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Characterization, classification, dry high intensity magnetic separation (DHIMS) and re-grinding techniques to improve the mineral performance of Sn-Ta-Nb mineral concentrates

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Abstract: Ta and Nb are considered critical raw materials; due to their properties and potential applications in wide sectors. This study deals with Sn-Ta-Nb minerals from the Penouta mine (Orense, Spain), the only active mine in Europe producing tantalum minerals. These are obtained from mining wastes accumulated during old mining jobs in tailing ponds. The industrial processing flowsheet is based on successive gravimetric stages followed by low intensity magnetic separation to reduce ferromagnetic contaminants. Sn-Ta-Nb concentrate, with grades between 35-45% Sn and 4-7% Ta_2O_5 and Nb_2O_5, is obtained in this stage with plant recoveries around 60-70%, respectively. A chemical-mineralogical characterization by size fractions, XRF and XRD was carried out to implement a size classification stage using a circular vibrating screen in the processing plant. The finest fractions, containing higher grades of well liberated Sn, Ta, Nb minerals, were the feeding for dry high intensity magnetic separation (DHIMS) multifactorial tests, while, coarse fractions were re-grinded to maximize performance. The good results obtained in these tests demonstrate that two products with commercial quality could be obtained, a cassiterite concentrate with grades between 70-78% SnO_2 and a tantalite-columbite concentrate with grades ranging between 12 and 14% Ta_2O_5 and Nb_2O_5, also increasing the overall recovery of the plant.

Keywords: high intensity magnetic separation; Sn-Ta-Nb; critical raw materials; Penouta mine.

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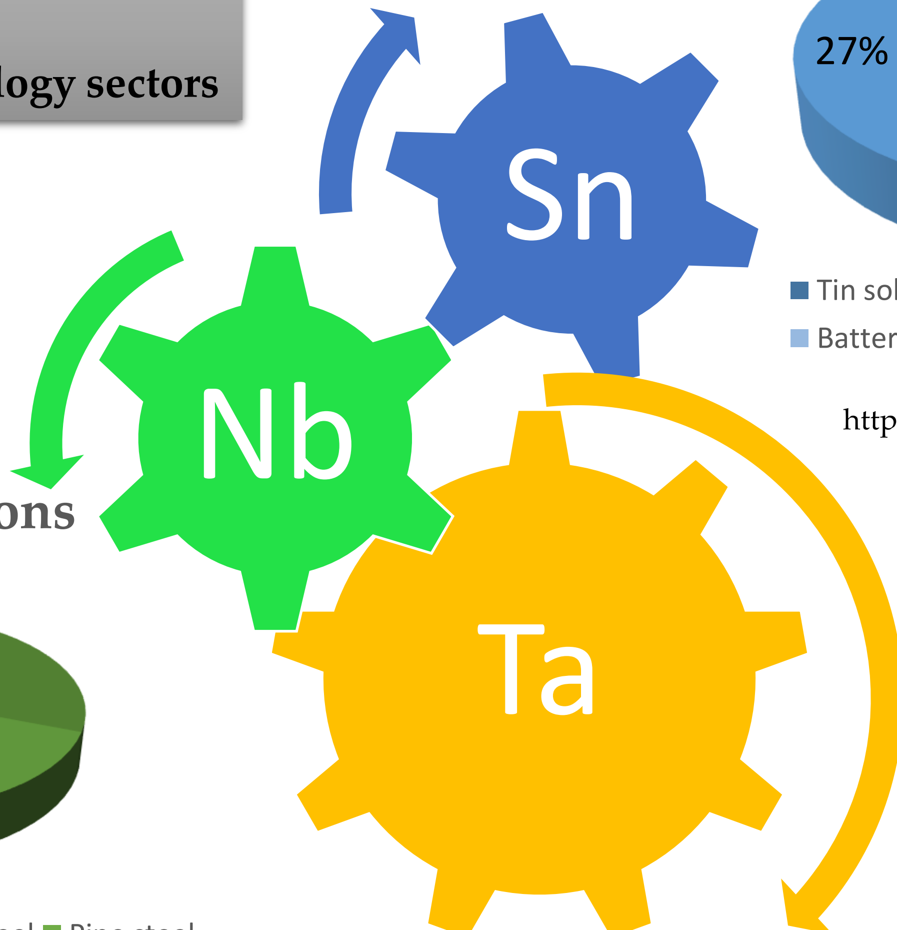
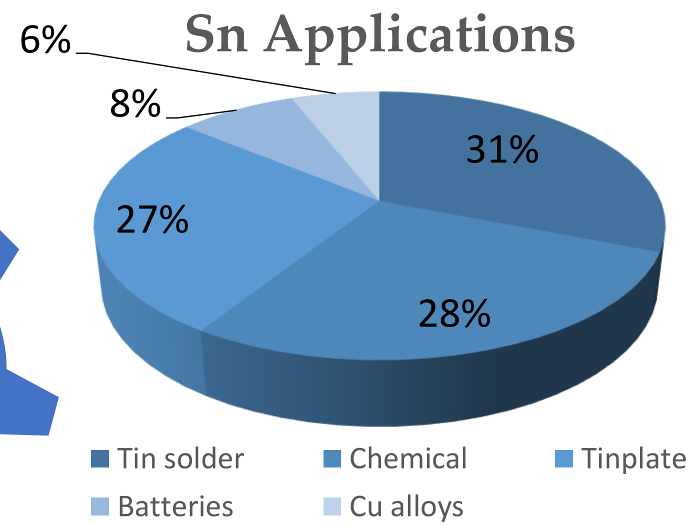
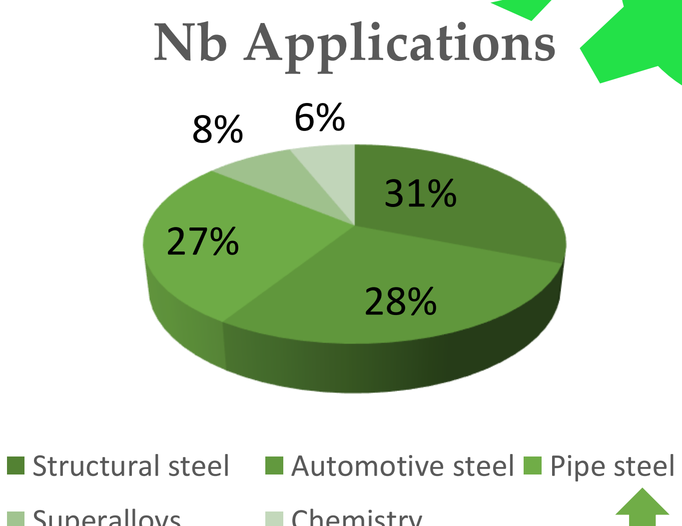
Introduction

