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Petrogenesis and Geological Structure of Tantan Granitoid in Sungai Manau District, Merangin Regency, Jambi Province

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ABSTRACT

Tantan granitoids are Late Triassic–Early Jurassic age intrusive rocks that are quite extensive and can be partially found in Sungai Manau Sub-district, Merangin Regency, Jambi Province. Tantan granitoids are found in the Barisan Hills physiography, a magmatic arc line on Sumatra Island. Tantan granitoids are interesting to observe to explain rock formation. The petrographic and XRF analyses can provide insight into the intrusive rock type, its relationship to the tectonic framework, and magmatism. The trend of potential mineral resources can be interpreted based on the granitoid-type approach. The Tantan Granitoid Intrusion has two types of rocks: granite and quartz monzodiorite. Granite and quartz monzodiorite are sub-alkaline magma types, with the granitoid type being I-type metaluminous, which tends to have potential with base metal minerals associated with hornblende minerals from observations or petrographic analysis. Based on the TAS diagram of Na_2O+K_2O vs. SiO_2 shows that the sub-alkaline magma type is a calc-alkaline series type in the K_2O vs. SiO_2 diagram and a calc-alkaline type in the AFM diagram. This data analysis shows that the tectonic formation of the Tantan Granitoid magma was formed from orogenic results in the form of a Continental Arc. This type can be associated with Meso-Thetic subduction activities against the West Sumatra Sundablock during the Late Triassic–Early Jurassic. Structures in the study area include northwest-southeast trending horizontal faults, including Batang Tantan Fault, Tiangko Fault, Sei Tengko Fault, and Serik Fault, then northeast–southwest trending regional faults, and relatively downward trending faults, namely Serik Fault and Betung Fault. The formation of fault structures is believed to result from subduction tectonic processes during this period.

Keywords: Tantan Granitoid, continental arc, petrogenesis, structural geology

INTRODUCTION

The subduction process on Sumatra Island between the Sundaland continental crust and the Indian Ocean crust has formed a magmatic arc path [1]-[8]. The tectonic framework in Sumatra, formed in the pre-Tertiary period, was formed from a small continental plate and an accreted oceanic plate in the Late Triassic. The small Mergui, Malacca, and East Malaya plates are joined to form the Sundaland continental plate [1],[2]. Then further accretion occurred and merged the west coast of the Woyla terrain in the Late Mesozoic. At that time, magmatism and faults occurred in Sundaland. Tantan granitoid is an intrusive rock in the Late Triassic–Early Jurassic, which is the result of magmatism from subduction tectonic movements from the Mesotetics to the northwestern edge of the West Sumatra terrane [1]-[4].

To characterize the Tantan Granitoid and the geological structure in the study area, an understanding of rock petrogenesis is required, complemented by analysis and interpretation of geological structures. Granitoid is a group of plutonic igneous rocks with phaneritic texture and acidic mineral composition. Its mineralogy consists mainly of K. Feldspar, Quartz, and Mica [7],[24]. Granitoid Tantan was exposed in Merangin Regency and was found in the research area of Sungai Manau Subdistrict, Merangin Regency, Jambi Province.

The Tantan granite is interesting to observe because it is known to have been formed by the horizontal movement of the terrane of West Sumatra against East Sumatra, known as the pre-Tertiary Sunda Mainland [2]-[6]. This study describes the petrogenesis of rocks using petrographic and geochemical analysis to explain the type of Granitoid Tantan intrusion rock, its relation to magmatism processes, tectonic framework, and the potential for mineral resources.

REGIONAL GEOLOGY

Based on physiography, Sumatra Island is divided into six (6) physiographic zones including: 1) Barisan Hills, 2) Sumatran Fault System, 3) Tigapuluh Hills, 4) Lowlands and Wavy Hills, 5) Sunda Shelf, and 6) Outer Arc Islands. The research area is in the Barisan Hills Zone [13] (Figure 1).

