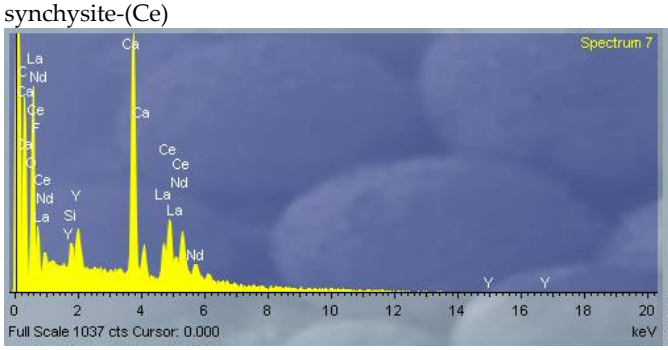
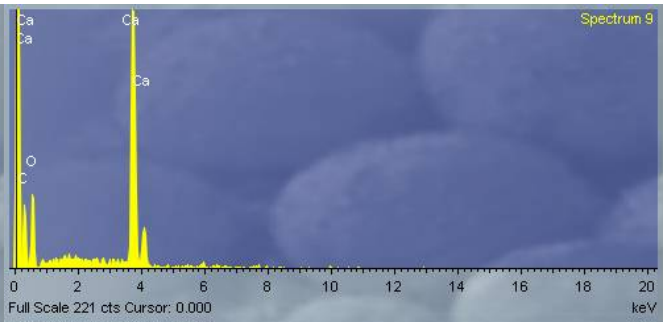
Figure S1. Selected EDS spectra of REE-bearing minerals shown in Figure 6, together with the spectra of other miscellaneous phases detected in the ten analyzed samples from the old processing plant of Assemini (Cagliari Italy).

SAMPLE #1

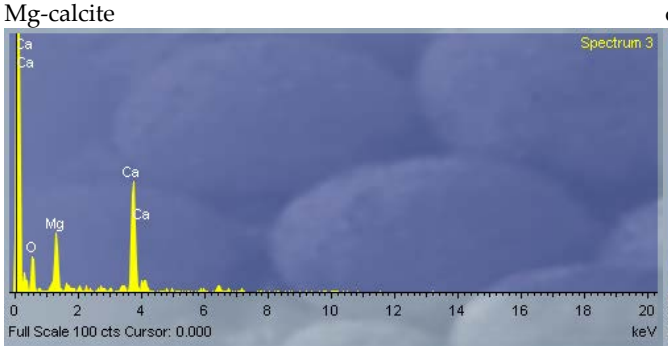
synchysite-(Ce)



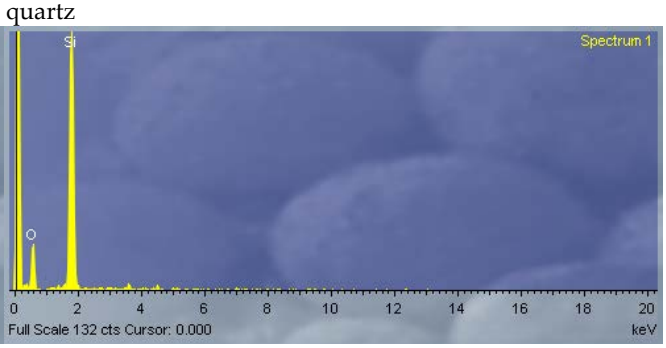
calcite



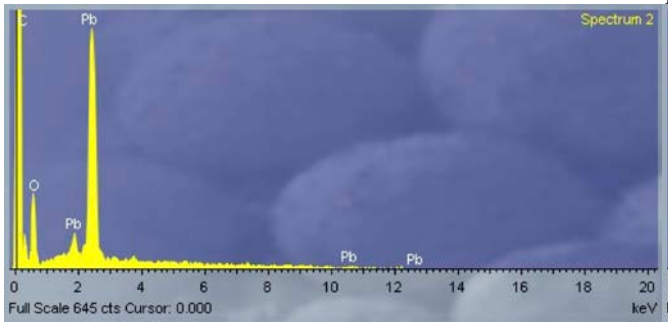
Mg-calcite



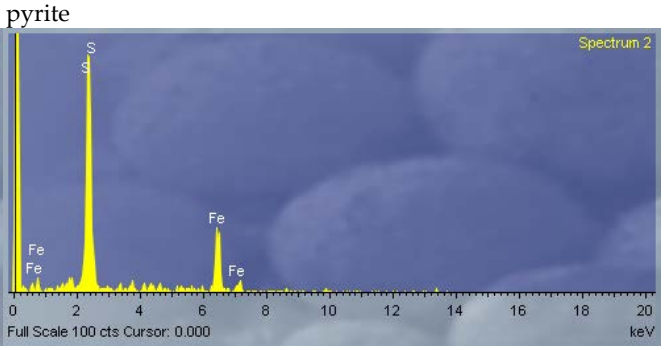
quartz



cerussite

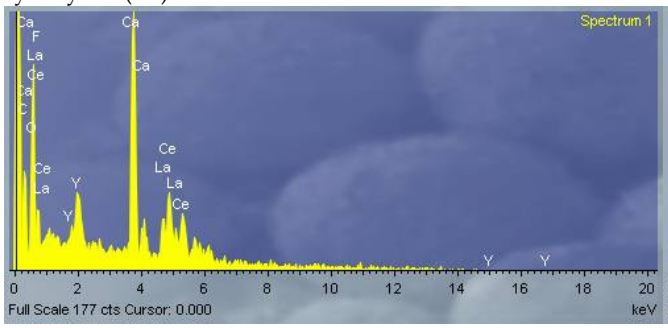


pyrite

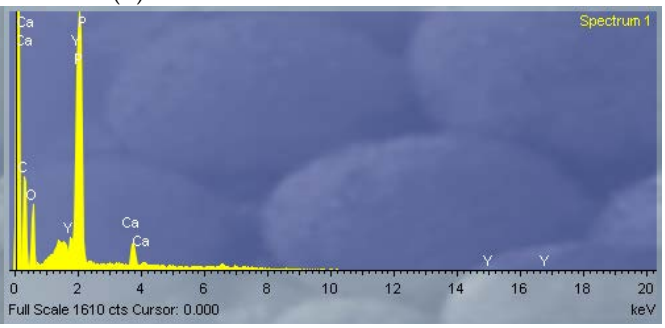


SAMPLE #2

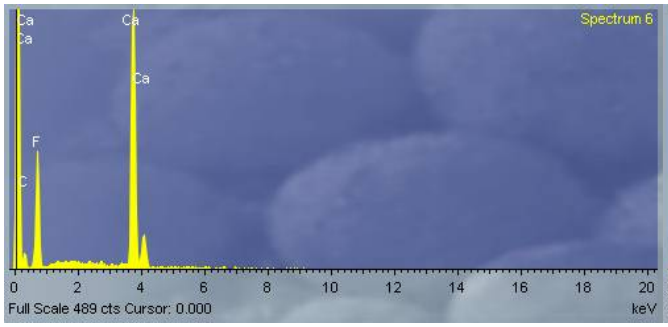
synchysite-(Ce)