Sn, Ta, Nb are strategic metals for the EU with important applications in technology sectors



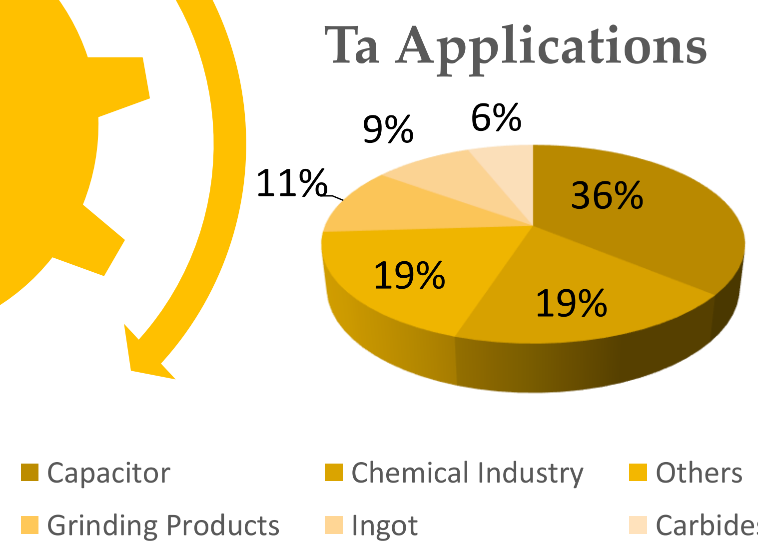


https://roskill.com/market-report/tin/ (10/25/20)



Roskill (2016)

