doi: 10.34312/jgeosrev.v5i1.16941 ejurnal.ung.ac.id/index.php/jgeosrev

Vol. 5, No. 1, January 2023: 63-70

Jambura Geoscience Review

p-ISSN 2623-0682 | e-ISSN 2656-0380

Department of Earth Science and Technology, Universitas Negeri Gorontalo

Study of Petrogenesis Andesite Rock in Bualemo Region, North Gorontalo Regency Based on XRF Geochemistry Analysis

Fandji Marfian[1], Aang Panji Permana[1], Noviar Akase[1]

[1]*Geological Engineering, Universitas Negeri Gorontalo, Jl. Prof. Dr. Ing. BJ. Habibie Bone Bolango Regency 96554, Indonesia*

ARTICLEINFO

Article history:
Received: 7 November 2022
Accepted: 13 January 2023
Published: 25 January 2023

Keywords:
Andesite; Bualemo; Geochemical; Petrogenesis

Correspondence:
Aang Panji Permana
Email: aang@ung.ac.id

ABSTRACT

Check for updates

The research area is Bualemo Village, Kwandang District, North Gorontalo Regency. With coordinates 0° 47' 10" - 0° 48' 40" North Latitude and 122° 55' 0" - 122° 57' 5" East Longitude with an area of about 10 km^2. This study aims to determine the petrogenesis of andesite rocks and the tectonic setting in the study area. The method used in this study is a mapping method to determine the geological conditions of the research site and X-ray fluorescence (XRF) geochemical analysis to determine the chemical content of rocks. The results showed that the stratigraphy of the study area, sorted from oldest to youngest, was an andesite unit, an altered andesite unit, and an alluvial deposit unit. The geological structure in the study area is a tension joint with a general direction of relative north-south. The tension joint structure data analysis results have a value of N 171°E/79°. Based on geochemistry results, it was found that the type of magma is tholeiitic, with its name basalt and basaltic trachyte andesite. The origin of the magma is island arc tholeiitic and island arc calc-alkaline basalt, with the tectonic setting of the study area being subduction between two oceans, namely between the Sulawesi sea plate and the Sula plate.

How to cite: Marfian, F., Permana, A. P., & Akase, N. (2023). Study of Petrogenesis Andesite Rock in Bualemo Region, North Gorontalo Regency Based on XRF Geochemistry Analysis. *Jambura Geoscience Review, 5*(1), 63-70. doi:https://doi.org/10.34312/jgeosrev.v5i1.16941

1. INTRODUCTION

Petrogenesis studies is a field of science that focuses on the abundance of minerals observed in rock incisions under a microscope or analyzes the content of chemical elements in rocks to determine the formation process in rocks and their tectonic environmental conditions (Yuwono, 2015). Geochemistry is a grouping of the relative and absolute abundances of various elements on earth, the study of the distribution and migration of single parts in multiple places on earth with objects in the form of basic patterns of distribution and migration of elements (Alekseenko & Alekseenko, 2013; Adi, 2021). This study used X-ray fluorescence (XRF) spectroscopy analysis, an analytical technique that detects X-ray radiation from the emitted sample in the analyzed sample as a basis (Simon, 2012; Nasrazadani & Shokrollah, 2016).

Sulawesi is located at the subduction of three large tectonic plates: the Indo-Australian, the Eurasian, and the Pacific. A smaller plate is also located to the north, namely the Philippines (Hamilton, 1979; Hutchison, 1989; Hall & Wilson, 2000; Payuyu et al., 2022; Permana et al., 2022). The island was formed due to the collision of Sunda land, the easternmost part of the Eurasian plate, with the microcontinent of the Australian plate (Bachri, 2011).

The geological setting of Kwandang is exciting to study because it is composed of complex rock formations of the Tertiary to Quaternary age. This rock formation was formed since the start of the collision of the Sula plate with the Sulawesi sea plate, which was then followed by a collision towards the eastern arm of Sulawesi in the mid-Pliocene along with the formation of a subduction strip along the northern arm of Sulawesi until now (Hall & Spakman, 2015). Harun (2020) research used the mapping method to determine the geological conditions of the study area. Bualemo Village is one of the villages located in the Kwandang District. In previous research in the Bualemo area, volcanic rocks were included in the Bualemo Andesite Unit (Harun, 2020). Bualemo andesite was thought to have formed in the Middle to Late Miocene period (Bachri et al., 1994). However, no previous studies describe the petrogenesis of andesite rocks. This research aims to describe the petrogenesis of andesite rocks in the Bualemo area, North Gorontalo Regency, based on XRF geochemistry analysis.

2. METHOD

2.1. Research Location

The research was conducted in Bualemo Village, Kwandang District, North Gorontalo Regency. With coordinates 0° 47' 10" - 0° 48' 40" and 122° 55' 0" - 122° 57' 5". The area of the research location is 10 km^2 (Figure 1).

