Mapping and Analysis of the physical properties of rocks for building materials in the Sunda Strait region

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Abstract. This research will connect the gravity value with the existence of andesite rock with good quality physics. Based on gravity mapping, high gravity anomalies in southern Lampung relate to igneous rocks, especially granite and andesite. Further geological observation and test of andesite rock physical properties become very important, in order to support the fulfillment of quantities with good quality for the acceleration of development of the Sunda Strait area. The andesite potentials in the Tarahan and Bakauheni areas are predominantly located on the medium Bouguer anomaly. The results of petrographic analysis showed three types of rocks, namely hornblende andesite, basalt amphibolite and tuff. The magma series based on the AAS test results on the three samples shows the calc-alkaline magma series. While from testing the physical properties of rock shows properties that meet the standard SII.0378-80 by the ultimate of the strength, force value range between 1125 to 1558 kg/cm^2, which is material that can be used for medium to heavy buildings raw materials.

Keywords: andesite, sunda strait, physical properties.

INTRODUCTION

The Sunda Strait area is located between the southeastern tip of Sumatra island with the northwest tip of Java island separated by the Sunda Strait. The area is surrounded by volcanoes with active to the ancient status. The strategic location for being the link between Java and Sumatra has made this area one of the strategic central government development programs. The construction of infrastructure such as highway, ports, reservoirs and irrigation networks, bridges, public housing and new university buildings are part of the national strategic development program of the Sunda Strait (KSN Selat Sunda).

As a strategic area under development, infrastructure development activities require the availability of sufficient and adequate raw material resources in quantity and quality. The need for rock material for the development of the Sunda Strait strategic area needs to be supported by exploration activities to map the potential location of rock material that can be utilized in accordance with the provisions of physical property standards. The availability of volcanic rock formations dominated by andesite rocks around the Sunda Strait area becomes an interesting option to explore. Exploration is needed to know the distribution of andesitic rock resources and the physical quality of the rocks. The distribution of rock resources can be done by mapping gravity response of gravity method, while the physical quality of the rock can be known by uniaxial compressive strength test.

This study aims to map the potential location of rock material resources by identifying gravity response and ultimate strength force (qu) from some geological observation sample especially in Tarahan and Bakauheni area. The utilization of gravity data as a density distribution response (Xu et al., 2015), is excellent for identifying subsurface structures (Evariste et al., 2014), lithology of bedrock and near surface rocks (Kilaru et al., 2013; Zahra, et al., 2016). This study will illustrate the gravity anomaly relationship, especially with regard to the existence of andesite rocks that have been and are being explored for an increasing need. In addition, physical properties tests are conducted to ensure that the andesite rocks meet the SII.0378-80 standard as good quality materials, for light to heavy building.

GEOLOGICAL SETTING

The schist rocks as the oldest rock in the study area consisted of mica-schist and amphibole-schist identified as the basement (Mangga et al., 1993) and interpreted as a metamorphism product of deep ocean sediments (Amin et al., 1994) and deformation during the accretion process at volcanic arc sediments are deposited in subduction trenches (Barber et al., 2005). It is intruded by granitoid (diorite & granodiorite) cretaceous rocks identified as Sulan Pluton with a hornblende-biotite composition. The pluton is also intruded by a tertiary granite pluton with a type I granite.

The tertiary andesitic lava exposed in the Tarahan and Bakauheni areas is a potential target as an area of observation and sampling. Volcanic rock in Tarahan area is dominated by tuff, breccia and some schist and andesite rock outcrops. This outcrop becomes the target measurement in the field to maximize the andesite potential area in the Tarahan. While in the area of Bakauheni there is tertiary-quaternary andesitic lava exposed from Rajabasa-Panengahan to Tangkil. The dominance of the quaternary hornblende andesite and the pyroclastic rocks are exposed on Mount Rajabasa (Darmawan et al., 2015; Haerudin et al., 2012).

Volcanic rock with tuff composition dominates quaternary rocks scattered between Tarahan and Bakauheni areas. Known as tuff formation Lampung, this rock is well exposed as welded tuff, tuffaceous sandstone and tuffaceous claystone.

