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Geology and Geochemistry of Batuan Gunungapi Walimbong Formation in Balepe Area, Tana Toraja Regency, South Sulawesi Province

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ABSTRACTS

The study area is located in the Regional Geological Sheet of Majene and Western Palopo, Precisely, administratively, the research location is located in the Balepe Area, Malimbong Balepe District, Tana Toraja Regency, South Sulawesi Province and astronomically located at the coordinates 119°39'20' 'E - 119°43'20'' E (East Longitude) and 03°03'25'' S - 03°06'25'' S (South Latitude). The purpose of the study was to find out the type and affinity of magma, the naming of rocks based on chemical composition, and the evolution of magma in the study area. The methods used are field observations and data collection, petrographic analysis, and geochemistry using XRF (X-Ray Fluorescence spectrometry). The data was processed using GCDKIT Software. Based on the results of geochemical analysis on the four rock samples, the rock types were based on Total Alkaline Silica (TAS), namely trachy basalt, basalt, rhyolite, and dacite, with magma affinity, namely Shoshonite Series and High-K calc-alkaline Series. Petrographic analysis in the form of naming rocks using the Pettijohn (1975) classification, namely lithic tuff, crystal vitric tuff, vitric crystal tuff, and vitric crystal tuff. The evolution of magma in the study area in the diagram of the variation of the content of major elements against SiO_2 compounds shows that some of the main elements are systematically differentiated, and some are not systematic.

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INTRODUCTION

Geochemistry of volcanic rocks is important because it provides information about the source of magma, the environmental conditions below the earth's surface, and the geological history of a region (Hartono, H. G., & Helmi, H., 2021). One of the techniques used in the geochemistry of volcanic rocks is the analysis of elements by mass spectrometry. This method allows for quantitative measurements of elements in volcanic rock samples, which can provide information about the characteristics of magma sources, such as pressure, temperature, and composition (Ariani, A. S., Haryanto, A. D., & Johanes Hutabarat, Y., 2019). Geochemistry of volcanic rocks can also aid in modeling volcanic activity. By studying the chemical composition of volcanic rocks derived from past eruptions, volcanologists can make predictions about the types of eruptions and possible dangers in the future (Usman, E., Sudradjat, A., Suparka, E. R., & Syafri, I., 2010).

In general, this research area includes the West Sulawesi Plutono-Volcanic Arc consisting of Cenozoic-aged sediments, volcanic sequences that superimpose pre-Cenozoic sediments, marine sediments, metamorphic rocks, and ultraalkaline igneous rocks (Sukamto, 1975; van Leeuwen, 1981). The rocks exposed in the research area are dating from the Middle Miocene – Pliocene, according to Djuri, et al. (1998) on the Geological Map of the Majene Sheet and the Western Part of Palopo scale 1: 250,000. This study aims to determine the type and affinity of magma, the naming of rocks based on chemical composition, and the evolution of magma in the research area.

METHODS

1. Literature Studies

At this stage of research, it is carried out by searching and studying from literature, both from books and research journals, in the form of theories and looking for a problem that is fundamentally related to with the background of research cases related to this thesis.

2. Data Retrieval

At the data collection stage, it is carried out in the form of data collection directly, including in the form of field and laboratory data.

2.1 Field Data

At the stage of data collection in the field, it is carried out by taking geomorphological data and lithological data at the same time sampling or Taking samples of rocks in the form of handspecimens from several station points at the location of the research area and a terrain orientation was carried out to find out conditions directly in the field using geological compasses, GPS, topographic maps and take the necessary photos using digital camera.

2.2 Laboratory Data

Data collection in this study was carried out by laboratory tests geochemistry using the X-Ray Fluorescence (XRF) method located in Laboratory of PT Jasa Mutu Mineral indonesia, Kendari City, Southeast Sulawesi to find out concentrations of major elements in the form of (Ni, Fe_2O_3, Fe, Al_2O_3, CaO, MgO, Cr_2O_3, Na_2O, K_2O, SiO_2, TiO_2, Co, MnO, P_2O_5, P, SO_3, S) as well as petrographic laboratory tests by using a microscope tool that is carried out directly In the past, preparations were made in the form of thin sections.

