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Interpretation of the Availability of Springs in Labuang Rano Village with a Geophysical Approach

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Abstract. Geologically speaking, Labuang Rano Village, Mamuju City area is composed of rocks from the Adang Volcano Formation. Based on the results of the site survey, it was found that there is a spring with a slight discharge. The emergence of these springs is not yet known, so further analysis is needed. An approach used to determine subsurface conditions is the geophysical approach, especially the geoelectric method. This study aims to analyse the subsurface geological conditions using geoelectric to find the factors that influence the emergence of springs. Geoelectrical measurements, observations of rock outcrops, and the findings of previous research are used as data sources. The results of the analysis show that the subsurface geological conditions consist of 3 layers. The topmost layer is tuff rock, the 2nd layer is volcanic breccia and the 3rd layer is andesite rock. Based on the resistivity cross-section, it can be seen that there is a fracture that cuts vertically in the tufa rock layer from a depth of 13 m to the surface in a northeast-southwest direction. Thus, it can be concluded that the emergence of springs at the study site was caused by a fracture that cut the tufa rock layers vertically from a depth of 13 to the surface. The fracture which is the medium for groundwater to emerge onto the land surface forms a spring.

Keywords: fracture; geoelectric; spring.

1 Background

The complicated tectonic order on Sulawesi Island is caused by the confluence of several plates involving the main plate, microcontinents, volcanic arcs, and island arcs. The movements between the plates lead to the formation of geological structures including faults, joints, and folds (figure 1), and even these geological structures can cause earthquakes [1]. According to Puspita et al. [2], the pattern of the geological structure formed in the sea area of West Sulawesi are folds and reverse fault paths (fold-thrust belts) that are relatively north-south in direction.

Based on the Sheet Mamuju geological map [3], Labuan Rano Village is located in the Adang Volcano Rock formation with a geological structure that controls the area, namely the Mamuju-Majene Fold Thrust Belt. According to Baillie and Decker [4] the cause of the earthquake in West Sulawesi on January 15th, 2021 was the reverse fault movement of the Mamuju-Majene Fold Thrust Belt.

The existence of a geological structure, both faults and fractures, is one of the factors that influences the availability of springs in an area and the geological structure is the flow medium from the subsurface to the surface. The results of the research by Umar, E., P. et al. [5] regarding the influence of geological structure on the emergence of hot water, that the emergence of hot water is caused by the influence of geological structures in the form of joints and shear faults. Moreover, research conducted by Anas, A.N. et al. [6] explained that fractures cause hot fluids in aquifers to have gaps in the surface and form hot springs.

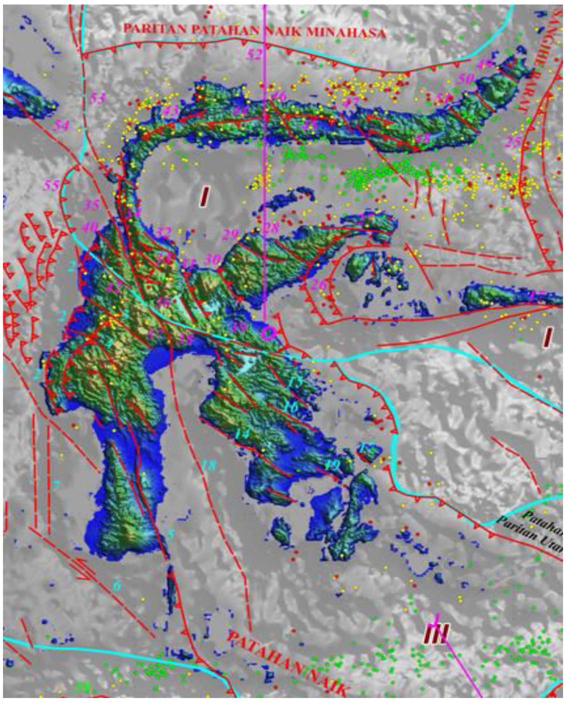

Figure 1. Geological Structure on Sulawesi Island (modification by Soehaimi, et.al.)