2.2. Research Method

In this study, geological mapping and geochemical analysis are applied. The geological mapping method was used during observation and data collection in the field. X-ray fluorescence (XRF) analysis at the Central Laboratory of Mineral Resources for Coal and Geothermal in Bandung was carried out on selected rock samples to determine the chemical content of the rocks. XRF analysis is essential to determine the major oxides and trace element composition of a rock, mineral, sediment, and liquid (Rollinson, 1993; Boogs, 2009; Shackley, 2011; Wahyudiono et al., 2016; Permana, 2018; Permana, 2019).

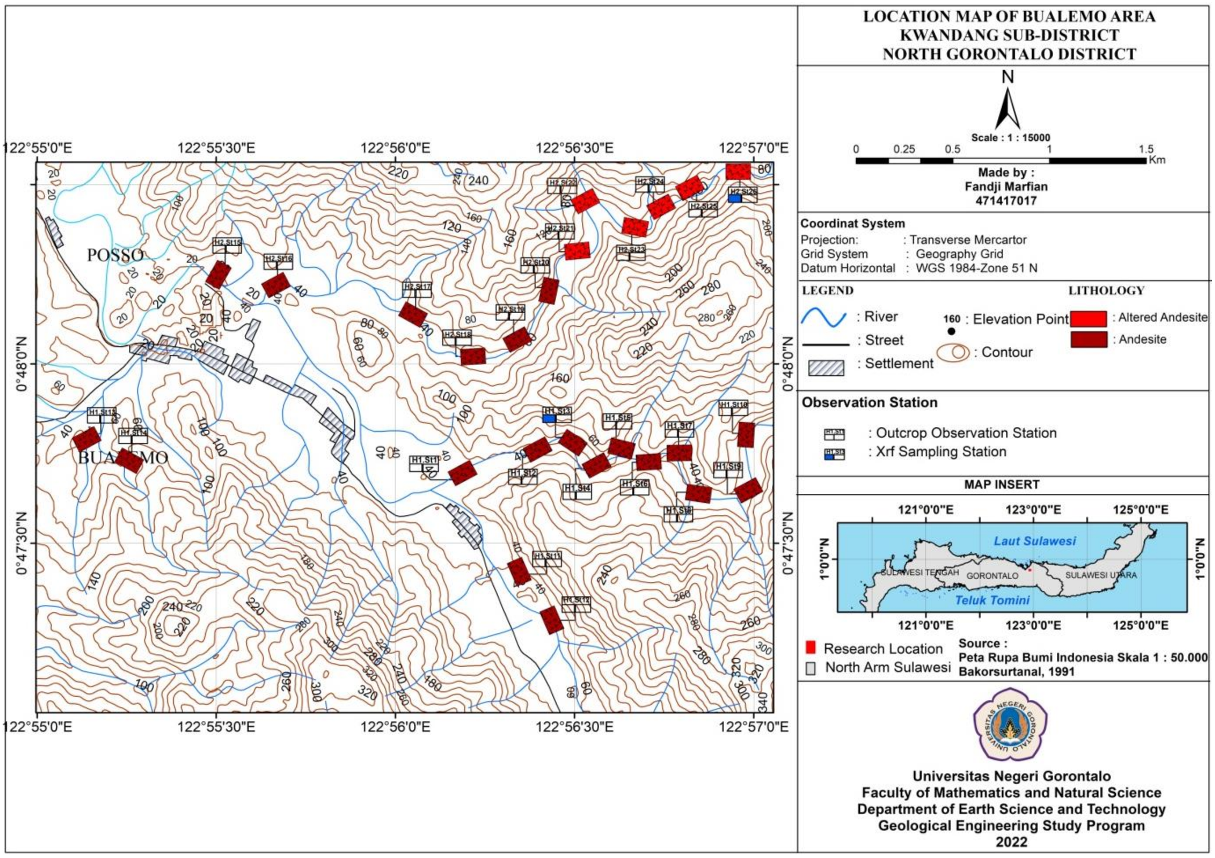

Figure 1. Research location map

Data collection in the field includes lithological data, geological structures, and sampling for XRF geochemistry analysis. Lithological data collection was carried out to determine the stratigraphy of the research area. Geological structure data collection was carried out to determine the general direction of the geological structure found in the research area. Samples for geochemistry analysis were selected to determine the name of the rock, magma series, magma origin, and tectonics in the research area. The software used to process geochemical data is *Petrograph*

3. RESULTS AND DISCUSSION

3.1. Stratigraphy

The stratigraphy of the study area consists of three lithological units, namely the andesite, altered andesite, and alluvial deposit. The andesite unit occupies 70% of the research location, with a thickness of 400 meters. The lithology contained in this unit is andesite rock with gray color, holocrystalline, massive, and mineral composition is plagioclase, pyroxene, and k-feldspar (Figure 2). This unit is included in the Bilungala Volcano Rock Formation (Tmbv) in the Tilamuta map geology sheet (Bachri et al., 1994).