3. Data Processing

At this stage explain and interpret further in detail About petrographic analysis and geochemical analysis.

3.1 Petrology Analysis

Petrological analysis is used to study rocks and their formation processes, as well as to understand the geological history and potential of natural resources.

3.2 Petrography Analysis

Petrographic analysis is carried out to determine the texture, mineral components constituent rocks, percentage of minerals to know in the naming of rocks by using classification Pettijohn (1975) so that it can help in interpreting the genealogy of these rocks.

3.3 Geochemical Analysis

Geochemical analysis is carried out from the results of research in the laboratory in the form of major element data using the It is necessary to know the characteristics in the form of types of rocks, types of magma, and evolution of magma using Geochemical Data Toolkit GCDkit ver 3.00 software.

Classification/diagram based on chemical content used in This research includes:

1. Based on the degree of acidity or SiO_2 content using the classification of Le Maitre et al., 1989 in Rollinson, Hugh R., 1993.
2. Based on the affinity of the magma used to determine the series magmatism in the study area with a comparison of K_2O and SiO_2 using classification Peccerillo and Taylor., 1976 in Rollinson, Hugh R., 1993.
3. Based on the major element in the form of a comparison of the number of percentages (%) Na_2O + K_2O with silica (SiO_2) used to find out naming of rocks in the classification of Le Bas et al., 1986.
4. Based on the diagram of the variation of the content of the Major Element in Comparison of the sum of percentages (Wt%) in the comparison of Al_2O_3, CaO, Na_2O, K_2O, MgO, P_2O5, TiO_2 and Fe_2O_3 against SiO_2 are used for Knowing the crystallization of fractination and enrichment during the evolutionary process magma using Harker's classification, 1909 in Rollinson, 1993.

4. Preparation of Reports

In the stage of preparing the report, it was obtained from the results of the literature study that will be a main reference before leaving for the research site. As well as carrying out field data collection activities, and data processing directly in the laboratory as well as compiling data both qualitatively and quantitative which are then compiled in the form of journals.

RESULTS AND DISCUSSION

Petrology

The lithology unit in the research area is divided into three, namely the volcanic breccia unit, the lapili tuff unit, and the coarse tuff unit. Sampling was carried out at several points. In the volcanic breccia unit, rock samples were taken, namely at station 16, the lapili tuff unit was sampled, rock samples were taken, namely at station 24, the coarse tuff unit was sampled as rock samples, namely at stations 41 and 39. The naming of volcanic breccia rocks in the field is based on the classification of pyroclastic rocks according to Fisher (1966) by paying attention to the characteristics of the rocks. Volcanic breccia in the Walimbong Volcanic Rock Formation in general based on its spectacular appearance shows a fresh gray color with a brownish weathered state. The texture of this rock with the grain size is angular chunks – subrounded. It contains minerals plagioclase, quartz, hornblende, and materials measuring 80 – 240 mm. (Figure 1)

Figure 1. Appearance of volcanic breccia at station 16 with the direction photo N 218° E.

The naming of lapili tuff rocks in the field is based on the classification of pyroclastic rocks according to Fisher (1966) by paying attention to the characteristics of the rocks. The lapili tuff in the Walimbong Volcanic Rock Formation in general based on its spectacular appearance shows a fresh gray color with a brownish weathered state. The texture of this rock with the grain size of lapili-coarse sand is subrounded – rounded. Contains the minerals quartz, plagioclase, hornblende (Figure 2)

Figure 2. The appearance of the lapili tuff at station 24 with the photo direction N 119° E.

The naming of coarse tuff rocks in the field is based on the classification of pyroclastic rocks according to Fisher (1966) by paying attention to the characteristics of the rocks. Coarse tuff in the Walimbong Volcanic Rock Formation in general based on its spectacular appearance shows a fresh grayish-white color with a blackish-brown weathered state. The texture of this rock with the size of a grain of coarse sand is subrounded – rounded. Contains orthoclase, quartz, biotite minerals (Figure 3).