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The results of the site survey, it was found that there is the emergence of springs even with a small discharge. To find out the controlling factors for the availability of the springs on the surface, a geophysical approach is needed. One of the geophysical instruments that can be used to find out subsurface geological conditions, such as geological structures, aquifers, and lithological profiles is the geoelectric method.

The purpose of this study is to analyse the subsurface geological conditions using geoelectric to determine the factors that influence the emergence of springs., authors and affiliations

2 Research Methods

The research location is in Labuang Rano Village, Mamuju Regency, West Sulawesi Province (figure 2). The location is geographically located at the coordinates 118°45'50.57" BT - 118°45'47.34" BT and 2°46'18.57" LS - 2°46'11.09" LS.

This study combines the results of a literature review, previous research, and field data. The entire data is compared, then an assessment and analysis is carried out, to conclude the geological factors that influence the availability of springs at the study site.

The data used in this study are primary data and secondary data. Primary data was obtained by conducting direct field observations consisting of observing rock outcrops, distribution of springs, and geoelectrical measurements. Multichannel geoelectrical measurements use the Wenner Schlumberger configuration with 1 path, 310 m span, and 10 m spacing for each electrode. While secondary data are references to the geology of the study area.

Data analysis was carried out on data obtained, such as on rock outcrops, megascopic analysis was carried out to determine the type of outcrop rock, distribution of springs to determine location details, and resistivity data analysis from geoelectric measurements using Res2Dinv Software to determine the geological conditions below the surface. All of these data were compared to determine the geological factors that influence the availability of springs at the study site.

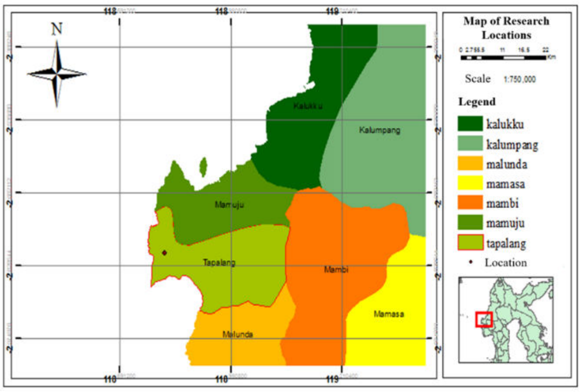


Figure 2. Map of research locations

3 Result and Discussion

The results of observations in the field found that there were springs but the discharge was slight (figure 3). The spring point is at the coordinates 118°45'48 BT - 2°46'12 LS. At the spring point and its surroundings, there are several fractures with opening widths of 2 cm - 6 cm. The appearance of the fracture can be seen in Figure 3. According to Supartoyo et al. [1], the formation of geological structures in Mamuju and its surroundings is caused by tectonic activity. Moreover, the effect of the activities forming geological structures, on a micro-scale, formed fractures or joints as found at the study site (figure 3). The overlay of the Sheet Mamuju geological map with the research location shows that the research location is in the Adang Volcano Formation. Based on the geological map, the Adang Volcano Formation is composed of tuff, lava, and volcanic breccia [3]. Based on the megascopic description carried out on outcrops in the field, it was found that the rocks have physical characteristics of brownish white to yellowish brown, pyroclastic texture, a grain size of 1/16 – 2 mm, and do not react when HCL solution is dropped. Based on the WTG classification, the rock is classified as Tuff. The results of this outcrop observation later become one of the references for interpreting subsurface geological conditions from geoelectric measurements.