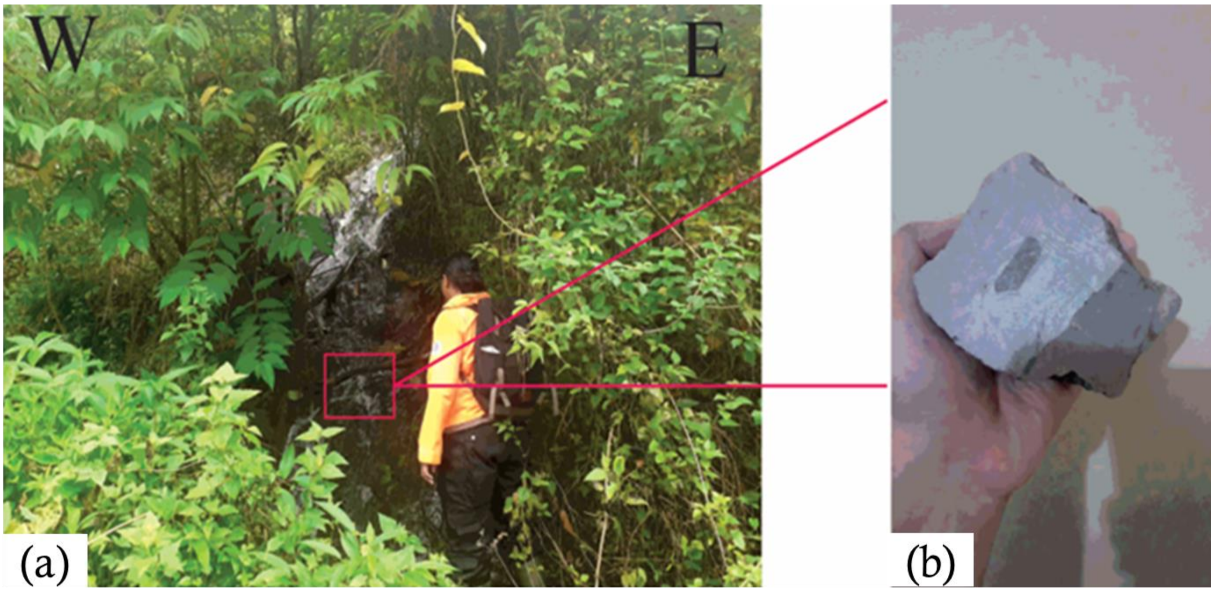

Figure 2. a) Outcrop of andesite unit at the research site; b) hand specimen of the andesite rock sample.

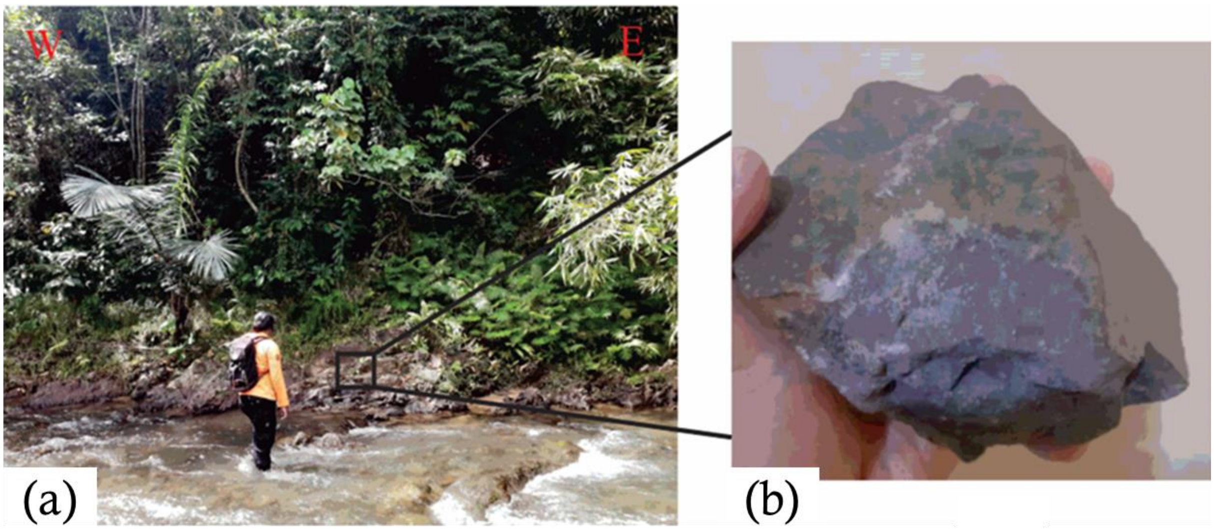

Figure 3. a) Outcrop of altered andesite unit at the study site; b) Hand specimen of the altered andesite rock sample.

