Science Education and Application Journal (SEAJ)
Program Studi Pendidikan IPA
Universitas Islam Lamongan
http://jurnalpendidikan.unisla.ac.id/index.php/SEAJ

March, 2021. Vol. 3, No, 1
p-ISSN: 2656-6672
e-ISSN: 2656-8365
pp. 36-44

Application of Magnetic Methods for Estimating Subsurface Rocks

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Article Info

Article History
Received: 03 February 2021
Revised: 18 February 2021
Published: 25 March 2021

Keywords
Magnetic anomaly, Proton precession magnetometer (PPM), north Pura, rock susceptibility.

Abstract

The magnetic method has been applied to the estimation of subsurface rocks in North Pura, Alor Nusa Tenggara Timur (NTT). The magnetic survey was performed using Proton Precession Magnetometer (PPM) type G-19T and measured on 54 magnetic stations. The magnetic data were processed by diurnal correction, IGRF correction, upward continuation, and 2D data modeling. The results showed that total magnetic intensity ranged from 50 nT to 770 nT. The regional anomaly contour map showed at the research area was dominated by the moderate anomaly. Estimation of subsurface profiles has been 2D forward modeling used regional anomaly of a contour map. The results showed that subsurface rocks in the research area. It's suspected was three types of rock in the research area as the volcanic sandstone, volcanic breccias, and basalt with a contrast susceptibility value of 0.0001 cgs unit, 0.0015 cgs unit, 0.0278 cgs unit, 0.0091 cgs unit, 0.0099 cgs unit, and 0.0134 cgs unit. The research study is expected to provide information for the local government especially in north Pura for in the existence of groundwater, depth and distribution of subsurface rocks.

Citations: Maubana, W.M. & Tanesib, J. L. (2021). Application of Magnetic Methods for Estimating Subsurface Rocks. *Science Education and Application Journal*. (3)1, 36-44

INTRODUCTION

Pura Island is region of Alor Regency, East Nusa Tenggara Province. Pura Island in between Pantar Island in the west, Alor Island in the east, Ternate Island in the north, and Tereweng Island in south (Dinkes Provinsi NTT, 2009). Pura Island is a volcanic island that is no longer active, which is marked by the flow of sulfur gas (Rema & Prihatmoko 2016). Based on information in the geological map of Pantar-Pura (Figure 1), Pura Island is dominated by old volcanic rock formations namely lava, agglomerate, basalt, andesite, pumice rock tuff, volcanic breccia, and volcanic sandstone. The lithology of Pura Island is dominated by andesite volcanic rocks and basalt rocks (Tanesib et al, 2017).

Water is a basic need for human survival, the increasing population of in area requires sufficient amount of water (Saranga et al, 2016). The problem experienced by residents on Pura Island is the lack of water sources so that residents use rainwater and salty well water to supply even though it is of poor quality, besides that its location is far from the city so that it results in residents not getting water supplies such as services PDAM water. This can be seen from the geology of Pura Island which is dominated by volcanic rocks so that it is difficult to get water. Therefore, it's necessary to use technology to convert saltwater into freshwater or subsurface investigations to know the points of groundwater through subsurface rock distribution (Takaeb & Sutaji 2018).

Surface investigations have been using geoelectric, geomagnetic, and satellite imagery methods by (Tanesib et al, 2017) to determine the potential for groundwater based on the interpretation of rock types, depth, the thickness of rocks, and analysis of satellite images to the topographic image of the location and watershed areas (DAS) in sub-district Pura and east

Pura. The results showed that types of aquifers in sub-district Pura were volcanic breccias, tuff breccias, volcanic sandstones, and coral limestones with a thickness of aquifer rock layers at depth of 5m to 68m. Types of aquifers in east Pura are volcanic breccia, tuff breccia, tuff rock, coral limestone insertion, sandstone tuff rock, and volcanic sandstone with a thickness of aquifer rock layers at depth of 60m to 150m. Analysis of satellite imagery obtained water potential areas around the watershed at a distance of 15m to 25m from the coastline.

Based on the description, it's necessary to furthermore research in north Pura which is one of the villages on Pura Island. The purpose of the research to determine the subsurface information of north Pura. This research is expected to provide information in the search for water points, depth, and subsurface rock distribution. The geographical position of north Pura is 124.3220 E 124.3350 E and -8.2880 N to -8.2780 N (Google earth, 2015). Figure 1 geological map of Pantar-Pura.

