Seismicity of Suwawa Timur area based on analysis of earthquake: the depth and magnitude

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Abstract. North Sulawesi is an area close to the earthquake source due to tectonic processes such as active faults. This study aims to analyze the earthquake in Suwawa Timur from the earthquake depth and magnitude data. The method used in this research is a qualitative method by collecting and processing earthquake data. The analysis was carried out by creating a seismicity map of the Suwawa Timur area. The map shows that the earthquake points in Suwawa Timur are at shallow earthquakes (0 - 70 km) and moderate earthquakes (70 - 300 km). Shallow earthquakes are usually sourced from active seismic movement activity. Lithological conditions and structural geology affect the magnitude and depth of the earthquake value. Zonation map relates to the epicenter point of Suwawa Timur. Suwawa Timur is dominated by minor earthquakes (0.0 - 3.9), light earthquakes (4 - 4.9), and there is one point of a moderate earthquake (5 - 5.9).

1. Introduction
Indonesia is a complex region due to the collision of three macro plates and one micro plate, namely the Indo-Australian plate, the Pacific plate, the Eurasian plate, and the Philippine plate [1–8]. The pressure due to the movement of the four plates has implications for the formation of active faults. This makes Indonesia vulnerable to earthquakes and tsunamis [9].

Sulawesi island has four arms with various tectonic processes that make the plate move and experienced the collision process [10]. The northern arm of Sulawesi was formed due to the subduction of North Sulawesi and the East Sangihe Subduction [1,11]. Earthquakes and several geological phenomena are formed due to these tectonic conditions.

There is a subduction in the northern part of Sulawesi, which is trending north-south. Subduction in the northern part of Sulawesi form the Gorontalo fault [11,12]. Gorontalo fault is described as a strike-slip fault. The fault is marked by the shape of the coastline around Tomini Bay which shows a shift [13]. Areas that are in the structural zone are prone to earthquakes.

Suwawa Timur is one of the earthquake-prone areas in Gorontalo that can be used as a study and consideration related to earthquakes. This study aims to find out the earthquake in Suwawa Timur District from the earthquake depth and magnitude data. Earthquake distribution patterns are used to determine the depth of an earthquake. Earthquake zonation is used to determine the strength of earthquakes in the research area.
2. Methods

2.1. Research site
The research location was in Suwawa Timur District, Bone Bolango Regency, Gorontalo Province with an area of 103.28 Km² (figure 1). Astronomically Suwawa Timur is located at coordinates between at 0º41'10" - 0º25'02" N and 123º13'02" - 123º35'05" E.

![Figure 1. Research site map.](image)

2.2. Data collection
The method used in this research is a qualitative method with secondary earthquake data collection. The study used earthquake data from the United States Geological Survey (USGS) 1936 - 2019 and used topographic maps as the base map.

2.3. Data analysis
The analysis was carried out by creating a seismicity map of the Suwawa Timur area. The map is made based on earthquake depth data and earthquake magnitude data in the study area [14, 15]. A seismicity map consists of an earthquake depth map and an earthquake magnitude map. Furthermore, a zoning map for the depth and magnitude of the earthquake was made. Seismicity of the Suwawa Timur area was analyzed based on the pattern of earthquake spread, earthquake zoning and its relation to the geological structure.

3. Results and discussion
The results of the earthquake depth map analysis showed that the epicenter of the earthquake in Suwawa Timur was at a shallow earthquake depth (0-70 km), and a moderate earthquake (70-300 km). Figure 2 shows the earthquake points in red and yellow. The red points have a depth value of 0 -70 km, including in the category of shallow earthquakes. Shallow earthquakes are categorized as destructive earthquakes because they are very close to the surface. The yellow earthquake points indicate a depth of 70 - 300 km, which is classified as a moderate earthquake. Many shallow earthquakes are scattered in Suwawa Timur. Suwawa Timur has several rock formations. Earthquakes that pass through non compact rocks can be destructive.
The magnitude of the earthquake consisted of six classes, namely minor (3 - 3.9), light (4 - 4.9), moderate (5 - 5.9), strong (6 - 6.9), major (7 - 7.9), and great earthquake (8 or more). Suwawa Timur is dominated by minor earthquakes and light earthquakes (figure 3). The northern part has one of the magnitude point with a moderate earthquake category. Lithology conditions related to earthquake magnitude. Non-compact rock lithology has a higher risk of vibrating than solid rock. There needs to be vigilance regarding the non-compact lithology in the Suwawa Timur area. Geological structure can affect the magnitude of the earthquake value. An earthquake that occurs at a fault causes a damaging earthquake. Several earthquakes in the Suwawa Timur area occurred in the fault zone. This indicates that the East Suwawa area is an earthquake prone area.

Figure 2. Seismicity map based on depth earthquake.

Figure 3. Magnitude-based earthquake distribution map.
The depth of the earthquake in Suwawa Timur is clearly visible on the depth zonation map (figure 4). The map color scale shows the earthquake depth value. Purple to blue colors are shallow earthquakes, green to orange are moderate earthquake, yellow to red are deep earthquake. This zone is associated with the epicenter of the earthquake depth spread over the Suwawa Timur area.

Figure 4. Earthquake depth zonation map

The central part of Suwawa Timur District is dominated by minor earthquakes (0.2 - 3.8) with a light purple - yellow color (figure 5). The northern, southern, eastern, and western regions are dominated by light earthquakes (4 - 4.8) and moderate earthquakes (5 - 5.8) with orange-red color. The magnitude of the earthquake is influenced by the focus or hypocenter where the earthquake energy propagates and vibrates. Earthquake zoning with minor magnitude is in the middle of the study area. The middle part of the research area based on the zoning magnitude is an area that has low vulnerability.

Figure 5. Earthquake magnitude zonation map
4. Conclusion
The results of seismicity analysis of Suwawa Timur show that the geological structure and lithology of rocks affecting earthquakes that occur in Suwawa Timur. Suwawa Timur has shallow earthquake points (0 - 70 km) and medium earthquake points (70 - 300 km). Suwawa Timur is dominated by minor earthquakes (0.0 - 3.9), light earthquakes (4 - 4.9), and there is one point of a moderate earthquake (5 - 5.9). The energy and force of the earthquake that spread in Suwawa Timur are clearly visible on the zonation map.

Acknowledgements
We would like to thank the Geological Engineering Lab assistants, Yasin Septian, Nova Payuyu, and Wa Ode Ami for their help in this research.

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