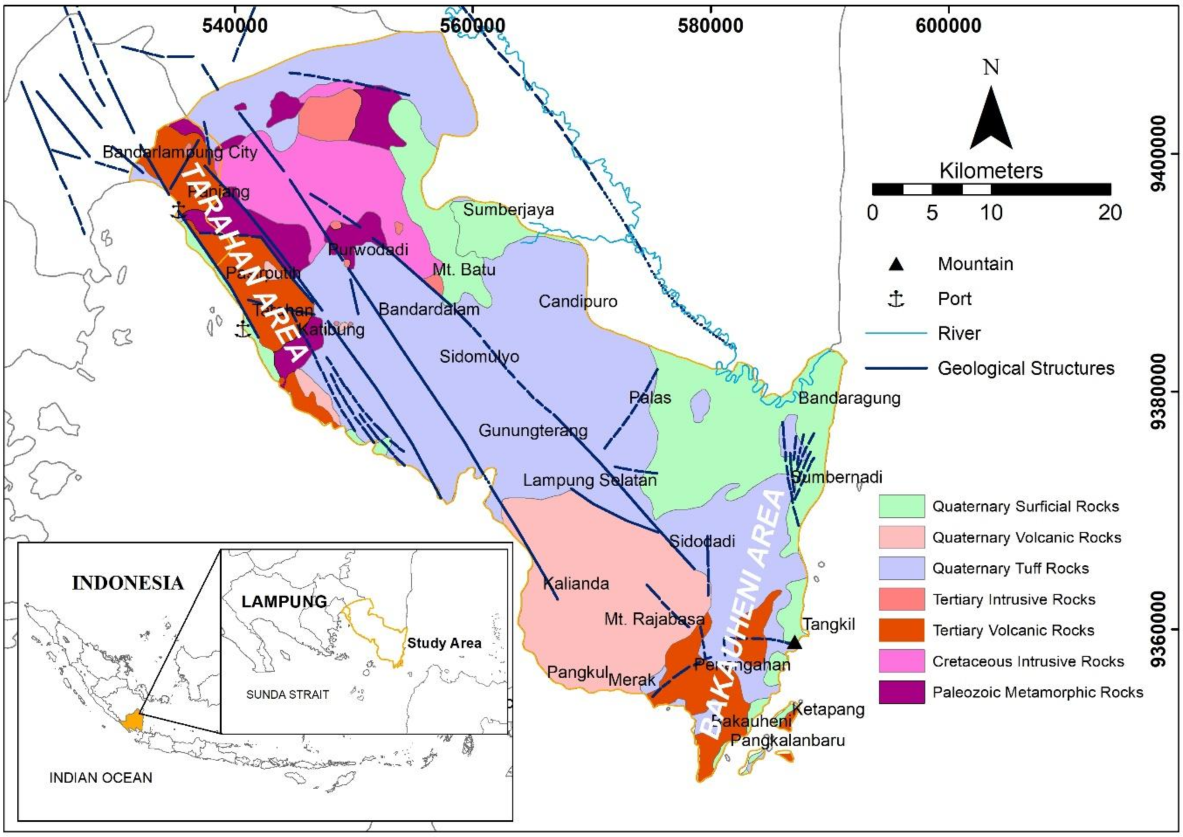

Figure 1. Geological map showing the geological conditions of the Tarahan and Rajabasa regions (modified from Mangga et al., 1993).

The dominant northwest-southeast fault structure (**Figure 1**) known as the Sumatran fault system (Pulunggono and Cameron, 1984), is interpreted as a result of a subduction system at an average rate of 7 cm / year in the Sunda arc. The complex accretion zones shown with anticlinal ridges and elevated faults (Malod et al., 1995) are thought to be the result of changes in the direction of subduction in the Sunda Strait. Faults along the front arc in the direction of the plate are thought to be a product of force release due to pressure in the subduction zone (Mangga et al, 1993).

The pattern of seismicity in the Sunda Strait shows the trend of hypocenter depth in harmony with the distance from the subduction trench. The farther from the trench to the Bakauheni area, the deeper the epicenter. If associated with the path of the volcano in the Sunda Strait, then the process of magmatism can be observed in Anak Krakatau volcano activity up to Mount Rajabasa. Even the volcanic system formed on Rajabasa mountain is the result of volcanic cone reconstruction of pre-Rajabasa (Bronto et al., 2012).