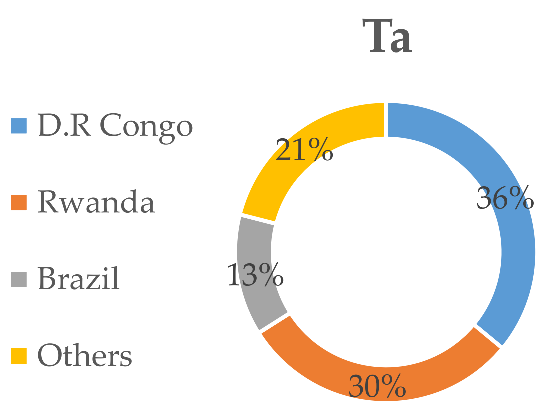
Tantalite-columbite contains Ta and Nb



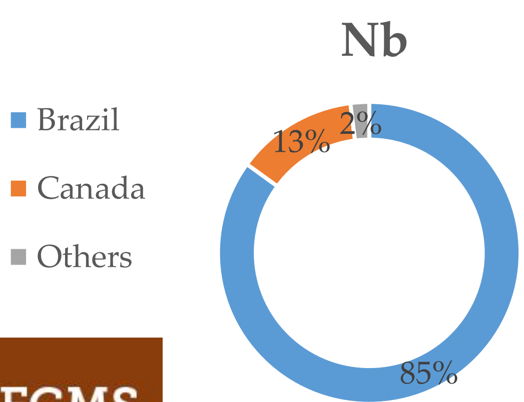
Consulting, C (2018)

Introduction

Origin of Ta and Nb imports in the EU



To decrease import dependence



(EC, 2020)

Import from conflict zones

Investigation of CRM deposits and processes in Europe

Dodd-Frank Law

Regulation of the European Parliament

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Introduction

Grinding-Classification Circuit Stage

Wet Low Intensity Magnetic Separation Stage

The Penouta mine (Orense, Spain), the only tantalite active mine in Europe

35-45% Sn and 4-7% Ta_2O_5 and Nb_2O_5

Gravimetric Concentration Stages

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Objective

35-45% Sn and 4-7% Ta_2O_5 and Nb_2O_5

How?

How?

¿ How to obtain independent concentrates of Sn and Ta-Nb that could be more competitive at the commercial level and thus contribute to an increasing yields in the industrial plant of the Penouta mine?

