The use of anomaly data in identifying faults in Sedoa village, Poso district

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Abstract. A magnitude (Mw) 6.6 Earthquake occurring on 29 May 2017 in Poso shows that there are active faults in these regions. In addition to Palu-Koro fault which is the major fault in the island of Sulawesi, one of secondary faults that may trigger earthquakes is a fault in Lore Utara Subdistrict, Poso District. This fault has been identified using magnetic anomaly in Sedoa Village Lore Utara Subdistrict. A measurement was done to obtain magnetic field intensity data and measurement time at base stations and position data at mobile stations. The data obtained was subjected to IGRF correction and diurnal variation correction. The result of the research shows different susceptibility (k) values with 0.00017 SI for clay rocks, 0.0209 SI for muddy sandstone, and 0.05 SI for granite rocks. This research also shows the existence of subsurface geological structures in Sedoa Village, Poso District, in the form of two normal faults in different directions. The first fault runs from Southeast toward Northwest and the second one runs from Northeast to Southwest.

1. Introduction

An earthquake with a magnitude of 6.6 Mw had shaken Poso District and surrounding on 29 May 2017 and devastated hundreds of houses, worship places, and office buildings. The location of this earthquake was at the coordinate of 1.33°S and 120.41°E. One of areas affected by the earthquake was Sedoa Village, Lore Utara Subdistrict, Poso District. The epicenter of the earthquake located southwest of this location.

The region of Sedoa Village, Poso District is affected by geological structures that develop in Sulawesi region. The presence of major faults such as Palu-Koro Fault and Poso Fault plays a role in the formation of local faults. These local faults can be found around the area of Sedoa Village. In fact, these faults are quite active, if based on earthquake data, including Poso earthquake on 29 May 2017. The earthquake is considered as part of local fault activity in Poso District.

Based on Geologic Map of Poso, Sulawesi Quadrangle, there are two faults that cut the region of Sedoa Village [1]. These faults appear to intersect with each other. One of the faults runs from Northeast to Southwest in Sedoa Village and is intersected at the formation of lake sedimentary rocks. The intersected fault is identified through a study to endure the subsurface condition.

A fault is a fracture structure that has undergone displacement [2]. Generally, it is accompanied with other structures such as folds, fractures and so on. The indications on the field that signify the
presence of faults are a fault scarp, breccia, gouge, mylonite, a chain of springs, hot springs, bedding attitude displacement and minor structural phenomenon such as fault mirrors, slickensides, folds and so on [3].

The Geological Map of Poso, Sulawesi Quadrangle also shows that rocks in Sedoa Village and surrounding areas, which are a lake sedimentation area, are clay, silt, sand, and gravel. The data also shows that the area of Sedoa Village and surrounding is passed by fault routes with normal characteristics [1]. The data needs further research to determine the subsurface condition, especially the geological structure models at this location. Faults that cut across Sedoa Village area are presented in figure 1.

![Geological Map of the research location](image)

**Figure 1.** Geological map of the research location

The geomagnetic method is one of the geophysical methods that utilizes the nature of the Earth's magnetism in examining objects beneath the earth's surface [4,5]. Data obtained from this method is contours illustrating the distribution of susceptibility of subsurface rocks [6–9]. In the geomagnetic field survey, the target of the measurement is magnetic field variations measured on the surface (magnetic anomaly). Broadly speaking, magnetic field anomaly is caused by remanent magnetic field and induction magnetic field [10–12].

To identify subsurface geological structures based on magnetic data, an interpretation technique is needed. There are several magnetic data interpretation techniques, one of them is forward modelling interpretation technique [13,14]. Therefore, forward modelling technique is done to identify subsurface geological structures such as fault types that run across Sedoa Village, Poso District.

The modelling of 2D forward is an approach based on geological intuition, magnetic field observations, theoretical magnetic fields (IGRF-International Geomagnetic Reference Field), and diurnal magnetic field, so that interpretation on subsurface objects can be carried out [15]. In this interpretation, a model is sought out that can generate responses that match the observation data. Thus, the model represents the subsurface condition [16].