GRAVITY ANOMALY

The result of rock density mapping represented by the Bouguer anomaly response in the research location is shown by **Figure 2**. Location of the rock observation in the field focused on two areas namely

Tarahan area and Bakauheni Area. The Bouguer anomaly response at the observation site in the Tarahan area is at a moderate to high value with an anomalous high trend in the Sulan Granitoid area. This condition is inversely proportional to the anomalous response in the Bakauheni area which shows a low-moderate anomaly pattern.

Based on the observations in the field, the andesite rock distribution is mostly located in medium gravity anomaly response. The pattern is generally the same as the pattern of andesitic rock distribution in Tarahan and Bakauheni area that is on the medium Bouguer anomaly. The low anomaly response is thought to be the dominance of surface rock and geothermal potential in the Mount Rajabasa. This condition is related to the fracture zone due to reservoir and geothermal fluid path in Mount Rajabasa.

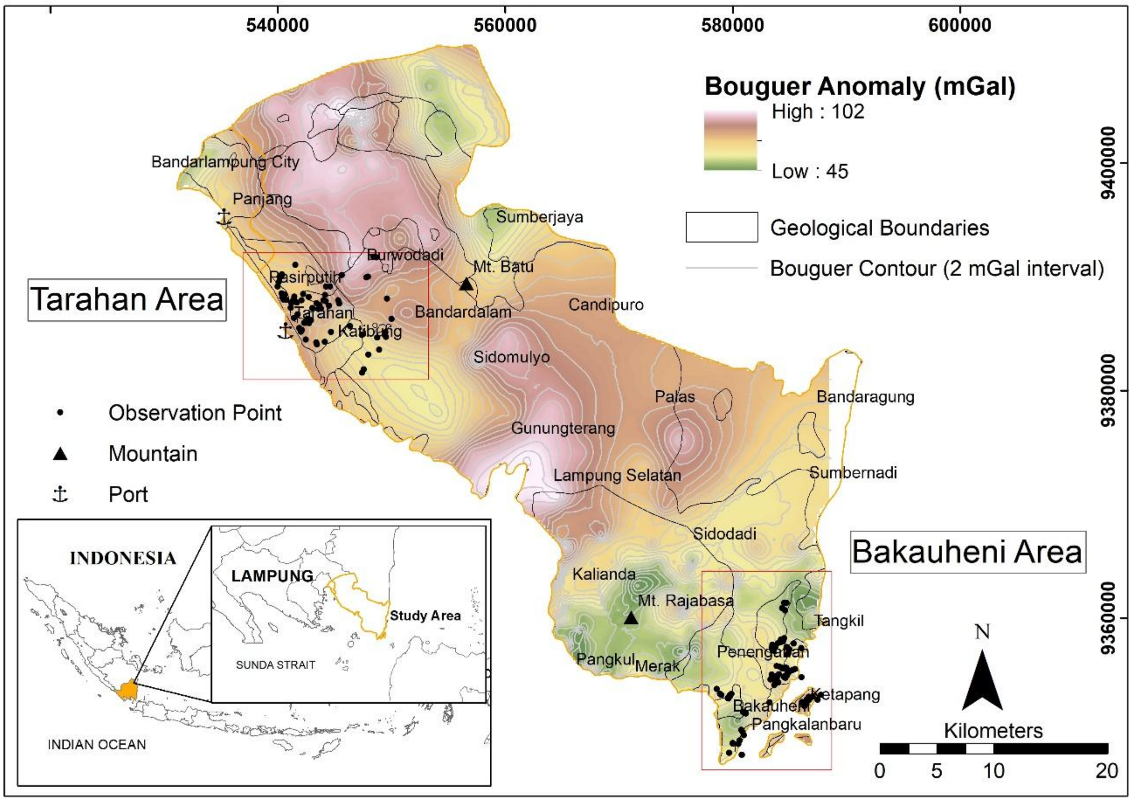

Figure 2. Complete Anomaly Bouguer Map of research area (Tarahan and Bakauheni). The red box is the location of observation and sampling. The black dots are a rock observation point.