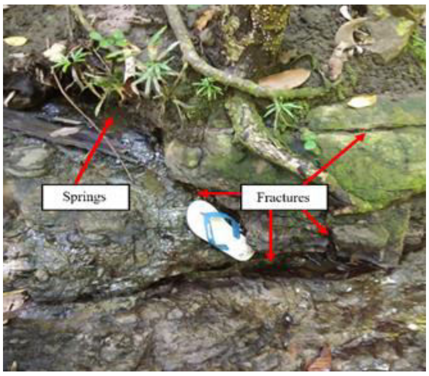


Figure 3. Springs and fractures at the study site

Based on the megascopic description carried out on outcrops in the field, it was found that the rocks have physical characteristics of brownish white to yellowish brown, pyroclastic texture, a grain size of 1/16 – 2 mm, and do not react when HCL solution is dropped. Based on the WTG classification, the rock is classified as Tuff. The results of this outcrop observation later become one of the references for interpreting subsurface geological conditions from geoelectric measurements.

The results of measurements and processing of geoelectrical data are 2D resistivity sections (Figure 4) with the lowest resistivity value of 0.05 Ωm and the highest resistivity value of 4000 Ωm. The penetration depth reached is 72 m.

Based on the 2D resistivity section in Figure 4, the subsurface geological conditions are interpreted to consist of 3 lithologies of constituent rocks and there is a geological structure (table 1):

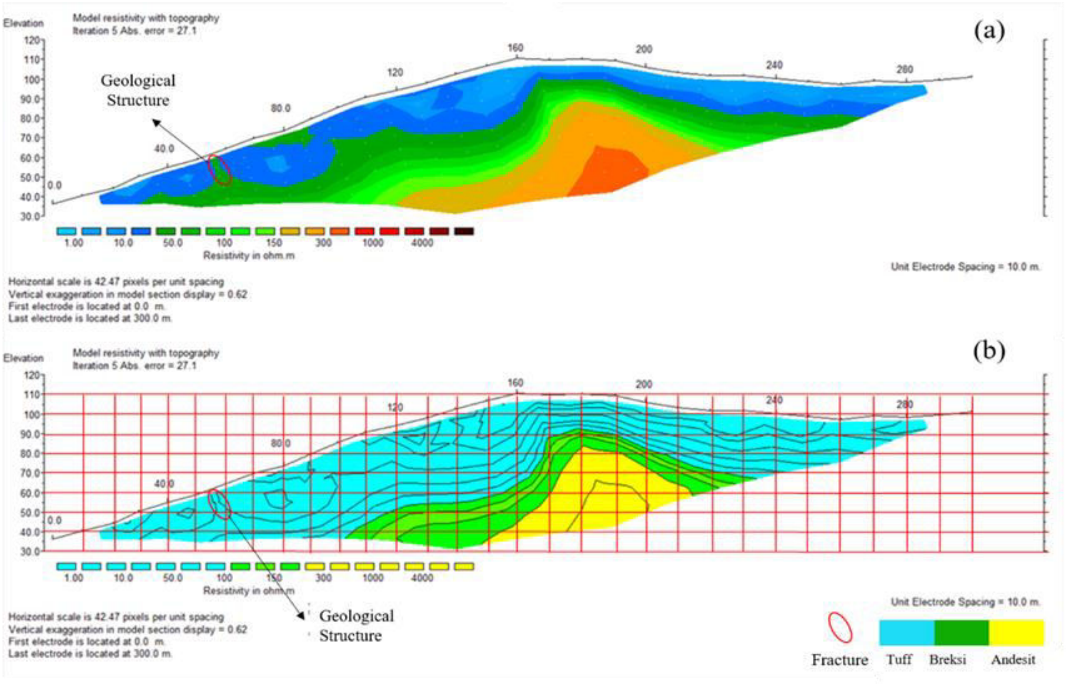
1. The first layer has a low resistivity of 0.05 Ωm - 100 Ωm (blue colour) with varying depths ranging from rock exposed on the surface to a depth of 18 metres and this layer is interpreted as tuff. This layer is part of the rock that is exposed on the surface as shown in Figure 3, where the megascopic description of the outcrop has been carried out and it is concluded that the rock is tuff. These results were reinforced by research conducted by Arsyad, A. [7] in the same formation, namely the Adang Volcano formation using the geoelectric method and the results showed that the resistivity value of the Lapili Tufa rock was 50 Ωm - 100 Ωm. In addition, research conducted by Masssinai, et al. [8] regarding the typology of volcanic aquifer systems using resistivity explains the resistivity value of tuff rocks is between 12.47 Ωm – 75 Ωm. In this tufa layer, there is a geological structure that is interpreted as a fracture. The location of the fracture is at a measuring point of 55 m and is at a depth of between 0 m or from the surface to a depth of 13 m (Figure 4). The layer is interpreted as a structure seen from changes in resistivity values that tend to increase, this can be seen in Figure 4.a. in the red circle.
2. The second layer has a resistivity of 100 Ωm - 200 Ωm (green colour in Figure 4. b) at a depth that varies between 18 m - 69 m. These layers are interpreted as volcanic breccia rocks. These results are in line with the research by Bundang, S. et al. [9] in volcanic areas, the resistivity value of volcanic breccia is 85.6 Ωm – 176 Ωm.
3. The third layer has a high resistivity between 200 Ωm (yellow colour) – 4,000 Ωm with a depth varying between 27 m – 70 m. The layers are interpreted as andesitic rocks. This is in line with the results of research conducted by Kusmita and Iwalzi [10], the resistivity value of andesitic rocks is 170 Ωm – 1,095 Ωm. Meanwhile, according to Jayadi et al. [10], the resistivity value of andesitic rocks is 300 Ωm – 600 Ωm.