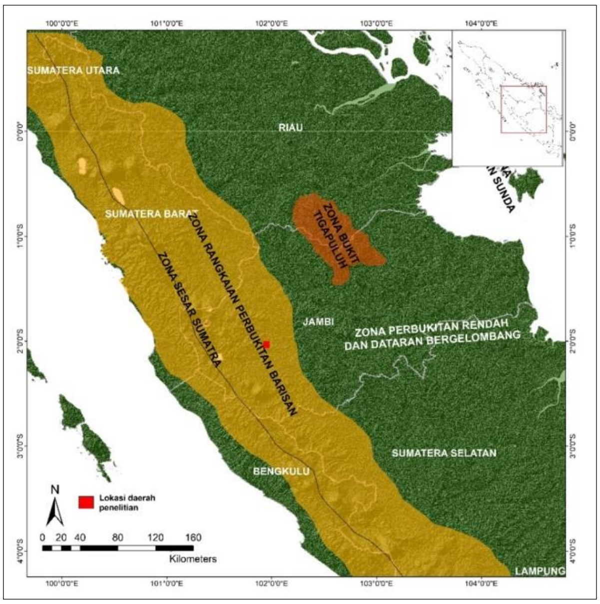

Figure 1. The research area is located in the Barisan Hills Zone [13].

Due to the collision of the Indian Ocean plate against the Sunda Mainland, three tectonic phases were formed on the island of Sumatra [5],[6],[15]. The first is a collision phase between the Sibumasu terrane and Indochina during the Permian Period, forming the Raub-Bentong Zone. The second phase is a horizontal movement between the West Sumatra and Sibumasu terrane during the Triassic–Jurassic Period, forming a horizontal movement of Central Sumatra tectonic. The third phase is the obduction process between the Woyla Arc and the West Sumatran terrane in the early Cretaceous to the beginning of the Late Cretaceous, indicating the end of the stratigraphic process and pre-Tertiary geological structure of Sumatra Island [6], [9].

During the Late Cretaceous–Late Paleogene, the island of Sumatra was controlled by tectonic subduction from the Indian Ocean with a clockwise rotation direction until it reached a relatively north–south position. Australian collision against the eastern edge of Sundaland in the early Neogene caused a change in the rotation of the island of Sumatra, which formed its current condition with a relatively northwest-southeast orientation [2],[9]. Orogens on Sumatra Island in the Barisan Hills were preceded by obduction by the Woyla Arc, followed by the Indian Ocean subduction process [16],[25], indicated by the presence of the Mesozoic–Cenozoic magmatic arc in the Barisan Hills and Tigapuluh Hills (Figure 2).

The complex tectonic framework on Sumatra Island and different bedrock sources are a configuration of stratigraphic composition and geological structures that have deformed rocks to date, such as faulting and rock folding [1]-[3]. Based on the

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Regional Geological Map of Sheets Sungai Penuh and Ketaun, the research area is controlled by Jurassic–Holocene tectonic events. The main geological structure activity of rocks in this section is faulting. Faults are formed in all pre-Quarterary rocks, and mostly the same fault direction is seen in pre-Tertiary and younger rocks. The fault consists of two general directions in the northwest–southeast and north–south directions [4].

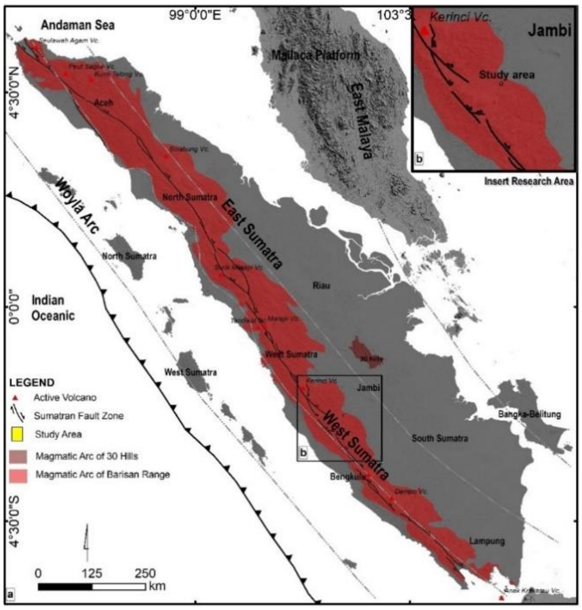

Figure 2. The Sumatra Island magmatic arc is located along the Barisan Hills and Tigapuluh Hills [25].