An interesting pattern of Bouguer anomalies is in the area between Tarahan and Bakauheni with a high value. This condition needs to be confirmed whether the high anomaly is caused by the presence of intrusive rocks or associated with bedrocks close to the surface. Due to the regional geology, the area is in the Lampung Tuff Formation and has not found any rock outcrops intrusion yet. This anomaly covers the Sidomulyo-Gunungterang-Palas area.

FIELD OBSERVATION

Several geological observations in the field have shown some of Tertiary volcanic rock outcrops in the Tarahan area such as amphibole and andesite rocks (**Figure 3**). Amphibole lithology is generally dark in color, very compact and hard, and hornfelsik texture. Based on the field observations, the main constituent are plagioclase and hornblende. While the andesitic outcrops are dark, hard and compact, there is a massive, heavily padded structure with afanitic-porphyritic textures. The results showed that the main constituent minerals in these andesite rock outcrops were composed of plagioclase and hornblende minerals.

Some tuff outcrops are also found in observations in the Tarahan area included in the Lampung Tuff unit. This unit is characterized by bright gray lithology, fragmental texture composed of fine-grained volcanic ash, coarse, low hard / relatively soft.

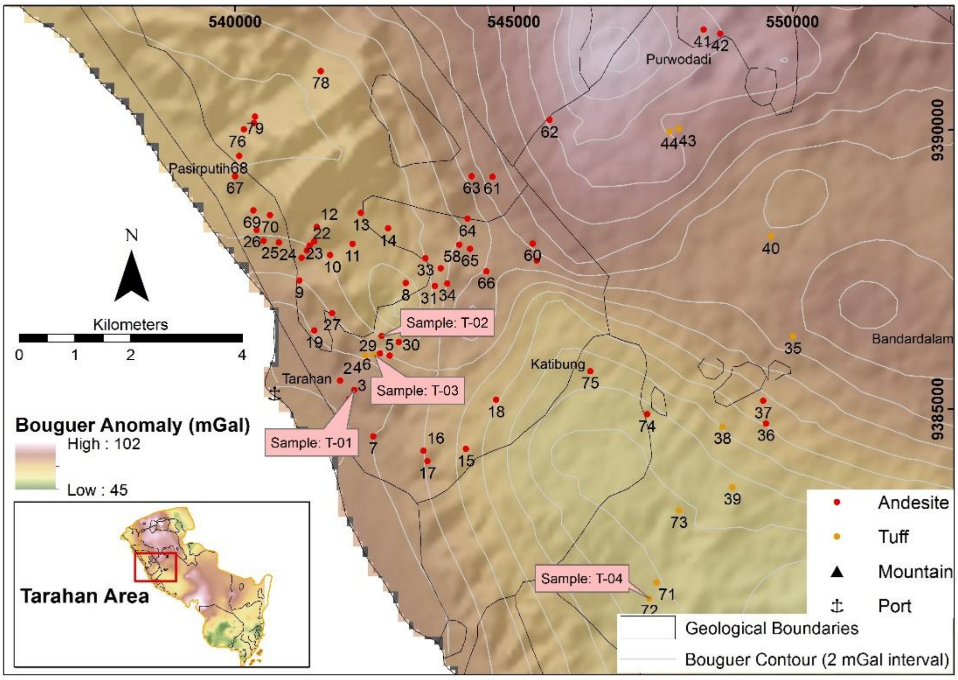

Figure 3. Geological observation and sampling point in Tarahan area. Red dots show the andesite outcrop and yellow dots is tuff.

The outcrop of andesite rock in the Bakauheni area has similar characteristics with the fresh color of dark gray and the brownish-gray color of the weather. This rock has aphanitic to porphyritic texture with sheeting joint structure. The condition of andesite rocks exposed in the fresh state is very harsh and the observation of mineral shows the main constituents of andesite rock in Bakauheni in the form of plagioclase and hornblende. Other outcrops of pyroclastic rocks such as tuffaceous are also often found mixed in tuffaceous sandstone and tuffaceous breccia (Figure 4).

