Radiological and mineralogical characterization of the tailings of a niobium ore treatment plant in Brazil

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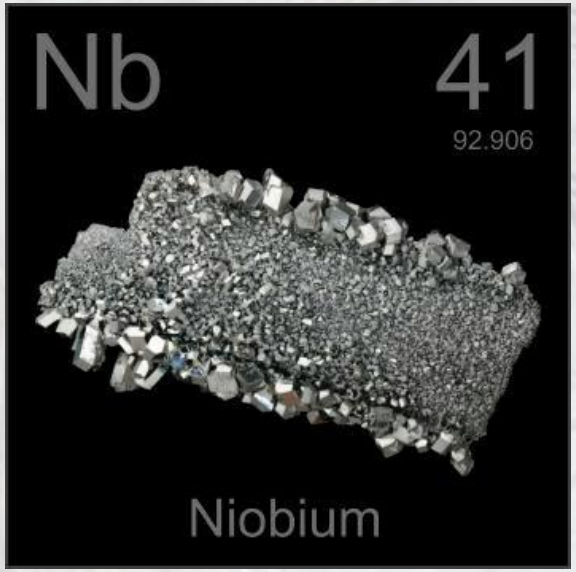


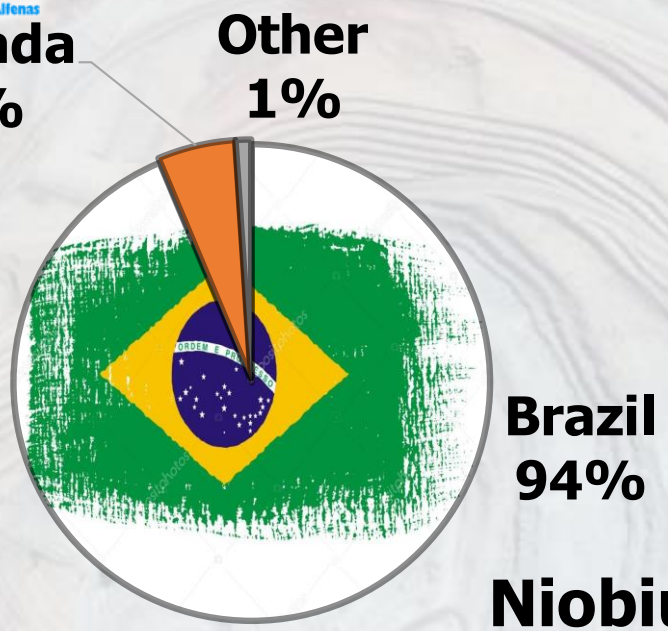
USES OF NIOBIUM

- Steel production
- Superalloys
- Superconducting magnets
- Hypoallergenic applications: medicine and jewelry

Niobium mine

Concentration and metallurgical process

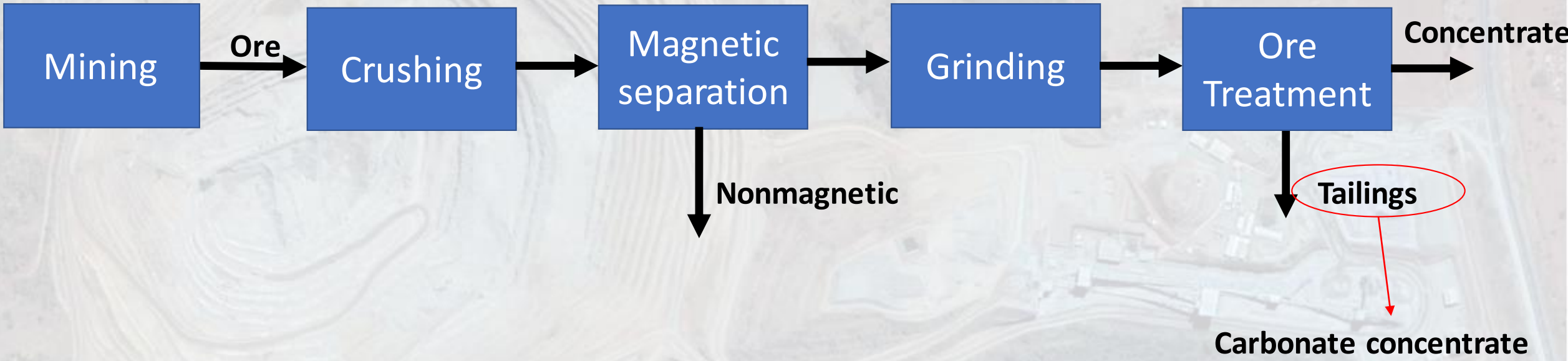
Niobium product



CMOC
≈ 8,6 thousand tones of niobium per year

Niobium production (t)

Country	Reserves (t)	Production (t)			
	2014	2012	2013	2014	(%)
Brazil	10.827.843,00	82.214,00	76.899,00	88.771,00	93,67
Canada	200.000,00	4.710,00	5.260,00	5.000,00	5,28
Other countries	nd	375,00	1.000,00	1.000,00	1,05
TOTAL	**11.027.843,00**	**87.299,00**	**83.159,00**	**94.771,00**	**100,00**


Mining
Ore
Crushing
Magnetic separation
Grinding
Ore Treatment
Concentrate
Nonmagnetic
Tailings
Carbonate concentrate

OBJECTIVE

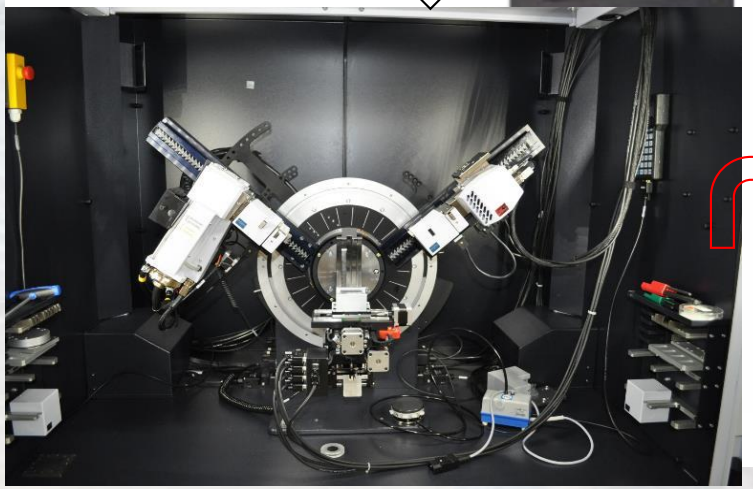
- Radiologically and mineralogically characterize the carbonate concentrate due to its potential to be used as soil amendment.