The regional stratigraphy of the observation area consists of pre-Tertiary age rock formations, including the Palepat Formation (Pp), Tantan Granitoid Intrusion (TRJgdt), Mersip Member Peneta Formation (KJpm), and Peneta Formation (KJp). The Palepat Formation consists of andesite-basalt volcanic rocks with sedimentary rock inserts. The Tantan Granitoid Intrusion formed in the Late Triassic–Early Jurassic Age. This formation is composed of biotite granite that has been transformed into granodiorite. Locally, there are porphyrites with sodium feldspar and potassium feldspar phenocrysts. The Asai Formation consists of marine metasedimentary rocks resembling flysch, and from fossils found, the rocks have a Middle Jurassic age. Based on paleontological evidence, the Peneta Formation indicates the Late Jurassic–Early Cretaceous age. The Peneta Formation consists of exposed marine sedimentary rocks, including reef limestones, fossils found in shale, slate, and metamorphic sandstones indicating Early Cretaceous age. Fossils, including limestone reefs, are interpreted as Late Jurassic, while Ammonite fossils are estimated to be Late Jurassic–Early Cretaceous [4],[12].

RESEARCH MATERIALS AND METHODS

The research area is Sungai Pinang Village, Sungai Manau District, Merangin Regency, Jambi Province (Figure 3). The research area is around the Jambi Merangin Geopark Area. The initial stage in this research is the observation of the Digital Elevation Model Image (DEM) by conducting remote sensing analysis to determine the straightness of the structure found in the research area. Arcgis 10.5 software was used using digitized contour data with 12.5 m intervals, roads, rivers, toponyms, elevations, and the administration of the research location, downloaded from the RBI Indonesia website. The data is overlapped with the Geological Map of the Sungaipenuh and Ketaun Sheets with a scale of 1:250,000. It is then digitized by adjusting the contour scale to 1:25,000, making the geological terrain orientation process easier.

The stage of collecting secondary data related to the geology of the research area and collecting data directly in the field in the form of structural data, geomorphological observations, observations of flow patterns, observations of outcrops, and also taking rock samples for analysis.

The preferred rock sample is the Tantan Granitoid formation for laboratory analysis. The characteristics of Tantan Granitoid rocks will be used as samples for petrographic and geochemical analysis. Petrographic analysis was conducted to determine the characteristics of each Tantan Granitoid rock sample related to the rock mineral composition. The geochemical analysis used is XRF (X-Ray Fluorescence) analysis conducted at the Center for Nuclear Minerals Technology, BATAN, to obtain data on major and minor rock elements.

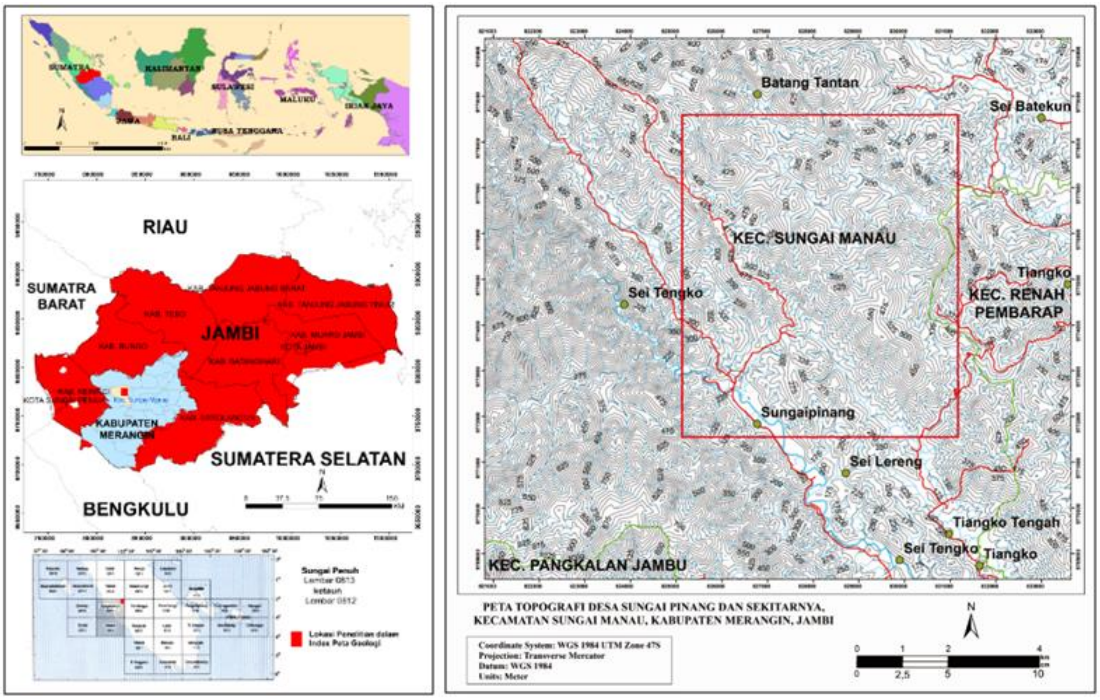

Figure 3. The research area is in Sungai Manau Subdistrict, Merangin Regency, Jambi (see red box).

