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Supergene Alteration and Copper Mineralization Anomaly in Peraluminous (s-Type) Granitoids at Teluk Tilan Site, Merangin Geopark, Jambi

Yudi Arista Yulanda[1*], Jarot Wiratama[2], Muhammad El Hakim[3], Muhammad Faisal Seprizal[4]

[1-4] Mining Engineering Department of Science and Technology Faculty, Jambi University, Jambi, Indonesia

*Coressponding Authors: yudiarista@unja.ac.id

Abstract

This study aims to identify geochemical and mineralogical anomalies within the Tantan Granite Formation at the Teluk Tilan site (Sample TL) in Merangin Geopark, Jambi, to understand the potential for metal enrichment. Petrographic, mineragraphic, and X-Ray Fluorescence (XRF) analyses were conducted on a granitoid sample from this specific location. Geochemically, Sample TL is classified as a Peraluminous (S-type) Granite, characterized by a molar A/CNK value of 1.282. This finding is considered anomalous because the rock exhibits the presence of Copper (Cu) mineralization with a concentration 0.1%. Mineragraphic analysis confirmed an association of metallic minerals, including chalcopyrite (CuFeS2), pyrite (FeS2), and most significantly, the presence of the secondary minerals Covellite (CuS) and Goethite (FeO(OH)). The occurrence of covellite indicates that this granitoid has undergone a post-magmatic supergene alteration process. This supergene process (weathering) triggers the leaching of primary copper and the re-precipitation of secondary copper, potentially leading to higher grades. The results support the interpretation that the Tantan Granite Formation records a complex magmatic evolution and holds indicators of a prospective base metal mineralization system within the Merangin Geopark area.

Keywords: Tantan Granite; Copper; Supergene Alteration; Covellite; Merangin Geopark

Cite This Article

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INTRODUCTION

The role of strategic minerals, such as base metals, has become increasingly critical in the global energy transition and digitalization era. Granitoid rocks, as products of magmatic processes, are primary hosts for various types of mineral deposits [1]. The Tantan Granite Formation, exposed in the Merangin Geopark region, Jambi, is Triassic in age around ~200 million years [2] and is suspected to possess hydrothermal mineralization potential.

Granitoids are generally classified into I-type (derived from igneous magma), often associated with Cu-Au-Mo deposits, and S-type (derived from melting of sedimentary rocks), typically associated with Sn-W mineralization [3]. While previous studies [2] indicated that parts of the Tantan Granite belong to the I-type, this investigation identifies a significant anomaly in a specific rock sample located at the Teluk Tilan site (TL).

The objective of this paper is to specifically examine and discuss the geochemical anomaly of the Teluk Tilan granitoid, where its genetic classification suggests an S-type source, yet it hosts substantial copper mineralization. This finding is crucial for evaluating exploration potential and understanding the complex geological evolution recorded by the Tantan Granite Formation.

The Merangin Geopark is globally recognized, notably for its geoheritage value, which encompasses the well-preserved flora and fauna fossils from the Permian period along the Batang Merangin River. Beyond paleontology, the region's geological significance includes its magmatic and structural evolution, making the Tantan Granitoid an important component of the local geoheritage. This study, by investigating the geochemical and mineralogical anomalies associated with the Tantan Granite, not only contributes to the global understanding of complex magmatic systems but also enhances the knowledge base necessary for sustainable management of the geopark's entire geoheritage, balancing conservation with potential resource insight.

METHODS

2.1. Fieldwork and Sampling

Rock sampling was conducted at the Teluk Tilan site, targeting fresh outcrops of the Tantan Granite Formation. The sampling technique employed was grab sampling. This method was selected to quickly collect a representative sample (Sample TL) focusing specifically on the visibly altered or mineralized portion of the outcrop, aiming to maximize the chance of capturing the geochemical anomaly under investigation. During the fieldwork, essential geological equipment such as a geological hammer was used to detach fresh rock fragments from the main outcrop (Figure 1). A compass-clinometer was utilized to record the orientation of the outcrop, and plastic sample bags were used to secure the rock fragments, ensuring minimal contamination before laboratory analysis.

Figure 1. Rock Sampling

2.2. Laboratory Analysis

The collected rock sample (TL) was subjected to three main analytical stages: petrography, mineragraphy, and geochemistry (XRF).

1. Petrographic and Mineragraphic Analysis: These analyses were performed to identify the rock type, primary and secondary mineral assemblages, and the mode of mineral occurrence.

