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Concentration of Tantalum, Niobium and Associated Elements in Tantalite Ore from the Mutala Region in Mozambique

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Abstract. The study of the richness in minerals, rare minerals especially, of our lands, became particularly important on recent years. It is therefore important to contribute to educate students and citizens on this issue.

This communication presents an example of a study on particular mineral elements present in tantalite ore coming from a region on central Mozambique. This study investigates the concentration of tantalum, niobium, and other elements found in tantalite ores from two reference samples and tantaliferous pegmatites in Mozambique. These minerals are important because tantalum is widely used in modern electronics, such as capacitors and microchips. To understand the composition of the samples, we used Scanning Electron Microscopy (SEM) together with Energy Dispersive X-ray Spectroscopy (EDS). These techniques allow us to observe the mineral surface and identify the elements present. The results were complemented by calculations of standard deviation and variance. The analyses confirmed typical components of tantalite, including tantalum, iron, oxygen, manganese, aluminum, silicon, and titanium.

Keywords. Tantalite, SEM-EDS, Zambézia, Mineral Heterogeneity, Tantalum Concentration.

1. Introduction

Together with tin, tungsten, and gold, tantalum is considered one of the most strategically important mineral resources worldwide. However, in several African countries, the lack of adequate technologies for exploration, extraction, and efficient mineral processing limits the contribution of these resources to local economic development [1-3].

Tantalum is a metal of high economic importance due to its physicochemical properties, such as a high dielectric constant, corrosion resistance, and the ability to form stable oxides, which make it essential in sectors such as electronics, aerospace, nuclear, and biomedical industries [1]. It commonly occurs associated with niobium, and both are mainly extracted from minerals of the tantalite–columbite group, as well as from granitic pegmatites and greisen-type rocks [4]. Together with tin, tungsten, and gold, tantalum is part of the strategically important 3TG minerals, often linked to conflict-affected regions [2,5]. The commercial value of concentrates depends primarily on their tantalum pentoxide (Ta_2O_5) content, and prices are negotiated directly between buyers and sellers [2,3]. Central African countries, such as Rwanda, play a significant role in global supply, although many African nations still possess undervalued reserves [5].

In Mozambique, the Zambézia Province and particularly the locality of Mutala hosts confirmed occurrences of tantalite, although they remain insufficiently studied [6]. Determining the grades of Ta, Nb, Sn, Ti, and rare earth elements is essential to evaluate the economic potential of the ore and to support the development of sustainable mining projects in the region [1].

2. Materials and Methods

In this study it was used tantalite and tantaliferous pegmatite samples collected from an active mine in Mutala, Zambézia Province, Mozambique. Tantalite was manually extracted, crushed, ground, sieved to <125 μm, washed with deionized water, and dried at 80 °C for 24 h. Pegmatite samples consisted of coarse crystals and fine-grained fractions [7]. Morphological characterization was performed using a FEG-SEM NOVA 200 NanoSEM, employing LVD and GAD detectors at accelerating voltages between 10–15 kV. Chemical composition was determined by EDS using an EDAX Si(Li) detector, applying ZAF corrections for qualitative and quantitative elemental analysis.

3. Microstructural Analysis

The Figures 1 and 2 below present SEM micrographs of the tantalite and tantaliferous

pegmatite samples, obtained using the LVD and GAD detectors at 1000× magnification and accelerating voltages of 10–15 kV. The objective was to observe the surface characteristics of the samples. In images (a) and (b), of Fig. 1, corresponding to the tantalite, distinct mineral phases with well-defined boundaries and strong brightness contrast are identified, mainly resulting from atomic number differences and surface topography.

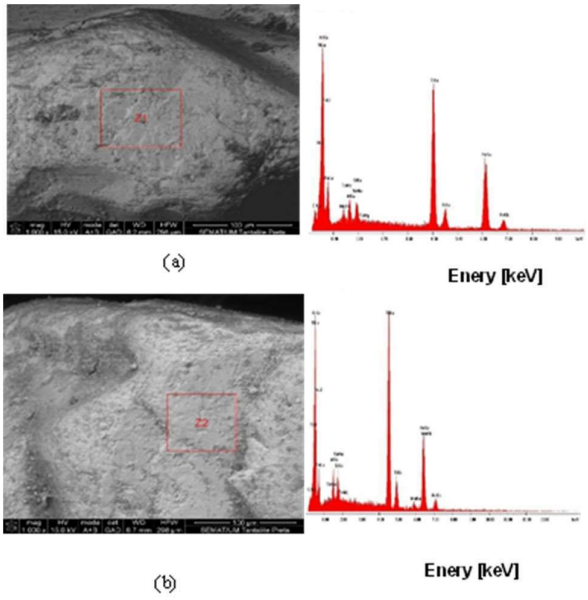


Figure 1. SEM and EDS analysis of the surface of tantalite, Ref. Z1 e Z2

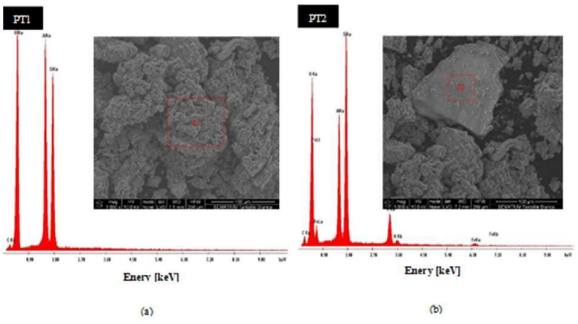


Figure 2. SEM-EDS analysis of the surface of tantaliferous pegmatites, examined in zones PT1 and PT2

In images (a) and (b), of Figure 2, referring to the pegmatites (PT1 and PT2), a partially homogeneous distribution is observed, with irregular structures, fragmentation, and particle aggregates, suggesting variations associated with crystallization processes or mechanical fracturing.