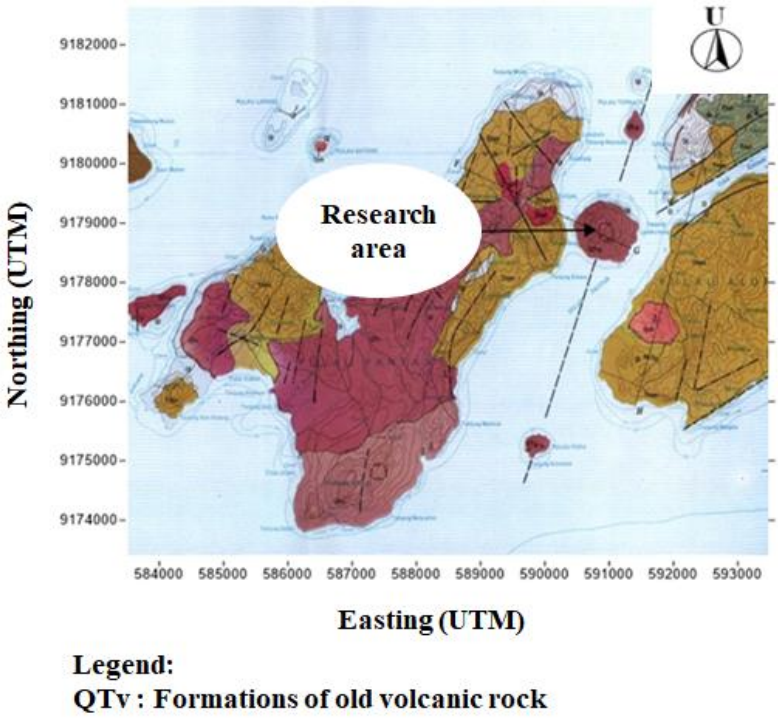

Figure 1. Geological map of Pantar-Pura

Subsurface investigations can be using geophysical methods including geological methods, georadar, geoelectric, geomagnetic, gravity, and so on. Based on these methods, the geomagnetic method is applied to investigate the subsurface of the study area, because of its unique properties for each metallic and non-metallic material (Blakely, 1995).

The geomagnetic method is a geophysical method that utilizes the magnetic properties of the earth. This method is based on measuring variations in magnetic field intensity. This variation is caused by the distribution of rock variations below the earth's surface and changes in the local geological structure (Maubana et al, 2019). The ability of rock or material to be magnetized depends on the susceptibility of each material. The value of susceptibility is influential in the search for anomaly source objects because of its unique properties for each type of metal material and non-metal material (Blakely, 1995).

Based on previous research using geomagnetic methods for subsurface investigation has been by (Anom et al, 2015), (Bakak et al, 2015), (El All et al, 2015), (Fanani, 2014), (Guo et al, 2018), (Lynch, 2011), (Manyoe et al, 2015), (Nurdin et al, 2017), and (Takaeb & Sutaji, 2018), the resulting research showed that geomagnetic methods are proven to be reliable in investigating subsurface materials.

The purpose of the geomagnetic survey is to find out information on the subsurface of north Pura. The results showed a sub-surface magnetic anomaly pattern of the study area. Based on the magnetic anomaly, subsurface rock estimates can be mapped.

METHODS

Magnetic Data Measurement

The magnetic survey was performed using Proton Precession Magnetometer (PPM) type GSM-19T is a versatile and easy-to-use instrument for sub-surface investigations and exploration. Proton system is designed for clients who need a low cost, however magnetometer for geophysical surveys of versatile and accurate with a sensitivity of 1nT (Wirasantosa, 1984). GPS (Global Positioning System) for directions, recording coordinates (latitude and longitude) and elevation, clocks for a time in the field, notebook to take notes the magnetic anomaly values, cameras to take geological of the study area, surfer software to create contour maps of a magnetic anomaly, magpick software used to the upward continuation, and software mag2DC for windows is used to 2D subsurface modeling in the study area (Indrarini Wulandari et al, 2017). Magnetic data acquisition in the study area using PPM type GSM-19T was has been randomly or in a grid system with intervals between distances ranging from 5-10 meters. There are 54 measuring points spread in the study area (Figure 5). Data mensurement obtain are in total magnetic intensity, time, latitude, longitude, and elevation. Correction of magnetic data includes diurnal correction and IGRF correction.