RESULTS

Petrology

In the research area, granitoid groups were found, namely Tantan Granite Intrusion and Tantan Monzodiorite Intrusion. Microscopic observations of Tantan Granite with 10x ocular magnification with 5x objective magnification and 10x ocular magnification with 4x objective magnification on observation of massive structure, the phaneritic texture of coarse–medium mineral size, subhedral–euhedral mineral shape, phenocryst (0.06–0.38 mm). The mineral is composed of quartz (Qz) with an amount of 30%. Observation of PPL is white, XPL is white-gray-black, low relief without cleavage, low pleochroism, measuring 0.05–18mm phenocryst, n<nKB, a weak double bias of order 1 anhedral crystal form, spreading in the incision. Plagioclase (Pl) with a 30% White-grey color, low relief, a prismatic subhedral shape measuring 0.05–0.22mm, and weak double refraction of order 1. Orthoclase (Or) with a value of 30% In bright color PPL observations, XPL pink–grey, anhedral, polysynthetic twinning, moderate pleochroism, 1-way cleavage. Hornblende (Hb) abundance 8% Color fawn-black, medium–high relief, prismatic euhedral, 0.10–0.25 mm in size, parallel blackout, length-slow orientation, moderate double refraction of order 2. Opaque (Opq), abundance 2 % Black color when observed parallel or cross Nikol, trigonal crystal

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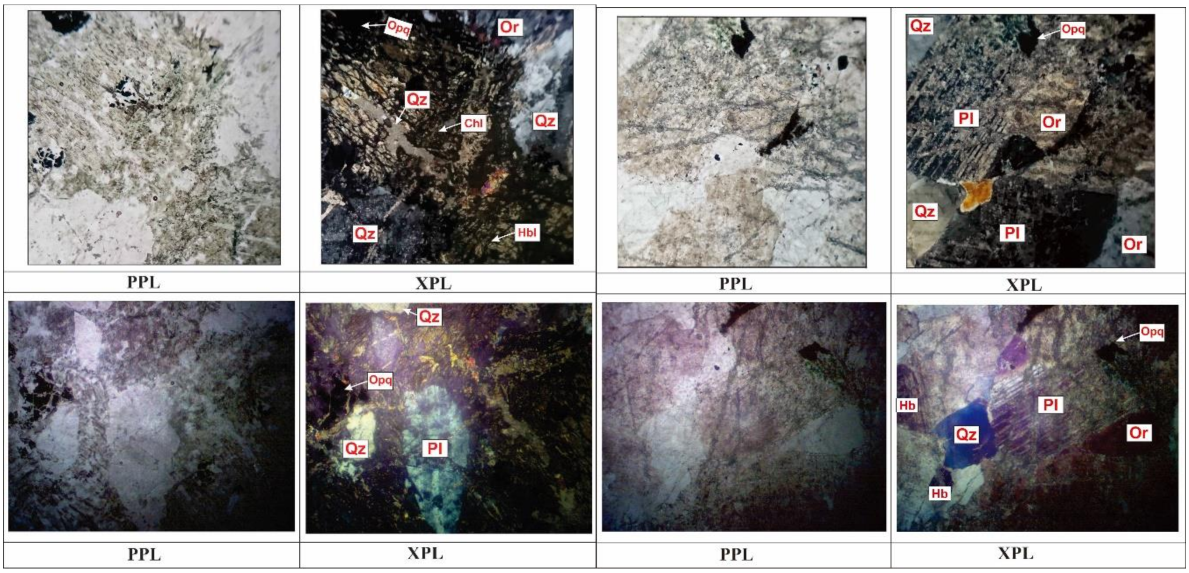
system, isotropic, high relief, measuring 0.05 mm. Based on the IUGS system of igneous rock classification, granite (Figure 4a).