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Figure 3. Appearance of coarse tuff at station 41 with photo direction N 21° E

The naming of coarse tuff rocks in the field is based on the classification of pyroclastic rocks according to Fisher (1966) by paying attention to the characteristics of the rocks. Coarse tuff in the Walimbong Volcanic Rock Formation in general based on its spectacular appearance shows fresh brown with a blackish-brown weathered state. The texture of this rock is medium to fine sand grain size, subrounded – rounded. Contains orthoclase minerals, quartz, biotite (Figure 4).

Figure 4. Appearance of coarse tuff at station 39 with photo direction N 237° E.

Petrography

Microscopic characteristics were determined using a polarizing microscope to observe the optical properties of volcanic breccia rock samples, lapili tuff, and coarse tuff in the form of thin sections at stations 16, 24, 41, and 39 with incision numbers ST.16/VF/Volcanic Breccia, ST.24/VF/Lapili Tuff, ST.41/VF/Coarse Tuff, and ST.39/VF/Coarse Tuff observed at the Optical Minerals Laboratory, Department of Geological Engineering, Faculty of Engineering, Hasanuddin University. The classification used to determine the naming of rocks is Pettijohn (1975).

In the observation of the petrographic sample on the thin incision number ST.16/VF/Volcanic Breccia which appears to show a brown absorption color and a light brown interference color. The texture of the clastic with the size of minerals is 0.01 – 0.625 mm, the rock fragment is 0.325 – 0.625 mm with subangular-rounded vegetation. There are 55% rock fragment minerals, 15% plagioclase, 10% volcanic glass, 8% hornblende, 5% orthoclase, 3% biotite, and 2% opaq. Based on the classification of Pettijohn (1975), the name of this petrographically rock is lithic tuff.

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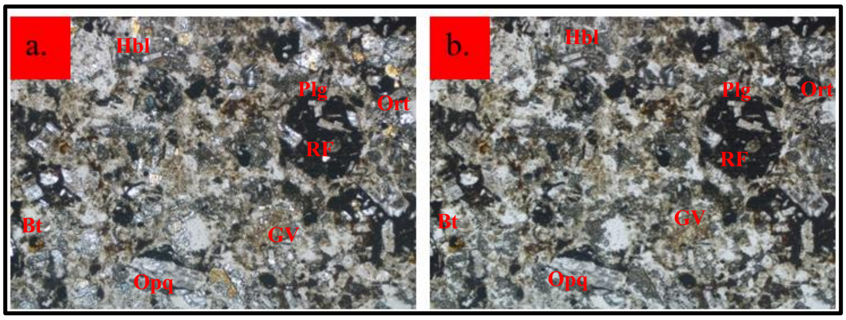

Figure 5. Appearance of petrography in cross nickel (a) and nickel parallel (b) lithic tuff rocks in ST.16/VF/Volcanic Breccia incision, which consists of rock fragment minerals, plagioclase, hornblende, volcanic glass, biotite, and orthoclase

In the observation of the petrographic sample on the thin incision number ST.24/VF/Lapili Tuff which appears to show a brownish absorption color and a blackish-gray interference color. The texture of the clastic with the mineral size of 0.0125 – 0.25 mm with subangular-rounded vegetation. There are 20% orthoclase minerals, 40% volcanic glass, and 5% biotic. Based on the classification of Pettijohn (1975), the name of this petrographically rock is crystal vitric tuff.