Figure 4. The appearance of alluvial deposits at the research site

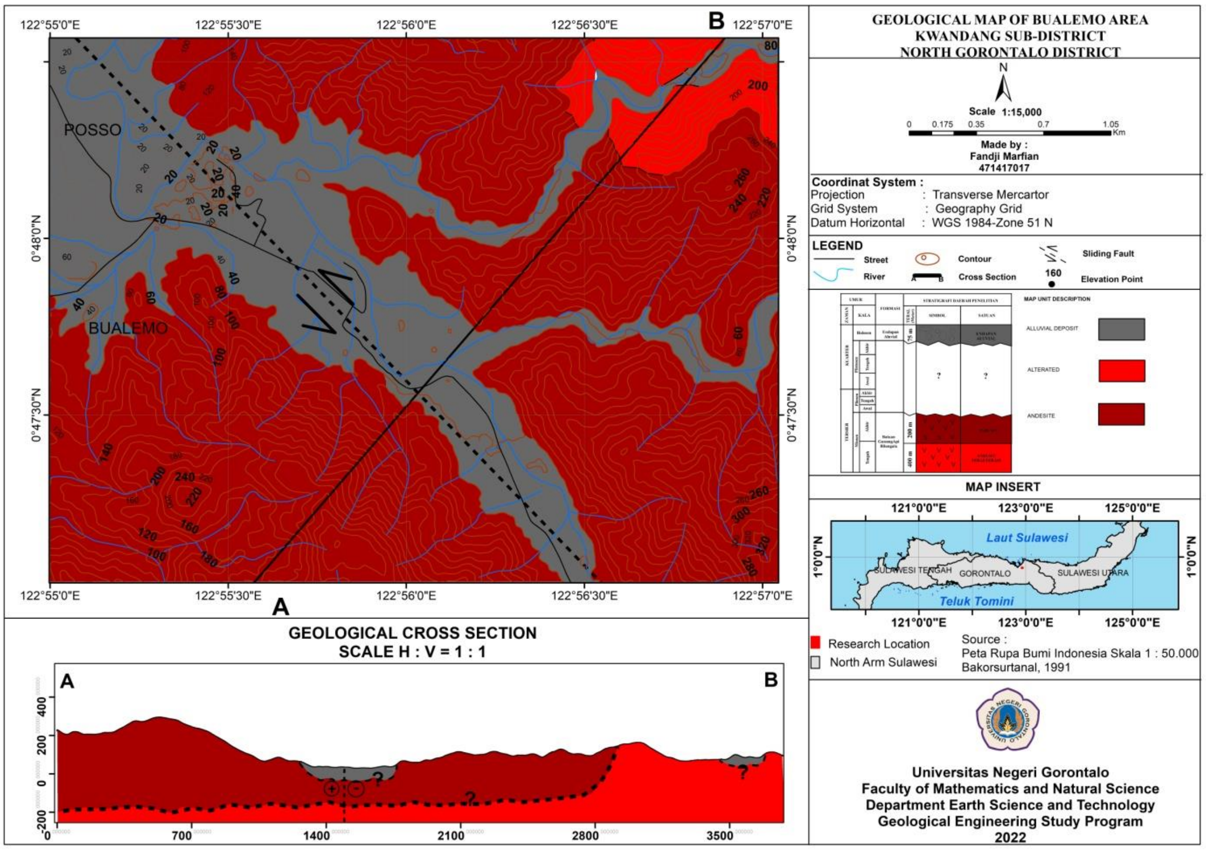

Figure 5. Geological map of the research area

The altered andesite unit at the study site occupies 5% of the studied location with a thickness of 200 meters. The lithology contained in this unit is andesite rock that has been altered with a brownish-gray color, aphanitic, and holocrystalline massive properties. The rock has a mineral composition such as a little quartz, k feldspar minerals, and plagioclase (Figure 3). This unit is included in the Bilungala Volcano Rock Formation unit (Tmbv) on the Tilamuta geological map sheet (Bachri et al., 1994).