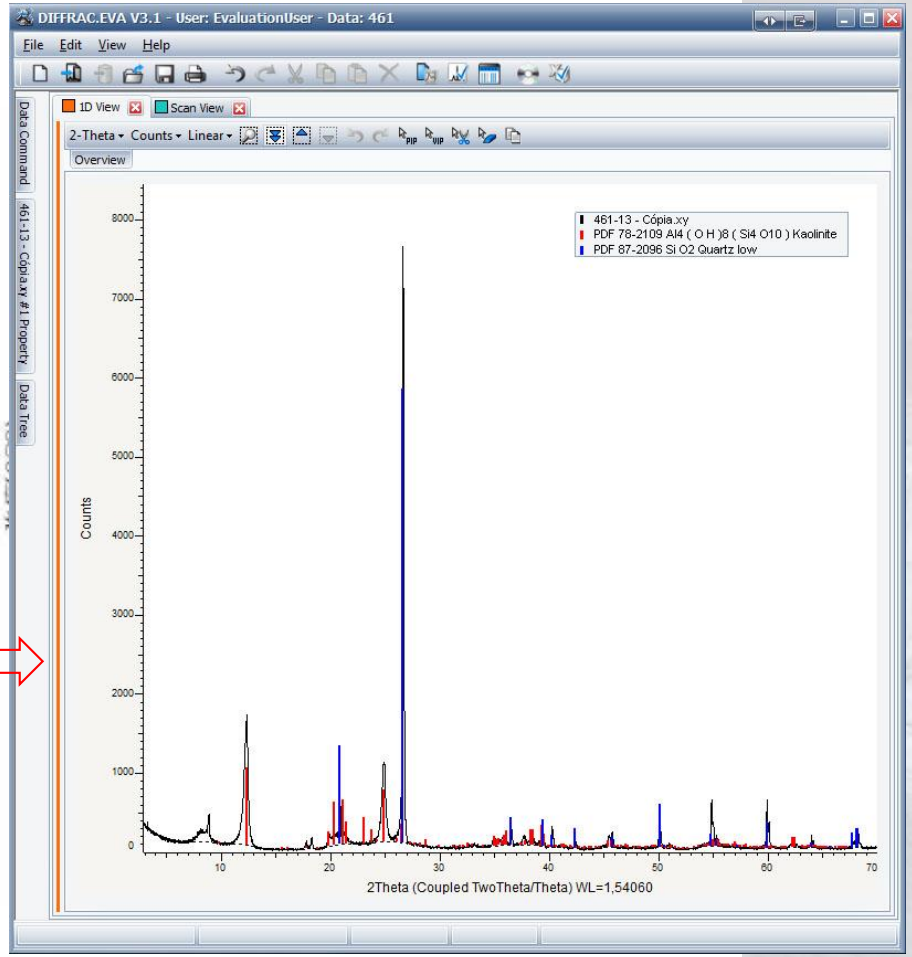
METHODOLOGY

- Neutron Activation Analysis (^{238}U and ^{232}Th, REE, Ba, Zn, Zr, As, Cr, Hf, Rb, Sc, Co, Sb and Ta)
- Gamma Spectrometry (^{226}Ra, ^{228}Ra, ^{228}Th, ^{210}Pb and ^{40}K).
- SEM analysis.
- X-Ray diffraction
- X-Ray fluorescence

X-RAY DIFRACTION

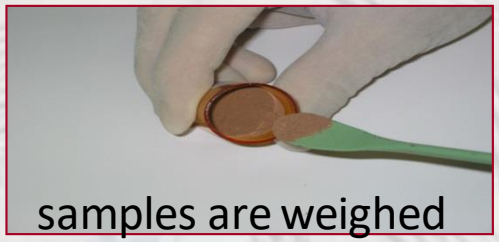
Samples were grinded and placed in a glass specimen holder

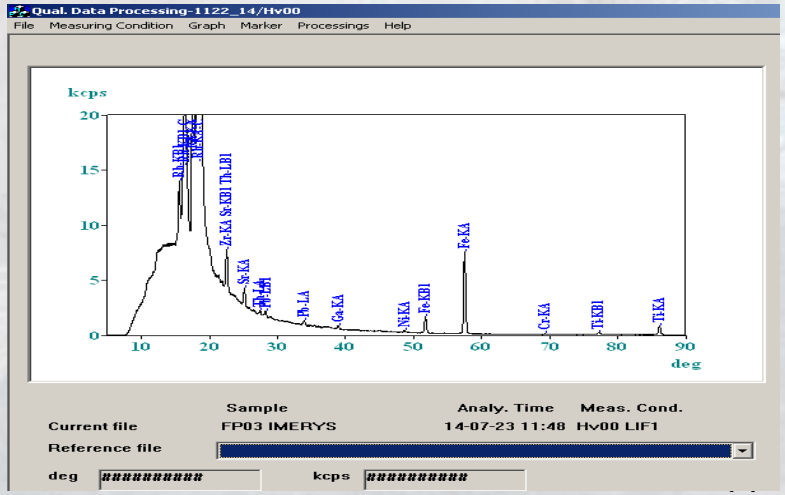




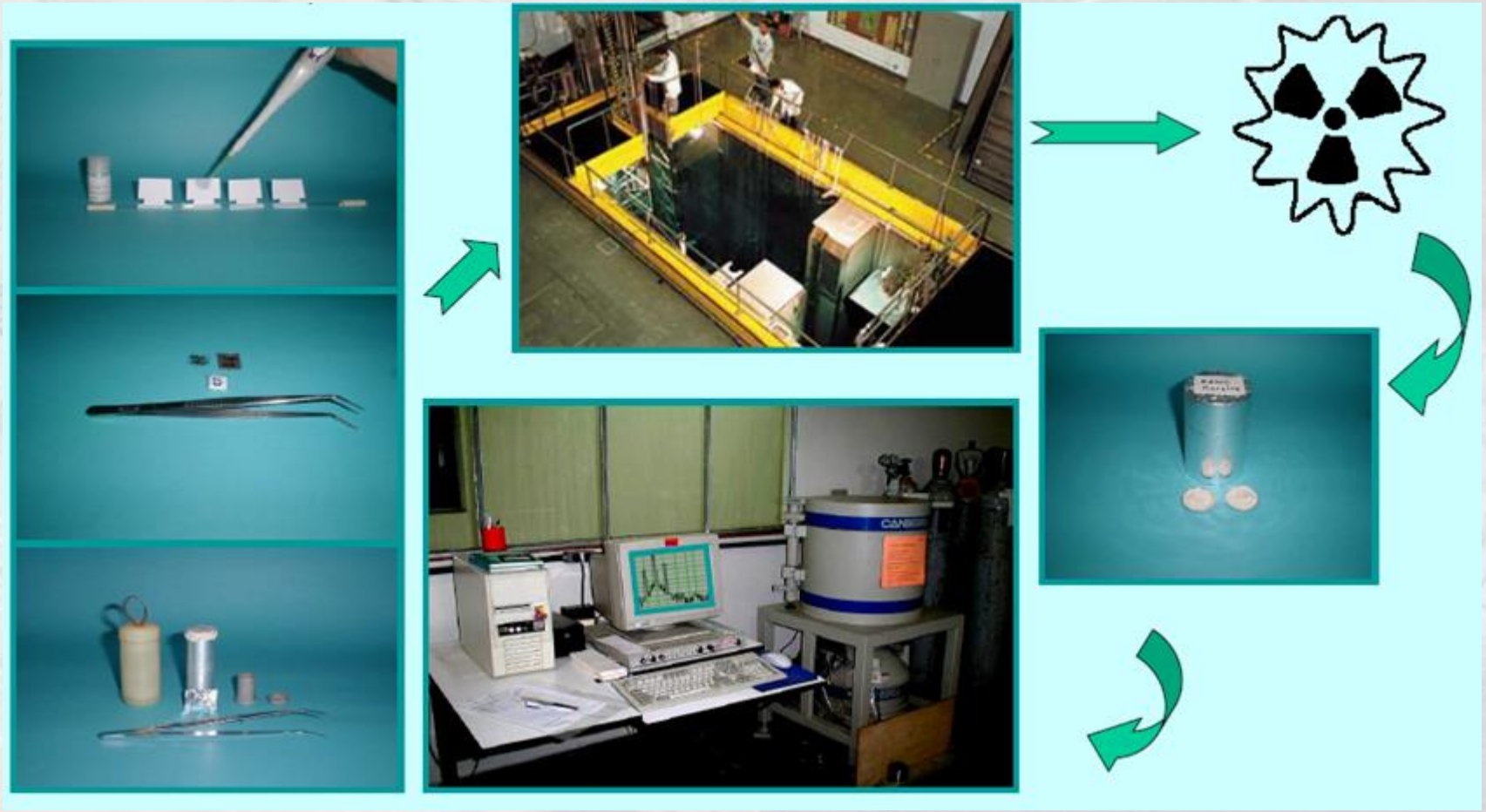
XRD results are compared with ICDD files using EVA software from Bruker

