Structural Control of Primary Tin Mineralization (Case Study: Parit Tiga, West Bangka Regency, Bangka Belitung)

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Abstract. Tins are important commodities of metal mineral deposits in Bangka and have been mined since the seventeenth century. The research aims to determine the characteristics of primary tin mineralization in Parit Tiga, West Bangka Regency, Bangka Belitung and the control of geological structures on mineralization. Rock samples were obtained from geological mapping and analyzed using X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF), petrography, and mineragraphy method. From the analysis, the alteration can be divided into four zones: quartz + tourmaline alteration, quartz + halloysite + chlorite + pyrophyllite alteration, quartz + illite alteration, and quartz + kaolinite + chlorite + dickite alteration. The cassiterite, hematite, and pyrite are found in the mineralization zone associated with the greisen deposit. Based on the structural analysis data conducted on the normal left slip fault, the shear stress has an orientation of NE-SW and resulting in the forming of NW-SE gash fractures. These gash fractures have been filled by quartz and the tourmaline as disseminated minerals. The distribution of mineralization and alteration are found adjacent to the sheeted quartz-tourmaline veins. The dominated-tin concentration in ore deposits has the same orientation as the fault structure. These infer that the mineralization and alteration in the research area are controlled by geological structure.

Keywords: Geological structure, tin deposit, alteration, granite, mineralization

1. Introduction

Indonesia is one of the countries nominated as the second-largest tin production and has been mined 70,900-ton tin in total from several areas until 2015, especially in Bangka Belitung [1]. Tins are the important commodities of metal mineral deposits in Bangka. There are so many utilizes of tins, either in several industries or daily use. These things affect the tins that have been exploited since the seventeenth century [2]. The number of tin mining activities is increasing, but fewer know where the tin resources are, especially the primary tins.

According to [3], the primary tins are tin deposits that still existed in the host rock when the tin ore deposits are formed. These deposits formed along with the granitic magmatic cooling process. The primary ore mineral of these deposits is cassiterite and also associated with fluorite and tourmaline. Cassiterite precipitation may increase pH (acidity level), temperature, or the combination of physical and chemical factors. These precipitations also depend on fluid-rock interaction. The deposit formation effected by structural geology and hydrothermal alteration [4]. Hydrothermal alteration is a complex mineral, chemical, and textural alteration process generated by fluid-rock interaction. The main factors that control these processes are the properties of wall rocks, the fluid composition, and the chemical element from the fluid component, e.g H⁺, CO₂, K⁺, H₂S, and SO₂ [4]. The fracture in tin deposits used for the fluid pathway and the hydrothermal vein may be formed. Most hydrothermal fluids consist of silica produced by the intrusion, metamorphic devolatilization, and mantle-bearing fluid [5].
The tin deposits are mostly found as greisen deposits. These greisens consist of quartz-muscovite with other associated minerals, such as fluorite, topaz, and tourmaline. According to [4], a system of greisen deposits marked by fracture, sheeted vein, and stockwork controls formed due to greisenization of granite to country rock.

This research is a fraction of primary tin mineralization characterization. The study aims to determine the characteristics of primary tin mineralization in Parit Tiga, West Bangka Regency, Bangka Belitung (Figure 1) and the effect of geological structures on mineralization. Rock samples were obtained from geological mapping and analyzed using X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF), petrography, and mineralgraphy methods. This kind of research has not been conducted before in this area (Figure 1).

![Figure 1. Map of the research location in Parit Tiga, West Bangka Regency, Bangka Belitung](image)

**2. Geological Overview of The Research Area**

Bangka is one of the islands located in Sunda Shelf [6]. Bangka Island is also part of the basement high, which bordered the South Sumatera Basin and Sunda Basin. Stratigraphy of Bangka consists of Pemali Complex, Late Permian Penyambung Diabase, Tanjunggenting Formation, Klabat Granite, Ranggam Formation, Swamp, and Alluvium Deposit units (Figure 2). Pemali Complex consists of phyllite and schist with intercalation of quartzite and Permian limestone. Penyambung Diabase has deposited in Late Permian and consists of diabase that is intruded by Klabat Granite. Tanjunggenting Formation consists of an alteration of meta-sandstone, sandstone, clayed sandstone and iron oxide. Klabat Granite consist of granodiorite, granite, adamelite, diorite and quartz diorite with aplite and pegmatite dykes. Ranggam Formation consists of an alteration of sandstone, claystone, tuffaceous claystone with intercalation of siltstone [7, 8].