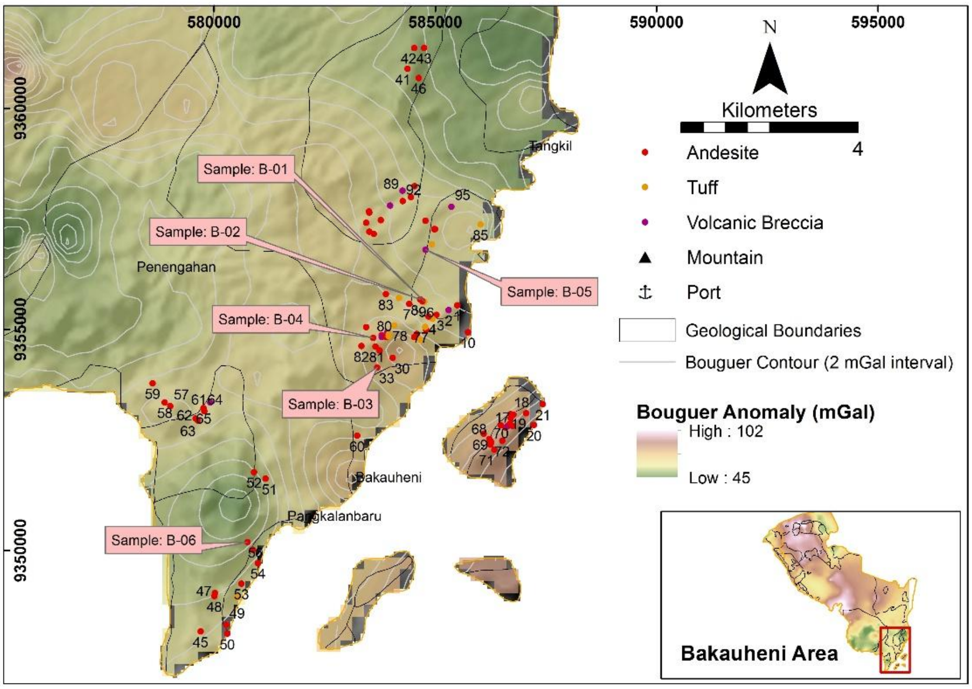

Figure 4. Geological observation and sampling point in Bakauheni area. Red dots show the andesite outcrop, purple dots is volcanic breccia and yellow dots is tuff.

PETROGRAPHY AND STRONG PRESSURE UNIAXSIAL

Petrography Analysis

Petrographic analysis of microscopic rock samples was performed with the object of analysis of the thin section from rocks sample, rocks cut and honed to a thickness of 0.03 mm, and then analyzed by using polarization microscope. Petrographic analysis is intended to identify the microscopic appearance of rocks, including textures, structures and types of minerals that make up the rocks along with their abundance. The determination of microscopic mineral types is based on differences in mineral optical properties (mineral properties associated with the ability of minerals to absorb and forward polarized light).

Petrographic analysis is needed to confirm the rock type and rock minerals more accurately, due to limited observations with the eyes without the use of tools. The analysis was performed on 10 selected samples that were considered representative of each visually visible variation of rocks, and represented rock units from each location in Tarahan and Bakauheni.

There are three types of rocks observed by petrography analysis: basalt-amphibol, hornblende andesite and tuff, with andesite rock texture variations including porphyry andesite, while tuff variations include fine/ash tuff and lapilli tuff. The constituent minerals from 10 samples of petrographic analysis is shown in **Table 1**.

Table 1. The constituent minerals from petrographic analysis of samples in both Tarahan and Bakauheni area.

Component	Sample (%):									
	T-01	T-02	T-04	T-04	B-01	B-02	B-03	B-04	B-05	B-06
Plagioclase	65	25	35	15	-	45	15	25	25	45
Hornblende	25	55	25	-	-	15	10	10	20	15
Opaque	10	10	5	-	-	10	10	10	10	30
Groundmass	-	10	10	-	35	40	65	55	45	10
Volcanic Glass	-	-	25	15	-	-	-	-	-	-
Volcanic Ash	-	-	-	70	65	-	-	-	-	-
Rock Type	Hornblende Andesite	Basalt Amphibole	Lapilli Tuff	Lapilli Tuff	Ash Tuff	Hornblende Andesite	Hornblende Andesite	Hornblende Andesite	Hornblende Andesite	Hornblende Andesite