Forward modelling with magnetic data is done on anomaly caused by objects with certain geometry and magnetism value. To obtain suitability between theoretical data (model response) and field data, trial and error process may be undertaken by altering model parameter value [17].
2. Research Methods

The research was done in Sedoa Village, Poso District, Central Sulawesi Province. The coordinate for this research location was 1.34350°S, 120.337310°E to 1.34350°S, 120.34683330°E and 1.35294440°S, 120.34686110°E to 1.35291670°S, 120.337250°E, as shown in figure 2.

This study used geomagnetic method which is one of geophysics methods. In geomagnetic measurement, the instrument position used is divided into two. The first position is base station position or stationary position and the other one is mobile station or moving position. The site for base stations must be away from objects that can cause noises to obtain accurate data. The data at base stations is measured at a measurement time interval of every 10 minutes and contains magnetic field intensity measured in the instrument in accordance with the measurement time interval. In mobile stations, the first thing to do is determining grid position of the measuring point so that the data obtained is the coordinates and elevations of every measuring point site. Then, magnetic field intensity measurement is done three times at each measuring point with the same time interval as base stations.

Figure 2. Research location

The subsequent step is processing the data, starting with diurnal variation correction (HVH) which is a correction of magnetic fields due to influence from outside the earth and IGRF correction (HIGRF) which is a correction of magnetic fields due to influence from inside the earth, yielding a total magnetic field, $\Delta H$, purely from measurement [19–22]. The formula used for total magnetic field anomaly is (Eq.1)

$$\Delta H = H_{obs} - H_{IGRF} - HVH$$  (Eq.1)
Total magnetic field obtained after correction is total magnetic field anomaly. Furthermore, a contour map is made and paths are made on it as input for 2D modeling. 3D imageries are also made to help interpretation. The next process is the analysis and interpretation of geological structure model and subsurface rock types based on obtained model.

3. Results and Discussion
The results of measurements of magnetic field values that have been obtained from the field are magnetic anomaly values that still carry the influence from inside and outside the earth (Hobs). Therefore, two corrections are needed to obtain magnetic anomaly values that are free from the influence of earth’s magnetic fields. Diurnal correction to obtain values that are free from earth’s external magnetic fields and IGRF correction to obtain values that are free from earth’s internal magnetic fields [23]. After those corrections, a total magnetic anomaly value (ΔH) is obtained which is a target of magnetic field measurement. Total magnetic anomaly (ΔH) is presented in anomaly contour map (figure 3).

The 2D modelling is done with GM-SYS software from Geosoft by inputting parameter values of intensity, inclination, declination, depth used in the creation of subsurface modelling. Subsurface structure modelling is done by connecting 2 parameters, namely the result of magnetic anomalies and geological data of the research location, which aims to obtain modelling results that are suitable with the conditions in the field. Based on the condition of the research location in which there are several indications of geological structures such as hot springs, springs, a river that cuts through the research area, damaged buildings due to bedding attitude displacement during the earthquake, and a fault that appears to be intersected in Geological Map of Poso Quadrangle (figure 1), traverses are made in the research location. In this study, 5 traverses were made, which will reconstruct subsurface model by connecting total magnetic anomaly value and research location geological data.

![Figure 3. Total magnetic anomaly contour (ΔH)](image-url)
In Figure 4 and Figure 5, there are 5 traverse profiles. These profiles show traverse direction that passes total magnetic anomaly distribution and rock distribution in the research location. One traverse was made across a hot spring (BB’ Traverse) with a relatively north-south direction, the DD’ and EE’ traverses were made across an area where buildings were damaged by the Poso earthquake on May 29, 2017, while the AA’ traverse crossed a river channel in Sedoa Village. CC’ Traverse was made diagonally across the research location to show subsurface model imageries in the direction different from other traverses.

