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Indonesian Tungsten Mineralogy and Processing Concept

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Abstract. Tungsten minerals which are major as Wolframite and Scheelite mineral are by-product minerals of Tin mineral known as Cassiterite. Tin minerals are mostly found in Bangka Island which is one of the islands in the Southeast Asian tin belt that makes Indonesia the largest Tin (Sn) producer in the world. This research aims to characterize the mineralogy of Tungsten and associated minerals for potential mineral processing to gain the Tungsten concentrates. The Tungsten minerals were collected from the eastern edge of Klabat Granite in Toboali District, South Bangka. The Tungsten minerals were magnetically separated up to 14000 Gauss. The magnetic and non-magnetic fractions were identified to analyze the associated mineral of Tungsten with SEM analysis. The associated minerals in the Tungsten mineralization system in Toboali were found along with Silicates, Oxides, Sulphides, and Carbonates where Silicates dominated up to 91.8% of the non-magnetic minerals while Wolframite presence up to 0.9% in the non-magnetic fraction. At magnetic fraction found that Silicates dominates also up to 84.6% while Wolframite existed at 1.1%. The results of element deportment in the non-magnetic fraction show that Tungsten is associated with iron minerals and also in liberated form. The potential Tungsten mineral is Wolframite $(Fe,Mn)WO_4$ in the magnetic and non-magnetic fraction. Mineral locking at P_{100} size 18.8 μ. shows that 84.4% Wolframite was locking with 3 (three) other minerals, 10.4% locking with 2 (two) other minerals, and only 4.8% Wolframite was 100% free in the magnetic fraction while in non-magnetic fraction P_{100} size 31.5 μ 77.5% Wolframite was locking with 3 (three) other minerals 18.3% locking with 2 (two) other minerals and only 4.2% Wolframite was 100% free. The processing concept is to liberate Tungsten from the associated minerals either with comminution or a combination of roasting alkali and leaching process and concentrate it up to marketable Tungsten concentrates.

1 Introduction

Tungsten is a critical mineral due to its low abundance (rare elements, which is estimated at 1.0 part per million [1] and extensive use as an essential component in hard metals, steel, and other alloys, well-known and identified in the EU list of Critical Raw Material [2]. The downstream industrialization policy on the mineral sector in Indonesia contributed to significant import growth of Tungsten in Indonesia since it is needed for supporting derivatives industries and strengthening economic development [3]. The import value of Tungsten ore and concentrate in Indonesia during 2021 reached USD 355,000, and put Indonesia as the 20th biggest importer of Tungsten in the world [4].

The natural abundance of Tungsten occurs in compounds form, for instance, as Tungstate which is comprised of Wolframite ($(Fe, Mn)WO_4$) and Scheelite ($CaWO_4$) as an economically proven for commercial [5]. The alternative route to produce tungsten from ore with a complex mixture of Wolframite, Scheelite, and Tin content become a spotlight nowadays, as primary resources since Wolframite and Scheelite contained 76.3% and 80.5% WO_3 respectively, and the amount of WO_3 to be considered as promising ore should be around 0.1 up to 1.0 percent[6].

PT Timah Tbk is the biggest tin producer in the world capable of producing 19.825 tons of tin in 2022 [7], and at the same time the tailing or disposal produced in high amounts, approximately 25,066 m^3 in 2020 (South Bangka), which indicated some valuable minerals still underlying and mostly composed of Cassiterite mineral [8]. Syafrizal et al reported the minerals characterization of tailing in Bangka Belitung which the Tin ore comes from granite pluton intrusion, which carries Rare Earth Element (REE) and high radioactive value on tailing related to fine-grained mineral inclusions that are carrying REE in quartz [9] [9] and drive further REE identification research.

Hutabarat et al in 2022 observed the Tungsten deposit in Toboali South Bangka which is inside the mining operation permit (IUP) of PT Timah. Tbk [10]. This area was a mining and tin ore washing plant. The identified mineral of Tungsten were Wolframite ($(Fe,Mn)WO_4$) and Scheelite ($CaWO_4$) [10].

As a by-product mineral, Tungsten follows the tin process route to the smelting process. Tungsten oxide (WO_3) is separated into slag, and accumulated in 2nd slag process in the Tin process in PT Timah, Tbk.

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Metallurgical extraction of Tungsten dominantly uses the hydrometalurgy route, which starts with digestion, solution purification, and crystallization as an established commercial process to make ammonium paratungstate (APT) neither utilize Liquid Ion Exchange (LIX) nor Solid Ion Exchange (SIX) [11] as shown in Fig.1, with more yield and high energy efficiency compared to hydrochloric acid process [5].