The Tantan Quartz Monzodiorite was observed in microscopic at 10x ocular magnification with 5x objective magnification and 10x ocular magnification with 4x objective magnification on observation of massive structures, phaneritic textures of coarse–medium mineral size, subhedral–euhedral mineral forms, phenocrysts (0.03–0.35 mm). The mineral composition comprises a plagioclase (Pl) abundance of 35%, Colored whitish gray on PPL observations, low relief, a prismatic subhedral shape measuring 0.8–0.18 mm, and weak double refraction of order 1. Quartz (Qz) abundance 20% In PPL observations, white color, XPL white-gray-black, low relief without cleavage, low pleochroism, anhedral crystal form, present diffusely in the incision. Hornblende (Hb) 30% abundance: yellowish brown, medium–high relief, prismatic euhedral, 0.35 mm in size, parallel blackout, length-slow orientation, moderate double refraction of order 2. Orthoclase (Or) 10% abundance In bright color PPL observations, XPL pink–grey, anhedral, polysynthetic twinning, moderate pleochroism, 1-way cleavage. Opaque (Opq) 3% abundance Black color when observed parallel and cross-linked Nikol, trigonal crystal system, isotropic, high relief, 0.15mm in size. Chlorite (Chl) abundance 2% In PPL observations, greenish–brown color, XPL greenish, 1-way cleavage–absent, moderate relief, moderate–weak pleochroism, present diffusely in the incision (Fig. 4b). Based on the IUGS system of igneous rock classification, the rock name is Quartz Monzodiorite [20].



[a] [b]

Figure 4. Thin incisions in (PPL) and (XPL). a) Granite, b) Quartz Monzodiorite

Geochemistry

Rock geochemical data were analyzed using the XRF analysis method on two types of Tantan Granitoid rocks: Granite and Quartz Monzodiorite. This data will be entered into several diagrams to determine the type of magma in the formation of the Tantan Granitoid rock. The magma type analysis diagrams are (a) TAS diagram (Total Alkali-Silica) with a ratio of SiO_2 to Na_2O+K_2O, (b) Na_2O+K_2O vs. SiO_2 diagram [6], (c) K_2O vs. SiO_2 diagram [14], (d) and AFM diagrams [11], and (e) granitoid tectonic order diagrams [24] to determine the source of formation of

Tantan Granitoid rocks (Figure 5). Rock geochemical data consists of major elements (Table 1), rare earth elements (Table 2), and trace elements (Table 3).

Table 1. Major elements of granite and quartz monzodiorite from XRF analysis.

No	Major Elements	Concentration	
		Granite	Quartz Monzodiorite
1.	SiO_2	69,62 %	66,58 %
2.	Al_2O_3	17,07 %	18,94 %
3.	Fe_2O_3	3,447 %	4,081 %
4.	Na_2O	4,35 %	5,79 %
5.	CaO	3,076 %	1,348 %
6.	MgO	0,747 %	3,741 %
7.	K_2O	1,493 %	1,391 %
8.	TiO_2	0,37 %	0,3032 %
9.	P_2O_5	0,2111 %	0,1061 %
10.	MnO	0,06887 %	0,08979%

Table 2. Rare earth elements of granite and quartz monzodiorite from XRF analysis.

No	Rare Earth Elements	Concentration	
		Granite	Quartz Monzodiorite
1.	Sc	0,00153 %	0,00103 %
2.	Y	0,00183 %	0,00215 %
3.	La_2O_3	0,00653 %	0,00653 %
4.	Ce_2O_3	0,01207 %	0,0171 %
5.	Pr	0,00244 %	0,00217 %
6.	Nd	0,00796 %	0,0105 %
7.	Sm	0,00024 %	0,00071 %

Table 3. Trace elements of granite and quartz monzodiorite from XRF analysis

No	Trace Elements	Concentration	
		Granite	Quartz Monzodiorite
1.	S	0,03187 %	0,0237 %
2.	Cl	0,02112 %	0,0991 %
3.	V	0,01067 %	0,0119 %
4.	Cr	0,00409 %	0,05223 %
5.	Ni	0,00085 %	0,00161 %
6.	Cu	0.00086 %	0,0042 %
7.	Zn	0,00446 %	0,00779 %
8.	Ga	0,00138 %	0,00078 %
9.	As	0,00111 %	0,00167 %
10.	Rb	0,00379 %	0,00692 %
11.	Sr	0,05744 %	0,03456 %
12.	Zr	0,04425 %	0,1673 %
13.	Nb	0,00511 %	0,02381 %
14.	Cd	0,00047 %	0,0001 %
15.	Sn	0,00431 %	0,01296 %
16.	Cs	0,00145 %	< 0,00076 %
17.	Ba	0,1136 %	0,1984 %
18.	Hf	< 0,0002 %	0,00029 %
19.	Ta	< 0,0002 %	< 0,00035 %
20.	W	< 0,00015 %	0,00039 %
21.	Pb	0,00091 %	0,00125 %
22.	Th	0,00054 %	0,00099 %
23.	U	0,00027 %	0,00027 %