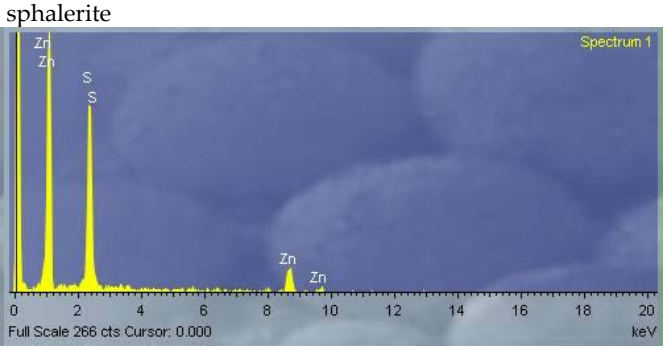
xenotime-(Y)



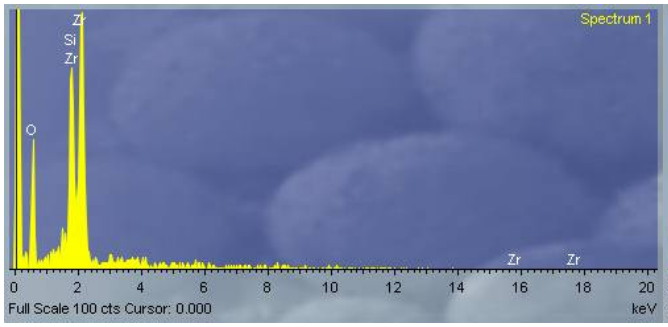
fluorite



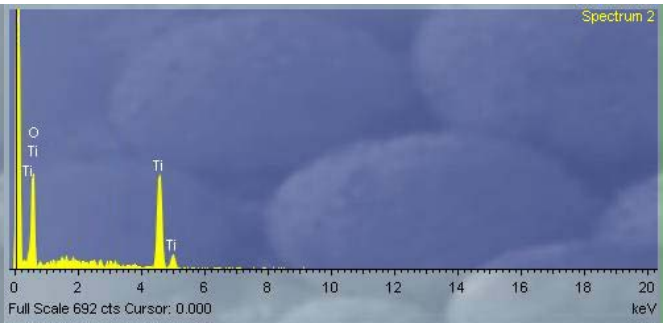
sphalerite



zircon

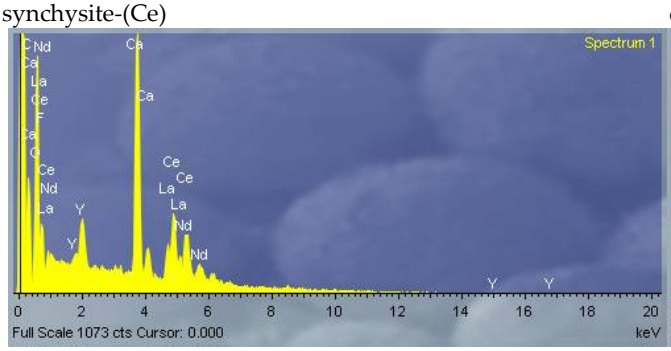


rutile

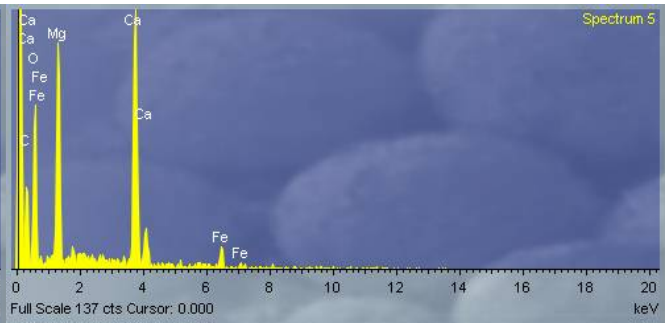


SAMPLE #3

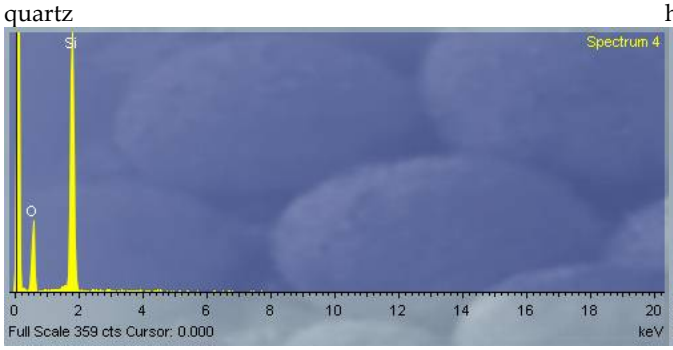
synchysite-(Ce)