Sn concentrate

Nb-Ta concentrate

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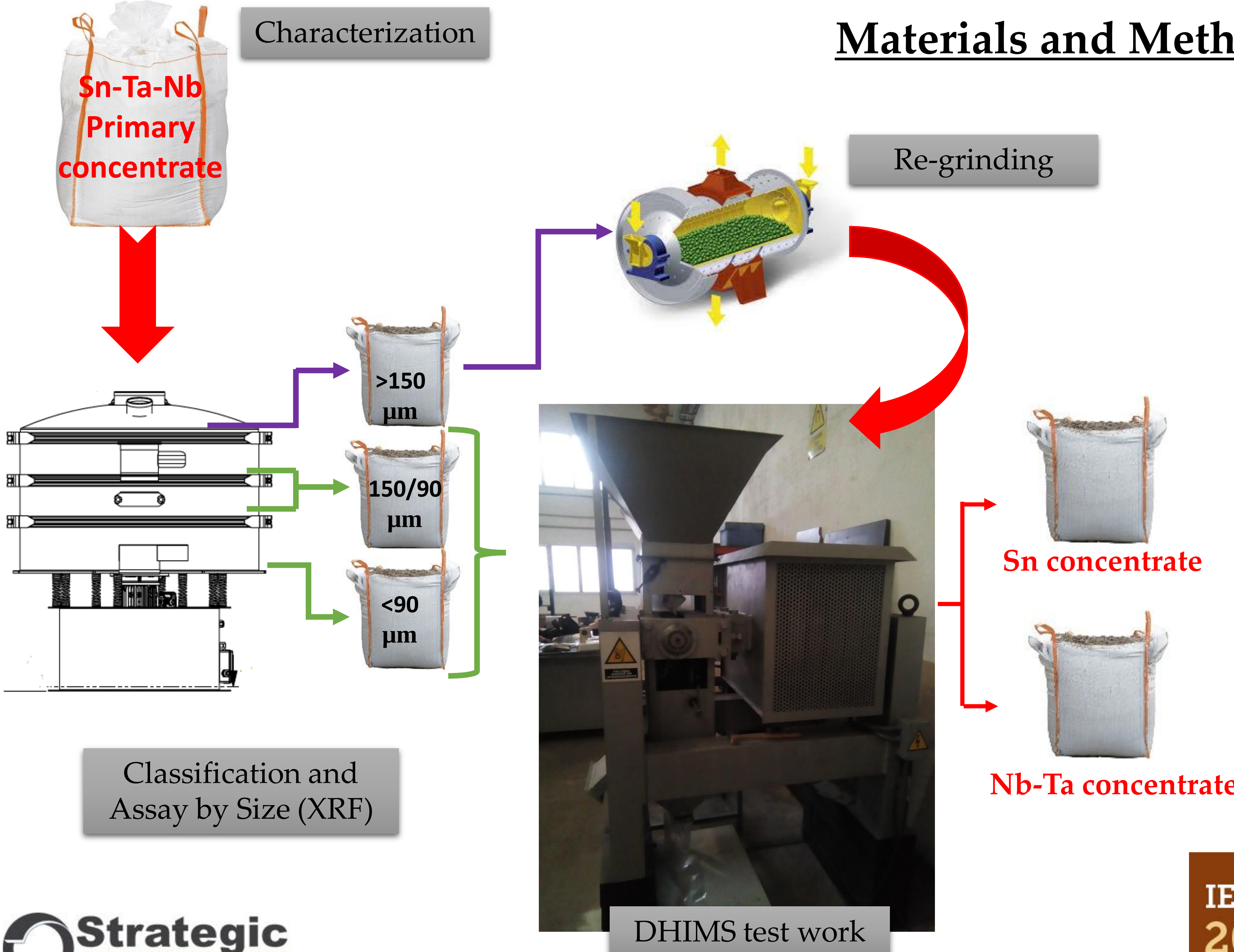
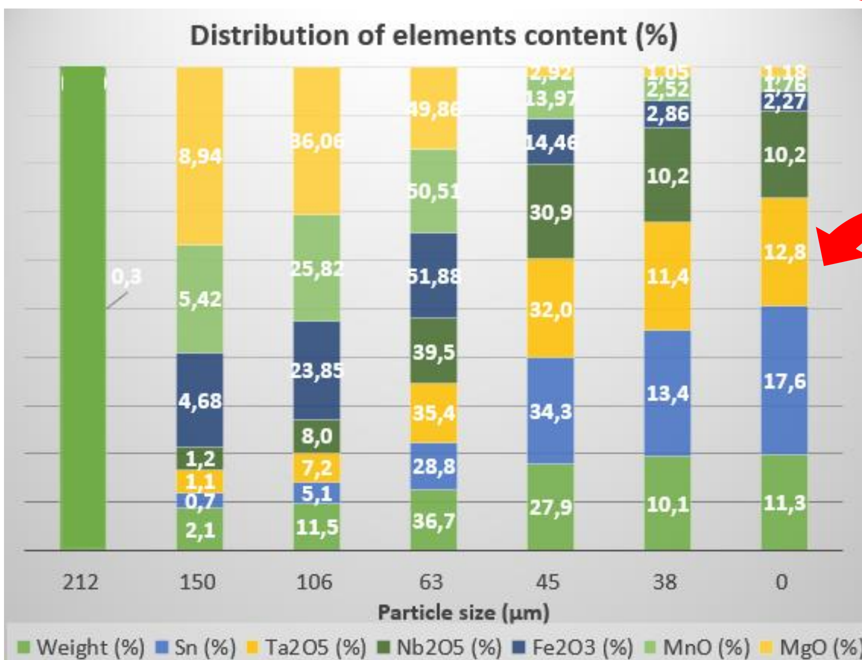
Materials and Methods