**Figure 4.** Traverses profiles on the geological map

**Figure 5.** Traverse profiles on total magnetic anomaly contour map

From the results of the AA’ traverse modeling (Figure 6), a total magnetic anomaly error value of 4.99% is obtained and 3 rock distributions have different susceptibility values with interpretation depths of up to 2.06 Km. The first bedding indicated with grey color has a susceptibility (k) value of 0.00017 SI. The rock has minimum depth and thickness of around 0.001 Km and height of around 0.691 Km, stretching from 0.464 Km up to 1.01 Km. These rocks are interpreted as claystone.

The second bedding, presented with green color, has a susceptibility value of 0.0209 SI. The rock has varied depths, the lowest being 0.002 Km up to 1.059 Km at the highest. The thickness also varies

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The second bedding, presented with green color, has a susceptibility value of 0.0209 SI. The rock has varied depths, the lowest being 0.002 Km up to 1.059 Km at the highest. The thickness also varies
from around 0.024 Km to 0.369 Km. These rocks are thought to be muddy sandstone that stretches along the AA’ traverse.

The third bedding, presented with red color, has a susceptibility value of 0.05 SI. The rock has varied depths, the lowest being 0.025 Km up to 1.06 Km at the highest. The thickness also varies from around 0.696 Km to 2.035 Km. These rocks are thought to be granite that stretches along the AA’ traverse.

![Figure 6. Subsurface structural model of AA’ traverse](image)

BB’ traverse cross section line was drawn across hot spring sources in the research location as an indication of a fault. From BB’ traverse modelling, a fairly good total magnetic anomaly error value of 3.89% was obtained. Based on 2D modelling results on BB’ traverse (figure 7), 3 rock distributions with different susceptibility values were obtained with an interpretation depth up to 3.547 Km. The first bedding shown in grey color has a susceptibility value of 0.00017 SI. The rock has a depth of around 0.005 Km and has varied thicknesses ranging from 0.874 to 3.546 Km. The distribution of this rock is divided into two parts, stretching from 0 Km to 0.417 Km and 0.5 Km to 1.006 Km. These rocks are interpreted as claystone.

The second bedding, presented with green color, has a susceptibility value of 0.0209 SI which is the same as the second bedding in AA’ traverse cross section. This bedding is thought to be muddy sandstone that stretches along the BB’ traverse. The depth and thickness of these rocks vary. The first depth is 0.036 Km with a thickness of 0.223 Km. The second and the third depths are 0.444 Km and 1.675 Km, respectively, with a similar thickness of 0.495 Km.

The third bedding, presented with red color, has a susceptibility value of 0.05 SI. The rocks have varied depths, the lowest being 0.023 Km, 1.058 Km up to 2.481 Km at the highest. The thickness also varies from around 1.066 Km, 2.489 Km to 3.234 Km. These rocks are thought to be granite that stretches along the BB’ traverse. CC’ traverse cross section line was drawn diagonally across the research location toward Northwest to show subsurface model in a direction different from other traverses (AA’, BB’, DD’ and EE’ traverse). From the CC’ traverse modelling (figure 8), a total magnetic anomaly error value of 3.64% was obtained with 3 rock distributions that have different susceptibility values with a depth up to 3.131 Km. The first bedding indicated with grey color has a susceptibility value of 0.00017 SI. The rocks have minimum depth and thickness of 0.031 Km and a height of around 2.023 Km, stretching along CC’ traverse. These rocks are interpreted as claystone.
The second bedding indicated with green color has a susceptibility value of 0.0209 SI. This bedding is thought to consist of muddy sandstone that stretches across CC’ traverse. The depth and thickness obtained across the CC’ traverse vary, ranging from 0.038 Km to 0.329 Km with a similar thickness of 0.409 Km. While at a depth of 0.913 Km, the thickness is around 0.569 Km.

![Figure 7. Subsurface bedding structural model of BB’ traverse](image)

The third bedding, indicated with pink color has a susceptibility value of 0.05 SI. Based on its susceptibility value, presumably in this bedding there are types of granite that stretch along the CC’ traverse. These rocks have a depth of around 0.255 Km and at this depth, the thickness is 0.539 Km. while at the depth of 2.592 Km, the thickness is 2.876 Km.