Magnetic Data Processing

The magnetic data that has been obtained is then processed to obtain the total magnetic anomaly. There are several corrections that used diurnal corrections and IGRF corrections. Diurnal correction must be done in order to eliminate differences in measurement time and the effect of sunlight in a day which causes deviations in the earth's magnetic field (Nurdin et al, 2017). The formula for calculating the diurnal correction (Maubana et al, 2019):

$$H_D = \frac{t_n - t_{base}}{t - t_{base}}(H - H_{base})$$

H_D = diurnal correction,
t_n = time at point n,
t_{base} = time at the start and end point,
H = the magnetic field value at the end point and
H_{base} = the magnetic field value at the starting point

IGRF (International Geomagnetic Reference Field) corrections are required to eliminate internal earth effects using the magnetic field calculator on the website NOAA (National Oceanic and Atmospheric Administration). IGRF value 44260,2 nT, inclination -32.5 and declination 1.7. Diurnal corrected and IGRF correction is followed by upward continuation. The upward continuation process aims to eliminate the effect of local magnets originating from various sources of magnetic objects scattered over the topographic surface (Darmawan et al, 2012). Upward continuation is obtained from field data that has been reduced to a flat plane. The result of the upward continuation process at a certain height is a regional anomaly (Maryanto et al, 2020). Residual anomaly from the reduction process between the total anomaly and the regional anomaly resulting from the continuation process (Susilo et al, 2017). Residual anomaly has been using in the interpretation and delineation of the subsurface structure in the study area. Information from the residual contour maps is used as consideration to determine the position of the slice data for the interpretation process (Mawarni, 2018).

Figure 2 shows the flowchart for magnetic data processing:

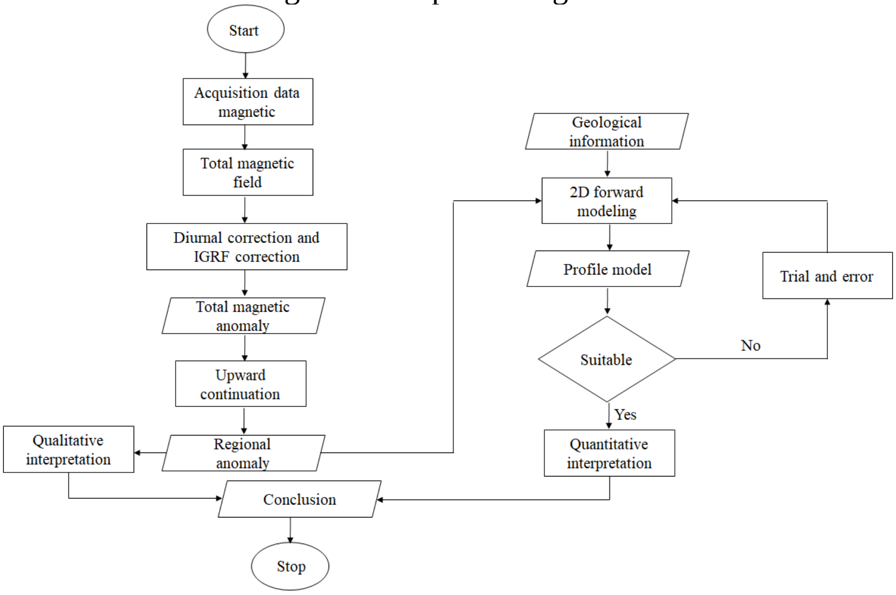

Figure 2. Flowchart for processing magnetic data

The interpretation in this study consists of qualitative interpretation and quantitative interpretation. The qualitative interpretation has been carried out to determine the subsurface structure based on the magnetic intensity value from measured data, by reading the pattern from the regional anomaly contour map (Maubana et al, 2019). Meanwhile, quantitative interpretation has been used to investigate the horizontal depth of the subsurface structures in the study area. Quantitative interpretation is carried out by making a 2D model on the contour map of the regional magnetic anomaly in the study area to determine the subsurface structure which is then obtained (Maryanto et al, 2020). 2D forward modeling by estimating the shape of the rock body. The main parameters are observing the shape of the magnetic anomaly data curve and modeling curve. The parameters were determined by the trial and error method to get a match between the two curves (Abdulkadir & Eritro 2017).