Results and Discussion

Size	Retained weight		Accumulated weight	Grades (%)						
(μm)	(g)	(%)	(%)	Sn	Ta_2O_5	Nb_2O_5	Fe_2O_3	Al_2O_3	MnO	SiO_2
300	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212	3.30	0.28	99.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150	25.30	2.14	97.58	11.80	2.77	2.58	13.30	14.20	23.50	20.40
106	136.10	11.51	86.07	14.85	3.30	3.23	12.60	12.75	20.80	17.55
63	434.30	36.74	49.32	26.50	5.05	4.99	8.59	7.32	12.75	13.40
45	330.10	27.93	21.40	41.50	6.06	5.13	3.15	1.80	4.64	7.19
38	118.90	10.06	11.34	45.10	5.94	4.69	1.73	0.58	2.32	6.30
0	134.00	11.34	0.00	52.30	5.93	4.19	1.22	0.11	1.44	4.99
Total:	1182.00	100.00	**Calculated feed grade:**	33.75	5.25	4.64	6.08	5.04	9.28	10.59
			***D*80 (μm):**	99						



Feed:
Sn-Ta-Nb concentrate

33.75% Sn, 5.24% Ta, 4.64% Nb

Increasing Sn, Ta and Nb contents with decreasing size particle. Highest concentrations below 106 μm.

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Results and Discussion

DHIMS multifactorial assays (XRF)

Test Nº	Size fraction (μm)	Magnetic field intensity (A)	Roll speed (rpm)
1	150/0	Low	High
2	150/90	Low	High
3	150/90	High	High
4	150/90	High	Low
5	150/90	Low	Low
6	150/90	Changing split inclination	
7	90/0	Low	High
8	90/0	High	High
9	90/0	High	Low
10	90/0	Low	Low
11	90/0	Changing split inclination	

DHIMS assays configuration.

(Due to SMS data protection, they are considered qualitatively)

Mineral	Ta_2O_5		SnO_2		Nb_2O_5		SiO_2		Fe_2O_3		MnO	
Test nº	G (%)	R (%)	G (%)	R (%)	G (%)	R (%)	G (%)	R (%)	G (%)	R (%)	G (%)	R (%)
1	12.20	57.62	7.10	2.95	12.65	76.76	8.97	30.87	8.74	65.87	12.71	79.18
2	10.33	68.18	3.34	2.09	11.10	89.39	13.44	52.81	12.01	83.44	17.36	96.14
3	10.15	68.09	3.33	2.11	11.02	88.59	13.83	55.02	12.13	83.38	17.51	95.22
4	8.80	69.82	26.99	19.18	8.79	85.61	9.41	49.87	7.62	78.34	10.84	89.55
5	8.79	68.96	28.09	19.82	8.78	85.97	9.31	50.78	7.50	78.38	10.66	90.97
6	11.71	70.11	7.29	3.87	12.21	91.88	10.13	42.86	9.47	80.89	13.86	97.86
7	13.66	67.78	10.09	4.23	13.21	89.42	6.30	25.49	6.83	71.40	10.04	92.31
8	13.47	67.80	10.77	4.61	13.61	90.95	6.15	24.76	6.65	70.24	9.75	91.11
9	8.89	76.07	39.01	28.59	8.23	91.63	5.47	36.89	4.37	76.75	6.01	94.01
10	9.03	76.34	37.93	26.69	8.42	94.08	5.38	35.81	4.38	77.93	6.03	95.78
11	13.13	68.24	13.65	5.93	13.24	91.15	5.36	22.51	5.89	69.52	8.69	90.58

Paramagnetic Concentrate (Tantalite-columbite)

Test 6: 150/90 μm fraction. The best grades and recovery.

Test 7: <90 μm fraction. The best grades.

Test 10: <90 μm fraction. The best recovery.

- ✓ Tantalite has a well-liberated size below 100 μm.
- ✓ Granulometric size influencing both the increase of the grades and the yields of the species.
- ✓ Higher content of SiO_2, Fe_2O_3 and MnO in coarser fraction.

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Results and Discussion

DHIMS multifactorial assays (XRF)

Test Nº	Size fraction (µm)	Magnetic field intensity (A)	Roll speed (rpm)
1	150/0	Low	High
2	150/90	Low	High
3	150/90	High	High
4	150/90	High	Low
5	150/90	Low	Low
6	150/90	Changing split inclination	
7	90/0	Low	High
8	90/0	High	High
9	90/0	High	Low
10	90/0	Low	Low
11	90/0	Changing split inclination	