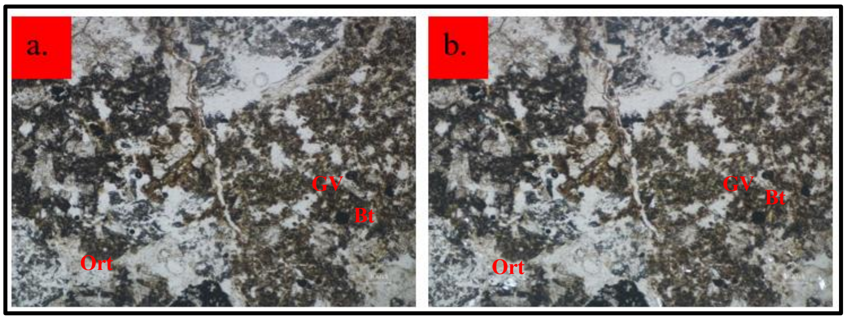

Figure 6. The appearance of petrography on parallel nickel (a) and cross nickel (b) crystal vitric tuff rocks in the ST.24/VF/Lapili Tuff incision, which consists of orthoclase minerals, volcanic glass, and biotites

In the observation of the petrographic sample on the thin incision number ST.41/VF/Coarse Tuff, which appears to show a brownish absorption color and a blackish-gray interference color. The texture of the mineral size is 0.01 – 0.525 mm with subangular-rounded vegetation. There are 55% volcanic glass minerals, 20% orthoclase, 10% sanidine, 3% biotite, 2% opaq. Based on the classification of Pettijohn (1975), the name of this petrographically rock is vitric crystal tuff.

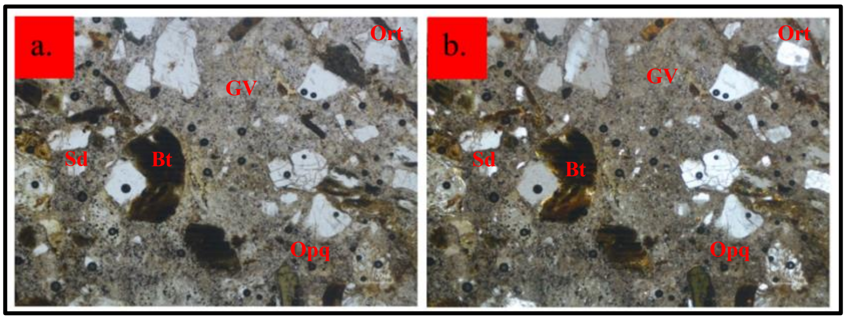

Figure 7 The appearance of petrography in parallel nickel (a) and cross nickel (b) vitric crystal tuff rocks in the ST.41/VF/Coarse Tuff incision, which consists of volcanic glass minerals, orthoclase, sanidine, biotite, opaq.

In the observation of the petrographic sample on the thin incision number ST.39/VF/Coarse Tuff where the appearance shows a light brown absorption color and a brown interference color. The texture of the mineral size is 0.5 – 0.7 mm with subangular-rounded vegetation. There are 65% volcanic glass

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minerals, 15% orthoclase, 10% biotite, 5% opaq, 2% sanidine. Based on the classification of Pettijohn (1975), the name of this petrographically rock is vitric crystal tuff.

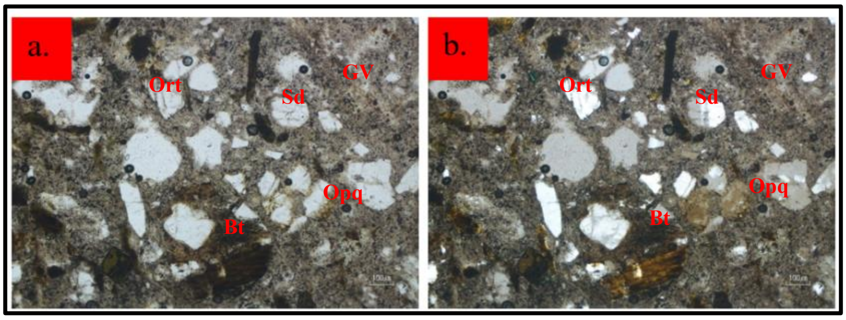

Figure 8. The appearance of petrography on parallel nickel (a) and cross nickel (b) vitric crystal tuff rocks in the ST.39/VF/VCoarse Tuff incision, which consists of volcanic glass minerals, orthoclase, sanidine, biotite, opaq.