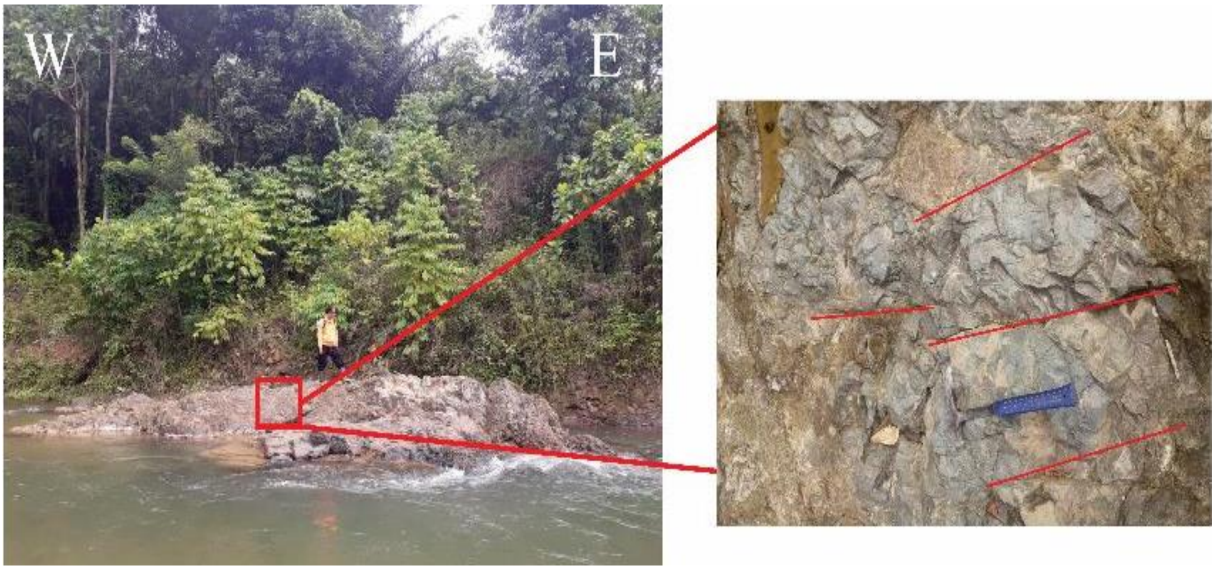

Figure 6. Andesite rock outcrop with joint tension structure at the research site.

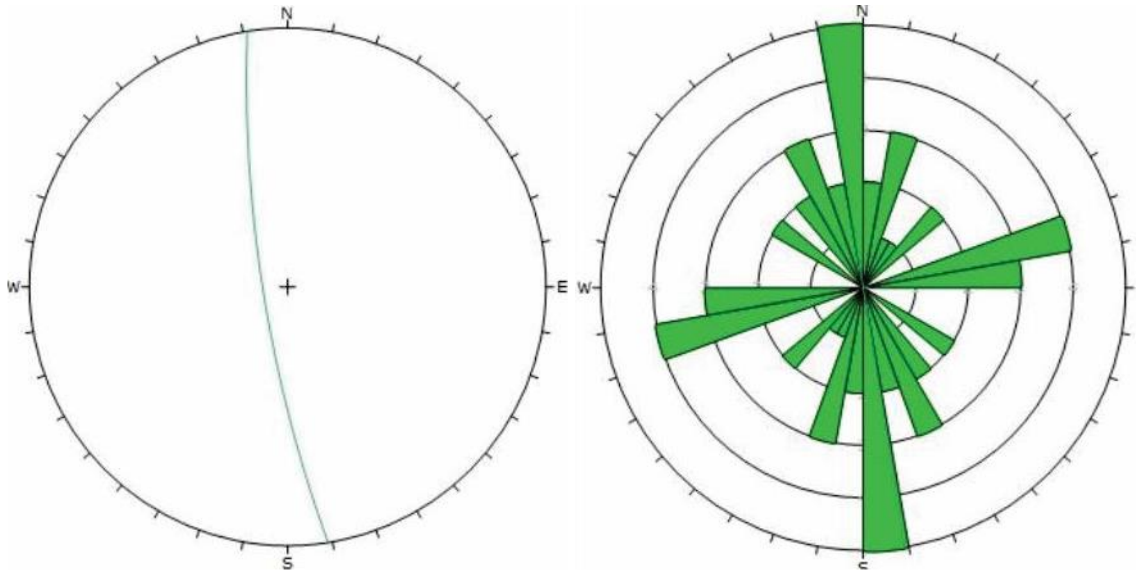

Figure 7. The results of the analysis of the joint tension structure.

The alluvial deposit unit occupies 25% of the studied area and has a thickness of 75 meters. The lithology in this unit results from weathering rocks in the form of sand, gravel, and gravel to lumps and is not compact (Figure 4). This unit belongs to the Alluvium Formation (Qal) on the geological map of the Tilamuta sheet (Bachri et al., 1994). The division of the three lithological units can be seen on the geological map of the Bualemo area, North Gorontalo Regency (Figure 5).

3.2. Geological Structure

At the research site, there is a primary geological structure in the form of a joint (*tension joint*) precisely located at ST 7 (Figure 6). After analyzing the joint structure data, the results of the relative joint direction are north-south with an value of N 171˚ E/79˚ (Figure 7).