X-RAY FLUORESCENCE



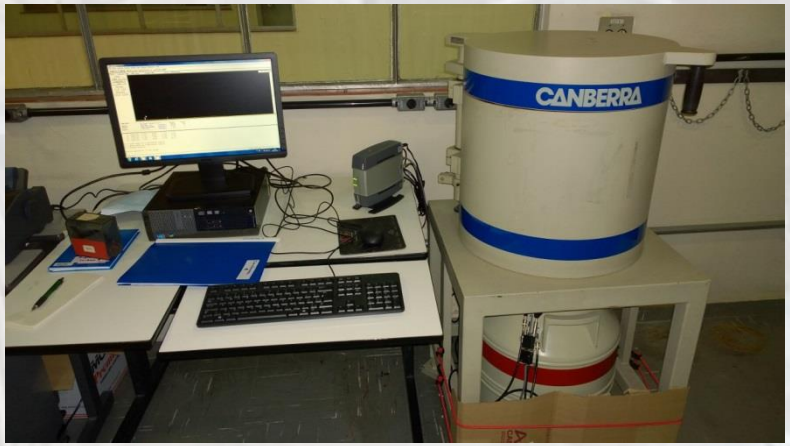


NEUTRON ACTIVATION ANALYSIS

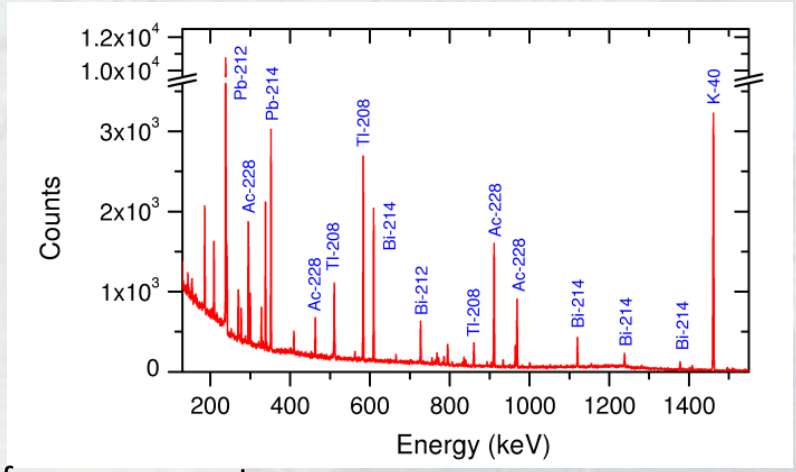


GAMMA-RAY SPECTROMETRY

Samples were packed in 100 cm^3 polyethylene flasks, sealed and set apart for about four weeks