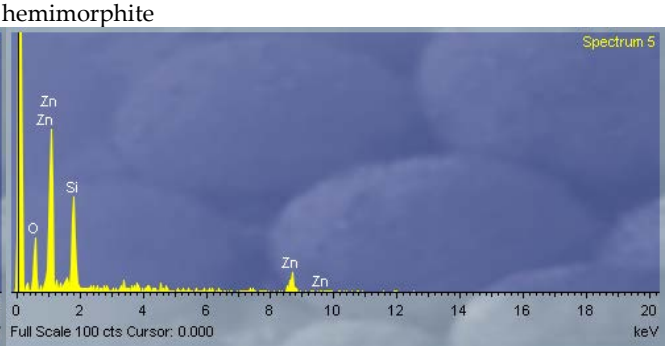
dolomite



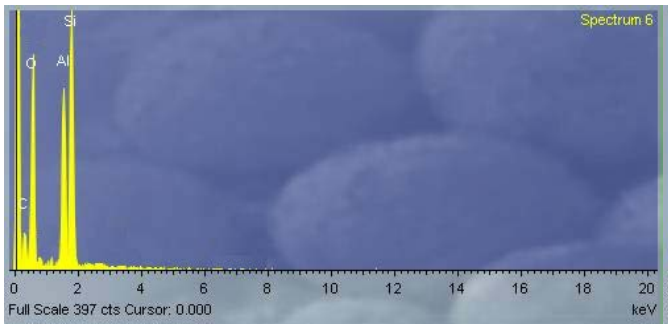
quartz



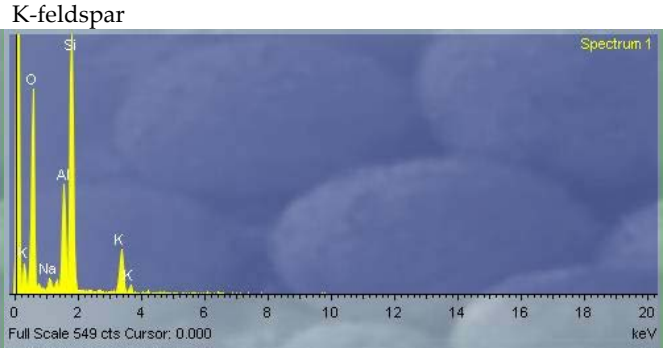
hemimorphite



kaolinite

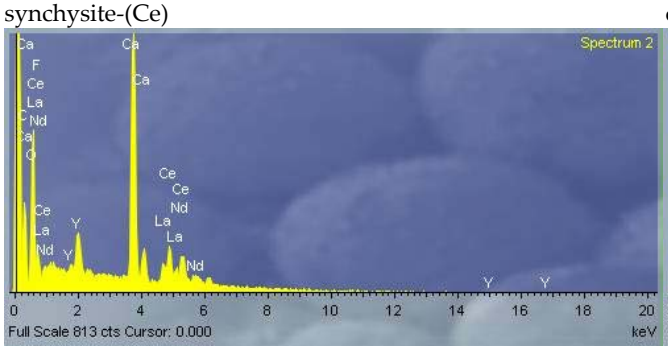


K-feldspar

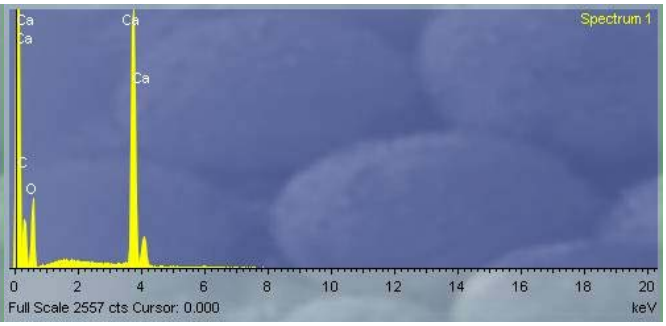


SAMPLE #4

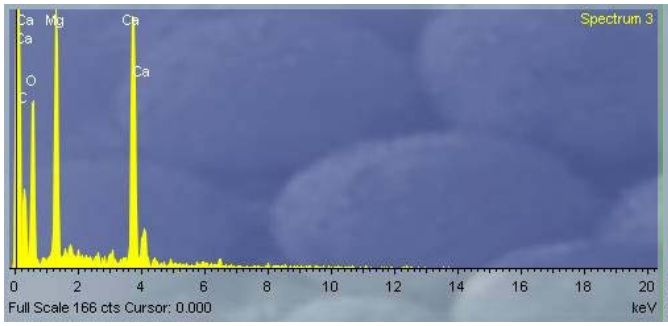
synchysite-(Ce)



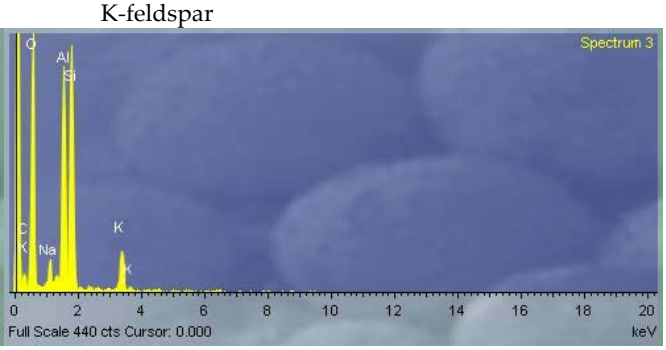
calcite



dolomite

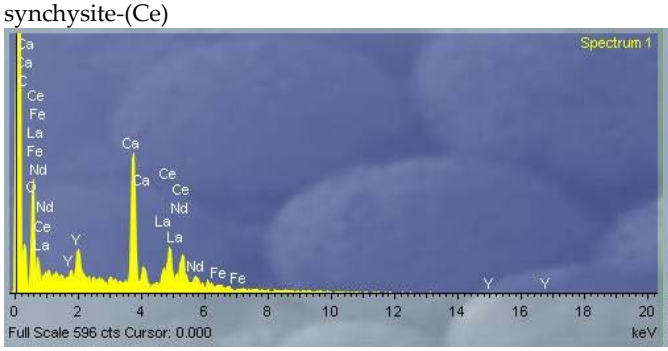


K-feldspar

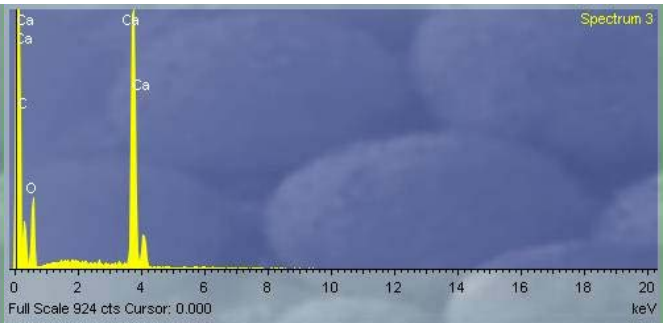


SAMPLE #5

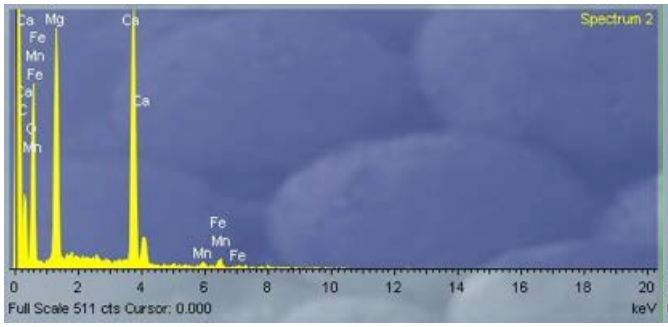
synchysite-(Ce)



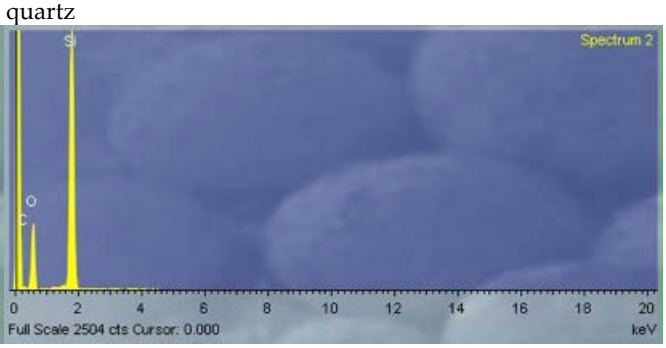
calcite



dolomite

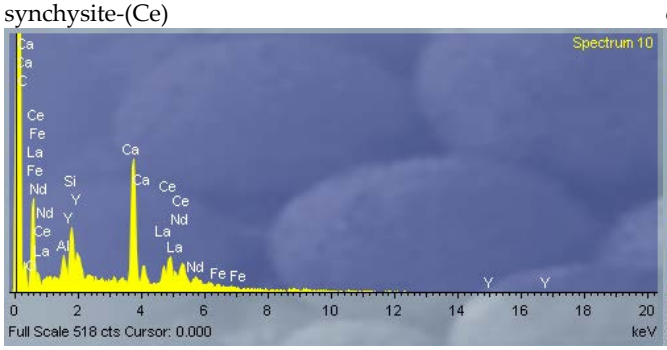


quartz

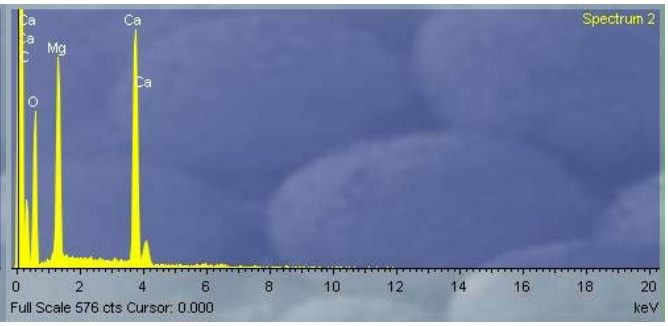


SAMPLE #6

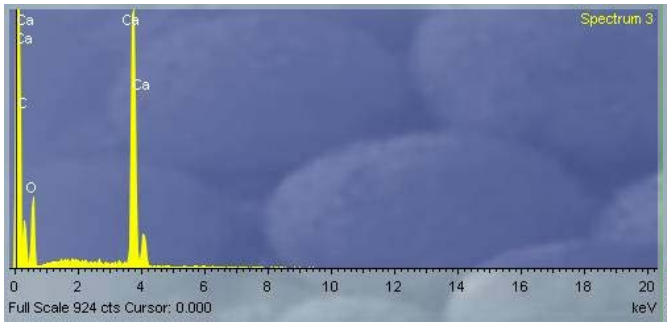
synchysite-(Ce)



