Seismicity map to analyze the depth and magnitude earthquake zone in Kwandang Area of North Gorontalo Regency

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Abstract. Kwandang is a district located in the northern part of Gorontalo. The purpose of this research is to analyze the depth and magnitude earthquake zone that occurred in the district of Kwandang, Gorontalo Utara regency based on seismicity map. The astronomical research location is located at 0° 49′ 39″ S, 122° 55′ 8″ E. The method used in this research is seismicity map analysis. The earthquake that dominates in Kwandang, based on the value of its depth, namely shallow earthquake (0-70 km) and medium earthquake (70-300 km). This is caused by subduction activity in the direction of the subduction of the north arm of Sulawesi towards south of Tomini Bay. Whereas based on the strength of the earthquake in Kwandang sub-district is dominated by small earthquakes with a light, mild earthquake. Based on the depth zonation, earthquakes mostly occurred in the west. Based on the magnitude, the earthquakes mostly occurred in the southwest.

1. Introduction

Indonesia is one of the regions in the Southeast Asia that lays in the equator and stretches between two continents of Asia and Australia. It is also surrounded by two oceans of the Pacific Ocean and Indian Ocean. Indonesia is one of the largest archipelago’s country in the world with 17,504 islands. Indonesia is also known as Nusantara. The population is approximately 270, 054, 853 people. Indonesia is one of densely populated countries in the world and is the world largest Muslim population, with more than 230 million of its people are Moslem [1], [2].

According to [1], Gorontalo Province is categorized as an area with mild to moderate earthquake damage. The earthquake in Gorontalo occurred due to subduction of the Sulawesi Sea and active faults in Gorontalo. In addition, the maximum ground acceleration rate in Gorontalo area is 1,462 -99,714 gal [1], [7].

The seismicity of the Gorontalo region is made in the form of a seismicity map. Seismicity maps are created using QGIS software. Seismicity maps are divided into two maps, namely seismicity map based on earthquake depth and seismicity map based on earthquake magnitude [1].

The complex and highly diverse condition of Sulawesi tectonic makes it prone to earthquake. To describe the complexity of the tectonic of Sulawesi, several studies have carried out the Sulawesi suture [5], [6]. It characterizes by the active faults in Gorontalo, both strike slip faults and thrust faults. This
study aims at finding out the degree of the earthquakes in Kwandang district of North Gorontalo regency based on its seismic data.

The north part of Sulawesi, especially Gorontalo city is the most complex area within the geological timeframe of the faults and tectonics. This area is the meeting point of three convergent plates, which interpreted as due to the interactions of three earth plates in Neogene area [5, 6].

The Gorontalo Fault, as a part of the Group B (the Gorontalo Fault Group), generally has been interpreted as dextral wrench fault. The present structural analysis suggests that this major fault was formerly developed as a dextral fault during Neogene, and later during Pleistocene it was reactivated in the sense of sinistral fault due to the changing of the stress system [4].

The Neogene stress orientation is supposed to be related to the subduction of the North Sulawesi Sea to the south, which during Pleistocene weakened as the Sangihe Subduction in the Mollucas Sea to the east commenced resulting in the change of field stress orientation [4].

Gorontalo is one of the areas that are vulnerable to earthquake disaster as it is located between two main faults of Pacific fault and Eurasian fault as well as other micro faults. Geological map of Gorontalo shows that the fault structure that crosses the Gorontalo city area. Gorontalo is one of the areas with complex tectonic condition as it is influenced by the subductions along the north and east of the north Sulawesi arm, and thus, critical to be properly mitigated. There are several local faults in Gorontalo that can move anytime and causes earthquakes, in areas such as Kwandang District of North Gorontalo regency. The purpose of this research is to find out the earthquake depth zonation and magnitude zonation based on the seismicity map.

2. Research Method

2.1. Research Site

The research site is in Kwandang Regency of North Gorontalo regency, of Gorontalo province with the total area of 1,230,07 km². administratively, this research site lays in the area of 0°49′ 39″ S, 122° 55′ 8″ E. This site can be reached using four or two-wheeled vehicles from Gorontalo city. The distance from the center of the city is ± 59 km and can be reached in 1 hour and 28 minutes.
2.2. Data Collection
The data used in this study are earthquake data taken from United States Geological Survey (USGS) which consisted of date, latitude, longitude, depth, magnitude, geological map, and topographic map obtained from RBI.

2.3. Data Analysis
The obtained-data are analyzed using seismic data analysis. The values are the depth magnitude taken from USGS. Further, the zonation is overlaid into the earthquake-depth map, and the zonation map of the magnitude of the earthquakes.

3. Results and Discussion
The figure below is the map of Kwandang district in North Gorontalo regency of Gorontalo province. The map has a scale of 1 : 250.000. Within this map, there are the geological structure, district borders, residence, rivers, and contour.

![Map of Kwandang district](image)

**Figure 2:** Research site map

The map below is the distribution of tectonic map points in the Kwandang district. Seismicity in the Gorontalo area and its surroundings is influenced by the Sulawesi Sea subduction. The direction of Sulawesi Sea subduction is north-south. Within the map, it describes the depth of the earthquake in the site is categorized as shallow and intermediate earthquakes. The shallow earthquakes happened in the depth between 0-70 kilometer from the surface, whereas the intermediate earthquake happen between 70-300 kilometer from the surface.
The figure below is the distribution of earthquakes based on their magnitudes in Kwandang district, of North Gorontalo regency using the scale of 1 : 250.000. Within the map, it is described that Kwandang experienced different magnitudes of earthquake, from shallow to deep magnitudes. The Kwandang regency is located into several soil formations such as, Qal, TQIs, Tmb, Tmbv and Tpwv.

**Figure 3:** Seismicity map based on depth earthquake.

The figure below is the distribution of earthquakes based on their magnitudes in Kwandang district, of North Gorontalo regency using the scale of 1 : 250.000. Within the map, it is described that Kwandang experienced different magnitudes of earthquake, from shallow to deep magnitudes. The Kwandang regency is located into several soil formations such as, Qal, TQIs, Tmb, Tmbv and Tpwv.
The map below is the zonation of the earthquake depth in Kwandang district. The zonation map shows that the depth of the earthquake varies from the shallowest of 45 km and the deepest is 90 km.

**Figure 4:** Magnitude-based earthquake distribution map

The map below is the zonation of the earthquake depth in Kwandang district. The zonation map shows that the depth of the earthquake varies from the shallowest of 45 km and the deepest is 90 km.

**Figure 5:** Earthquake depth zonation map
This map is the zonation of the earthquake magnitude in the Kwandang district with the scale of 1:250,000. The magnitude level of the earthquake is quite vary from the lowest of 3.8 in Richter Scale indicated by the purple color to the highest magnitude of 6 in Richter Scale indicated with the yellow color within the map.

**Figure 6:** Earthquake magnitude zonation

4. Conclusion

Based on the map analysis, the earthquakes in Kwandang district are categorized into shallow earthquakes (0-70 km) to intermediate earthquakes (70-300 km). Whereas the deep earthquake (>300 km) is undetected in this area. The magnitude of the earthquakes in Kwandang district ranges from 4.0 - 4.9, 5.0 - 5.9, to > 80.

5. References

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