Measued in a gamma-ray spectrometer



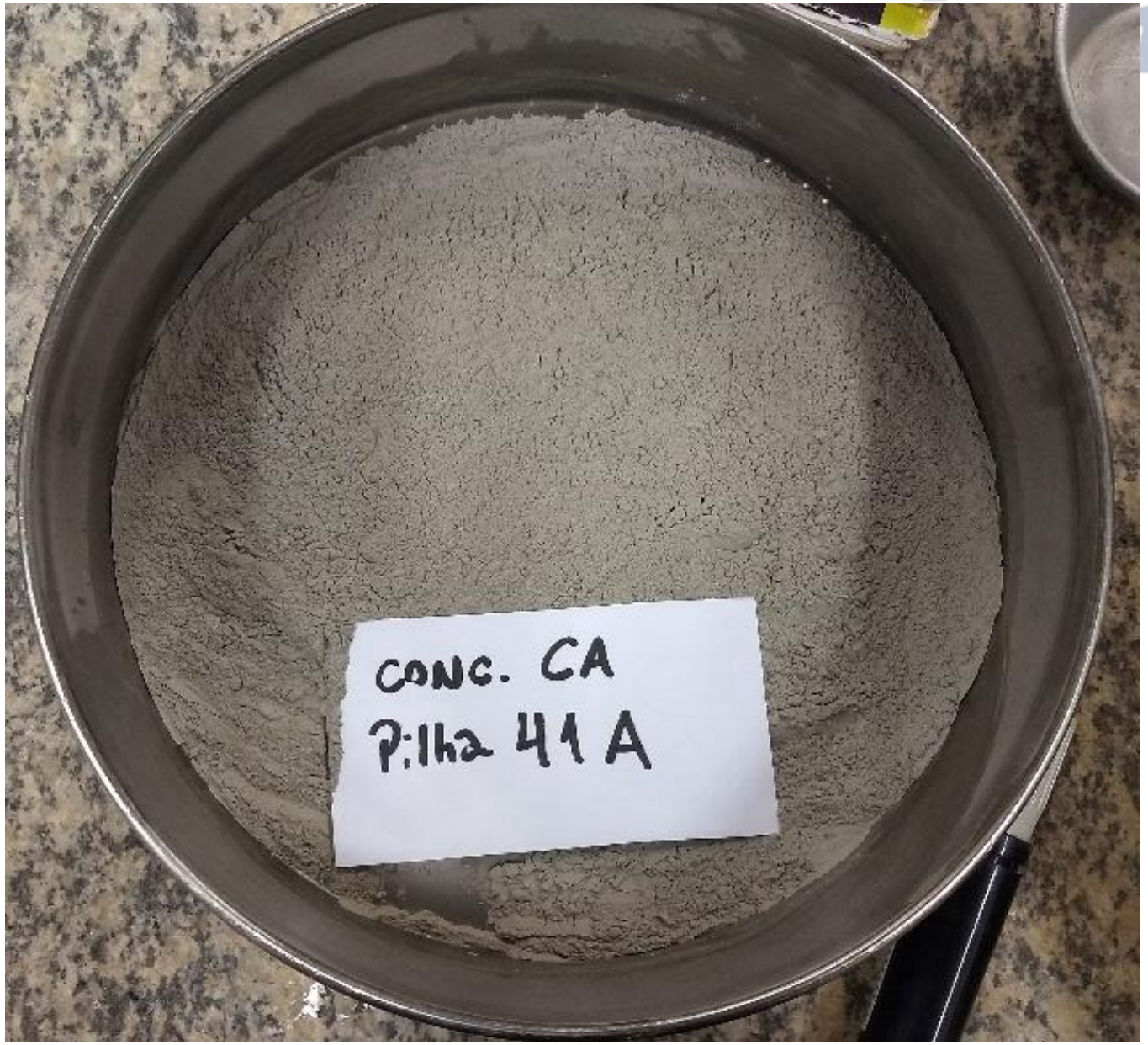
Ilustration of a gamma spectrum

Genie™ 2000 Spectroscopy Software V3.2

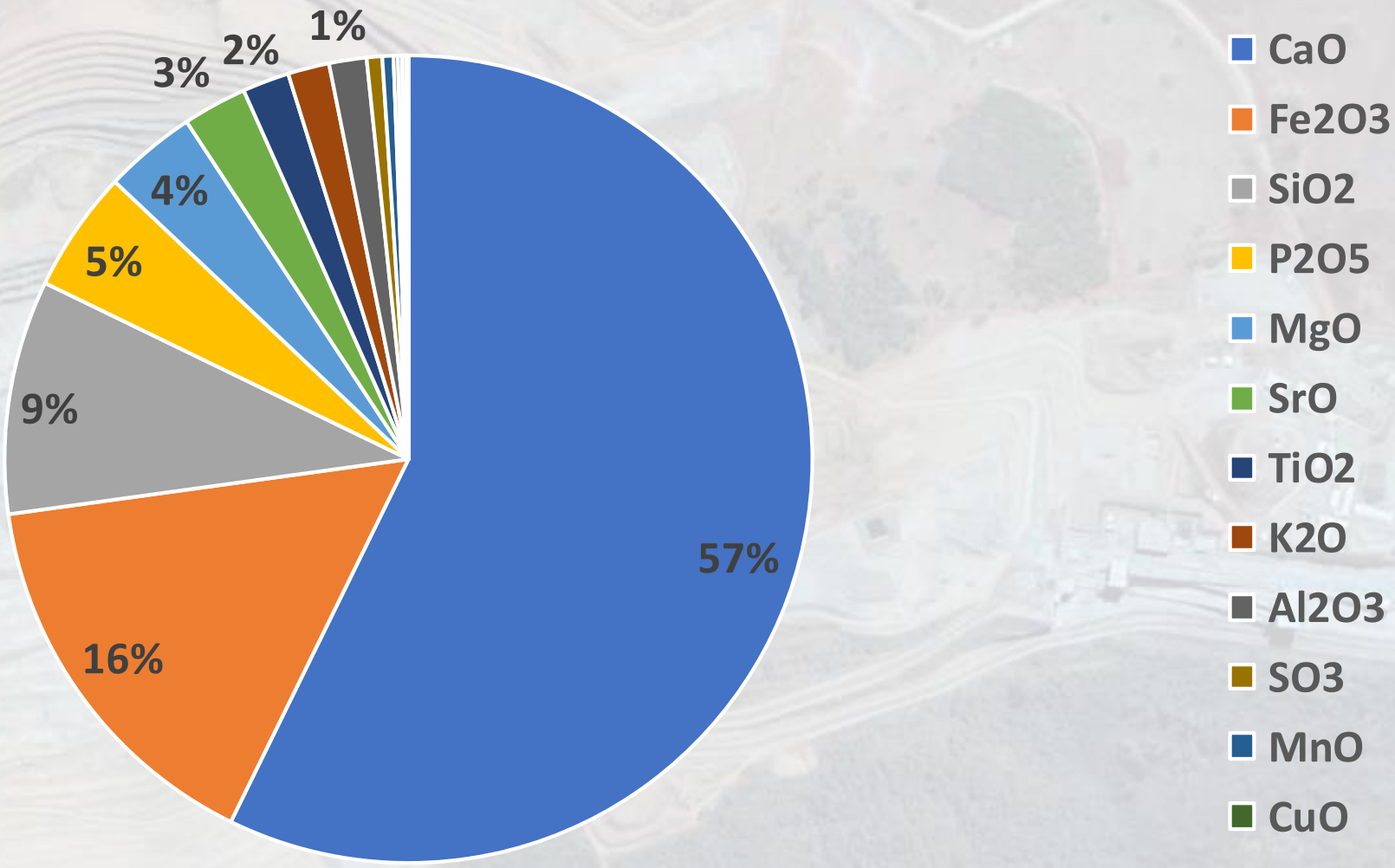
SAMPLES