Strong Test Press Uniaxial

The uniaxial pressure on samples of cylinder rocks is the most commonly used tests of mechanical properties. The uniaxial compressive strength test is performed to determine the compressive strength of the rock (σt), Young's Modulus (E), Poisson's Ratio (v), and stress-strain curve. Examples of cylindrical rocks are pressed or burdened to collapse. The comparison between the height and diameter of the commonly used cylinder example is 2 to 2.5 with a flat, smooth and parallel loading surface perpendicular to the axis of the rock sample axis. From the test results will be obtained data compressive strength of rock (σc or qu) as follows:

The voltage price at which the rock sample is destroyed is defined as the uniaxial strength of the rock and is given by the relationship:

$$\sigma c = F/A \quad (1)$$

by :

σc = Uniaxial rock strength (MPa)
F = Force that work when rock samples are destroyed (kN)
A = Area of the initial cross-section of rock samples perpendicular to the force (mm)

Based on the analysis of compressive strength and rock density of 3 samples from Tarahan and Bakauheni, generally showed a high compressive strength value, andesite had the ultimate compressive strength range of 1125 to 1364 kg/cm^2 while ampibolite had a greater compressive strength value of 1558 kg/cm^2 (Table 1).

When referring to SII.0378-80, the minimum compressive strength for heavy building foundations is 1500 kg/cm^2 and the minimum compressive strength for medium building foundations is 1000 kg/cm^2, then ampibolite type rocks are eligible for heavy building foundation (qu > 1500 kg/cm^2), while all tested andesite meets the criteria as a medium building foundation because of the 1500> qu-value> 1000 kg/cm^2 (**Table 2**).

Tabel 2. Strong Pressure and rock density analysis results

Code	Location	Rock type	Ultimate strength force (qu) kg/cm^2	Receive strength force (qa) kg/cm^2	Density (gr/cm^3)
T-01	Tarahan	Andesite	1364.755	454.9184	2.89
T-02	Tarahan	Andesite	1558.244	519.4148	3.23
T-03	Tarahan	Andesite	1254.858	418.2859	2.83
B-02	Bakauheni	Andesite	1294.154	431.3846	2.79
B-03	Bakauheni	Andesite	1125.224	375.0746	2.86
B-04	Bakauheni	Andesite	1232.621	410.8738	2.77
B-05	Bakauheni	Andesite	1253.924	417.9746	2.74
B-06	Bakauheni	Andesite	1139.289	379.7629	2.59

ATOMIC ABSORPTION SPECTROMETRY (AAS)

To find out the magma series of andesite rocks in Tarahan and Bakauheni, AAS test was conducted on three selected samples. This test is performed to determine the source of magma and the ratio of quartz content to other major oxides. This analysis is also used to determine the abundance of the major oxides that are closely related to the formation of the main mineral in the rocks. The Abundance of certain minerals also characterizes the process of tectonic formation and setting, one of which is an alkaline compound. represented by oxides K_2O and Na_2O. The result of AAS analysis is shown by **Table 3**.

Table 3. Analysis result of AAS test show the major oxide of rocks sample.

Molecular	T-02	B-02	B-06
SiO_2	59.3	60.1	61.9
TiO_2	0.52	0.7	0.6
Al_2O_3	15.9	14.8	16.4
Fe_2O_3	6.4	6.9	5.1
MgO	2.7	2.8	1.7
CaO	7.2	5.9	6.6
Na_2O	4.6	3.8	4.3
K_2O	2.1	2.5	1.9
LOI	1.3	1.8	1.6
	99.96	99.3	100.1

