Surface and subsurface analysis based on the geological structure and electrical resistivity Data in Gorontalo Outer Ring Road (GORR), Huidu Utara

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Abstract. Gorontalo is one of the areas prone to earthquakes because Gorontalo has a geological structure, which is a fault. This fault has a northwest-southeast direction that cuts across the Gorontalo City area and crosses Lake Limboto. The research objective is to determine the direction of subsurface geological structures and analyze the impact of geological structures on the GORR development infrastructure. The research method is divided into several stages, namely, the preparation phase, the stage of data collection and the stage of data processing and analysis. The preparatory phase includes literature studies and regional geological studies. The next step is data collection in the field including lithology, geomorphology and structural data. And finally, data processing and analysis uses several classifications. Based on surface data, there are several types of lithology such as tuff, clay, and limestone which have started to decay. Geological structure in the form of fault / normal fault with northwest-southeast direction is also found in the study area. Based on subsurface data there are three types of layers namely clay sand, alluvial, and sandstone which are determined based on the classification of rock and mineral resistivity. Subsurface data also shows faults, in the same direction. And based on the vertical resistivity cross section shows the slip area seen from the resistivity value of the layer above it has a lower value than the layer below, it is very possible for landslides because the layer is more easily eroded and flowed, plus supported by a fairly steep field and rainfall in the GORR Region high enough.

1. Introduction

Gorontalo is one of the areas prone to earthquake disasters because Gorontalo has a geological structure, namely faults. This fault / fault has a northwest-southeast direction which cuts through Gorontalo City and crosses Limboto Lake. Limboto lake in Gorontalo district and Gorontalo city, Indonesia is an example of a very rapid environmental change, because the area of the lake is decreasing. Because a lot of sediment flows into the lake every year, the water depth becomes shallow and the lake area becomes narrow [1]. The existence of the Gorontalo fault is the result of a subduction in the Sulawesi Sea [2]. This fault is named the Gorontalo Fault.

GORR is a ring road that connects Gorontalo City with Djalaluddin Airport. GORR includes a fault zone that extends from the Leato area that passes through Lake Limboto to Kwandang Bay [3]. The fault in GORR is included in the active fault. Because of the active faults, the GORR area mostly has minor faults.

North Huidu Village is located in Gorontalo District, including in the GORR Area, which means it is in a fault zone. Based on the Regional Geological Map of the GORR Area, the Study Area includes the Klastika Limestone Formation (TQl) and the Bilungala Volcano Rock Formation (TmBv).

Based on research by Usman et al. [4], the problems that exist in the GORR area are the high frequency of ground motion related to natural factors that cause ground motion which includes morphology, land use, lithology, geological structure, rainfall, and slope. In this area, there were a number of landslides that caused damage to the road body, thus hampering the completion of the GORR which is targeted to be completed in 2019. The research conducted by Usman, et al. Used Landsat landslides as evidence of landslides in the GORR area. Based on Kompas, 2016 landslides have often occurred since the beginning of GORR construction, it was recorded that in 2016 new landslides occurred again and even resulted in the collapse of the 150 kW SUTT power tower. The research conducted by Usman et al did not discuss infrastructure and rainfall that caused landslides.

From the geological conditions above Huidu Village to be an attractive location for conducting research, especially in infrastructure control of faults / faults in Huidu Village. The geoelectric method stated by Reynold on 1997 is a method used to determine the resistivity of the rock layer below the surface by flowing an electric current below the surface with two- electrode rocks. With this method, it can be seen that the subsurface layer and subsurface structure can be seen from the resistivity section. From the method used, this study aims to determine the direction of the subsurface geological structure and to analyze the impact of the geological structure on the GORR development infrastructure.

2. Research methods

This research is divided into several stages, namely, the preparation stage, the data collection stage and the data processing and analysis stage.

2.1. The preparation stage

This preparation stage is divided into two parts, namely regional geological studies and literature studies. In this stage, we will learn about the geology of the research area. Starting from lithology, stratigraphy, physiography, tectonics, and the geological structure of the research area.

2.2. Data collection stage

Retrieval of surface geological data by observing the condition of the outcrop, geological structure and lithology, and geomorphology of the study area. For detailed lithology observations, it is carried out by looking at the conditions of the outcrop then taking samples of each rock using a geological hammer and describing in detail the lithology of the outcrop, whether it is color, grain size, grain shape, grain relationship, packaging, texture homogeneity, mineral composition, formation genesis and geological structure with analysis using a large grain classification using the Wentworth Scale, 1922. The tools and materials used to perform surface geological retrieval such as Compass, Geological Hammer, Stationery, Hcl, Camera, Sample Bag, Melamine Board and Geological Map.