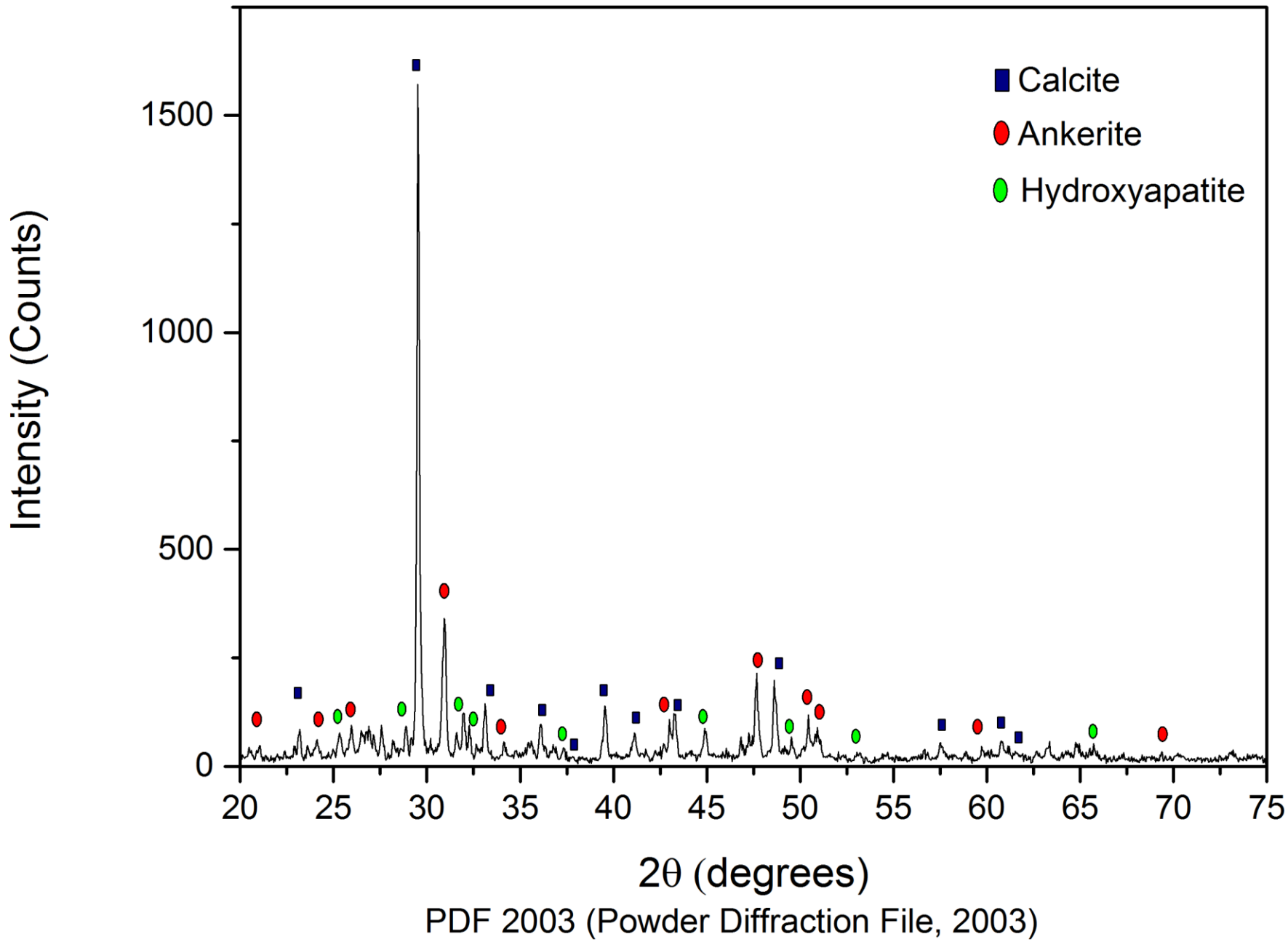
10 SAMPLES – 100% < 0.106 MM

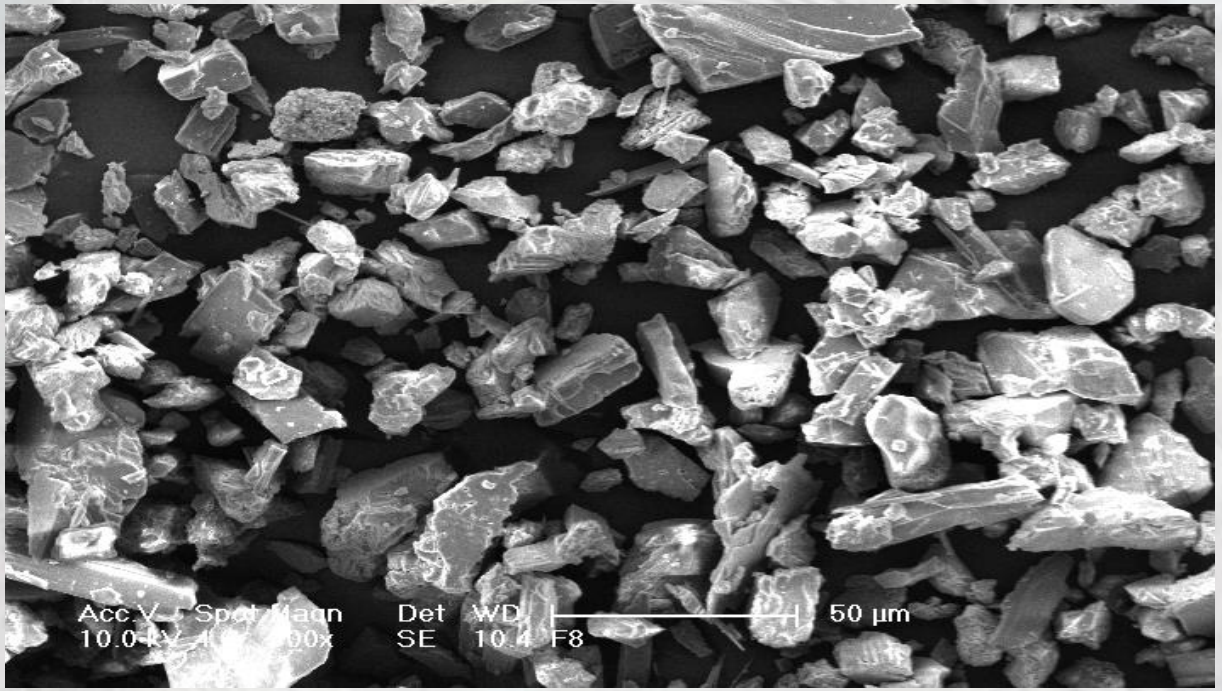
10/8/2019

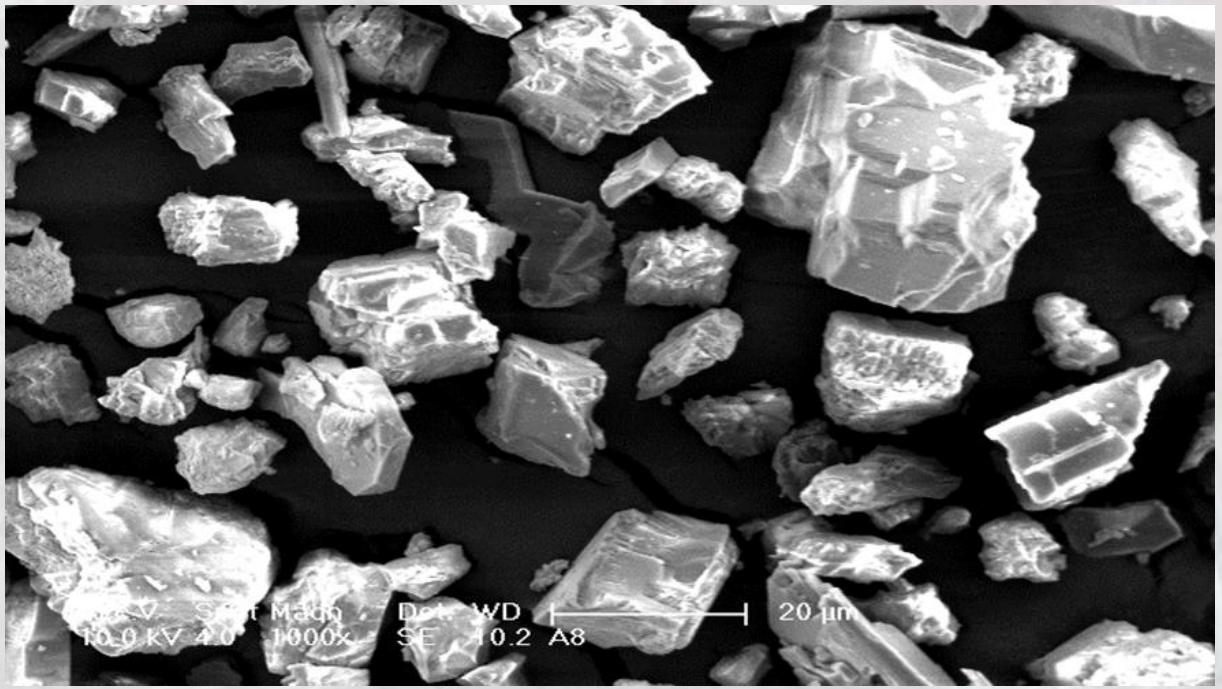


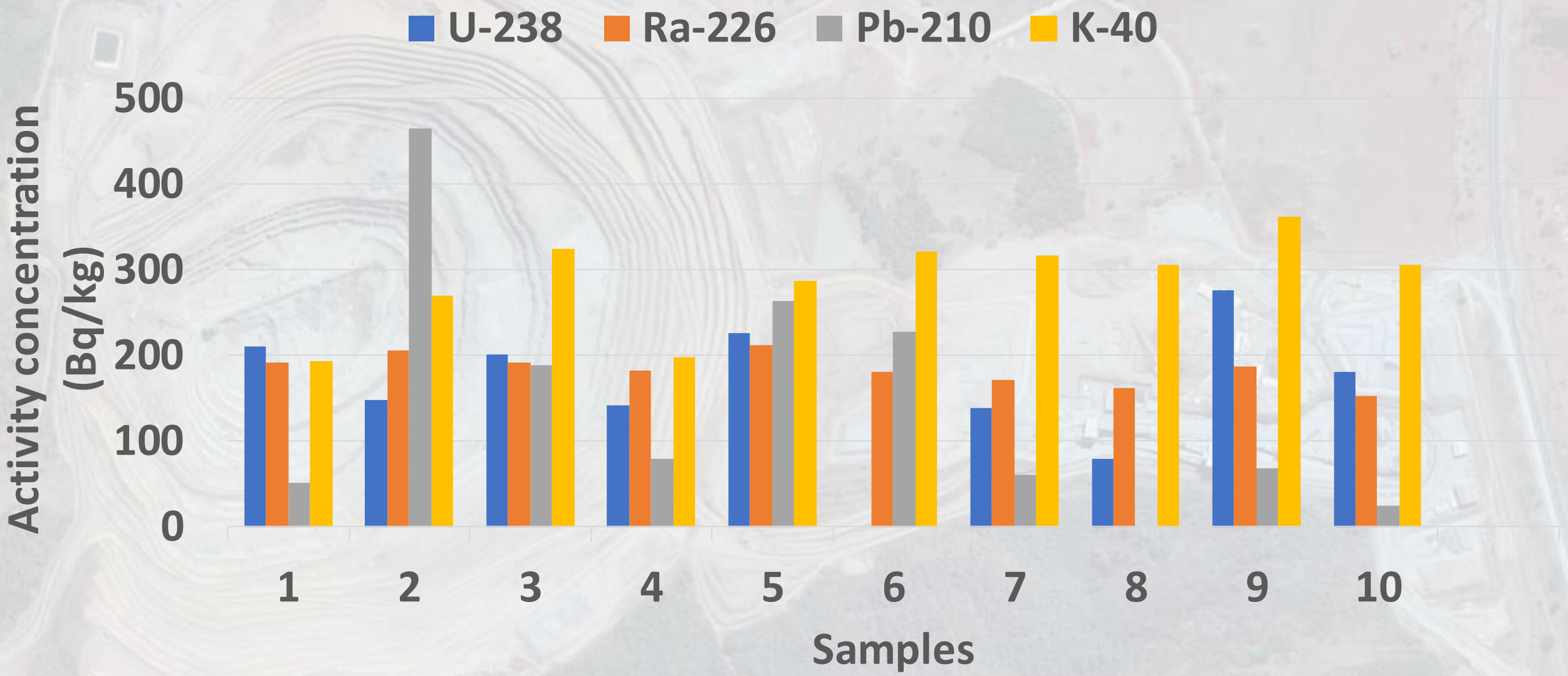
Composition (%)