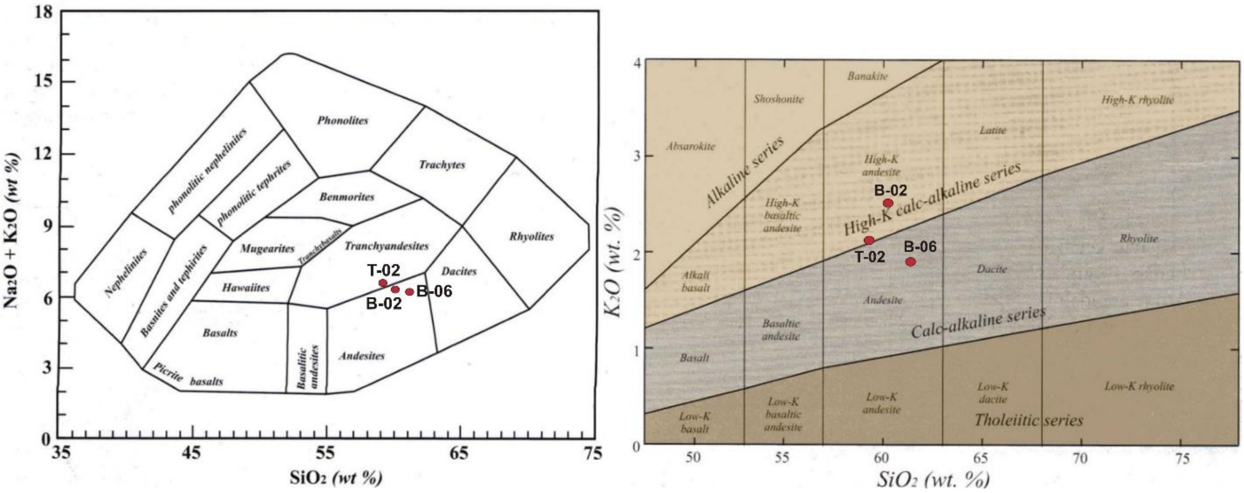

Figure 5. Plot of magma classification based on percentage of major oxide SiO_2 with alkaline (right) and total alkaline (left). The plot was based on AAS analysis data on three samples (indicated by red dots).

Based on its silica abundance (SiO_2) ranging from 59-62%, still within the range of slightly acidic intermediate magma composition, reinforced with significant Al_2O_3 concentration, approximately 15% indicates a close association with plagioclase abundance. Alkali (sodium and potassium) are present in significant amounts in which K_2O ranges from 1.9-2.5% and Na_2O 3.8-4.6% shows a slight influence of continental crust and magma formation is closely related to subduction of Indian oceanic crust with the influence of Eurasian Continental Crust.

Based on the results of the major oxide plot shown in **Figure 5**, it is known that the andesite rock magma series at the study site is calc-alkaline. The composition of magma in the sample rocks is dominated by partial melting and mixing between continental crust and oceanic crust that undergo fractional crystallization and become felsic magma with low magnesium and iron content. Calc-alkaline type rocks are commonly found in subduction zones, especially in volcanic arcs located above continental plates.

The plot results also support the results of petrographic analysis, which indicating that rock samples analyzed are andesite rocks with the condition of one sample is an trachyandesite (sample T-02). The composition of the sample rock texture with the appearance of the orientation of minerals / orientation direction is the direction of flow visible on the petrography section. These results confirm that the andesite rocks in the Tarahan area, especially in the T-02 sample are intermediate rocks formed on the back arc tectonic order. The trachyte texture of this sample also characterizes the development of rocks in shallow intrusions or lava.

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CONCLUTION

1. The andesite rock distribution is mostly located in medium gravity anomaly response. The pattern is generally the same as the pattern of andesitic rock distribution in Tarahan and Bakauheni area that is on the medium Bouguer anomaly.
2. The outcrop of andesite rock in both Tarahan-Bakauheni area has similar characteristics with the dark color, hard and compact to dark gray and the brownish-gray color with aphanitic to porphyritic texture and composed of plagioclase and hornblende minerals.
3. There are three types of rocks observed by petrography analysis: basalt-amphibole, hornblende andesite and tuff, with andesite rock texture variations including porphyry andesite, while tuff variations include fine/ash tuff and lapilli tuff.
4. Based on compressive strength analysis generally shows a high enough value of compressive strength, where andesite has the ultimate compressive strength between 1125 to 1364 kg/cm^2 while ampibolite has a greater compressive strength value of 1558 kg/cm^2. Referring to SII.0378-80, the ampibolite type rocks are eligible for heavy building foundations (number of > 1500 kg/cm^2), while all tested andesite meet the criteria as medium building foundation material because 1500 > its value > 1000 kg/cm^2.
5. The andesite rock magma series at the study site is calc-alkaline dominated by partial melting and mixing between continental crust and oceanic crust, meanwhile the trachyandesite rocks in the Tarahan area are intermediate rocks formed on the back arc tectonic order .

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