RESULTS AND DISCUSSION

Figure 3 shows the distribution of the total magnetic intensity in the study area ranging from 50 nT to 770 nT. The difference in the value of total magnetic intensity is caused by differences in mineral content in the rock below the surface in the study area (Afandi et al, 2016).

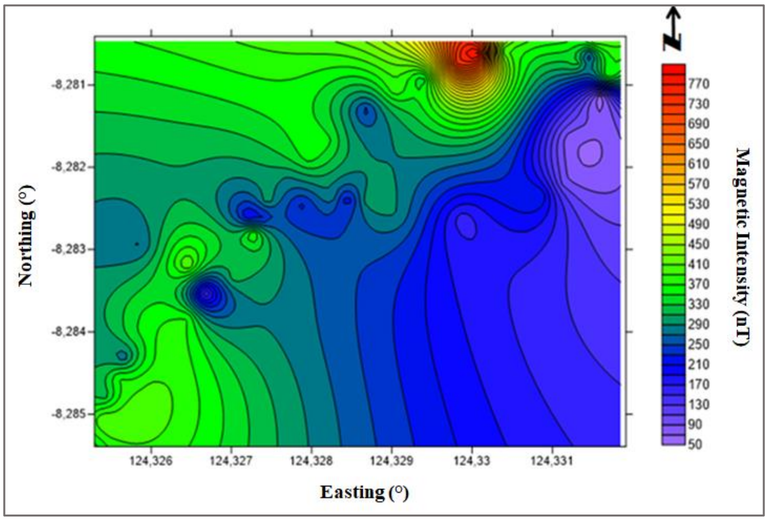

Figure 3. Total magnetic anomaly contour map in the study area

Regional magnetic anomalies are caused by broad and deep geological structures (Juniarti E, 2017). Residual anomalies explain a clearer distribution and more specific subsurface geological structures (Maubana et al, 2019). In this study area, a regional magnetic anomaly is used because the research target is to determine the subsurface geological structure which is quite extensive (Telford et al, 1990).

Qualitative Interpretation

Based on the regional anomaly contour map of the study area (Figure 4) shows that the magnetic intensity ranges from -250 nT to 550 nT that are spread out in the study area. There are three anomaly patterns, namely, high anomalies with a value range of 550 nT to 200 nT, moderate and low anomalies with a range of values from 190 nT to -250 nT. High magnetic anomalies have high magnetic susceptibility values which also indicate the presence of magnetic minerals under the surface (Broto, 2011). Rocks that have a high susceptibility value include volcanic rock in the form of igneous rock whose formation process comes from intrusive and extrusive freezing magma (Patya et al, 2019). Medium-low magnetic anomaly indicates the presence of grabens (Maubana et al, 2019).

Regional anomaly contour map analysis is done by correlating with geological map information. Based on geological map information (Figure 1) the study area is dominated by old volcanic rock formations (QTV), namely lava, agglomerate, basalt, andesite, pumice rock tuff, volcanic breccia, and volcanic sandstone (Tanesib et al, 2017).

