Identification of subsurface soil layers in Sutami Dam area and its surroundings using magnetic methods

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Abstract. The research was conducted to determine the subsurface layer type in the Sutami Dam area using magnetic methods. This study aims to determine the subsurface soil type in the area around the Sutami Dam. The instrument used in data collection was the Proton Precession Magnetometer (PPM) Scientrex Model G-8. The data collection area covers the Kromengan region (11°2.494′E; 8°12.9′S) to the Sukorame area (11°2.358′E; -8°21.3′S). The area covers the Sutami Dam area. The research area is 15 km x 15 km or with an area of 225 KM with a space between points 300 m. From the data acquisition, it was found that the number of data collection points was 1372 points. The types of subsurface layers based on the 2,5 D Talwani modeling are soil, pumice, limestone, sandy tuff, sandstone, andesite, and lava.

1. Introduction
Sutami Dam is a dam located in Karangkates Village, Sumberpucung District, Malang Regency. Sutami Dam is a dam that was built Sutami Dam is a dam that was built in 1964-1973 and started operating in 1977 [1]. Sutami Dam has an embankment length of about 800 meters and a top width of 13.7 meters. The road at the top of the Sutami Dam connects Sumberpucung District and Kalipare District. The Dams based on the geological map of the Lembar Blitar, Karangkates Village is in a tuff deposit unit. The rocks in this unit consist of tuff, lapilli tuff, pumice, and lava. Moreover, the Sutami Dam is located in the contact area between limestone and andesite lava deposits, and is in the shear fault area around Pohgajih [2]. This dam is also located in an earthquake-prone area [1].

Based on previous research, the sutami dam is in an area prone to soil movement [3]. Meanwhile, in the western part of Sutami Dam, there is a weak zone which is indicated by the local shear fracture, Selorejo local fault, and the limestone-andesite contact area [4]. The results of the study using Peak Ground Acceleration (PGA) data, the Lahor Dam, which is located near to the Sutami Dam, has a vulnerable area. The location of the prone areas is on the side of the dam body and the wall of the dam on the side of the sewer [5]. So, it is necessary to research with further geophysical methods to determine the type of subsurface soil with a wider area coverage.
One of the geophysical methods that can be used to determine the type of subsurface soil layer in the Sutami Dam is the magnetic method. The magnetic method is used to determine variations in the magnetic field in the study area. This magnetic field variation arises due to the non-homogeneous nature of magnetism in the earth's crust [6]. The magnetic methods are often used to determine the type of subsurface soil due to changes in lithology and variations in the body of magnetic objects [7]. Besides that, magnetic methods can determine subsurface depth and structure, that can obtain a clearer local and regional anomalies [8], mapping of archaeological objects [9], geothermal structures [10], distribution of subsurface waste contaminants [11], and detect subsurface faults [12].

Based on the description above, therefore, a study entitled “Identification of the types of subsurface soil layers in Sutami Dam area and its surroundings using magnetic methods”. This research was conducted to determine the type of subsurface soil layers in the Sutami Dam area and its surroundings by measuring the variation of the magnetic field in the study area. This study will present the results of research using magnetic methods both in qualitative and quantitative interpretations.

2. Methods
Some of the steps taken in this study were data acquisition, processing, and interpretation, including modeling of subsurface structures to determine the types of subsurface layers. The instrument used in the data collection process was the Proton Precession Magnetometer (PPM) Scientrex Model G-8. The data collection area covers the Kromengan region (112.494°E; 8.129°S) to the Sukorame area (112.358°E; -8.213°S). The area covers the Sutami Dam its surroundings. The area of the research area is 15 km x 15 km or with an area of 225 km² with a space between points 300 m. From the data acquisition, it was found that the number of data collection points was 1372 points. In the data collection process, the method used was the looping method, hence the daily variation value can be controlled. The values obtained in data collection include magnetic field intensity, latitude and longitude position, altitude, and time.

Data processing was conducted by making some corrections to the data acquisition results. Daily corrections are corrections made to correct for temporary changes in the earth's magnetic field. Daily correction (diurnal correction) occurs due to deviations in the value of the earth's magnetic field due to time differences and the effects of solar radiation in one day. Earth's magnetic field values differ during the day and night. Correction due to the influence of the main magnetic intensity of the earth was performed with the correction of the International Geomagnetic Reference Field (IGRF) which is usually updated every 5 years. IGRF corrections was performed using calculations from the NGDC which was accessed online. The parameters needed to obtain the IGRF value were the latitude and longitude position data of the measurement acquisition point, the height, as well as the date, month, and year of measurement. The output obtained was the declination, inclination, horizontal intensity, magnetic field on the x, y, and z components, as well as the total magnetic field anomaly value. The residual anomaly was obtained by reducing the data on the topography by reducing the data to the even surface (XY) through the continuity mechanism [4].