↑ Roller speed → greater recoveries

↓ Particle size → greater intensity is necessary

↑ The selectivity, when the feed is classified in two fractions

Mineral / Test nº	Ta_2O_5 G (%)	Ta_2O_5 R (%)	SnO_2 G (%)	SnO_2 R (%)	Nb_2O_5 G (%)	Nb_2O_5 R (%)	SiO_2 G (%)	SiO_2 R (%)	Fe_2O_3 G (%)	Fe_2O_3 R (%)	MnO G (%)	MnO R (%)
1	1.84	27.12	75.06	97.51	0.41	7.78	6.56	70.89	0.62	14.61	0.13	2.53
2	2.01	26.37	75.57	93.73	0.58	9.25	6.36	49.62	0.84	11.59	0.29	3.19
3	1.95	25.00	76.96	93.40	0.49	7.50	6.34	48.28	0.72	9.47	0.21	2.19
4	2.13	24.93	73.91	77.48	0.78	11.18	6.56	51.28	0.88	13.35	0.51	6.21
5	2.15	25.13	73.91	77.61	0.80	11.67	6.58	53.42	0.86	13.37	0.52	6.61
6	1.89	25.76	78.23	94.39	0.41	7.07	6.27	60.37	0.61	11.86	0.12	1.93
7	1.85	26.81	76.58	93.96	0.37	7.13	6.67	78.87	0.57	17.43	0.11	2.96
8	1.85	26.93	77.34	95.57	0.38	7.26	6.70	77.81	0.58	17.67	0.11	2.97
9	1.65	18.67	74.17	71.30	0.35	5.12	7.52	67.25	0.53	12.35	0.11	2.28
10	1.65	19.17	74.68	72.33	0.34	5.21	7.63	69.90	0.54	13.23	0.10	2.19
11	1.79	26.26	75.57	92.72	0.36	6.96	6.73	79.90	0.55	18.36	0.10	2.95

No magnetic Concentrate (Cassiterite)

Test 6: 150/90 µm fraction. The best grades and recovery.

Test 8: <90 µm fraction. The best grades and recovery.

Finally, the **test 6** is the optimal configuration to treat the **150/90 µm** fraction, since it shows the best results for both grades and yields of SnO_2 and Ta_2O_5. The fraction **<90 µm** through the configuration of the **test 7**.

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Results and Discussion

Tantalite-columbite concentrate <90 µm (XRD)

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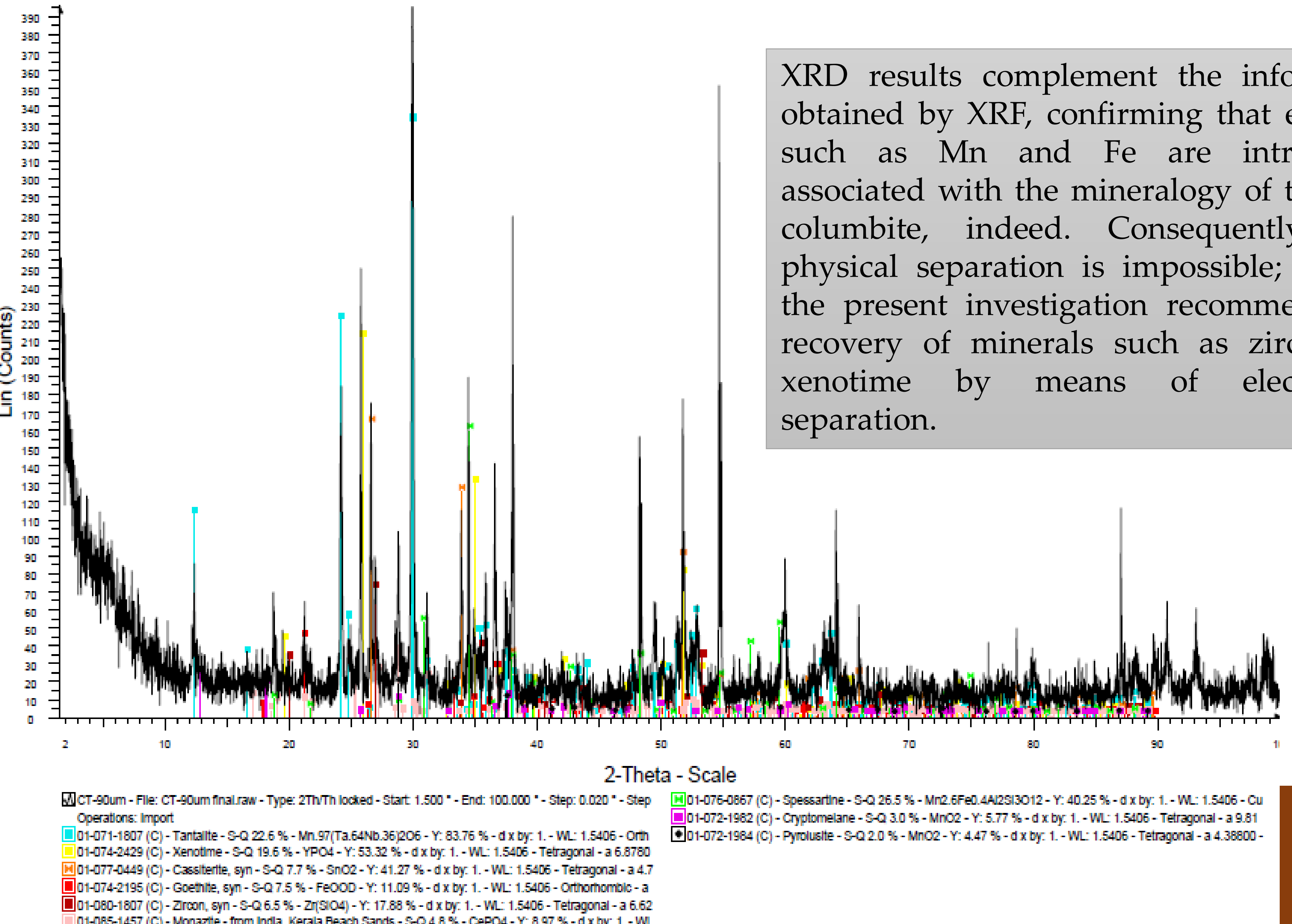
XRD results complement the information obtained by XRF, confirming that elements such as Mn and Fe are intrinsically associated with the mineralogy of tantalite-columbite, indeed. Consequently, their physical separation is impossible; despite, the present investigation recommends the recovery of minerals such as zircon and xenotime by means of electrostatic separation.