Tectonically, Bangka Island has been associated with Sundaland formation and Indochina-East Malaya Block [9]. According to Katili (1967) in [10], the existence of cross-anticline caused by two deformations has occurred.
in metamorphic and sedimentary rocks in Bangka. The first deformation occurred in the NS-SE anticline with undefined age, and another deformation occurred in the NE-SW anticline structure in the Late Jurassic. The anticline structure may be produced by collision in the western Sumatera due to the relative stability of Bangka Island that does not affect by tectonic movement in the back volcanic arc [10].

Figure 2. Geological map of North Bangka (Modified from Mangga and Djamal, 1991) [11].

3. Characteristic of Primary Tin Deposits in Bangka

According to [12], biotite granite in Bangka can be divided into two granitoid provinces: The Main Range, which located in Menumbing (West Bangka), Belinyu (North Bangka), Pemali and Permisan; and The Eastern Range, which located in Pading (Central Bangka) and Toboali (South Bangka) (Figure 3). The types of granites that found in Bangka are I-type and S-type granite, but most of granite that is associated with tin deposits are S-type granite. The I-type granite composition has hornblende on one side, and the S-type granite has rich-cordierite on the other side. The S-type granite produced by a magma source that experienced chemical fractionation. This granite type mostly has low sodium concentration, less than 3.2% Na₂O concentration in rocks with 5% K₂O and less than 2.2% Na₂O concentration in rocks with 2% K₂O. According to [13] and [14], the primary tin deposits found in Bangka are pegmatite, dissemination, quartz-cassiterite, sulfide-cassiterite, hydrothermal breccia, greisen, stanniferous veins, cornish lodes, and metasomatism. The greisen deposit has been associated with geological structure such as fracture and sheeted vein.
Figure 3. Distribution of granitoid type in Bangka Island. The main province consists of S-type granite, meanwhile the eastern province consists of I-type granite [12].

4. Methods

The samples were obtained by geological mapping in a 20 km² area. Geological mapping determined the rocks in macroscopic and measured the structures. The structure’s orientation was defined by DEM (Digital Elevation Model) analysis and field measurement data. All samples were analyzed using X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF), petrography, and mineragraphy methods. Petrography and mineragraphy are used to define the exact lithology and its minerals which correlated with field data. The 113 samples were analyzed using XRF to determine the concentration of Sn and also Mn, Fe, Zn, W, and U which serve as the Sn-associated elements. The alteration zones were determined by using XRD analysis. The XRD results were serving the mineral contained in all samples which may be associated with the alteration zone. Ultimately, all analysis result will then be compared to interpret the primary tin characterization and its structural controls.

5. Result and Discussion

5.1 Geological Structure

In the research area there are shear fractures with NW-SE orientation and gash fractures with NE-SW orientation (Figure 4). The gash fractures are filled by quartz and the tourmaline. The structures were obtained by geological mapping. Based on field data, the analysis of the structure result showed that the research area has controlled by normal left slip fault. This structure was found in granite as its lithology. The normal left slip fault has the same orientation as mineralized vein such as tourmaline and quartz vein. This assumes that the fault has been formed along the alteration and mineralization process.
Figure 4. The fractures in granite and its analysis result using stereonet.

Other than the fault, the research area was found two sheeted veins: tourmaline and quartz vein. Those sheeted veins occurred in granite as its lithology. Based on structure analysis result data, the quartz vein and tourmaline vein has NE-SW orientation (Figure 5 & 6). The size of sheeted veins is around 1 mm – 5 mm. Meanwhile, the size of sheeted veinlets are less than 1 mm.
5.2 *Alteration Zone*

Cassiterite, hematite and pyrite were found in the research area. Those minerals are associated with a greisen deposit. The cassiterite is the main tin ore-bearing mineral within the disseminated texture and associated with tourmaline and quartz vein. This may indicate the alteration zone. Based on the field data and XRD analysis, the alteration zone in research area can be divided into four zones, that explained in the following subsections.

5.2.1 *Quartz+Kaolinite+Chlorite+Dickite Alteration Zone*

The characteristic of this zone is the primary mineral that has been replaced by quartz, kaolinite, chlorite and dickite (Figure 7). The altered lithology that found in this zone is fine-grained granite. The XRD analysis showed the existence of secondary minerals such as quartz, kaolinite, chlorite and dickite. The minerals that have been replaced occurred at a temperature around 140° – 220° Celsius [15] due to the increasing of meteoric water. The
meteoric water may cause the decreasing of temperature in this zone. There is no high-temperature mineral such as tourmaline has been found and away from structures.