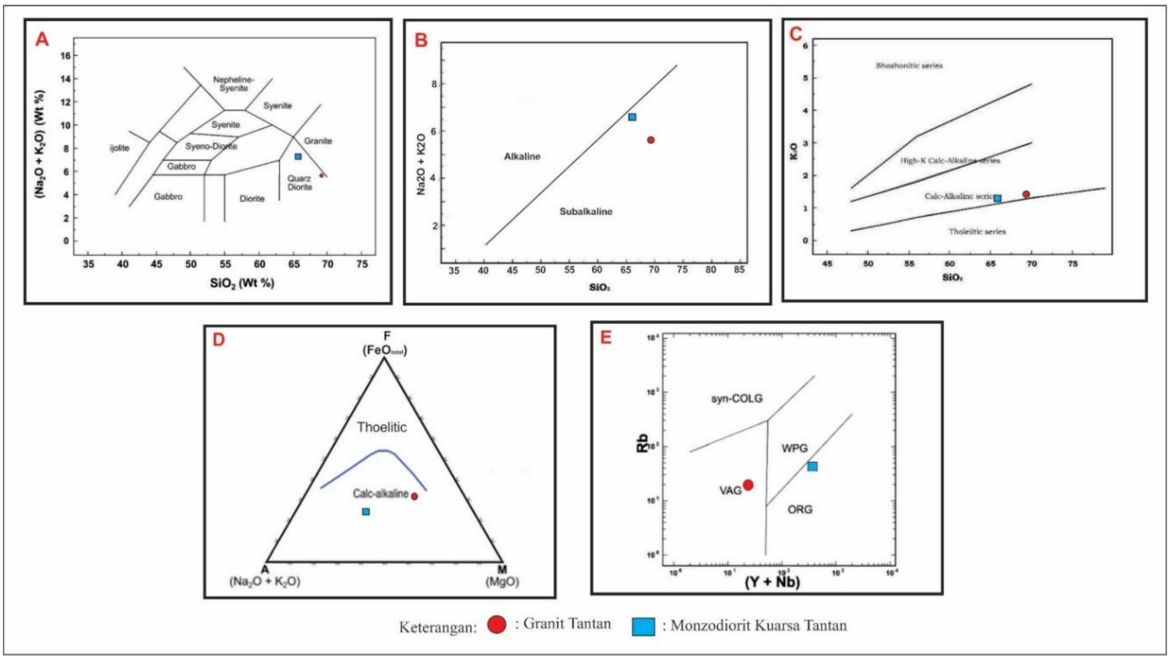


Figure 5. Plotting Results on Magma Type Analysis Diagram. (a) TAS (Total Alkali Silica) diagram with SiO_2 comparison to Na_2O+K_2O; (b) Diagram of Na_2O+K_2O vs SiO_2 [7]; (c) Diagram of K_2O vs SiO_2 [14]; (d) AFM Diagram [11]; and (e) layout diagram granitoid tectonics [24].

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Geological Structure

The faults observed are faults with regional trends, namely northwest–southeast and northeast–southwest (Figure 6). Three faults are identified in the area, Batang Tantan, Tianko River, and Betung Faults.

The Batang Tantan Fault is a left horizontal fault that separates the Palepat Formation from the Tantan Granitoid Intrusion, which has a northwest–southeast trend. This fault is found in andesite rocks with the characteristic of streak lines. The direction of the fault plane is N 119° E/67°, with a plunging value of 18°, bearing N 290° E and rake of 9°. This fault is a left slip fault.