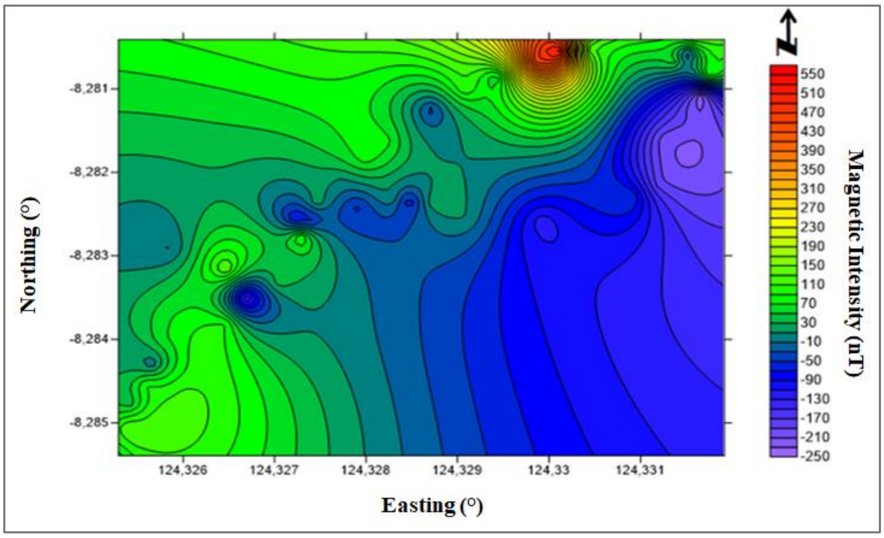

Figure 4. Regional anomaly contour map in the study area

Quantitative Interpretation

The determination of the slices in the regional anomaly contour map is correlated with the geological map of the study area (Figure 1). These incisions represent subsurface information in the study area. The incision is sliced from positive anomaly to negative anomaly (dipole pair) which is suspected as the source of the magnetic anomaly on the regional magnetic anomaly contour map. The incision is placed over the zone which is thought to be the source of the strongest magnetic anomaly, but must go through the original measuring points and not just the result of interpolation, (Figure 5):

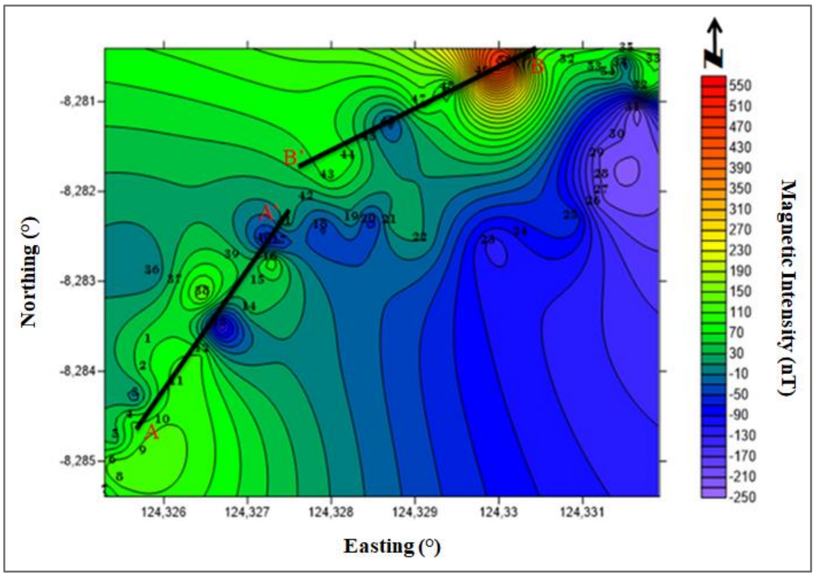

Figure 5. Slices in the regional anomaly contour map

The results of 2D modeling of the A-A' slice and the B B' slice can be seen in Figure 6 and Figure 7. It is suspected that there are three rock types with a susceptibility contrast value of 0.0278 cgs units, which are found in a depth of 200 m to a depth of 300 m. These rocks are thought to be volcanic breccia. In addition, there are rocks with a susceptibility contrast value of 0.0001 cgs units and 0.0015 cgs units which are thought to be volcanic sandstones found in a depth of 20 m to 200 m, and rocks with a susceptibility contrast value of 0.0091 cgs units and 0.0134 cgs units that are thought to be basalt in the depth of 25 m to 300 m.