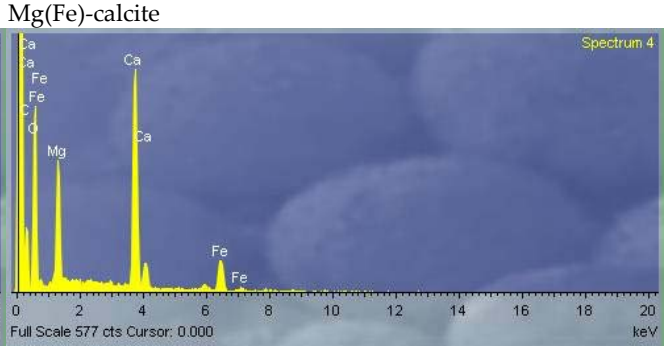
dolomite



calcite

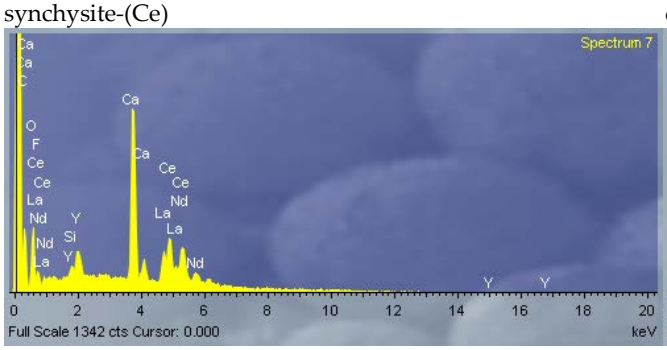


Mg(Fe)-calcite

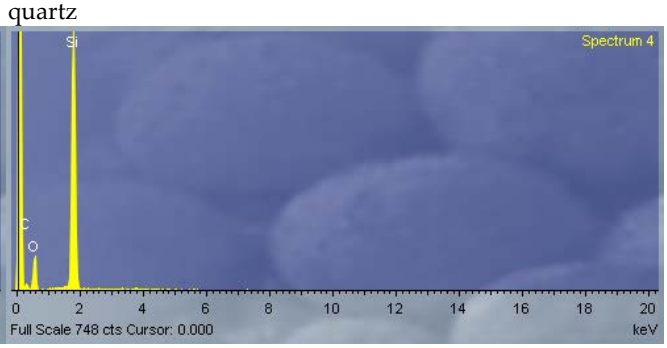


SAMPLE #7

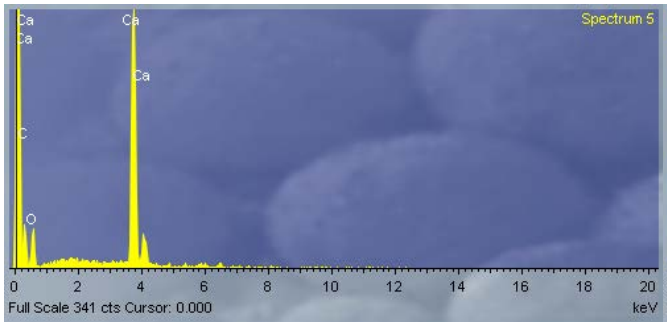
synchysite-(Ce)