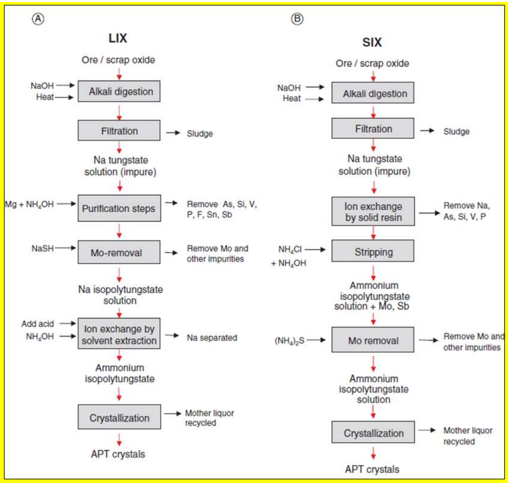


Fig. 1. Current APT route process [11]

The research purpose is to identify and characterize Tungsten's mineral carrier in Cassiterite ore from Bangka Island and a potential route for further concentration process.

2 Methodology

Samples were collected from a mining area in Toboali South Bangka District, Indonesia. Samples were crushed, ground, and, magnetically separated. The flow sheet of sample preparation can be seen in **Fig. 2**.

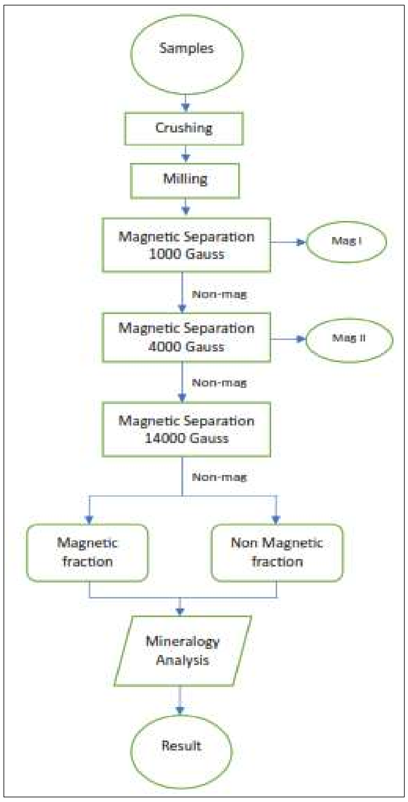


Fig. 2. Flowsheet of research

Particle size distribution of Wolframite was performed from crushing to milling. The Crusher type is Jaw Crusher MT -120 5" X 8" and the milling type is ring mill MT 250 MT Pulverizer Automatic.

For mineralogy testing, the samples were resin-mounted and polished with diamond suspension up to 0.3 μ. Polished samples were checked under an optical microscope and carbon-coated. SEM analyses were performed using SEM Automated Mineralogy for mineral liberation, locking, and size of Wolframite. Mineral liberation is based on covered area and counted in percentage as can be seen in Fig. 3.

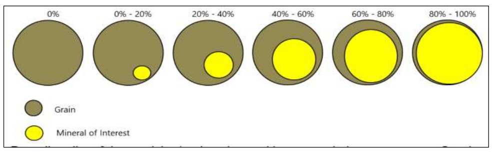


Fig. 3. Liberation classes

3 Particle Size Distribution

Particle size distribution of Wolframite in non-magnetic fraction showed that P_{80} at 29.9 μ. As can be seen in **Fig. 4** below.

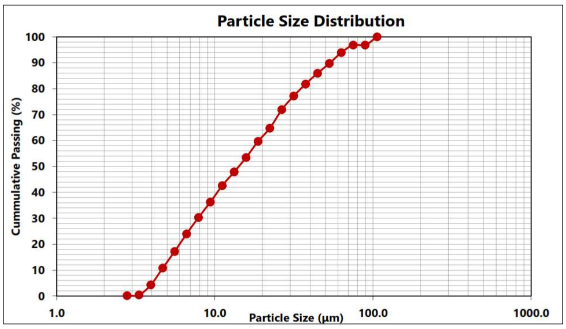


Fig 4. Particle size distribution in a non-magnetic fraction

Particle size distribution of Wolframite in magnetic fraction showed that P_{80} is only 15.9 µ as can be seen in **Fig 5**.

