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Model 2D of Subsurface Structures in the Dempo Magnetic Area of Pagar Alam City Using Geomagnetic Method

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ABSTRAK

Metode geomagnetik digunakan dalam penelitian ini untuk membuat model 2D struktur bawah permukaan di kawasan Dempo Magnet kota Pagar Alam berdasarkan sebaran anomali. Terdapat 48 titik pengukuran pada lokasi penelitian. Pengolahan data dilakukan dengan membuat peta anomali magnetik total. Koreksi diurnal dan koreksi international geomagnetic reference field (IGRF) dilakukan untuk mendapatkan nilai anomali magnetik total. Data magnetik tersebut kemudian diolah untuk memisahkan anomali regional dan anomali residual menggunakan bandpass filter, kemudian dilakukan transformasi reduksi ke kutub, dan pemodelan 2D menggunakan metode forward modeling. Hasil analisis kisaran nilai anomali magnet di kawasan magnet Dempo kota Pagar Alam diperoleh nilai anomali magnet tertinggi sebesar 781,8 nT, sedangkan anomali magnet terendah sebesar -796,6 nt. Hasil pemodelan 2D pada data magnetik diperoleh 4 lapisan batuan bawah permukaan dengan kedalaman sekitar 165 meter, dimana lapisan batuan pertama berupa breksi gunung api, lapisan batuan kedua berupa endapan piroklastik, lapisan batuan ketiga berupa basal, dan lapisan batuan terakhir. adalah gabro.

Kata Kunci: Metode Magnetik, Intensitas Anomali Medan, Pemodelan 2D, Struktur Bawah Permukaan

ABSTRACT

The geomagnetic method was used in this research to create a 2D model of subsurface structures in the Dempo Magnet area of Pagar Alam city based on the distribution of anomalies. There were 48 measurement points at the researched location. Data processing was carried out by creating a total magnetic anomaly map. Diurnal correction and international geomagnetic reference field (IGRF) correction were carried out to obtain total magnetic anomaly values. The magnetic data was then processed to separate regional anomalies and residual anomalies used a bandpass filter, then a reduction transformation to the poles was carried out, and 2D modeling used the forward modeling method. The results of the analysis of the range of magnetic anomaly values in the Dempo magnet area of Pagar Alam city obtained the highest magnetic anomaly valued of 781, 8 nT, while the lowest magnetic anomaly was -796, 6 nt. The results of 2D modeling on magnetic data obtained 4 subsurface rock layers with a depth of around 165 meters, where the first rock layer was volcanic breccia, the second rock layer was pyroclastic sediment, the third rock layer was basalt, and the last rock layer was gabbro.

Keywords: Magnetic method, Field anomaly intensity, 2D modeling, Subsurface structures

I. INTRODUCTION

Based on its geographical location, the Dempo Magnet is located in the area of Mount Dempo, Pagar Alam City. Mount Dempo has experienced several recorded eruptions since 1818-2009, with eruption results. Mount Dempo last recorded an eruption in 2009. Mount Dempo is the highest volcano in South Sumatra, with a strato volcano type. The highest peak of Mount Dempo is Mount Merapi with an altitude of 3173 m above sea level or 2900 m above the plains. The morphology of Mount Dempo is formed by lava covered with pyroclastic deposits. Mount Dempo produces volcanic deposits such as lava, andesite-basaltic lava, pyroclastic falls, and pyroclastic flows. The youngest deposits are alluvium. The geological structures that develop are shear faults (dextral and sinistral), normal faults, fractures in the peak area, and topographic lineament (1).

Sahputra (2) at Dempo volcano, Pagar Alam City, conducted surveys using global positioning system (GPS) data to conduct a study of deformation related to this volcanic activity. This research shows that the vector direction tends to the north with a speed of around 10 mm/year to 39. 96 mm/year towards the ALVI reference station. However, the research was only limited to providing information on the deformation of Mount Dempo and did not provide information regarding magnetic anomaly values as well as the shape of subsurface models and rock susceptibility values in the research area.