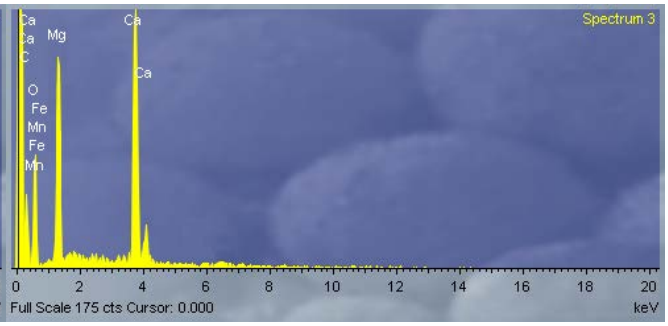
quartz



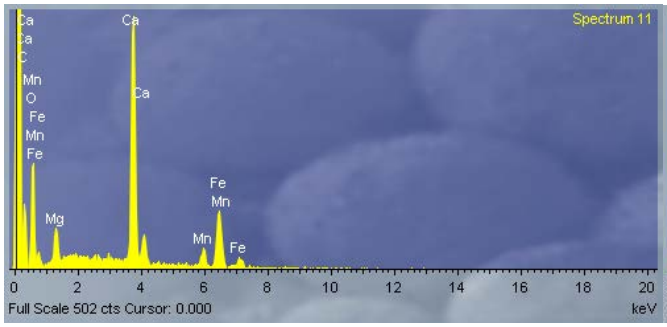
calcite



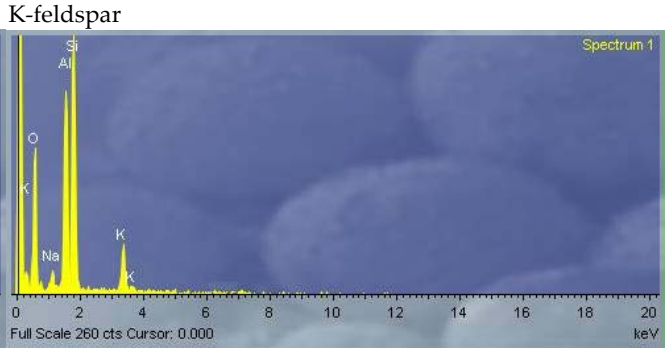
dolomite



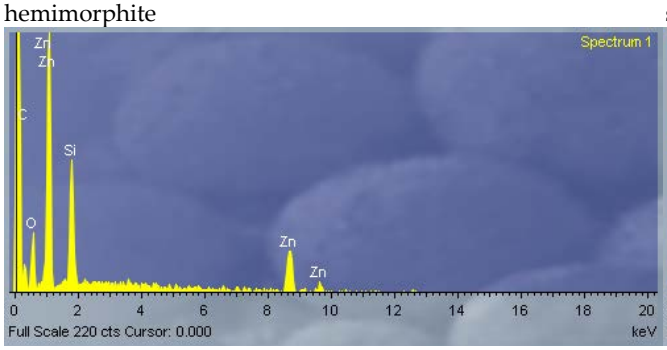
ankerite



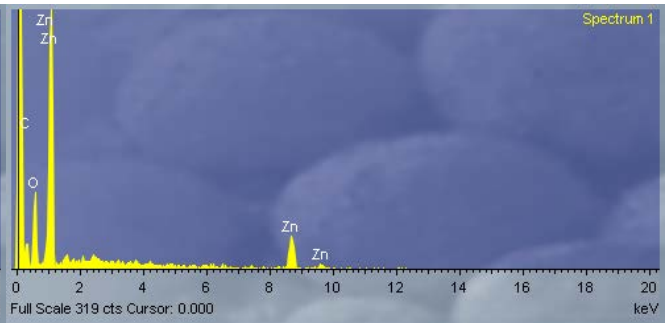
K-feldspar



hemimorphite

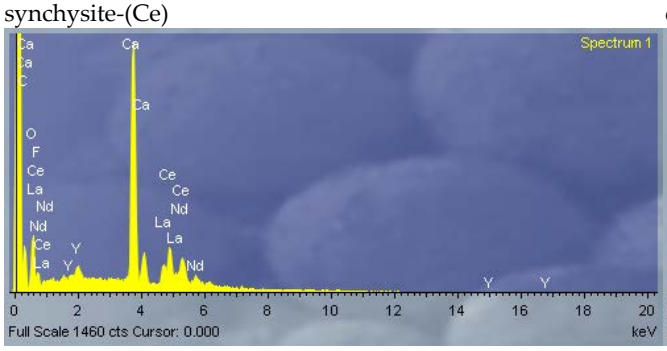


smithsonite

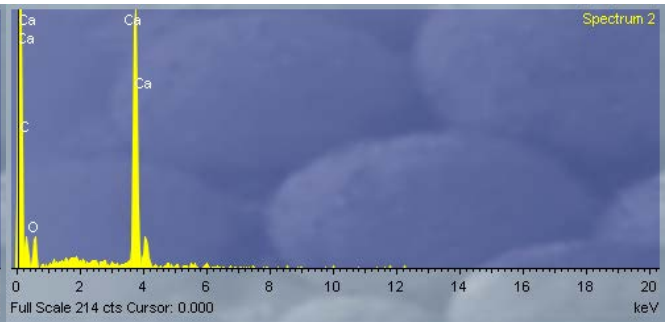


SAMPLE #8

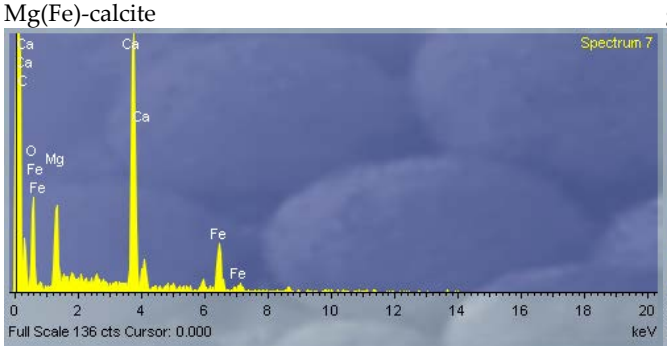
synchysite-(Ce)



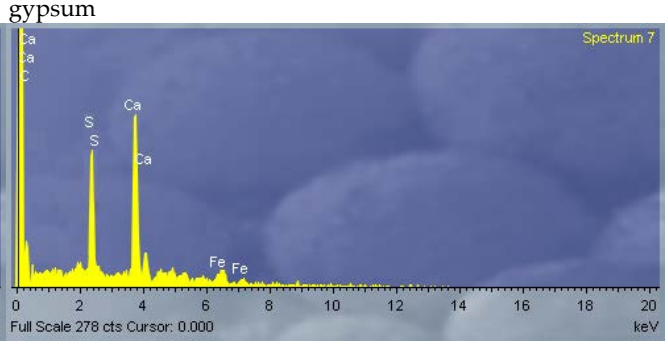
calcite



Mg(Fe)-calcite

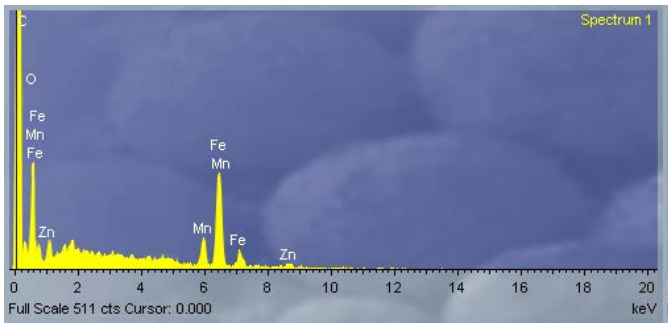


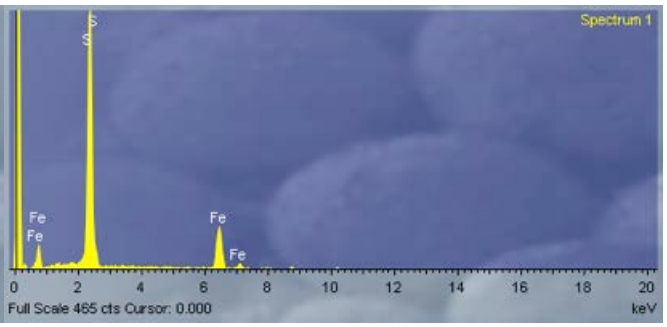
gypsum



Fe-Mn-oxy-hydroxides

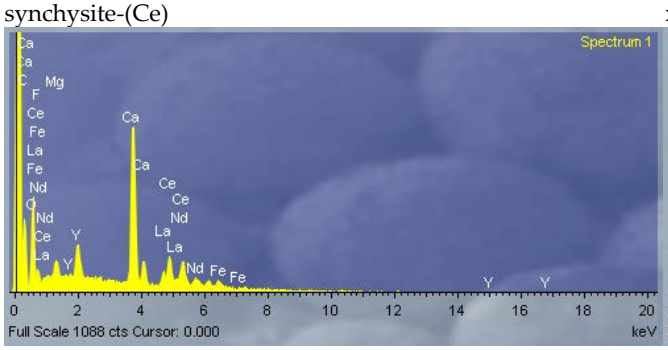
pyrite



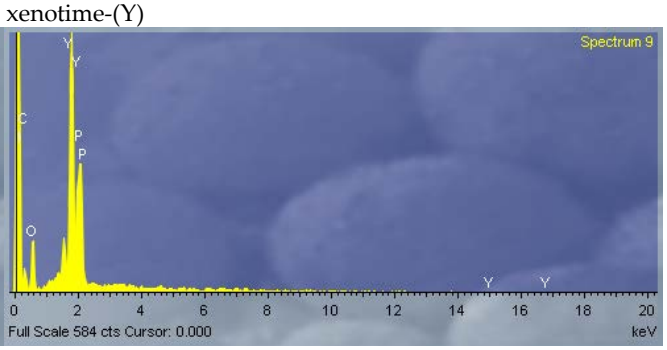


SAMPLE #9

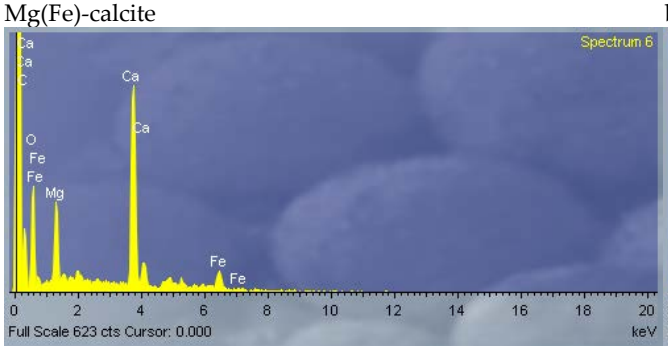
synchysite-(Ce)