The Tianko River Fault is a Lag Right Slip Fault which is the boundary between the Peneta Formation and the Tantan Granitoid Intrusion. This fault is found in shale rock mapped into slate in the Peneta Formation. With direction data, Fault plane N 330° E/58°, with a plunging value of 55°, bearing N 7 °E and rake of 18°. The Serik River Fault shows that two fault phases occurred there. The first phase is in the northwest–southeast direction, cut by the northeast–southwest direction phase. As in Figure 6, the fault is northwest–southeast with the direction of the fault plane N 289° E/82°, with a plunging value of 55°, bearing N 100° E and a rake size of 24°. The results of the stereonet analysis show that the movement of this fault is a Normal Left Slip Fault, then it is cut by a northeast–southwest fault with a fault plane in the direction of N 200° E/68°, with a plunging value of 15°, bearing N 271° E and a large rake of 47° which is a Right Normal Slip Fault.

The Betung Fault has a northeast–southwest direction with N 56° E/66° fault plane data, with a plunging value of 70°, bearing N 132° E and rake size of 72°. This data shows a pure downward fault movement, indicated by the presence of a waterfall at this location.

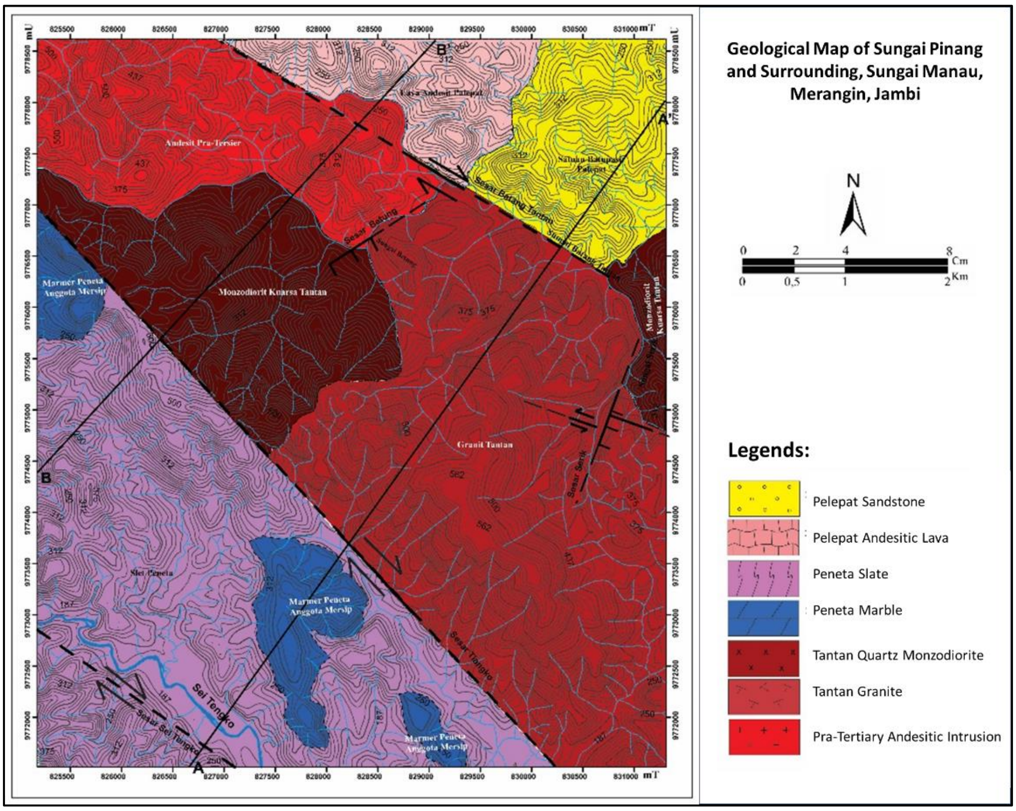

Figure 6. Geological map of Sungai Pinang area, Sungai Manau District on Tantan Granitoid Intrusion

DISCUSSION

There are two types of intrusive rocks in the Tantan Granitoid, proving that the intrusion occurred during the Late Triassic–Early Jurassic with more than one intrusion phase. Based on the mineral composition of granitoid rocks, the presence of hornblende in granite and quartz monzodiorite indicates that the granitoids are the I-Type that formed from the orogenic result of the Continental Magmatic Arc by the subduction activities that occurred in Sumatra in the Late Triassic–Early Jurassic.

Rock headings based on chemical data using the TAS (Total Alkali-Silica) diagram with a ratio of SiO_2 values to Na_2O+K_2O values for Tantan Granitoid rocks, indicating that the rock type is quartz diorite (granodiorite) and one rock sample is relative to granite because it is on a linear boundary line of quartz diorite.