   Sample Preparation: A fragment of the TL sample was cut using a diamond saw to produce two types of sections. The first was polished on both sides and mounted on a glass slide to produce a thin section for petrographic analysis under transmitted light. The second was ground and polished on one side to produce a polished section for mineragraphic analysis under reflected light, focusing on opaque minerals.

2. Geochemical Analysis (XRF): This analysis quantified the major element oxides.

   Sample Preparation: A portion of the TL sample was crushed using a jaw crusher and pulverized into a fine powder (mesh 200#) to ensure homogeneity. The powder was then prepared into a pressed pellet for XRF analysis.

RESULTS AND DISCUSSION

3.1. Petrographic Characteristics and Alteration

Based on the QAPF classification, Sample TL is classified as Tonalite (Figure 2). The rock is dominated by felsic minerals, specifically Quartz (46%) and Plagioclase (43%), with a low content of mafic minerals (8%).

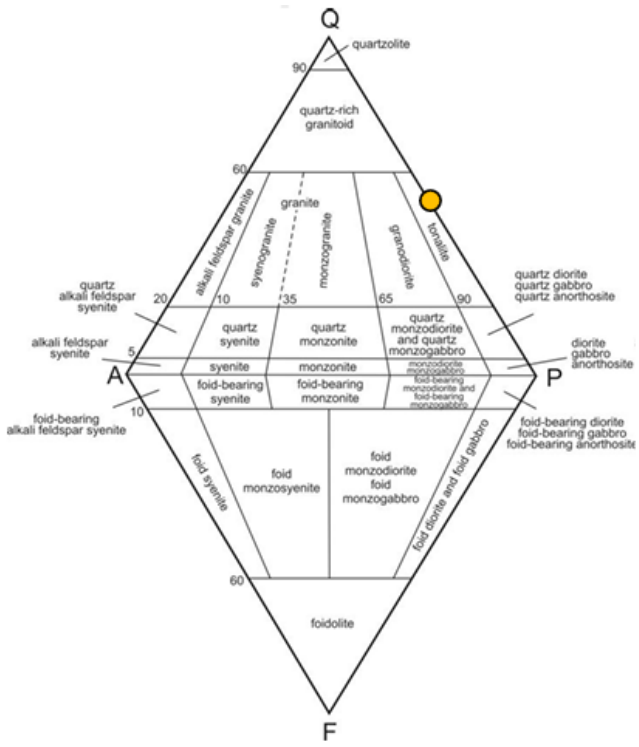

Figure 2. QAPF Diagram of TL Sample

Alteration Traces: The primary mafic minerals have been altered into the secondary mineral Chlorite (8%) (Figure 3). The presence of chloPerite indicates low-intensity propylitic alteration has affected the rock [4]. This alteration is typically associated with opaque minerals, which is a key marker of a hydrothermal system.

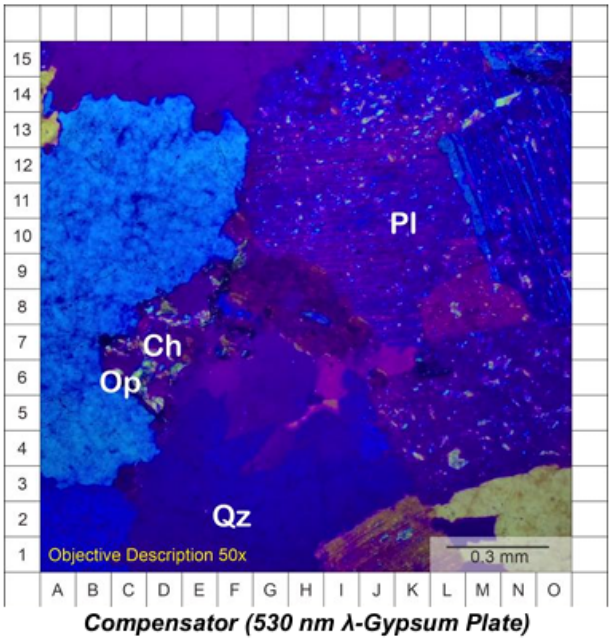

Figure 3. Petrography of TL Sample

3.2. Geochemical Anomaly and Granitoid Classification

XRF analysis for Sample TL shows an SiO2 content of 68.69% and Fe2O3 8.93%. Granitoid typing was conducted using the A/CNK index [molar Al2O3 / CaO+Na2O+K2] [5] as shown in Table 1.