Geochemistry

Geochemical analysis of the three rock samples using the X-Ray Fluorescence (XRF) method explains the content of the Major Element. The results of geochemical analysis of the major element on the four rock samples in the study area can be seen as shown in (Table 1) below.

Table 1 Results of geochemical analysis of Major Elements in rocks in the study area

Sampel	ST.16/VF/Volcanic Breccia	ST.24/VF/Lapili Tuff	ST.41/VF/Coarse Tuff	ST.39/VF/Coarse Tuff
Unsur				
Ni	<0,01	<0,01	<0,01	<0,01
Fe_2O_3	11,62	8,11	2,12	1,38
Fe	8,13	5,67	1,48	0,97
Al_2O_3	19	16,79	2,12	15,53
CaO	2,8	8,25	1,71	2,67
MgO	2,72	5,74	1,73	1,49
Cr_2O_3	0,01	0,01	0,01	0,01
Na_2O	0,54	2,94	1,68	2,5
K_2O	2,84	2,66	5,71	4,05
SiO_2	46,68	48,59	67,62	67,16
TiO_2	1,05	0,83	0,42	0,39
Co	<0,01	<0,01	<0,01	<0,01
MnO	0,19	0,15	0,05	0,04
P_2O_5	3,92	2,9	0,83	0,76
P	1,71	1,27	0,36	0,33
SO_3	<0,01	<0,01	<0,01	<0,01
S	<0,01	<0,01	<0,01	<0,01

Types and Affinity of Magma

Based on the amount of SiO_2 content in the three rock samples in the ST. 16/VF/Volcanic Breccia has a content of 46.68%, the sample of ST.24/VF/Lapili Tuff has a content of 48.59%, the sample of ST.41/VF/Coarse Tuff has a content of 67.62%, and the sample of ST.39/VF/Coarse Tuff has a content of 67.16%. From these results, the types of magma that make up the study area come from different magma, namely for the ST.16/VF/Volcanic Breccia and ST.24/VF/Lapili Tuff samples from alkaline

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magma, while the ST.41/VF/Coarse Tuff and ST.39/VF/Coarse Tuff samples come from acidic magma (Table 2).

Table 2. Classification of magma based on SiO_2 content (%) or degree of acidity (Le Maitre et al., 1989 in Rollinson, Hugh R., 1993).

Nama Batuan	Kandungan Silika
Batuan Asam	>63%
Batuan Intermediet	52-63%
Batuan Basa	45-52%
Batuan Ultrabasa	<45%

Based on the results of magma affinity plotting which showed the weight ratio (%) of K_2O and SiO_2, the magma series from the samples of ST.16/VF/Volcanic Breccia, ST.24/VF/Lapili Tuff, and ST.41/VF/Coarse Tuff were Shoshonite Series and ST.39/VF/Coarse Tuff was the High-K calc-alkaline Series (Figure 9) in the magma affinity classification (Peccerillo and Taylor, 1976 in Rollinson, 1993). The major element content in the ST.16/VF/Volcanic Breccia sample showed K_2O = 2.84% and SiO_2 = 46.68%, the ST.24/VF/Lapili Tuff sample showed K_2O = 2.66% and SiO_2 = 48.59%, ST.41/VF/Coarse Tuff showed K_2O = 5.71% and SiO_2 = 67.62%, and the ST.39/VF/Coarse Tuff sample showed K_2O = 4.05% and SiO_2 = 67.16%.