In general, the chemical composition of the two rock samples indicated a linear increase in SiO_2 of granite and quartz monzodiorite with a decrease in the content of other main elements such as Al_2O_3, Fe_2O_3, CaO, MgO, K_2O (See Table 1 and Figure 5). It shows that magma evolution occurred during the rock forming.

The magma type in granite and quartz monzodiorite, according to the SiO_2 content [10], is a granite magma type because it contains 65–75% SiO_2 with low Fe and Mg content while the Na value content is higher (See Table 1). Granite magma is usually associated with subduction areas due to the melting of part of the oceanic crust and continental crust, where the temperature and pressure are very high. Magma trapped under the crust will cause continental crust rocks (Sundaland), which contain continental sedimentary rocks, not to be metamorphosed so that it undergoes assimilation so that the magma shows the characteristics of high K_2O, Na_2O, and CaO [17]-[23]. It shows magma differentiation in Tantan Granitoid changing from basaltic or ultramafic primary to acidic magma.

Based on the TAS plotting diagram, the magma types in Tantan Granite and Tantan Quartz Monzodiorite have the same magma type (See Figure 5). Based on the Na_2O+K_2O vs. SiO_2 diagram shows that the type of magma is calc-alkali (sub-alkali), and the K_2O vs. SiO_2 diagram [11] of granite and quartz monzodiorite derived from the result of convergence. The AFM diagram describes the evolution of the Bowen reaction series, magmatic evolution, which is characterized by no enrichment of Fe elements at the beginning of the magma differentiation process. This process can be seen from the low total FeO content, and this tendency occurs in calc-alkali series magma types. So that, it is known the type of granite and quartz monzodiorite, based on the classification table for granitoid rocks, is I-Type metaluminous. Determining granitoid type can be used to interpret mineral resources in metallic minerals such as arsenic, zinc, and tin (Table 1).

Granitoid Tantan from granite and quartz monzodiorite is associated with the mineral hornblende. It can be seen in the photomicrograph (Figure 5). This data approach shows that the tectonic formation of Tantan Granitoid magma in the observation area is formed from subduction orogenic plate activity, where magma comes from the melting part of the oceanic crust to the continental crust.

The results of the tectonic diagram show that granite and quartz monzodiorite were formed at different tectonic conditions.

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However, based on the approach to the chemical composition of rocks by using an interpretation based on the ratio diagram of the main elements, it is explained that granite and quartz monzodiorite are formed in the tectonic setting of the volcanic arc granitoid or volcanic arc from the results of subduction. In this case, it is believed to result from subduction in the Late Triassic–Early Jurassic of the Indian Plate subducting under Sundaland (Figure 7). From the previous discussion, a tectonic sketch was made to describe the forming of the Tantan Granitoid below, which refers to the granitoid rock classification table [24].

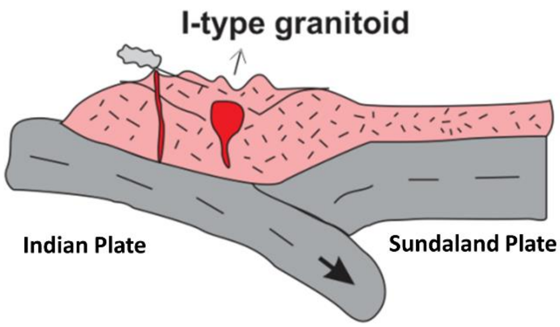

Figure 7: The Tectonic Sketch to describe the forming of the Tantan Granitoid [24].

CONCLUSION

The Tantan granitoid intrusion includes granite and quartz monzodiorite originating from calc-alkali magma based on the TAS Na_2O+K_2O vs. SiO_2 diagram and the AFM K_2O vs. SiO_2 diagram, with I-type metaluminous granitoids. The petrogenesis of the Tantan Granitoid in the study area results from orogenic from the continental arc, the subduction activity of the Indian Ocean plate to the Sundaland Plate during the Late Triassic–Early Jurassic. The geological structure of the study area is a horizontal fault with a northwest–southeast trend, such as the left slip fault of Batang Tantan, the lag right slip fault of Tiangko, the Sei Tengko fault, and the normal left slip fault of Serik. The faults are trending northeast–southwest, which moves relatively downwards, namely the Serik and Betung normal faults.

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