Retrieval of subsurface geological data using the Wenner Schlumberger method to determine subsurface lithological conditions and geological structures, with tools and materials such as IPMGEO geoelectric tools, electrodes, geological hammer, roll cables, roll meters, stationery, cameras, GPS and umbrellas. How to take field data measurements starting by determining the direction of the spread using a compass and determining the datum point by paying attention to the surrounding environmental conditions then making a straight line stretch using a roll meter with a stretch of 0- 105 m, then the electrodes are plugged into the

ground according to predetermined intervals Then clamp the AB and MN connector cables to the electrode rods and the geoelectric device, then a DC (direct current) electric current which has a high voltage will be injected into the ground so that data recording in the form of alignment of waves below the surface will be recorded automatically by the geoelectric dial and then the data is processed and analyzed using Formula

$$K = \prod n \, (n + 1) \, a$$

to find the value of K and the formula $\rho a = K \times V / I$ to find the value of *pa* .

2.3. Data processing and geological data analysis
After taking the data in the field, the lithology data is processed and analyzed using predetermined classifications. In addition to the lithology, geomorphological data are analyzed starting from the slope data, the genetic type of the river, and the flow pattern of the river.

2.4. Geoelectric data
After the data from the resistivity measurement is obtained, then it is analyzed using the Microsoft Excel application with the formula $K = \prod n \, (n + 1) \, a$ to find the value of K and the formula $\rho a = K \times V / I$ to find the value of *pa.* so that it can display the vertical cross section of the resistivity model.

3. Results and discussion
Based on Brahmantyo [5], the physiographic zone in Gorontalo is divided into 3 parts, namely, the Tilongkabila-Boliyohuto Mountain Zone, the Paguyaman-Limboto Interior Plains Zone, and the Bone-Tilamuta-Modello Southern Mountain Zone. The research area includes the interior-limboto plain zone which stretches from the East of Gorontalo City to Lombongo which is thought to be a basin controlled by normal fault structures. See figure 1 below.


Figure 1. Geomorphology of the study area.

Based on the regional geological map of the study area and its surroundings, this area consists of the rock formations of Bilungala Volcano (TmBv), Clastic Limestone (TQl), Lake Sediment (Qpl), Diorite Bone (Tmb), Coral Limestone (Ql). research covered by Tuff (Tmbv) which consists of Volcanic Tuff; Clastic Limestone (TQl) which consists of Coral Limestone; Lake sediment (Qpl) which consists of clay [6]. Based on observations that have been made in North Huidu Area, Limboto Barat District, Gorontalo District at the first station geographically it is at coordinates 122 ° 57'31,55 "E- 0 ° 39'5,85" N. Where the outcrop is on the south side of the road, the direction of the expanse east to west, with dimensions of ± 10m high and ± 30m long. The outcrop conditions are weathered, and the outcrop has three rock layers and a fault structure. See figure 2 below.
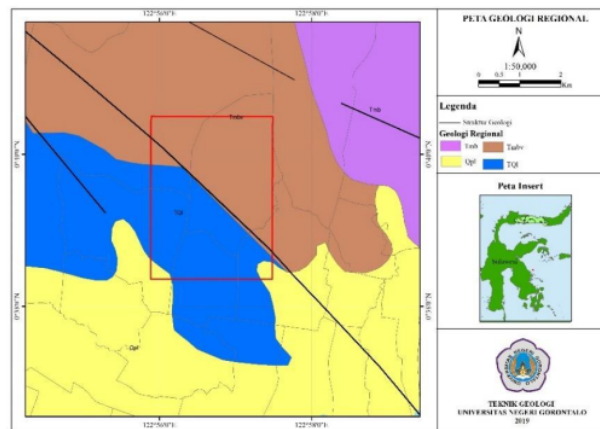
**Figure 2.** Regional geological map of the research area.

At station 1 there is a sedimentary outcrop having 3 types of lithology, namely Tuff, Clay, and weathered limestone. In the outcrop there is also a fault structure with a strike / dip value of 314 ° / E55 °, the fault in the outcrop is characterized by the left moving downward, the dip value is steep (> 45 ° -60 °), from some of the above characteristics it can be concluded that the fault in study area is normal fault. See figure 3 below.
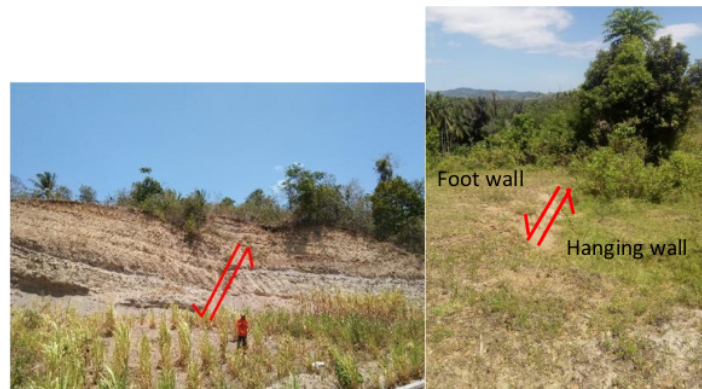
Figure 3. Normal fault / normal fault ST.1.