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Results and Discussion-Regrinding of >150 μm fraction.

The assay by size of the resulting products passing the 100 μm mesh, after regrinding of the >150 μm fraction for each grinding time (0.5, 2.5, 5, 10 and 15 min)

Time (min)	Pass weight through 100 μm (%)	P_{80} (μm)	Distribution of metal content (%) Sn	Ta_2O_5	Nb_2O_5	Al_2O_3	Fe_2O_3	MnO	SiO_2
0.5	11.20	218	26.26	21.07	20.44	5.59	7.45	5.45	7.13
2.5	17.60	197	38.25	30.81	29.66	8.77	11.67	8.91	11.39
5.00	22.40	192	43.74	36.57	34.43	12.93	16.53	13.13	15.60
10.0	30.90	185	51.09	46.81	43.13	20.75	26.47	22.14	23.05
15.00	32.90	184	50.39	47.47	43.93	24.44	29.89	25.54	26.49

- ✓ As grinding time increase, the amount of mineral ground through the 100 μm mesh increase.
- ✓ The distribution of the metal content in the ground product through the 100 μm mesh after the milling time has elapsed, shows an increase, reaching a well-liberated of at least 50% in the species of interest such as Sn, Ta and Nb after 10 min to avoid regrinding of fines and loss of energy efficiency.

Conclusions

- ✓ Implementing a size classification, better grades and recoveries of Sn, Ta and Nb are obtained when performing DHIMS instead of using a wide granulometric interval (150/0 μm), since selectivity increases during operation, and for this reason, the fraction >150 μm is also regrinded.
- ✓ The multifactorial DHIMS test works on the Sn, Ta and Nb primary concentrate generate two new products, a magnetic columbo-tantalite concentrate and a non-magnetic cassiterite concentrate with better grades and feasibility for the Penouta mine project.
- ✓ The XRF and XRD techniques combined with size fraction analysis were key for the characterization of both the feeds and the products obtained in all the test works carried out.
- ✓ The present work proposes to achieve electrostatic separation multifactorial tests to cut down on minerals such as zircon, monazite and xenotime and to purify the paramagnetic and non-magnetic concentrates obtained.

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thanks for your attention...

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