Geomagnetic exploration can give information about subsurface geological structures such as faults, folds, igneous intrusions, and geothermal reservoirs (3). The principle of this geomagnetic method is based on the variations of the magnetization intensity under the earth's surface. This is due to differences in the magnetization properties of the rocks in the earth's crust. This difference in the magnetization of the rocks determines the existence of a source of the earth's magnetic field, called a magnetic field anomaly (4).

The geomagnetic method is one of the geophysical techniques to identify subsurface geological structures. Based on a rock's magnetic susceptibility, the geomagnetic method is a passive, sensitive, and analytical technique (5). The susceptibility values of the rocks can be used to differentiate between those that contain magnets and those that do not, as well as to determine the direction in which the rocks are distributed. Horizontal modelling provides depth information so that the direction and depth distribution of magnetic and non-magnetic rocks can be determined (6).

This magnetic method has advantages such as relatively easy data processing and magnetic data correction. However, the magnetic method has drawbacks such as the complexity of performing a qualitative interpretation of magnetic data due to the inherent properties of the magnetic field dipole. Therefore, additional data processing techniques are required to be able to lessen the impact of the earth's magnetic field dipole and make it easier to interpret magnetic data qualitatively. Reduce to pole transformation is one technique that can be use (7).

The geophysical method, namely the geomagnetic method, can map subsurface conditions based on the physical parameters of the measured rocks such as density and susceptibility (8). The geomagnetic method is generally used as a preliminary survey to determine the geological structure controlling mineralization (9)

Geological structures such as fractures and faults are zones of rock magnetic destruction that produce negative magnetic anomalies (10). Analysis using the geomagnetic method can be used as a first step to understanding the condition and structure of the underground layer (11). In addition, it can be used in efforts to explore the potential of natural resources for mining materials such as andesite rock mining materials (12).

The geomagnetic method in geophysical surveys is used to map subsurface anomaly sources. In this study, we get a magnetic anomaly which can be defined as a magnetic field originating from the distribution of objects that are below the magnetized surface. The amount of magnetization that occurs in this material is consistent with its track record while in the Earth's magnetic field, so the magnetization can be assumed to be solely due to magnetic induction received from the Earth's magnetic field(13).

Geomagnetic research is divided into three stages, namely field data collection includes the stage of determining observation points and measuring tools, processing includes corrections to data obtained from field measurements including corrections at this stage including daily corrections, topographic corrections, and other corrections, and the last stage data interpretation includes qualitative and quantitative(14).

The data obtained during field measurements is still distributed by external magnetic fields and subsurface magnetic fields, therefore it needs to be corrected daily (diurnal) IGRF correction set (International Geomagnetic Reference Field), as well as other corrections (15). Daily correction is a deviation of the earth's magnetic field intensity caused by differences in measurement time and the effects of sunlight in one measurement day. The purpose of the IGRF correction is to remove the earth's main magnetic field, which changes over time. The main magnetic field value is nothing but the IGRF value (16).

Forward Modeling 2D is creating a model using an approach based on geological and geophysical intuition that provides a mathematical description of the object's geometry causing the anomaly. Carried out using a trial and error process (a process of trial and error or guesswork to obtain a match between theoretical data and field data) (17). This study aims to determine the 2D model of the earth's subsurface structure, based on the distribution of magnetic anomaly values in the Dempo Magnet area of Pagar Alam city using the geomagnetic method

II. METHOD

The tools used in the research were the Proton Procession Magnetometer (PPM G-857), Global positioning system (GPS), Geological compass, Notebook, and some software to process data. This study consisted of 48 measurement-pointed or field stations and 1 base station. The researched location was in the Mount Dempo Magnet Dempo area, Pagar Alam, South Sumatra. Research pointed field Stations that would have been used were spread out in the research area, the location of the research could have been seen in Figure 1.