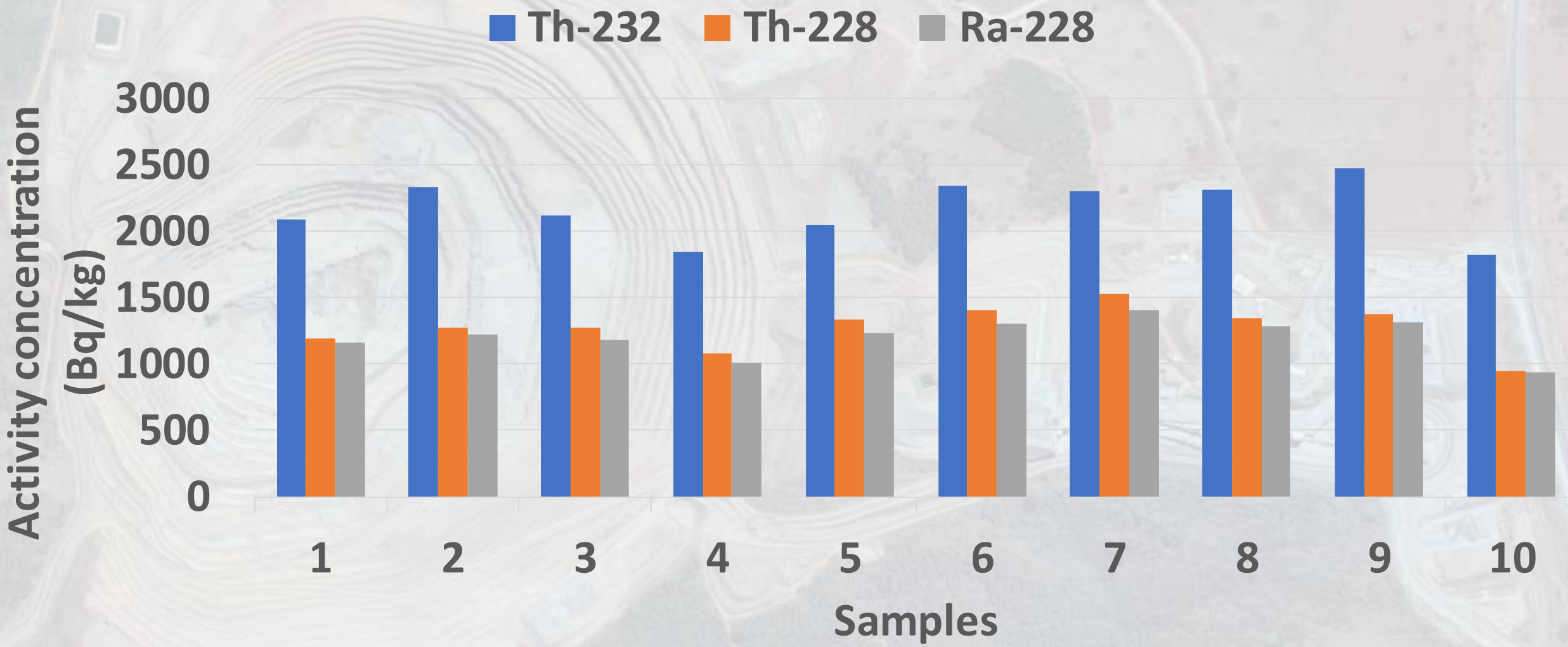


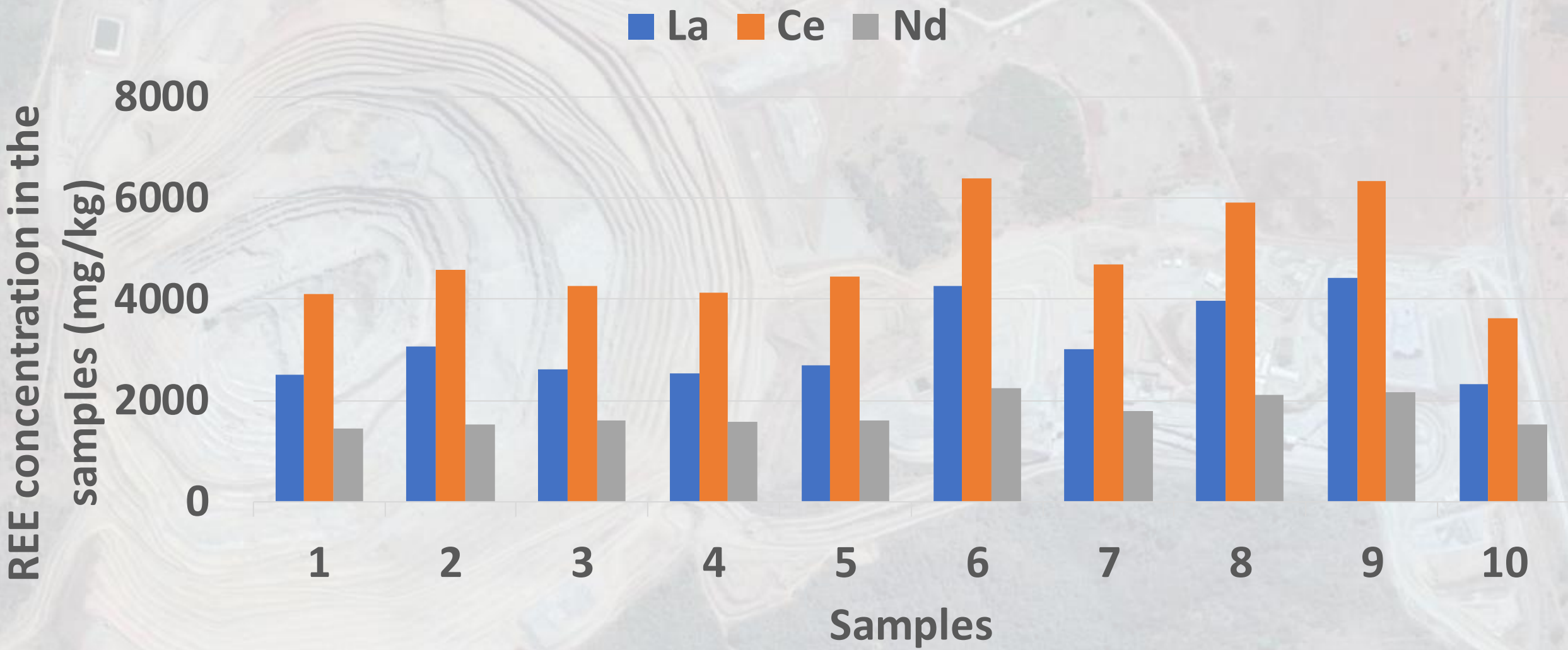

Calcite
Ankerite
Hydroxyapatite
Intensity (Counts)
0
500
1000
1500
20
25
30
35
40
45
50
55
60
65
70
75
2θ (degrees)
PDF 2003 (Powder Diffraction File, 2003)