The second station is geographically located at coordinates 122 ° 57'37,205 "E - 0 ° 39'11,123" N. Where the outcrop is on the south side of the road, with an east-west expanse. Where in this outcrop there are 3 faults or faults with the value of strike / dip = 117 ° E / 79 ° in the first fault, strike / dip = 358 ° E / 50 ° in the second fault, strike / dip = 332 ° E / 75 ° at third fault. See figure 4 below.
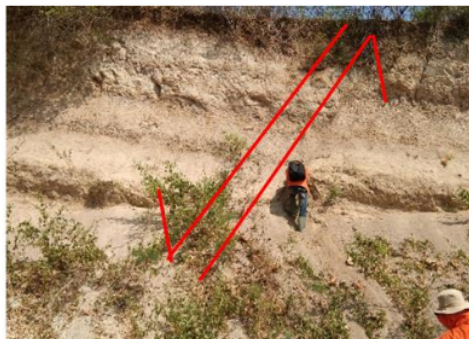
**Figure 4.** Normal fault / normal fault ST.2.

Based on subsurface research with the Wenner Schlumberger method, which obtained geoelectrical data with analysis using Microsoft Excel with the formula $K = \prod n\,(n+1)\,a$ to find the value of K and the formula $\rho a = K \times V / I$ to find the value of *pa*. The processed data will be analyzed further to determine the resistivity of the rock. The data consists of 100 data on 1 datum point with a length of 0-105 m, 4 points n.

After the data is processed and analyzed, the rock resistivity value will be obtained, from these data the lowest resistivity value is sandstone and the highest resistivity value is Alluvium [7]. See table 1 below.

Table 1. Rock resistivity value.

No	Resistivity (Ωm)	Rocks
1	2,3	Sandstone
2	5,6	Claystone
3	13,6- 495	Alluvial

The results of Geoelectric Processing are presented in the form of a resistivity section. The cross section contains the distribution of resistivity values represented by different values. The value of 2.3 Ohm means low resistivity, while the value of 5.6 Ohm means that the resistivity value is greater than the previous value, the data analysis is carried out qualitatively on the 2D resistivity cross-sectional map, so that the difference in resistivity that indicates the existence of a fault is obtained. Geoelectric measurements are limited to paths that are proven to have a northwest-southeast trending line, based on Regional Geological Data and Geological Research Location Data. See figure 5 below.
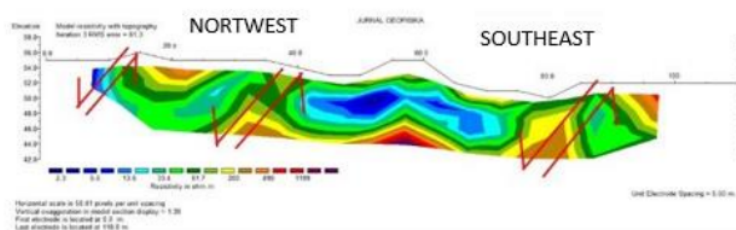
Figure 5. Results of resistivity analysis.

Based on the resistivity section above, there are different resistivity values, namely sandstone with a resistivity value of 2.3 Ohm, clay with a resistivity value of 5.6 Ohm, and Alluvium 13.6-495 Ohm. The resistivity section above also causes the resistivity value at the top to be lower than at the bottom. At the research location, there is a structure in the form of a normal fault in the northwest direction - southeast, at the location that has been studied based on surface data there are 3 fault structures, the subsurface analysis also gets the same results. This means that the location has a low rock resistivity value, so it has the potential for landslides to occur. Clay, sandstone and alluvial have undergone intensive weathering, the intensity of the three rocks can accelerate the process of rock erosion. Especially in clay stone which has a high water absorption so that it can increase the weight of the soil.

4. Conclusion

Based on surface data, there are several types of rock lithology such as sandstone, clay and alluvial. There is also a geological structure, namely a normal fault with a northwest-southeast stretch direction. And based on subsurface data sandstone has the lowest resistivity value and alluvial has the highest resistivity value, the data analysis results show that there are three normal faults in the northwest-southeast direction, and based on the vertical resistivity section shows the slip area seen from the resistivity value of the layer above it has a lower value than the layer below, it is very possible for landslides because the layers are more easily eroded and flowing, plus it is supported by fairly steep terrain and rainfall in the area. GORR is quite high.

Acknowledgements

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