3.3. Geochemistry

Geochemistry analysis (XRF) to determine the type of rock, magma series, and origin of magma to the tectonic setting in the research area. The following data results from geochemistry analysis (XRF) produce major element data (Table 1). The chemicals composition for samples ST 3 and ST 26 is SiO_2 (50.53-52.77%), Al_2O_3 (15.68-18.50%), Fe_2O_{3T} (13.28-9.86%), MgO (11.39-5.82%), CaO (2.81-5.39%), Na_2O (3.72-3.29%), K_2O (1.07-2.71%), TiO_2 (1.09-1.00%), P_2O_5 (0.13-0.28%), MnO (0.30-0.38%). The two samples, after being analyzed, produce ten main elements, which will be processed in several diagrams.

Table 1. Geochemistry analysis (XRF) produce major element data

Sample Code	ST 3 (% Weight)	ST 26 (% Weight)
SiO_2	50.53	52.77
Al_2O_3	15.68	18.50
Fe_2O_3	13.28	9.86
MgO	11.39	5.82
CaO	2.81	5.39
Na_2O	3.72	3.29
K_2O	1.07	2.71
TiO_2	1.09	1.00
P_2O_5	0.13	0.28
MnO	0.30	0.38
LOI	3.22	4.11

3.3.1. Rock type

The diagram used to determine the rock type ST 3 and ST 26 samples is the binary diagram of Le Bass et al. (1986). This diagram is Total Alkali-Silica (TAS), namely the accumulation of Na_2O + K_2O (Total Alkali) and SiO_2 (Silica). The two rock samples belong to the basic igneous rock group, Basalt (St 3) and Basaltic-Trachy Andesite (St 26) (Figure 8a).

3.3.2. Magma series

Furthermore, the plotting was carried out on the AFM diagram of F (Total FeO), A (K_2O+NaO), and M (MgO) (Irvine & Baragar, 1971), as shown in Figure 8b. In this diagram, two types of magma are divided: Calc-Alkaline and Thoeleitic. Based on this diagram, it belongs to the Tholeitic magma series, where in the tholeiitic magma series, the Fe content is vibrant and higher than that of the Tholeiitic magma series alkaline element value. Based on the geochemistry analysis (XRF) results, the elemental Fe values at both stations were 6.89%-9.28%.

Then plotting the FeO/MgO vs. SiO_2 diagram (Miyashiro & Shido, 1975); both samples belong to the Tholeiitic magma series. This diagram is aligned with the Ternary AFM diagram (Irvine & Baragar, 1971). Tholeiitic magma can form in all tectonic settings (Figure 9a).

3.3.3. Magma origin

The diagram of Figure 9b shows magma's origin in more detail, based on the plotting results from the ternary diagram (Mullen, 1983). St 3 belongs to the Tholeiitic Island Arc, while ST 26 belongs to the Calc-Alkaline Basalt Island tectonic setting. Based on the diagram above, it is possible that other tectonic events occurred in the ST 26 sample, which resulted in more acidic magma in the St 26 sample (Figure 9b).

3.4. Tectonic Setting

The magma series formed at St 3 and St 26 is Tholeitic based on the magma series diagram of Irvine & Baragar (1971) and the diagram binary from (Miyashiro & Shido, 1975). The tholeiitic magma series is a typical magma that forms in the early stages of island arc formation. The tholeiitic magma series is a type of magma that can exist in various tectonic settings. For St 3 basalt rocks belonging to a convergent tectonic setting or subduction zone. This is evidenced by the TiO_2 content of <1.3% (Gill, 1981 in Yuwono, 2015), where the TiO_2 content in St 3 rock is 1.08%. The St. 26 rock, according to the binary diagram (Le Bass et al., 1986), belongs to the Basaltic Trachyte Andesite rock. So it can be concluded that these two samples belong to the island arc. It is clarified by the analysis results from diagrams of TiO_2, $MnOx_{10}$, and $P_2O_5x_{10}$ from (Mullen, 1983), where St 3 rock belongs to the origin of Tholeiitic Island Arc magma, and St 26 rock belongs to the origin of Island Arc Calc Alkaline Basalt magma. These magma origins are included in the subduction zone.