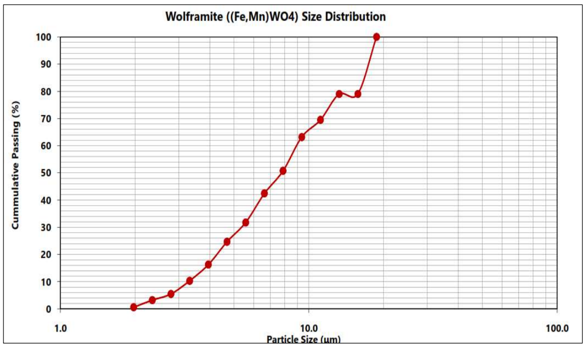


Fig 5. Particle size distribution in a non-magnetic fraction

The differences are Wolframite's size in the magnetic fraction is larger and bonded in other minerals, while in the non-magnetic fraction, Wolframite tends to be easily de-attached from other minerals even though it has to achieve smaller particle sizes up to 15.9 µ.

4 Mineral Composition

SEM analyses were conducted using the Backscattered Electron Imaging (BSE) method that showed Wolframite (Wol) within the Quartz (Qz) and Cassiterite (Cst) in the magnetic fraction as can be seen in **Fig 6**.

Fig. 6. Mineral composition of magnetic and non-magnetic fraction

Detailed SEM picture from the magnetic fraction that showed several minerals together with Wolframite can be seen in **Fig. 7.**

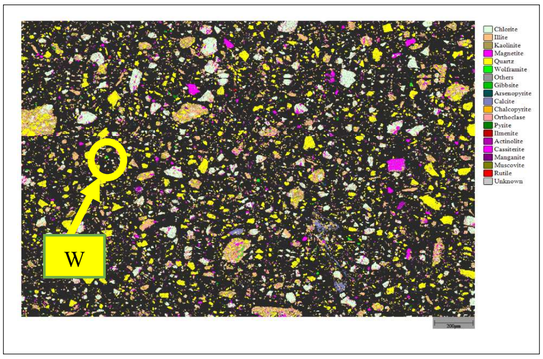


Fig. 7. Mineral composition of magnetic and non-magnetic fraction

Both magnetic and non-magnetic fraction from the magnetic separation of 14000 Gauss was analyzed with SEM Automated Mineralogy and showed the composition of minerals as seen in **Fig. 8**.

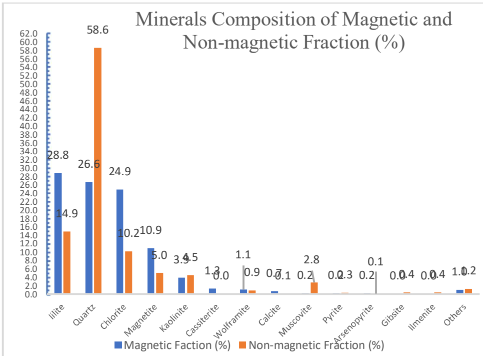


Fig. 8. Mineral composition of magnetic and non-magnetic fraction

Wolframite was identified as oxide with 1.1% from magnetic fraction. Other identified minerals in magnetic fraction were Illite (28.8%), Quartz (26.6%), Chlorite (24.9%), and Magnetite (10.9%). In the non-magnetic fraction, identified minerals were Quartz (58.6%), Ilite (14.9%), and Chlorite (10.2%) while Wolframite was found at 0.9% under SEM analysis.

5 Element Deportment

In element deportment for magnetic fraction found that the source of Tungsten (W) was found only from Wolframite ($(Fe,Mn)WO_4$) mineral. It contributed 0.2% to Iron (Fe) sources and 0.8% to Tungsten (W) while for magnetic fraction, Wolframite contributed 0.1% to Iron sources and 0.6% to Tungsten (W).

Table 1. Source of Tungsten at a magnetic fraction

Element	Mineral Phase	Quantity (%)
Fe	Arsenopyrite	0.1
	Chlorite	5.9

	Iilite	0.8
	Magnetite	6.9
	Pyrite	0.1
	Wolframite	**0.1**
	Other Mineral	0.1
W	**Wolframite**	**0.6**

Based on **Table 1**, the source of Tungsten in the magnetics fraction comes only from Wolframite which contributes to Iron (Fe) and Tungsten (W). In **Table 2** it can be seen the source of Tungsten at non-magnetic fraction. Both magnetic and non-magnetic showed that the mineral source of Tungsten is Wolframite.