DD’ traverse was made across the location where there are damaged buildings in the research location. It is located in West of the research location and intersected by CC’ traverse. From the DD’ traverse modelling, total magnetic anomaly error value of 3.59% was obtained. Based on 2D modelling results (figure 9), 3 rock distributions were obtained with different susceptibility values with an interpretation depth up to 2.022 Km. The first bedding, grey color, has a susceptibility value of 0.00017 SI. These rocks have a minimum depth and thickness of 0.028 Km and a height of 1.04 Km, stretching along the DD’ traverse. These rocks were interpreted as claystone.

The second bedding, indicated with green color as in figure 10, has a susceptibility value of 0.0209 SI. Based on its susceptibility value, these rocks are thought to be muddy sandstone that stretches along the DD’ traverse. Based on the results, this bedding has varied depth and thickness. At a depth of 0.028 Km, the thickness is 0.092 Km, while at the depth of 0.577 Km, the thickness is 0.507 Km.

The third bedding, indicated with pink color has a susceptibility value of 0.05 SI. These rocks are thought to be granite that stretches along the DD’ traverse. Based on the results, this rock type has varied depth, around 0.120 Km to 2.022 Km. The thickness of this bedding also varies, from 0.727 Km to 1.902 Km. EE’ traverse is located exactly in the center of the research location from North to South/N 180° and intersected by CC’ traverse. Based on 2D modelling results (figure 7), 3 rock distributions with different susceptibility values were obtained with an interpretation depth up to 2.415 Km. The first bedding, indicated with grey color, has a susceptibility value of 0.00017 SI. The rocks have a minimum depth and thickness of 0.004 Km and a height of 1.602 Km, stretching from 0 Km to 0.419 Km and 0.500 Km to 1.004 Km. These rocks are interpreted as claystone.
The second bedding, indicated with green color as in figure 10, has a susceptibility value of 0.0209 SI. The rocks have varied depths, the lowest being 0.004 Km up to 1.602 Km at the highest. The thickness also varies from around 0.362 Km to 0.733 Km. These rocks are thought to be muddy sandstone that stretches along the EE’ traverse.

The third bedding, indicated with pink color, has a susceptibility value of 0.05 SI. The rocks have varied depths, the lowest being 0.272 Km up to 2.335 Km at the highest. The thickness also varies from around 0.08 Km to 2.143 Km. These rocks are thought to be granite that stretches along the EE’ traverse.
The modelling was done through several iterations until suitability was obtained between magnetic data response model and measurement data response with error percentage of less than 5%. Two-dimensional (2D) model of rock bedding distribution was created up to the depth of ±3 km. After the 2D subsurface modelling was obtained, a geological structure in the form of faults that bordered the contact between rock units was found. The shape of faults formed from the overall modelling was normal faults with varied depths and they can be seen in AA’, BB’, CC’, DD’ traverses modelling (figure 6 until figure 10). The geological structure was presumed to be normal faults because there were fractures that underwent depression on the rock bedding. The normal faults obtained did not appear on the surface of the research location. This was due to the rock bedding that underwent depression was covered with rock bedding over it. By referring to fault location points on each cross-section traverse and connecting them with Geological Map, fault images in the form of red-colored traverses like in figure 11 were obtained.

![Image]

Figure 10. Subsurface bedding structural model of EE’ traverse

![Image]

Figure 11. Normal fault profiles in the research location on geological map
Figure 11 shows two fault traverses in different directions. The first fault traverse intersects the AA’ and CC’ traverse that run from the Southeast to the Northwest direction, while the second fault traverse intersects the AA’, EE’, DD’, CC’ and BB’ traverses that run from Northeast to Southwest. After reaching the DD’ traverse, the direction changes to the Northwest past the CC’ and BB’ traverses. Based on figure 11, it is assumed that the two normal faults obtained from the modeling results are a continuation of the local faults that were around the research location.