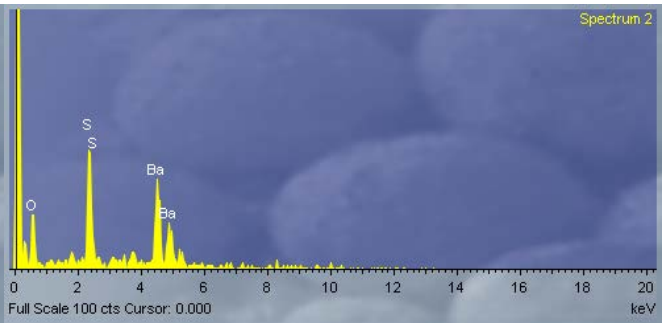
xenotime-(Y)



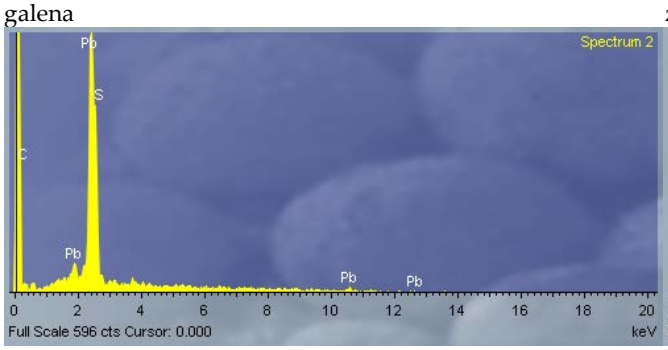
Mg(Fe)-calcite



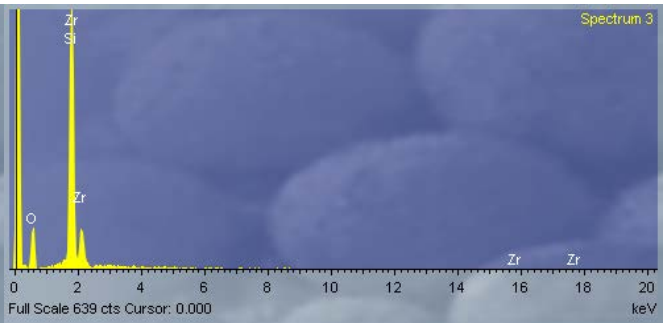
barite



galena

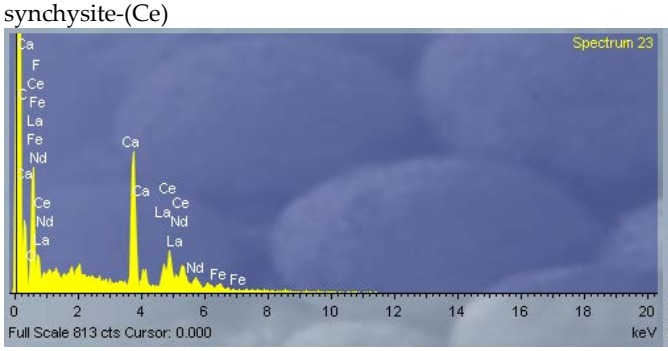


zircon

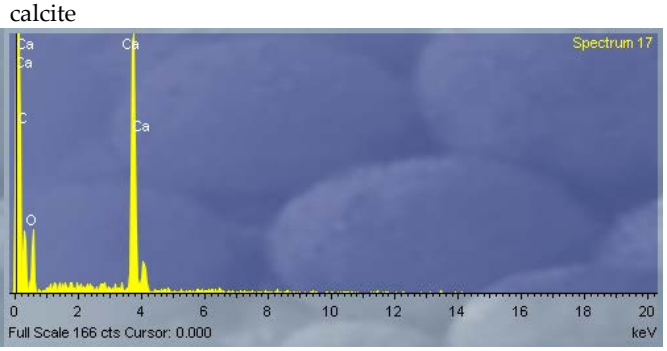


SAMPLE #10

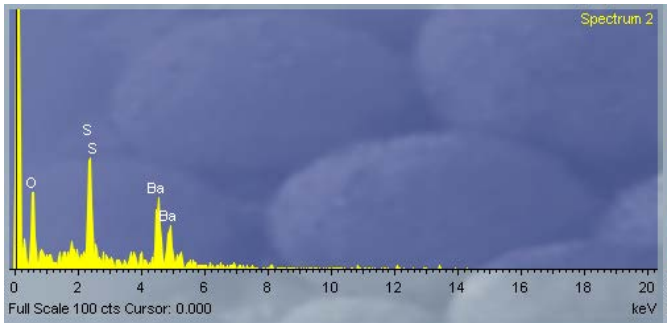
synchysite-(Ce)



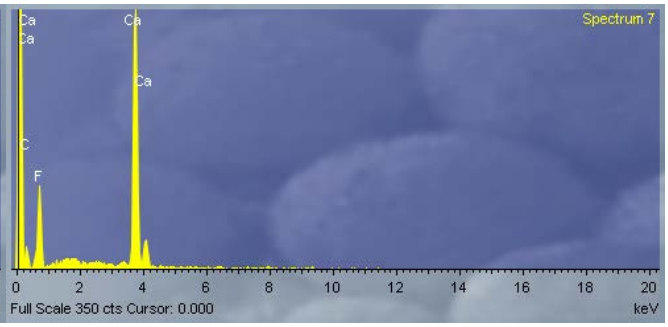
calcite



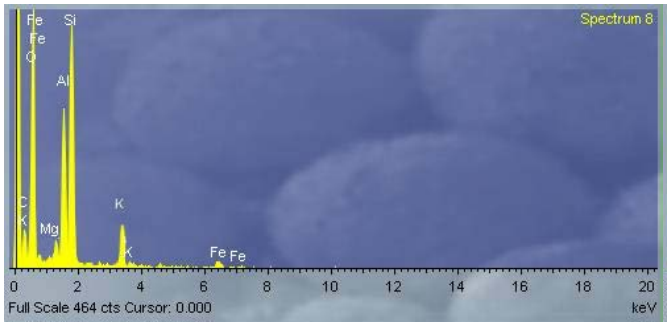
barite



fluorite



illite



muscovite

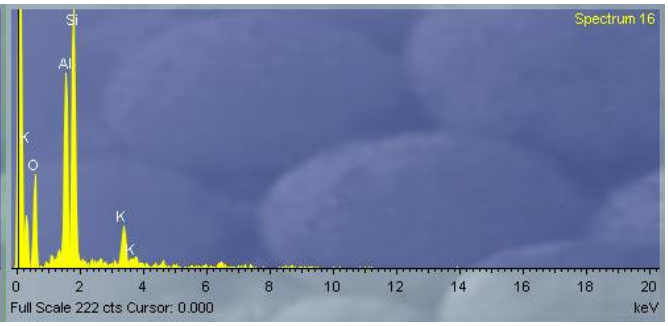


Table S1. Chemical composition (EDS analyses) of synchysite-(Ce) found in the samples from Assemini, expressed in weight % of oxides (Σ_{REO}, sum of REE oxides).