Table 1. Rock lithology based on geoelectrical interpretation

No.	Lithology	Resistivity (Ωm)	Depth
1	Tufa	0.05 - 100	0 - 18
2	Volcanic Breccia	100 - 200	18 - 69
3	Andesite	200 – 4.000	27 - 70

Interpretation of the geoelectrical data that can be seen in the 2D resistivity section (figure 4) indicates the presence of a geological structure in the form of a fracture. The fracture plane cuts the layers of tuff rock, this is reinforced by the difference in resistivity values in the surrounding rock. The 2D resistivity section shows that the structure cuts the surrounding rock layers vertically up to the surface. In addition, the position of the fracture plane that intersects the layer on the resistivity section is found on the surface of the fracture which is a spring point. According to Syamsuddin et al. [6], the resistivity value in a geological structure area will show a higher or lower value than the surrounding rocks.

Fractures at the study site are found on the surface continuously vertically to a depth of 13 m with a fracture direction northeast-southwest. The existence of these joints is inseparable from the tectonic activity



around the West Sulawesi region. This is reinforced by several previous studies. According to Ratman and Atmawinata [3], the formation of geological structures, whether faults, joints, or fractures and folds, is the effect of tectonic activity. According to Indrastomo et al. [11] in the research conducted to identify the geological structure around Mamuju, the results show that in the Tappalang area, there is a lineament that can be interpreted as a fault with a relatively northeast-southwest direction.

The macro-geological structure formed in the sea in the West Sulawesi region, namely the Mamuju – Majene Fold Thrust Belt [2]. There was a movement of the Mamuju-Majene Fold Thrust Belt rising fault which was the cause of the earthquake in West Sulawesi on January 15th, 2021 [4]. This activity also controls the formation of minor structures including fractures at the study site. This is supported by the results of research conducted by Supartoyo, et al. [1] who found a spring with a small discharge in Karema Village, Mamuju Regency which is not too far from the research location, after the earthquake in West Sulawesi on January 15th, 2021.

Based on the analysis of geoelectrical data, regional geology, and outcrops at the study site, it can be concluded that the presence of springs found on the surface is caused by a fracture below the surface reaching a depth of 13 m which is a medium for groundwater to emerge onto the land surface forms a spring.

4 Conclusion

Based on the analysis and interpretation of resistivity data from geoelectrical measurements, observations of outcrops, and geological conditions, it can be concluded that the emergence of springs is caused by a fracture below the surface that cuts the tufa rock layer vertically from a depth of 13 to the surface, with the fracture direction northeast-southwest. The fracture which is the medium for groundwater to emerge onto the land surface forms a spring.

5 Acknowledgment

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