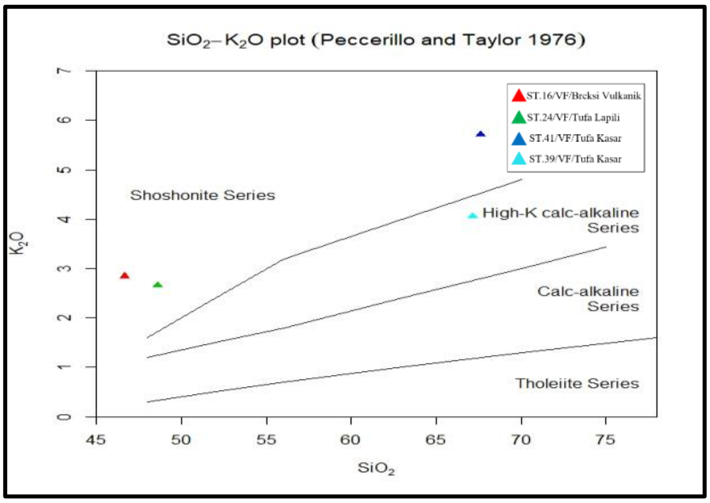

Figure 9. Plotting results on magma affinity classification based on K_2O and SiO_2 comparison (Peccerillo and Taylor., 1976 in Rollinson, Hugh R., 1993)

Naming of Rocks Based on Chemical Composition

Based on the content of Major Elements in samples with the codes ST.16/VF/Volcanic Breccia, ST.24/VF/Lapili Tuff, ST.41/VF/Coarse Tuff, ST.39/VF/Coarse Tuff, respectively, had a result in the form of a percentage value of chemical composition (SiO_2) of 46.68%; 48,59% ; 67,62% ; 67.16% and the percentage of chemical composition ($Na_2O + K_2O$) 3.38%; 5,6% ; 7,39%, ; 6.55%. Therefore, the results of plotting the classification of igneous rocks based on the content of SiO_2 and $Na_2O + K_2O$ (Le Bas et al., 1986) (Figure 10) of the ST.16/VF/Volcanic Breccia samples show that the names of rocks based on the composition are included in Basalt, the ST.24/VF/Lapili Tuff samples are included in Trachy-Basalt, the ST.41/VF/Coarse Tuff samples are included in Rhyolite, and the ST.39/VF/Coarse Tuff samples are included in Dacite. This classification can also identify magma series visible from the dotted curved line dividing between the alkaline series and the sub-alkaline series. The results of geochemical analysis show that the rocks of ST.16/VF/Volcanic Breccia, ST.41/VF/Coarse Tuff, and ST.39/VF/Coarse Tuff in the study area are included in the sub-alkaline series zone and ST.24/VF/Lapili Tuff rocks are included in the alkaline series zone.

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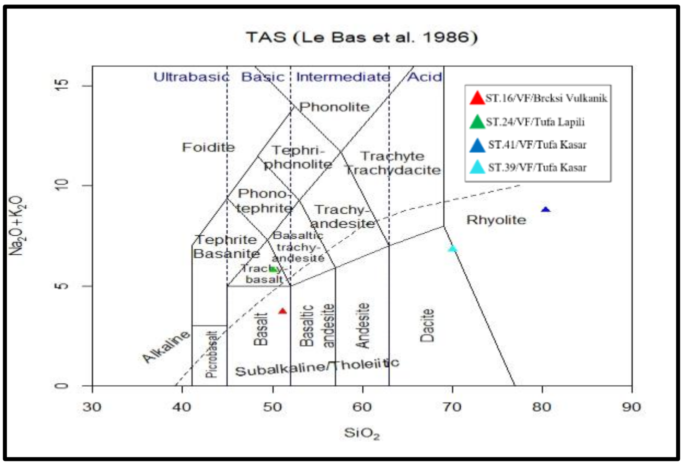

Figure 10. Plotting results on the classification of volcanic igneous rocks (Le Bas et al, 1986)

Magma Evolution

Based on plotting the content of Major Element to SiO_2 (Harker, 1909 in Rollinson, 1993) that K_2O and Na_2O show a positive correlation pattern; while Al_2O_3, CaO, MgO, TiO_2, P_2O_5, FeOt showed a negative correlation pattern. The plotting results of the analyzed major elements showed that K2O and Na2O were distributed, but generally increased with increasing SiO_2. The other elements (Al_2O_3, CaO, MgO) are dispersed, but generally decrease with the increase of SiO_2, while TiO_2, P_2O_5, FeOt are predominantly distributed in groups in a straight line and decrease with the increase of SiO_2. This situation shows that some of the main elements are systematically differentiated, while others are not systematic (Figure 11)