![Figure 7](image7.png)

**Figure 7.** The outcrop of quartz + kaolinite + chlorite + dickite alteration zone and its samples. Black box show the sampling location.

5.2.2 Quartz+Tourmaline Alteration Zone

The primary mineral in this zone has been replaced by quartz and tourmaline (Figure 8). The alteration zone was found in fine-grained granite as its lithology. The mineral in granite has been replaced by quartz and tourmaline. This replacement occurred at a temperature around 200° – 320° Celsius [15] with pH level around 3 – 6 and also generated with structure. The tourmaline distribution is affected by fault, which both of them have the similar orientation. hydrothermal fluid went out though the fault as its fluid pathway. This zone also has high concentration of tin elements due to the existences of tourmaline.

![Figure 8](image8.png)

**Figure 8.** The outcrop of quartz + tourmaline alteration zone and its samples. Black box show the sampling location.
5.2.3 Quartz+Illite Alteration Zone

The characteristics of this zone has primary mineral that has been replaced by secondary quartz and illite (Figure 9). This zone consists of fine-grained granite as its lithology, which has been altered. The mineral replacement occurred at a temperature around 140° – 300° Celsius [15]. The high-temperature hydrothermal fluid formed close to the existence of structure in the research area.

![Figure 9](image1.png)

Figure 9. The outcrop of quartz + illite alteration zone and its samples. Black box shows the sampling location.

5.2.4 Quartz+Halloysite+Chlorite+Pyrophyllite Alteration Zone

The lithology that has been altered in this zone is fine-grained granite. According to XRD analysis result, the mineral has been replaced by quartz, halloysite, chlorite, and pyrophyllite (Figure 10). According to [15] this zone formed at a temperature around 100° – 200° Celsius. The decreasing temperature of hydrothermal occurred due to the significance of meteoric water contamination and away from structures.

![Figure 10](image2.png)

Figure 10. The outcrop of quartz + illite alteration zone and its samples. Black box show the sampling location.
5.3 The Relationship Between Geological Structure and Alteration Zone

The hydrothermal alteration and mineralization in the research area are related to geological structure and lithology based on field data (Figure 10). The granite was found as host rock in primary tin deposits. Besides veins, the alteration rock may formed the primary tin mineralization due to the hydrothermal fluid deposits in rocks’s pore. High-temperature mineral such as tourmaline may indicate the existences of tin deposits. The alteration zone that consist of tourmaline is in quartz+tourmaline alteration zone. This zone also generated by normal left slip fault, which created veins and gash fractures that have been filled by quartz and disseminated minerals of tourmaline around the fault plane. It indicates that the area around the fault plane has a higher quartz-tourmaline alteration rate, which resulted in higher tin concentration. These things imply that the tin concentration will be increased when it is located close to the fault zone. The higher tin concentration located close to the fault zone may occur due to the fault control as the hydrothermal fluid pathway for the mineralization of the research area. Some veins have the same orientation as the fault. It can be concluded that these veins also controlled the mineralization of primary tins.

Figure 11. Distribution of alteration zone map and its structures.
6. Conclusion

The primary tin deposit has characteristic as granite as its lithology. Cassiterite was found dominant in the research area as the disseminated mineral in granite. Cassiterite also associated with tourmaline and quartz veins. The alteration zone can be divided into four zones. The quartz + kaolinite + chlorite + dickite alteration zone and quartz + halloysite + chlorite + pyrophyllite alteration zone has decreasing temperature due to the contamination of meteoric water. This zone also away from the existence of structure. However, the quartz + tourmaline alteration and quartz + illite alteration zone have a high-temperature mineral such as tourmaline and close to the structures. This zone also has a high concentration of tin element due to the existence of tourmaline as its associated-mineral. The structures were found as shear fractures, which has NW-SE orientation, and gash fractures, which has NE-SW orientation. From analysis data, it was conducted to the normal left slip fault. The sheeted veins consist of quartz and tourmaline, and the gash fractures have been filled by quartz vein and tourmaline as its disseminated mineral. These assume that the geological structure controlled the mineralization and alteration in the research area.

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