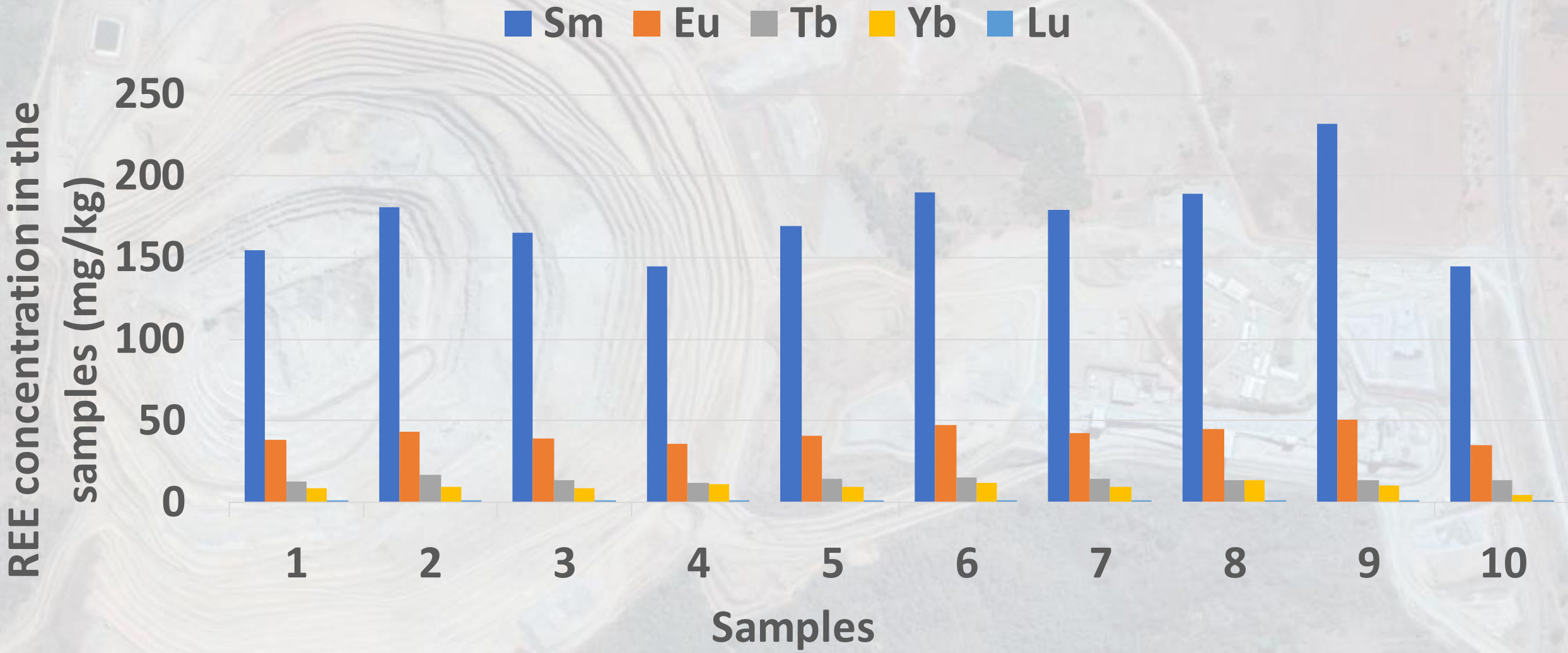

Det WD
SE 10.4 F8
50 µm

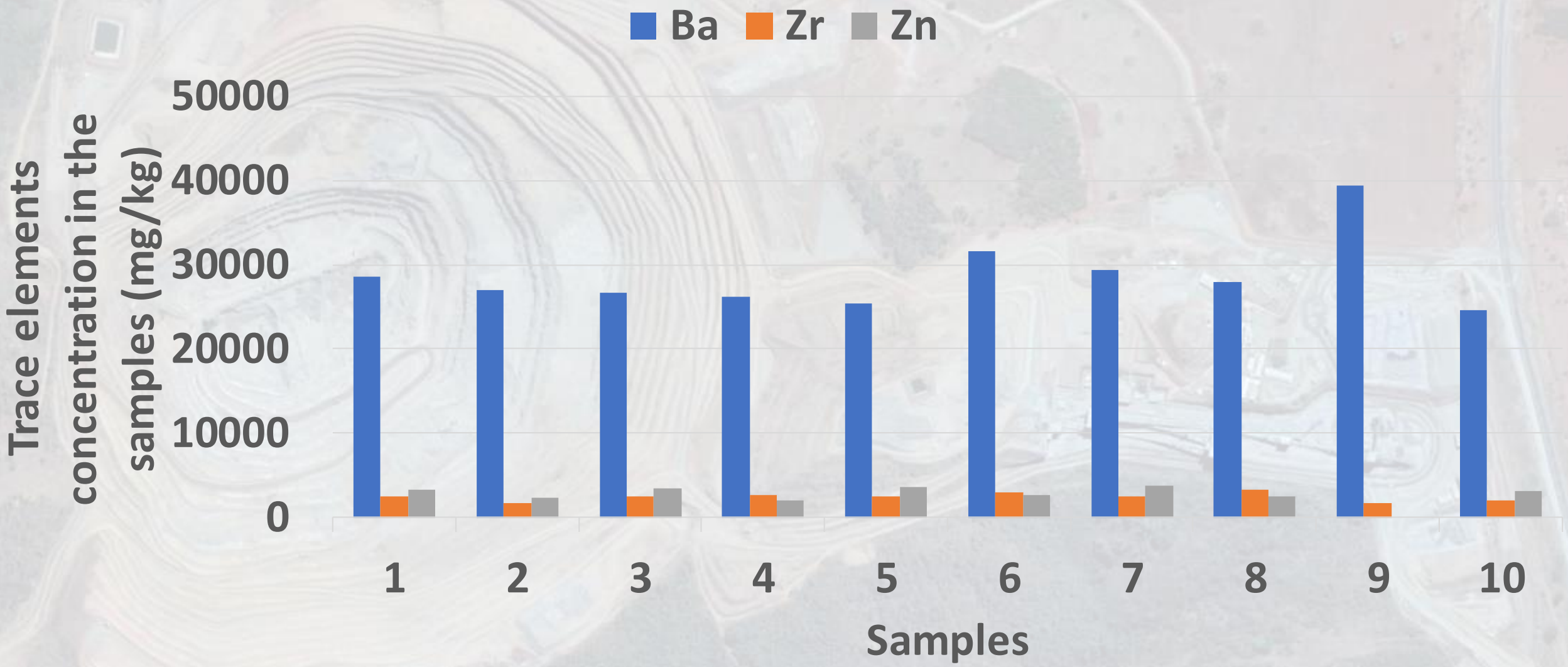

Det WD
SE 10.2 A8
20 µm

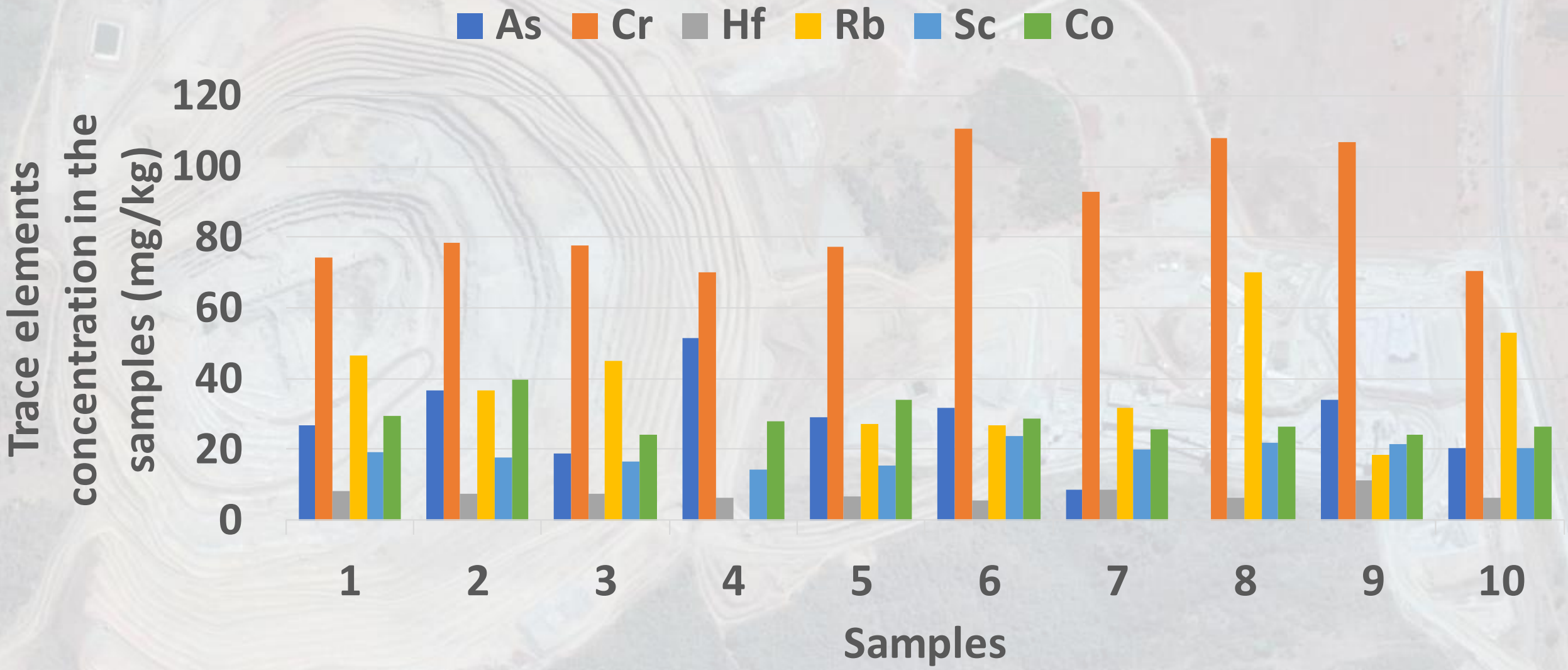

U-238
Ra-226
Pb-210
K-40
Activity concentration (Bq/kg)
500
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10
Samples

