthymios.balomenos-external@alhellas.gr
* Correspondence: roberto.bruno@unibo.it (R.B.); sara.kasmaeeyazdi2@unibo.it (S.K.); Tel.: +39-05-1209-0241 (S.K.)

Abstract: Remote sensing can be fruitfully used in the characterization of metals within stockpiles and tailings, produced from mining activities. Satellite information, in the form of band ratio, can act as an auxiliary variable, with a certain correlation with the ground primary data. In the presence of this auxiliary variable, modeled with nested structures, the spatial components without correlation can be filtered out, so that the useful correlation with ground data grows. This paper investigates the possibility to substitute in a co-kriging system, the whole band ratio information, with only the correlated components. The method has been applied over a bauxite residues case study and presents three estimation alternatives: ordinary kriging, co-kriging, component co-kriging. Results have shown how using the most correlated component reduces the estimation variance and improves the estimation results. In general terms, when a good correlation with ground samples exists, co-kriging of the satellite band-ratio Component improves the reconstruction of mineral grade distribution, thus affecting the selectivity. On the other hand, the use of the components approach exalts the distance variability.

Keywords: resources characterization; bauxite residues; band ratio; kriging of component; mineral grade

check for updates

Citation: Bruno, R.; Kasmaeeyazdi, S.; Tinti, F.; Mandanici, E.; Balomenos, E. Spatial Component Analysis to Improve Mineral Estimation Using Sentinel-2 Band Ratio: Application to a Greek Bauxite Residue. *Minerals* **2021**, *11*, 549. https://doi.org/10.3390/min11060549

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