Table 1. The Result of A/CNK Index

Sample	A/CNK	Classification	Granitoid Type
TL	1.282	Peraluminous	S-type

The classification of Sample TL as S-type Granite is anomalous because this rock contains significant copper mineralization (Cu 0.1%). Porphyry copper deposit systems are classically more closely linked to I-type Granites [6] [7].

This anomaly can be explained by two complex geological scenarios:

1. Magma Contamination: An I-type magma (a Cu carrier from the mantle/lower crust) assimilated aluminum-rich upper crustal rocks during ascent. This resulted in a hybrid rock that geochemically exhibits an S-type signature but still carries the Cu fluid and metals from its original I-type source.
2. Hydrothermal Overprinting: The TL rock, which might have initially been a sterile S-type granite, was later injected or exposed to hydrothermal fluids originating from a nearby I-type intrusion post-crystallization.

3.3. Evidence of Supergene Enrichment Process

Mineragraphic results show a significant association of metallic minerals (Figure 4). Primary Minerals: Chalcopyrite (CuFeS2) and Pyrite (FeS2). The chalcopyrite (Ccp)-pyrite (Py) association is a classic indicator of a hydrothermal system. Secondary/Supergene Minerals: The presence of Covellite (CuS) and Goethite (FeO(OH)).

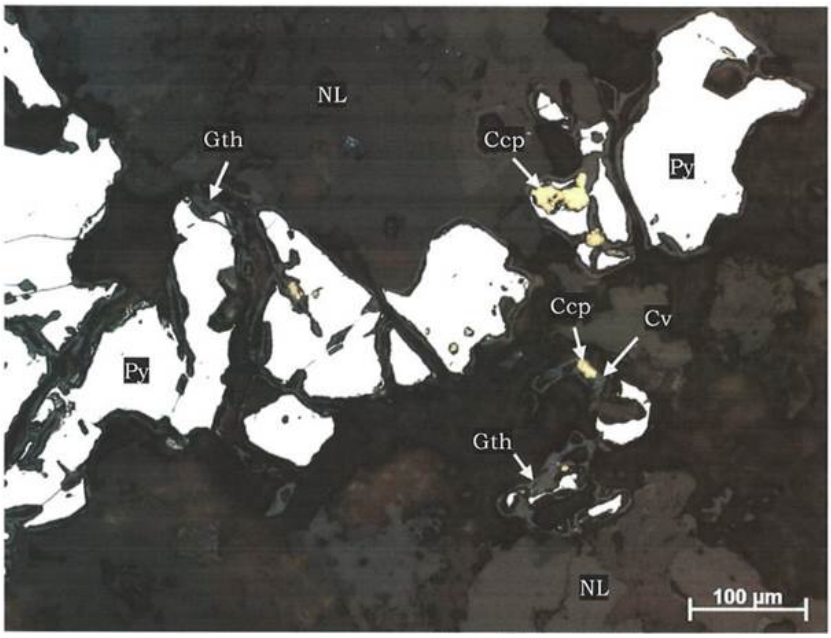

Figure 4. Mineragraphic Result of TL Sample

The presence of Covellite (Cv) is a key piece of evidence that the Tantan Granite at Teluk Tilan has undergone a supergene alteration process. This process involves the leaching of copper from primary minerals (chalcopyrite) due to the circulation of meteoric water, and its subsequent re-precipitation in the underlying zone as secondary, higher-grade copper minerals (covellite).

This complete geological record from primary hydrothermal mineralization to secondary supergene enrichment makes the Teluk Tilan Site an interesting target for base metal mineral exploration.

CONCLUSIONS

The Tantan Granite Formation at the Teluk Tilan Site, Merangin Geopark, exhibits an interesting geochemical anomaly: the rock is classified as S-type (Peraluminous) Granite with an A/CNK of 1.282, yet it contains Copper mineralization. This anomaly is interpreted to result from magma contamination or overprinting hydrothermal activity.

Most significantly, mineragraphic analysis reveals the presence of the secondary copper mineral Covellite and Goethite, which proves that a supergene alteration process has occurred. This finding indicates that the Tantan Granite Formation not only hosts primary mineralization but also a secondary enrichment cycle, which is highly relevant for the prospect of strategic mineral resources in the future.

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