4. Energy Dispersive X-ray Spectroscopy (EDS)

The images to the right in Figure 1 show the EDS spectra obtained from different surface regions of the tantalite sample. The results consistently reveal the presence of Ta, Ti, Fe, O, Si, Al, Mg, C, and Mn, although peak intensities vary between zones Z1 and Z2, reflecting differences in relative elemental abundances and indicating local chemical heterogeneity. In the tantaliferous pegmatites (Fig. 2), the spectra display predominant concentrations of O, Si, and Al, accompanied by lower amounts of Bi, P, C, K, and Fe, which are consistent with mineral phases characteristic of pegmatitic lithologies [16]. The presence of carbon peaks suggests possible carbonate minerals, whereas silicon is associated with silicate phases such as quartz or feldspar [8,10].

Overall, the analyses identified metals (Ta, Fe, Mn, Ti, Al), nonmetals (O, C), and the metalloid Si. Tantalum concentrations ranged from 0.10 to 1.23 wt%, while Nb was not detected in any of the analyzed regions. The high Fe and O contents support the classification of the sample as Tantalite-(Fe), according to established mineralogical nomenclature.

Table 1. Classification of Weight Percentages (wt%) and Atomic Percentages (at%) from EDS of the Tantalite Sample (Reference)

Elements	Chemical Composition of the Sample					
	Weight Percentage (wt%) and Atomic Percentage (at%)					
	Ref.1		Ref.2		Ref.3	
	Wt %	At %	Wt %	At %	Wt %	At %
Ti	26.92	15.23	31.34	19.16	23.46	12.35
Si	1.42	1.37	1.32	1.37	1.88	1.69
O	33.55	56.83	29.71	54.39	41.73	65.76
Al	1.54	1.55	1.80	1.95	2.39	2.23
Mg	0.94	1.05			12.32	20.04
Ta	0.01	0.10	1.23	0.20	1.00	0.20
Mn			1.84	0.98	1.65	0.76
C	3.77	8.51	2.48	6.06	2.53	5.31
Fe	31.86	15.46	30.28	15.88	26.36	11.90

The concentration levels identified in this study are consistent with those reported by Habinshuti et al. (2021), who also observed high concentrations of oxygen (O), silicon (Si), and aluminum (Al), as well as low levels of economically relevant elements such as tantalum (Ta) and niobium (Nb) prior to gangue mineral removal. The results obtained here align with the literature describing samples analyzed before gangue separation. However, they

diverge from the findings reported in [13-15], which document significantly higher concentrations of Ta and Nb using leaching-based separation techniques.

Table 2. Classification of Weight (wt%) and Atomic (at%) obtainned from EDS (PT samples)

Elements	Chemical Composition of the Sample							
	Weight Percentage (wt%) and Atomic Percentage (at%)							
	PT.1		PT.2		PT.3		PT.4	
	Wt %	At %	Wt %	At %	Wt %	At %	Wt %	At %
Si	24.51	17.08	29.61	22.49	11.19	7.78	20.49	14.99
O	49.58	60.66	45.47	60.63	46.92	57.30	50.03	64.29
Al	22.08	16.02	14.99	11.85	15.91	11.52	20.67	15.75
C	3.83	6.24			12.32	20.04	1.73	2.97
K			7.57	4.13				
P					3.88	2.45	2.32	1.54
Bi					9.78	0.91	4.76	0.47
Fe			2.35	0.90				

Table 1 presents the quantitative concentrations of the elements identified in the tantalite sample, expressed in weight percent and atomic percent. The low concentrations of tantalum (Ta) and niobium (Nb) observed may result from both geological factors and analytical limitations. From a geological perspective, Ta- and Nb-bearing minerals such as Tantalite-(Fe) and Tantalite-(Mn) are heterogeneously distributed within the mineralized body, which affects point-based analyses conducted on small areas. Surface weathering processes may also cause partial leaching of these elements [9,12]. From an analytical standpoint, the EDS technique has relatively high detection limits, which may underestimate elements present in low concentrations.

Table 2 presents the quantitative results for the tantaliferous pegmatites, revealing high concentrations of oxygen, silicon, and aluminum, and lower amounts of iron, bismuth, carbon, and potassium. This elemental distribution is consistent with mineral assemblages typical of pegmatitic environments, reflecting the presence of accessory minerals associated with the mineralogical evolution of tantalite-bearing pegmatites [11].

5. Conclusion

In this study, it was possible to evaluate the concentration levels of tantalum and associated elements. The evaluation was performed both directly in the tantalite ore and indirectly through tantaliferous pegmatite obtained from Alto Molocué, Mutala region, Zambézia Province, Mozambique. The surface morphology and elemental composition of the samples were analyzed using Scanning Electron Microscopy (SEM) for morphological characterization and Energy-Dispersive X-ray Spectroscopy (EDS) for quantitative elemental analysis.

The concentrations of tantalum observed in are comparable to those reported in recent works analyzing samples before the removal of gangue minerals. However, the results differ from studies that employ leaching-based concentration techniques, such as Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and X-ray Fluorescence (XRF), which typically report significantly higher Ta and Nb contents after mineral processing.

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