The making of 3D imagery model in this study was done using RockWorks 16 software. Below is the view of 3D imagery model. From the results of the 3D model, the CC traverse intersects AA’, BB’, DD’ and EE’ (figure 12 until figure 13) traverses and shows the overall subsurface shape in the study location. Figure 12 shows the condition of the study location in the form of a 3D view from the South and East directions, while in figure 13 the condition of the study location is shown in the form of a 3D view from the West and South directions. Based on the results of the 3D cross section model, it appears that the entire study location consists of 3 types of rock bedding distribution. The three types of rock bedding are claystone, muddy sandstone and granite. Geological structure is also shown from the results of this modeling in the form of a normal fault that appears to intersect the area of the study location, where the fault location tends to be in the southern area of the study area.
4. Conclusion
Based on the result of the modelling, it can be concluded that there are 2 geological structures in the form of 2 normal faults in the different directions. The faults are thought to be a continuation of local faults in Sedoa Village. There are 3 types of rocks in Sedoa Village subsurface bedding structure. They consist of claystone with a susceptibility (k) value of 0.0017, muddy sandstone with a susceptibility (k) value of 0.0209 SI and granite with a susceptibility (k) value of 0.05 SI.

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References
[1] Simanjuntak T O, Surono, and Supandjonu J 1997 Peta Geologi Lembar Poso, Sulawesi
[2] Peacock D C P, Nixon C W, Rotevatn A, Sanderson D J, Zuluaga L F 2016 J Struct Geol. 92 12-29.
[3] Noor D. 2009 Pengantar Geologi. Bogor: Pakuan University, Bogor.
[4] Hasibuan J, Berutu A, Saktidah H, and Rahmatsyah R 2017 Studi Penentuan Anomali Situs Purbakala di Tapanulu Tengah Dengan Metode Geomagnetik. (Wahana Visi: Indonesia)
[5] Rusydi M, Efendi R, Hermanto Y, Rugayya S, Hendra S, and Ngembas R H 2019 American Research Journal of Humanities Social Science
[6] Hakim A R, Susilo A, and Maryanto S 2014 Nat B. 2 281 - 289
[7] Harahap M A T and Tampubolon T 2017 Einstein E-Journal 5 1-6
[8] Octavani A S and Kadri M 2018 Einstein E-Journal 6 1-7
[9] Soemantri D D 2003 Laporan Kuliah Lapangan Geofisika (Kebumen: Indonesia)
[10] Schubert G and Soderlund K M 2011 Phys Earth Planet Inter. 187 92-108
[11] Telford W M, Geldart L P, and Sheriff R E 1990 Applied geophysics Second Edition. University of Cambridge
[12] Walker M M, Dennis T E, and Kirschvink J L 2002 Current Opinion in Neurobiology 12 735-744
[13] Junursyah G M L and Rahmat W 2019 Jurnal Geologi dan Sumberdaya Mineral 20 57-83
[14] Nurdin N H, Massinai M A, and Aswad S 2017 Jurnal Geocelbes 1
[15] Thébault E, Finlay C, and Toh H. 2015 Earth, Planets, and Space 67 79
[16] Deniyatno 2010 Pemodelan Kedepan (Forward Modeling) 2 Dimensi Data Magnetik untuk Identifikasi Bjih Besi di Lokasi X Propinsi Sumatera Barat (Universitas Haluoleo, Indonesia)
[17] Grant F Sand West G F 1965 Interpretation theory in applied geophysics
[18] Campbell W H and Banerjee S K 1998 Phys Today 51 55
[19] Finlay C C, Maus S, Beggan C D, Bondar T N, Chambodut A, Chernova T A, et al. 2010 Geophys J Int. 183 1216-1230
[20] Mandea M and Macmillan S 2006 Earth, Planets, and Space 52 1119-1124
[21] Monster M W L, de Groot L V., Biggin A J, and Dekkers M 2015 J. Phys Earth Planet Inter 242 36-49
[22] Olsen N, Sabaka T J, and Tøffner-Clausen L 2000 Earth, Planets, and Space 52 1175-1182
[23] Campos-Enriquez J O, Hernandez-Quintero E, Nolasco-Chávez H, Orozco-Torres A, Cañon-Amaro C, Alvarez-García G, et al. 1994 Phys Earth Planet Inter. 82 105-111