	Sample #															
wt.%	1	1	**1**	**1**	**2**	**2**	**2**	**3**	**3**	**3**	**4**	**4**	**4**	**5**	**5**	**5**
CaO	17.78	18.17	19.98	20.51	18.90	18.43	18.49	18.58	18.22	17.23	26.34	24.67	19.30	20.94	19.33	17.39
MgO	0.38	0.03	0.84	1.20	0.00	0.13	0.50	0.00	0.49	0.49	0.05	0.00	0.18	0.27	0.00	0.49
Al_2O_3	0.40	0.09	0.14	0.00	0.10	0.00	0.00	0.12	0.00	0.54	0.25	0.63	0.00	0.00	0.38	0.00
SiO_2	1.47	0.57	0.73	0.45	0.53	0.96	0.09	0.90	0.00	0.97	0.94	0.00	0.35	0.39	0.72	1.34
Y_2O_3	4.46	3.94	6.72	3.27	2.65	4.20	3.29	4.98	3.48	2.77	6.73	5.33	5.62	2.99	8.01	8.34
La_2O_3	9.92	9.93	7.45	7.70	10.19	10.56	12.27	9.86	10.15	15.18	9.19	8.75	12.96	13.47	7.92	8.71
Ce_2O_3	19.37	21.24	17.74	18.37	17.84	20.45	23.66	20.44	17.63	23.24	18.52	16.25	22.92	19.00	14.27	17.14
Pr_2O_3	0.63	1.21	1.12	0.00	1.51	1.19	0.00	1.92	3.87	4.64	3.67	0.01	0.17	0.00	1.90	2.89
Nd_2O_3	8.26	7.34	7.96	4.56	9.29	9.69	8.41	9.09	13.70	8.90	8.41	7.65	7.22	4.59	7.72	7.27
Sm_2O_3	1.99	0.73	1.39	0.00	2.43	2.42	4.15	1.88	3.30	2.33	1.34	4.60	0.24	2.31	1.59	0.00
Eu_2O_3	0.53	0.17	0.03	0.00	1.06	0.00	2.47	0.17	1.35	0.00	0.76	1.77	0.91	2.17	1.08	2.01
Gd_2O_3	1.08	1.82	2.00	2.08	3.16	1.23	4.27	1.27	1.29	0.00	1.95	3.20	1.46	1.83	2.77	3.41
Dy_2O_3	1.84	1.62	0.70	2.20	0.00	1.02	0.35	0.89	2.08	0.41	1.45	0.00	0.62	0.00	0.46	0.58
F	6.09	4.09	6.33	6.71	4.99	4.60	4.12	6.44	4.49	7.00	3.29	4.22	5.64	3.36	3.24	4.01
Total	74.21	70.96	73.12	67.05	72.66	74.87	82.07	76.55	80.06	83.69	82.89	77.08	77.59	71.31	69.39	73.58
◎ REO	48.09	48.00	45.11	38.18	48.13	50.74	58.88	50.50	56.86	57.46	52.02	47.56	52.11	46.35	45.72	50.36

	Sample #															
wt.%	**6**	**6**	**6**	**7**	**7**	**8**	**8**	**8**	**8**	**9**	**9**	**9**	**10**	**10**	**10**	**10**
CaO	18.11	17.41	17.00	18.15	19.35	17.31	18.81	26.29	20.95	19.24	17.67	26.67	14.43	17.42	17.35	18.74
MgO	0.00	0.00	1.04	0.00	0.00	0.11	0.00	0.25	0.48	2.42	0.12	0.19	0.00	0.71	0.00	0.35
Al_2O_3	0.00	0.19	0.55	0.00	0.22	0.27	1.03	0.56	0.00	0.00	1.15	0.30	0.38	0.33	0.00	0.00
SiO_2	0.68	0.67	1.66	0.88	0.67	0.75	0.10	0.57	0.79	0.29	3.45	0.39	0.92	0.27	0.59	0.78
Y_2O_3	5.30	5.84	8.46	6.52	5.98	6.56	6.14	1.86	7.35	5.87	0.88	2.30	2.99	5.96	4.27	8.44
La_2O_3	14.04	10.21	9.79	9.54	10.11	8.01	9.97	9.98	5.82	7.37	12.12	7.99	9.47	9.32	11.87	9.96
Ce_2O_3	22.12	20.72	17.61	18.64	17.81	16.45	19.20	20.23	14.05	16.35	17.69	15.81	18.73	19.93	22.25	20.27
Pr_2O_3	1.42	1.74	5.34	0.58	1.22	0.68	2.08	1.07	0.12	0.73	2.12	1.92	0.00	0.60	1.45	2.44
Nd_2O_3	6.84	7.57	7.83	7.30	6.43	6.96	6.50	6.50	6.90	5.96	7.41	7.96	7.66	5.65	7.75	9.45
Sm_2O_3	2.17	1.70	3.91	1.80	1.04	2.13	1.77	0.93	1.81	0.09	0.00	1.69	1.27	0.88	0.29	3.30
Eu_2O_3	1.49	1.96	2.21	1.27	2.21	0.79	1.30	0.76	1.33	0.50	0.10	0.00	0.00	0.89	0.00	1.83
Gd_2O_3	0.00	1.29	3.26	1.60	3.09	1.25	1.66	0.79	1.96	2.27	0.76	2.27	0.12	0.00	1.44	2.22
Dy_2O_3	0.56	1.31	1.47	0.77	0.73	1.96	0.97	0.00	1.13	0.92	1.44	0.60	0.10	1.15	0.00	0.13
F	4.83	6.42	6.20	3.60	3.44	3.85	2.54	3.47	4.39	3.19	3.72	3.38	5.96	4.94	4.01	9.89
Total	77.55	77.02	86.33	70.66	72.29	67.08	72.09	73.26	67.10	65.20	68.64	71.47	62.02	68.04	71.26	87.81
Σ_{REO}	53.93	52.33	59.88	48.03	48.62	44.79	49.61	42.12	40.48	40.07	42.53	40.54	40.33	44.38	49.31	58.05

Table S2. Initial REE abundances (mg·kg^{-1}) in the analyzed bulk samples.

Sample#	Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
1	65.90	70.00	126.30	13.59	52.2.0	12.06	5.51	14.15	1.79	9.29	1.70	4.27	0.47	3.01	0.45
2	68.00	67.00	118.60	13.21	50.00	11.54	5.55	13.29	1.80	9.47	1.74	3.86	0.50	3.01	0.39
3	57.40	56.40	101.70	11.13	44.20	9.87	4.18	11.18	1.56	8.48	1.54	3.85	0.46	2.86	0.40
4	62.40	59.50	108.90	11.85	46.30	10.78	4.65	12.14	1.69	9.54	1.64	3.93	0.49	3.00	0.42
5	91.20	100.50	180.100	19.31	75.00	15.91	7.85	18.96	2.43	13.17	2.18	5.11	0.60	3.59	0.43
6	56.70	58.50	105.10	11.51	46.00	9.93	4.15	11.62	1.63	8.68	1.47	3.92	0.47	2.83	0.36
7	47.10	54.20	100.00	10.32	40.60	9.11	3.86	10.14	1.39	7.61	1.37	3.32	0.44	2.69	0.35
8	65.50	71.70	132.80	14.33	54.80	12.82	5.64	13.91	1.92	10.04	1.70	4.30	0.53	2.96	0.39
9	104.50	84.20	156.10	17.05	66.30	15.09	6.73	18.38	2.51	13.41	2.31	5.12	0.59	3.54	0.44
10	53.80	51.40	92.80	10.20	38.20	8.67	2.85	10.60	1.40	8.00	1.40	3.63	0.43	2.51	0.36

Table S3. REEs extracted (mg·kg^{-1}) in the analyzed samples.