The subduction process will produce heat in the bending path so that high heat flow can cause magma activity in the Benioff line. To find out the depth of magma origin can be calculated using the content of SiO_2 and K_2O (Hutchinson, 1977). Calculations carried out to determine the depth of origin of magma can use the formula:

$$h= [320-(3,65 \times \% SiO_2)] + (25,52 \times \% K_2O) \quad (1)$$

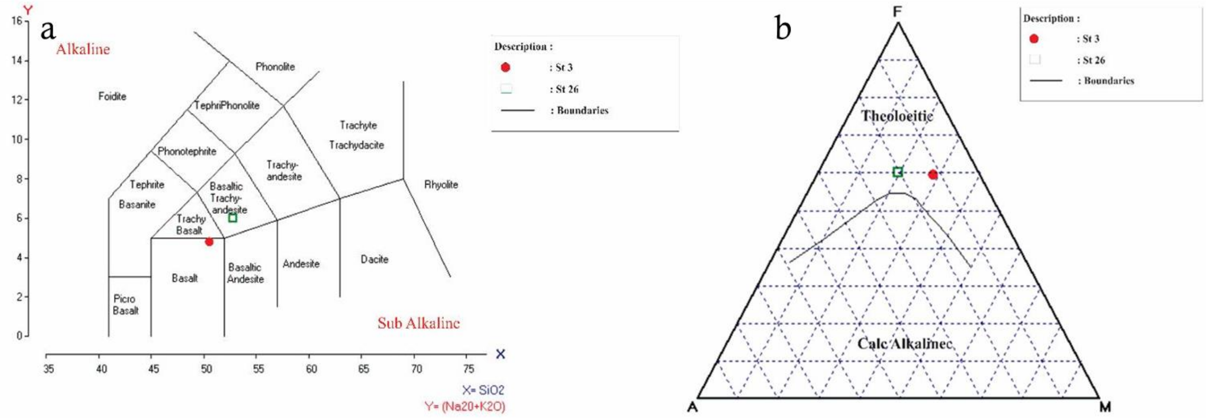

Figure 8. a) Na_2O+K_2O vs. SiO_2 diagram (Le Bass et al., 1986) of the studied rocks; b) AFM diagram (Irvine & Baragar, 1971) of the studied rocks.

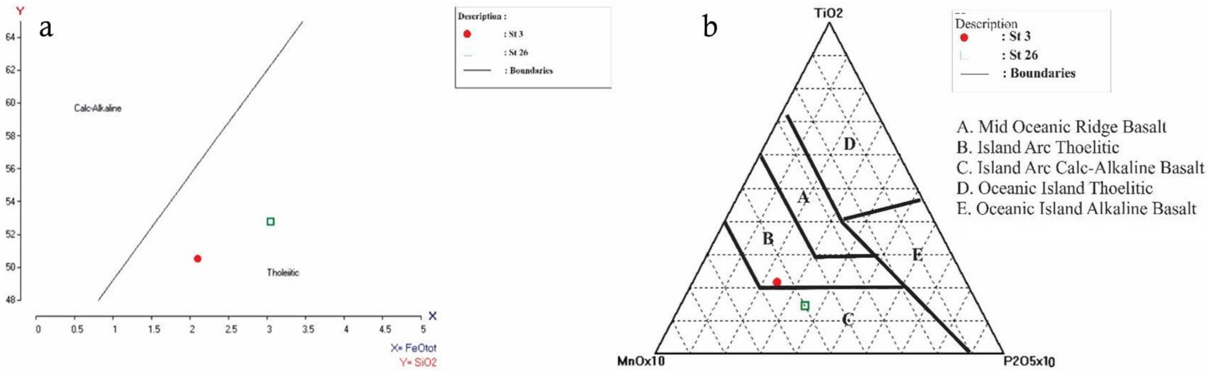

Figure 9. a) FeO/MgO vs. SiO_2 diagram (Miyashiro & Shido, 1975); b) TiO_2, MnOx10, P_2O_5x10 triangle diagram (Mullen, 1983) of the studied rocks.

Based on calculations using this formula, it can be seen that the depth of origin of magma from rocks in the study area is at a depth of about 163-196 km below the earth's surface in the Benioff Zone. It is estimated that the rock was formed during the Middle Miocene to Late Miocene, when subduction occurred between two oceanic plates, namely between the Sulawesi sea plate and the Sula ocean plate, about 15 to 10 million years ago (Hall & Spakman, 2015).

4. CONCLUSIONS

Based on the petrological and geochemical analysis, the constituent rocks in the study area are andesite and altered andesite. The rock types obtained based on geochemical analysis are basalt and basaltic trachy andesite, with the type of magma being tholeiitic. The origin of magma in the rock comes from island arc tholeiitic and island arc calc-alkaline basalt. The research location area is the result of subduction between 2 oceans, namely between the Sulawesi sea plate and the Sula sea plate, around 15-10 million years ago, with a depth of origin of magma of 163-196 km, including in the Benioff zone.

5. REFERENCES

Adi, A, N, I, Y, W. (2021). *Anomali geokimia distribusi logam dasar pada Daerah Bulamaraung Kabupaten Barru Provinsi Sulawesi Selatan*. Tesis Program Studi Magister Teknik Geologi Fakultas Teknik Universitas Hasanuddin.