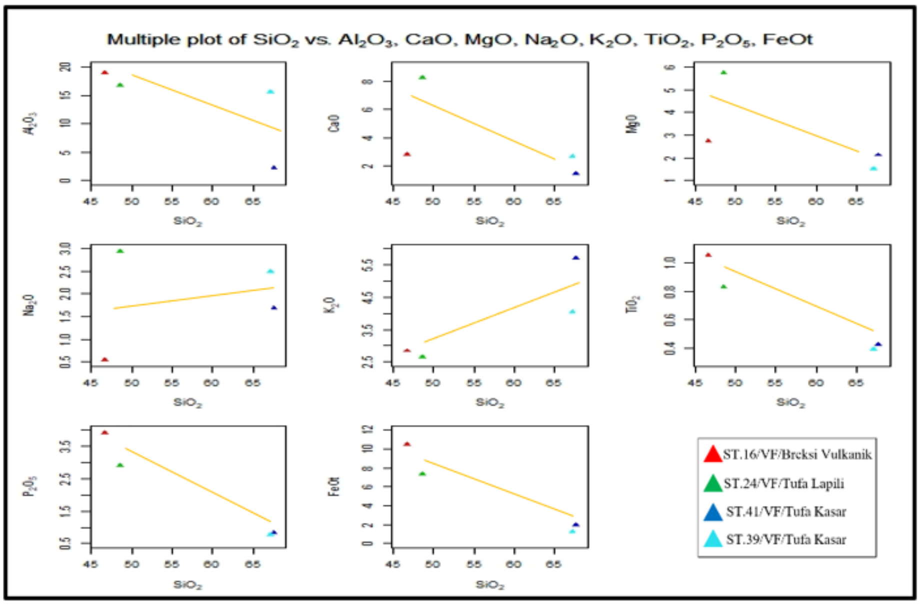

Figure 11. Results of plotting the content of major elements against SiO_2 (Harker, 1909 in Rollinson, 1993)

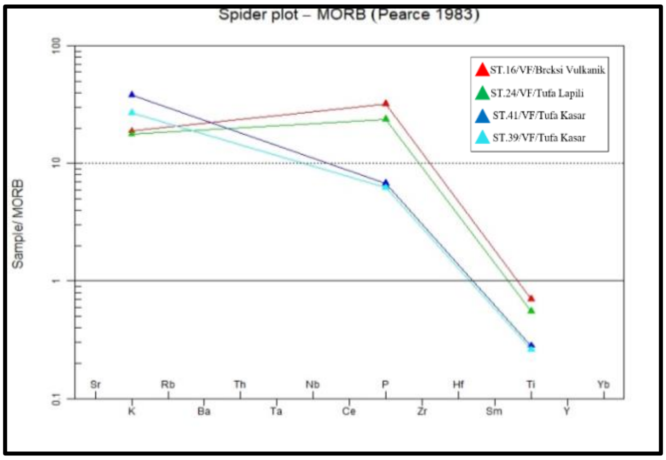

Figure 12. The results of plotting the classification of Spider plot – MORB (Pearce, 1983)

CONCLUSION

Based on the results of geochemical analysis of rock naming based on Total Alkaline Silica (TAS), namely trachy basalt, basalt, rhyolite, and dacite with the affinity of magma shoshonite series, petrographic analysis of rock naming using Pettijohn (1975) classification, namely lithic tuff, crystall vitric tuff, vitric crystall tuff, and vitric crystall tuff. The evolution of magma in the study area in the diagram of the variation of the content of the major element to the compound SiO_2 (Harker., 1909 in Rollinson, Hugh R., 1993) shows that some of the main elements are systematically differentiated and some are not systematic.

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