Table 2. Source of Tungsten at non-magnetic fraction

Element	**Mineral Phase**	**Quantity (%)**
Fe	Arsenopyrite	0.1
	Chlorite	2.4
	Iilite	0.4
	Magnetite	3.3
	Pyrite	0.1
	Wolframite	**0.1**
	Other Mineral	0.3
W	**Wolframite**	**0.8**

6 Mineral Locking

Tungsten in the magnetic fraction was only found at 4.2% fully liberated (100%) while at the non-magnetic fraction, it reached 4.8% as can be seen in **Fig. 9** and **Fig. 10** respectively. It means Wolframite mineral in fully liberated at magnetic separation 14000 Gauss will be found in non-magnetic fraction. At 80-100% liberated Wolframite in magnetic fraction reaches 95.8% and 89.4% in non-magnetic. Liberation of Wolframite in magnetic fraction, mostly Wolframites

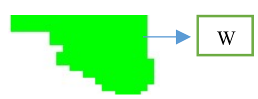
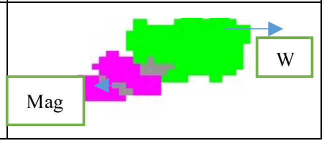
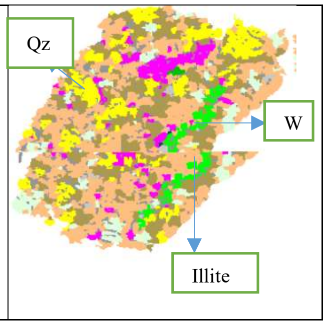
Condition	Wolframite in magnetic fraction
100% fully liberated (4.2%)	
Binary (18.3 %)	
Ternary; Locked <20% (77.5%)	

Fig 9. Mineral locking in magnetic fraction

were attracted to magnetic fraction because of bonding with Magnetite. While in non-magnetic fraction Wolframite is locked by Quartz (Qz) and Illite.

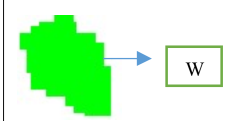
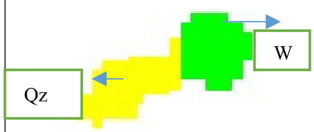
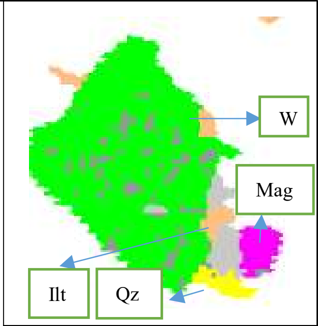
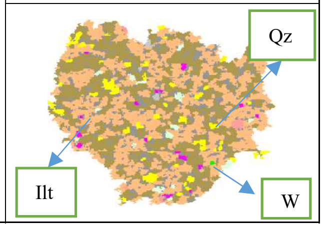
Condition	Wolframite in non-magnetic fraction
100% fully liberated (4.8%)	
Binary (10.8 %)	
Ternary (84.4%)	
	

Fig 10. Mineral locking in a non-magnetic fraction

7 Processing Concept

Referring to particle size obtained in this research and the mineral locking and liberation achieved, it is recommended to have particle size up to 15.5 μ to liberate the Wolframite from the ores. It will be considered high energy to reach 15.5 μ. Another alternative route of processing could be the hydrometallurgical route. Since Tungsten ores are dominated by Silicates, it would be easier to concentrate the Tungsten mineral by reducing the gangue minerals.

In the leaching process of Silicates in combination with alkali roasting, Silicates minerals will be processed further by water leaching [12].

$$SiO_2(s) + Na_2CO_3(s) \rightarrow Na_2SiO_3 + CO_2(g)$$

Alkali roasting decomposed Wolframite at a temperature of 800°C - 900°C, following to the reactions [13]:

$$2FeWO_4 + 2Na_2CO_3 + {}^{1}/_{2}\,O_2 \rightarrow 2Na_2WO_4 + Fe_2O_3 + 2CO_2$$

$$3MnWO_4 + 3Na_2CO_3 + {}^{1}/_{2}\,O_2 \rightarrow 3Na_2WO_4 + Mn_3O_4 + 3CO_2$$

The filtration process can be used to separate Sodium Tungstate solution since the oxide of iron and manganese is stable as an insoluble compound. The main intermediate product in industrial tungsten production is Ammonium para tungstate (APT) usually obtained from tungsten concentrates by a caustic or soda or acid treatment. Hydrochloric acid, nitric acid, or sulfuric acid can be used to decompose tungsten ore and produce insoluble tungstic acid (H_2WO_4) [14]. Wolframite concentrates can be further processed by discomposing tungsten concentrates to produce soluble tungsten compounds in several steps and thus could lower the energy level of the Wolframite concentration process.

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