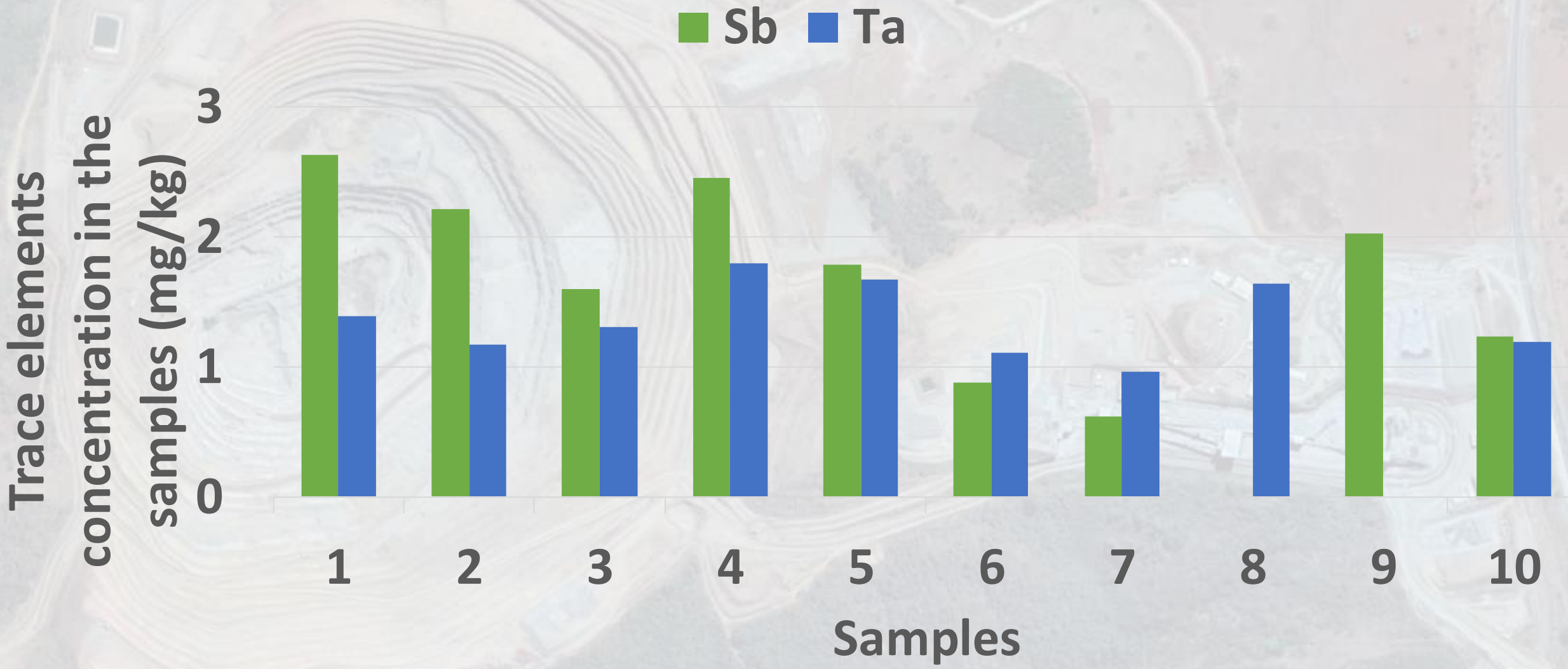

Th-232
Th-228
Ra-228
Activity concentration (Bq/kg)
3000
2500
2000
1500
1000
500
0
1
2
3
4
5
6
7
8
9
10
Samples


La
Ce
Nd
REE concentration in the samples (mg/kg)
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8
9
10
Samples


Sm
Eu
Tb
Yb
Lu
REE concentration in the samples (mg/kg)
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
Samples


Ba
Zr
Zn
Trace elements concentration in the samples (mg/kg)
50000
40000
30000
20000
10000
0
1
2
3
4
5
6
7
8
9
10
Samples


As
Cr
Hf
Rb
Sc
Co
Trace elements concentration in the samples (mg/kg)
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
Samples


Sb
Ta
Trace elements concentration in the samples (mg/kg)
0
1
2
3
1
2
3
4
5
6
7
8
9
10
Samples

$$D_{ab} = 0{,}462 \times C_U + 0{,}604 \times C_{Th} + 0{,}0417 \times C_K$$

$$Ra_{eq} = C_U + 1{,}43 \times C_{Th} + 0{,}077 \times C_K$$

$$Hex = \frac{C_U}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810}$$

$$Hin = \frac{C_U}{185} + \frac{1{,}43 \times C_{Th}}{259} + \frac{0{,}077 \times C_K}{4810}$$

RADIOLOGICAL HAZARD INDICES

Sample #	^{238}U		^{226}Ra		^{232}Th		^{228}Th		^{228}Ra		^{40}K		Ra eq	Hex	Hin	D
	Bq/kg	±	Bq/kg	±	Bq/kg	±	Bq/kg	±	Bq/kg	±	Bq/kg	±	(Bq/kg)			(nGy/h)
1	210,7	19,7	191,5	3,7	2092,9	130,4	1197,5	18,5	1160,8	7,8	193,1	7,5	1866	2,5	5,6	798
2	0,0	0,0	205,6	2,7	0,0	0,0	1278,0	24,7	1219,1	8,3	270,5	8,4	1970	2,7	5,9	843
3	201,3	17,6	192,3	3,4	2122,4	132,3	1272,6	17,4	1187,4	8,1	324,6	8,2	1915	2,6	5,7	820
4	142,1	18,4	182,7	2,6	1843,7	109,0	1082,8	11,2	1013,7	7,6	197,5	7,6	1648	2,2	4,9	705
5	225,8	24,9	211,3	3,1	2049,1	127,7	2049,1	127,7	1337,3	10,8	1231,1	8,6	287	5,4	6,6	957
6	0,0	0,0	180,7	2,9	2341,6	138,4	1404,3	18,3	1306,9	7,4	321,2	9,0	2074	2,8	6,1	886
7	138,1	18,2	171,0	3,0	2303,3	143,6	1530,8	20,9	1403,6	9,0	316,9	9,4	2202	3,0	6,4	940
8	79,0	20,7	161,8	3,7	2312,4	136,7	1342,8	19,4	1282,3	8,3	306,1	8,8	2019	2,7	5,9	862
9	0,0	0,0	187,4	3,8	0,0	0,0	1374,3	20,1	1312,1	7,8	362,1	5,8	2092	2,8	6,2	894
10	180,9	18,1	152,5	3,5	1826,2	113,8	949,3	17,4	938,1	10,1	306,2	9,1	1518	2,0	4,5	650
Average 10 samples	117,8	13,8	183,7	3,2	1689,1	103,2	1348,1	29,6	1216,1	8,5	382,9	8,2	1759,0	2,9	5,8	835,4
DP 10 samples	91,5	9,7	18,3	0,4	908,0	55,4	296,5	34,7	146,7	1,1	303,0	1,1	557,1	0,9	0,6	97,5
Reference value or Global average													370	1	1	84

RADIOLOGICAL HAZARD INDICES

Sample	Ra_{eq} $[\frac{Bq}{kg}]$	H_{ex}	H_{in}	D $[\frac{nGy}{h}]$
A	116.46	0.1570	0.4106	54.27
B	117.12	0.1579	0.4123	54.55
C	114.91	0.1549	0.4063	53.61
D	116.34	0.1568	0.4105	54.22
E	114.99	0.1550	0.4066	53.65
F	117.35	0.1582	0.4129	54.65

CONCLUSIONS

The carbonate tailing samples , resulting from niobium production analyzed in this study is characterized by :

- Calcium carbonate as main constituent;
- Iron, silica, phosphorus, magnesium, strontium, potassium and aluminum;
- Calcite and ankerite as the calcium minerals ;
- U-series nuclides activity concentration around 200 Bq/kg;
- Th-series nuclides activity concentrations around 1200 Bq/kg;
- Enriched in La, Ce, Nd and Ba;
- Carbonate samples presents Ra-228 activity concentration higher than the limit of exemption for use in agriculture stablished for phosphogypsum according to Brazilian regulation;
- Dilution factor resulting from applications of the carbonate as soil amendment results in radiological hazard indices in acceptable levels.

NEXT STEPS

Leaching study of the radionuclides from:

- Carbonate
- Soil + carbonate

Up take of the radionuclides determination by vegetables growth in soil amended with the carbonate tailing

Thank you

- Dr. Paulo Sergio Cardoso da Silva – IPEN

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