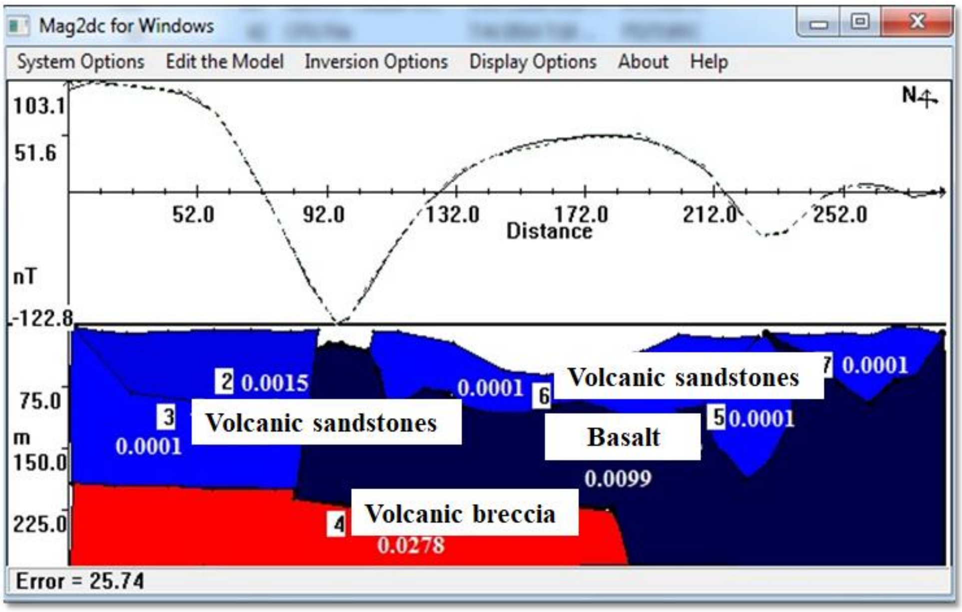

Figure 6. Forward modeling that shows AA’ slice in the study area

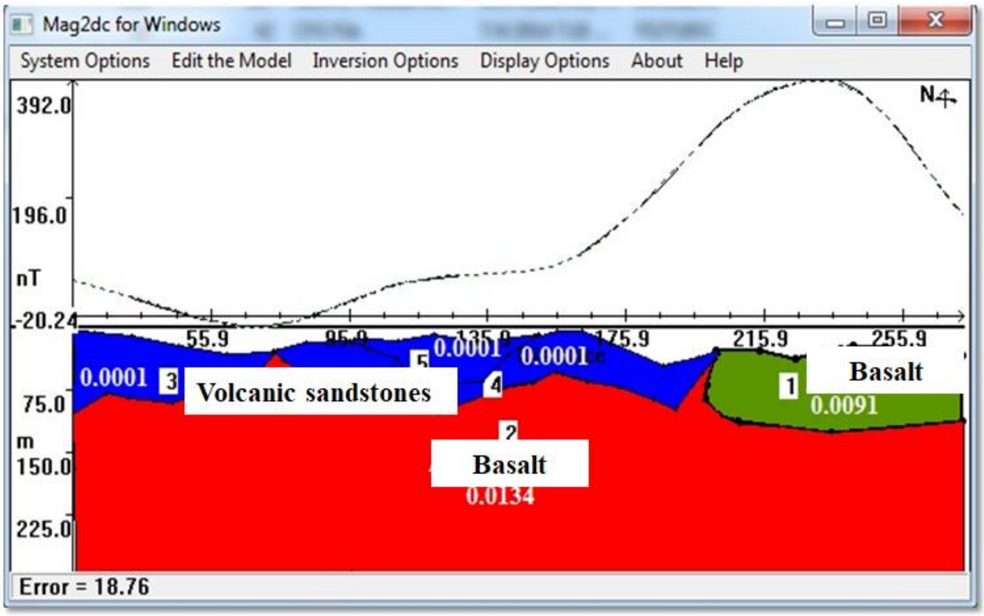

Figure 7. Forward modeling that shows BB' slice in the study area

Based on the results, it can be concluded that the research area is dominated by old volcanic rocks, namely, basalt rock and volcanic breccia, there are also volcanic sandstones. The results of this study are in accordance with previous research by (Tanesib et al, 2017) conducted in sub-district Pura and north Pura using geoelectric, geomagnetic, and satellite imagery methods.

CONCLUSION

The geomagnetic method is able to identify the subsurface rocks of north Pura. Data processing shows that there are differences in the value of the total magnetic intensity, which is caused by differences in subsurface rocks in the study area. The qualitative interpretation shows that the research area is dominated by moderate anomalies. The quantitative interpretation based on 2D modeling shows that it's suspected that there are three types of rock in the study area, namely basalt, volcanic sandstone, and volcanic breccias.

SUGGESTION

Future research is expected to apply other geophysical methods so that the results obtained are more accurate so that they can provide the latest information about the potential for groundwater in north Pura.

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