Sample #	Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
1	9.60	3.20	8.60	1.60	6.00	2.00	1.10	2.40	0.65	1.70	0.62	0.99	<0.50	0.79	<0.50
2	18.0	6.70	16.40	2.60	10.60	3.60	2.00	4.30	0.92	2.90	0.85	1.50	<0.50	1.10	<0.50
3	7.70	2.90	7.00	1.40	5.10	1.70	0.92	2.10	0.62	1.60	0.60	0.90	<0.50	0.73	<0.50
4	7.40	2.80	7.10	1.20	4.50	1.70	0.91	1.90	0.56	1.40	0.56	0.81	<0.50	0.64	<0.50
5	3.70	1.10	2.30	0.66	1.80	0.90	0.54	1.00	0.44	0.79	0.44	0.53	<0.50	0.44	<0.50
6	4.40	1.40	3.40	0.75	2.20	1.10	0.64	1.10	0.46	0.89	0.46	0.58	<0.50	0.46	<0.50
7	2.60	2.80	5.30	0.88	2.60	2.10	1.20	1.00	0.39	0.73	0.38	0.48	<0.50	0.41	<0.50
8	4.60	2.10	4.70	0.93	3.10	1.60	0.96	1.30	0.47	0.98	0.47	0.61	<0.50	0.49	<0.50
9	10.70	4.60	10.10	1.60	5.80	2.40	1.20	2.30	0.59	1.70	0.55	0.83	<0.50	0.60	<0.50
10	3.80	1.90	4.30	0.85	2.70	1.20	0.57	1.10	0.42	0.86	0.42	0.56	<0.50	0.46	<0.50

Table S4. REEs extracted (% w/w) in the analyzed samples.

Sample #	Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
1	15	5	7	12	11	17	21	17	36	19	36	23	-	26	-
2	26	10	14	20	21	31	36	32	51	31	50	38	-	37	-
3	13	5	7	12	12	17	22	19	38	19	40	23	-	25	-
4	12	5	7	10	10	16	20	15	33	15	35	21	-	21	-
5	4	1	1	3	2	6	7	5	19	6	20	10	-	12	-
6	8	2	3	7	5	11	15	10	29	10	30	15	-	17	-

7	6	5	5	9	6	22	32	10	28	10	27	15	-	15	-
8	7	3	4	7	6	13	17	9	25	10	27	14	-	16	-
9	10	5	6	9	9	16	18	13	23	12	24	16	-	17	-
10	7	4	5	8	7	14	20	11	30	11	30	15	-	19	-

Table S5. Comparison between the amount ($mg \cdot kg^{-1}$) of lanthanide extracted after a first treatment (a) (as in Table S3) and a second one on the same residue (a_R), for each sample.

Sample #	Treatment	Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
1	a	9.58	3.22	8.58	1.57	5.97	2.02	1.14	2.43	0.65	1.73	0.62	0.99	<0.50	0.79	<0.50
	a_R	12.26	8.97	21.79	3.08	11.92	3.53	2.21	4.38	0.78	2.25	0.64	1.11	<0.50	0.79	<0.50
2	a	17.94	6.69	16.36	2.61	10.62	3.59	2.02	4.31	0.92	2.95	0.85	1.50	<0.50	1.12	<0.50
	a_R	13.81	9.12	23.93	3.33	12.59	3.82	2.97	4.15	0.76	2.17	0.63	1.04	<0.50	0.69	<0.50
3	a	7.71	2.89	6.99	1.37	5.11	1.71	0.92	2.12	0.62	1.61	0.61	0.90	<0.50	0.73	<0.50
	a_R	4.18	1.36	3.80	0.91	3.31	1.37	0.77	1.50	0.46	0.95	0.43	0.55	<0.50	0.44	<0.50
4	a	7.41	2.80	7.12	1.25	4.47	1.71	0.91	1.86	0.57	1.41	0.56	0.81	<0.50	0.64	<0.50
	a_R	6.00	1.95	5.25	1.11	4.28	1.73	0.87	1.79	0.50	1.22	0.47	0.68	<0.50	0.53	<0.50
5	a	3.75	1.12	2.33	0.66	1.80	0.88	0.54	1.03	0.45	0.79	0.44	0.53	<0.50	0.44	<0.50
	a_R	7.08	2.88	8.22	1.48	5.46	1.87	1.06	2.08	0.54	1.27	0.48	0.65	<0.50	0.46	<0.50
6	a	4.36	1.45	3.36	0.76	2.21	1.07	0.64	1.11	0.46	0.89	0.46	0.58	<0.50	0.46	<0.50
	a_R	4.57	1.84	4.54	0.98	3.43	1.46	0.73	1.47	0.48	1.05	0.46	0.60	<0.50	0.49	<0.50
7	a	2.61	2.85	5.27	0.88	2.55	2.04	1.23	1.00	0.39	0.73	0.38	0.48	<0.50	0.41	<0.50
	a_R	2.47	3.09	6.11	0.92	2.81	1.17	0.65	1.03	0.38	0.69	0.36	0.45	<0.50	0.38	<0.50
8	a	4.57	2.13	4.68	0.94	3.06	1.63	0.96	1.30	0.47	0.98	0.47	0.61	<0.50	0.49	<0.50
	a_R	4.59	1.43	3.89	0.82	2.51	1.17	0.63	1.14	0.43	0.86	0.42	0.55	<0.50	0.43	<0.50
9	a	10.69	4.56	10.08	1.60	5.83	2.36	1.18	2.32	0.59	1.65	0.55	0.83	<0.50	0.60	<0.50
	a_R	7.86	2.81	5.90	1.03	3.31	1.47	0.79	1.54	0.48	1.16	0.47	0.66	<0.50	0.50	<0.50
10	a	3.78	1.88	4.31	0.85	2.75	1.18	0.57	1.11	0.42	0.86	0.42	0.56	<0.50	0.46	<0.50
	a_R	1.98	1.18	2.25	0.53	1.23	0.68	0.40	0.64	0.36	0.53	0.36	0.42	<0.50	0.37	<0.50

Table S6. REEs extracted (mg·kg^{-1}) in the analyzed samples by microwave mineralization.

Sample #	Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
1	5.29	1.79	6.50	0.36	1.11	0.30	0.34	0.27	0.09	0.52	0.12	0.36	0.06	0.25	0.04
2	8.17	2.19	9.20	0.39	1.45	0.49	0.43	0.36	0.14	0.78	0.17	0.43	0.07	0.33	0.05
3	5.01	1.00	5.91	0.24	0.72	0.23	0.19	0.20	0.07	0.42	0.10	0.28	0.06	0.22	0.05
4	7.91	2.21	9.56	0.42	1.29	0.45	0.34	0.32	0.10	0.70	0.15	0.46	0.07	0.30	0.05
5	6.10	0.94	7.21	0.19	0.76	0.42	0.26	0.20	0.08	0.54	0.12	0.27	0.05	0.24	0.04
6	4.86	1.37	7.07	0.25	0.88	0.31	0.23	0.20	0.07	0.48	0.12	0.32	0.04	0.25	0.03
7	1.14	0.39	1.90	0.05	0.17	0.07	0.06	0.05	<0.02	0.10	0.02	0.07	<0.02	0.07	<0.05
8	4.01	1.02	4.68	0.19	0.85	0.23	0.15	0.17	0.04	0.28	0.08	0.22	0.04	0.20	0.02
9	10.80	1.18	13.20	0.28	0.97	0.24	0.40	0.27	0.12	0.91	0.24	0.61	0.08	0.33	0.07
10	<0.1	0.03	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02