Alekseenko, V., & Alekseenko, A. (2013). *Chemical elements in geochemical systems. The abundances in urban soils.* Publisher: Rostov-on-Don, Publishing House of Southern Federal University.

Bachri, S., Sukindo, & Ratman, N. (1994). *Peta geologi lembar Tilamuta, Sulawesi skala 1:250.000.* Pusat dan Penelitian dan Pengembangan Geologi, Bandung.

Bachri, S. (2011). *Structural pattern and stress system evolution during neogene-pleistocene times in the central part of the north arm of Sulawesi.* Centre for Geological Survey, Bandung.
Boogs, S. (2009). *Petrology of sedimentary rock*. Cambridge University Press, 600 p.
Hall, R., & Spakman, W. (2015). Mantle structure and tectonic history of SE Asia. *Tectonophysics*, 658: 14-45.
Hall, R., & Wilson, M. E. J. (2000). Neogene sutures in eastern Indonesia. *Journal of Asian Earth Sciences*.18:781–808.
Harun, B. (2020). *Geologi Daerah Posso dan Sekitarnya, Kabupaten Gorontalo Utara, Provinsi Gorontalo.* Skripsi Prodi Teknik Geologi Jurusan Ilmu dan Teknologi Kebumian Fakultas Matematika dan IPA Universitas Negeri Gorontalo.
Hamilton, W. (1979). *Tectonics of the Indonesian region*.Geological Survey Professional Paper 1078, U.S. Govern. Printing Office, Washington. U.S.G.S. Professional Paper 1078. 345 p.
Hutchison, C.S. (1989). *Geological evolution of southeast Asia.* Oxford Monographon Geology and Geophysic no 13, Oxford. 368 p.
Irvine, T., & Baragar W. R. A. (1971). A guide to the chemical classification of the common volcanic rocks Canadian.*Journal of Earth Sciences*. 8: 523-548.
Le Bass, M.J., Maltre, R., Streickensen, A., & Zannetin, B. (1986). A chemical classification of volcanic-rocks based on total alkali silica diagram. *Journal of Petrology*. 27 (3): 745-750
Miyashiro, A., & Shido, F. (1975). Thoeleiitic and calc-alkaline series in relation to the behaviors of titanium, vanadium, chromium, and nickel. *American Journal of Science*. 275: 265-277.
Mullen, E. D. (1983). $MnO/TiO_2/P_2O_5$; a minor element discriminant for basaltic rocks of oceanic environments and its implication for petrogenesis. *Earth Planet. Sci. Lett.62*: 53-62.
Nasrazadani, S., & H, Shokrollah. (2016). *Modern analytical techniques in failure analysis of aerospace, chemical, and oil and gas industries.* Handbook of Materials Failure Analysis with Case Studies from the Oil and Gas Industry, P. 39-54.
Payuyu, N., Permana., A.P., & Hutagalung, R. (2022). Analisis tipe batuan dasar pembentuk nikel laterit pada block X Kabupaten Banggai, Provinsi Sulawesi Tengah. *Jurnal Sains Informasi Geografi [J SIG]*. 5(*2*) : 76-83. http://dx.doi.org/10.31314/j%20sig.v5i2.1551.
Permana, A.P. (2018). Potensi batugamping terumbu Gorontalo sebagai bahan galian industri berdasarkan analisis geokimia XRF. *Enviroscienteae*. 14 (*3*) : 174-179. http://dx.doi.org/10.20527/es.v14i3.5688.
Permana, A.P. (2019). Kualitas fosil kayu Tohupo berdasarkan perbandingan analisis petrografi, XRF dan XRD. *Jurnal GEOSAPTA.* 5(*2*) : 99-102. http://dx.doi.org/10.20527/jg.v5i2.5653.
Permana, A.P., Eraku, S.S., Hutagalung, R., & Isa, D.R. (2022). Limestone facies and diagenesis Analysis in the Southern of Gorontalo Province, Indonesia. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences,* 6 (*456*) : 185-195. https://doi.org/10.32014/2022.2518-170X.248.
Rollinson, H. R. (1993). *Using geochemical data: evaluation, presentation and interpretation*. PrenticeHall. England.
Shackley, M. S. (2011). *X-Ray fluorescence spectrometry (XRF) in geoarchaeology*, 7. Springer Science+Business Media, LLC.
Simon, A, H. (2012). *Sputter Processing.* Handbook of Thin Film Deposition (Third Edition), p. 55-88.
Wahyudiono, J., Syafri, I., Sudrajat, A., & Panggabean, H. (2016). Geokimia batuan gunungapi di pulau Timor bagian barat dan implikasi tektoniknya. *Jurnal Geologi dan Sumber Daya Mineral*. 17 (4): 241- 252.
Yuwono, S. Y. (2015). *Pengantar petrogenesis.* Diktat Kuliah ITB Press.