The data interpretation used qualitative and quantitative methods. Qualitative methods were used to determine the horizontal boundaries of the anomaly target by reading total magnetic intensity contour map. Qualitative interpretation must also be using judgment of geological map on the local sheet to get the interpretation that valid the local circumstances [4]. Quantitative methods were used to determine the type of subsurface layer obtained by modeling and adjusted to the geological map of the study area. The modeling used was 2,5 D Talwani method.

3. Results and discussion
Magnetic field anomaly is the value of its magnetic field generated by subsurface rock that is the target of the measurement. The contours of the total magnetic field anomaly describe general subsurface geological conditions caused by anomalies shallow sources and deep sources. Total magnetic field anomaly data is obtained from the total magnetic field data measured in the field which has corrected the external magnetic field or diurnal corrections and the earth's main magnetic field correction or IGRF.
Based on the total magnetic field anomaly (Figure 1), the anomaly difference obtained ranged from -210 nT to 554 nT. The figure shows the presence of positive and negative closures. This positive and negative closure pair indicates that the field anomaly magnetic is a dipole.

**Figure 1.** Total magnetic intensity contour map.

Based on the range of total magnetic (figure 1) anomaly values, it can be grouped into 2 groups, i.e. low anomaly, and high anomaly. High anomaly in the southern part is shown in yellow to pink with a value range of 226.7 nT to 554.0 nT. This anomaly is expected to be andesite to basalt lava and porphyry latite of the Mandalika Formation (Tomm), with tuff members of the Mandalika Formation (Tomt) in the form of tuffs composed of dacite and rhyolite. The Mandalika Formation stretches approximately 15 km from the south coast of Blitar. And the presence of a high anomaly in the northeast is expected to be part of the Mount Kawi lava dome. Low anomaly in the northern part is shown in blue to green with values ranging from -210 nT to 209.5 nT. This anomaly is a combination of several formations, consisting of the Campurdarat Formation, Wuni Formation, Nampol Formation, and Wonosari Formation. Campurdarat Formation (Tmcl) is in the form of limestone and claystone. Wuni Formation (Tmw) consists of breccia, lava, andesitic-basaltic lava with coarse calcareous tuffaceous intercalation. Nampol Formation (Tmn) is in the form of sandstone, sandstone clay, sandy stone, tuffaceous sandstone, and calcareous limestone.

An A-A’ 2.5 D Talwani model was slice on the residual anomaly to obtain a subsurface model (Figure 2). The modeling results (Figure 3) reveal that there are 5 bodies in the study area. The first body is soil and pumice which has a susceptibility of 0,1x10^-3. The second body is a sandy tuff which has a susceptibility value of 6,8x10^-3. The third body is limestone with rock susceptibility of 5,7x10^-3. The fourth body is sandstone and andesite with a susceptibility value of 0,8x10^-3; 75,6x10^-3. The last layer is lava which has a susceptibility value of 75,6x10^-3.
4. Conclusion
Based on the results of the research that was conducted, it can be concluded that the total magnetic anomaly value ranges from -210 nT to 554 nT and is classified into a high anomaly and low anomaly.
High anomalies in the southern part are shown in yellow to pink with a value range of 226.7 nT to 554.0 nT. This anomaly is expected to be andesite to basalt lava and porphyry latite of Mandalika Formation (Tomm), with the tuff members of Mandalika Formation (Tomt) in the form of tuffs composed of dacites and rhyolites. While the low anomaly in the north is shown in blue to green with a value range of -210 nT to 209.5 nT. Which is a combination of several formations, consisting of the Campurdarat Formation, Wuni Formation, Nampol Formation, and Wonosari Formation.

The qualitative interpretation was performed based on the results of the 2.5-D Talwani model, slice A-A' showing that there are 5 bodies in the study area. The first body consists of soil and pumice which has a susceptibility of 0,1x10^-3. The body consists of a sandy tuff that has a susceptibility value of 6,8x10^-3. The third body consists of limestone with rock susceptibility of 5,7x10^-3. The fourth body consists of sandstone and andesite with a susceptibility value of 0,8x10^-3; 75,6x10^-3. The last fifth body is lava with a susceptibility value of 75,6x10^-3.

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