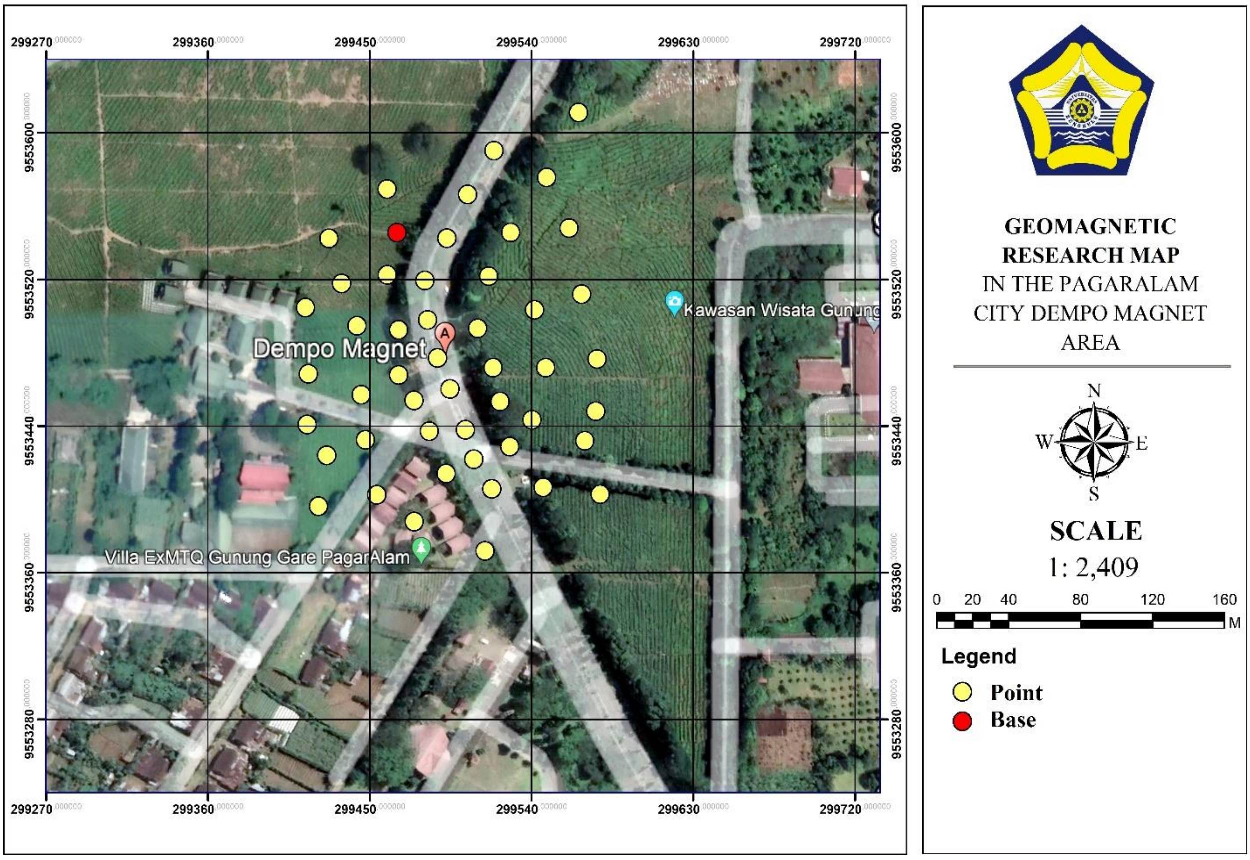

Figure 1. Map of research location

Research location map Field measurement data included the strength of the magnetic field at the base station and field station at each researched point, as well as the time and coordinates at the time of measurement at each point. First, data measurements were carried out at the base station automatically every 2 minutes, then data measurements at each point or station were read 25 times, the measurement points at the station were square on each side, the readings were taken 5 times, the sides are 1 meter apart and one side formed a diagonal. Data recorded in data collection included day, date, time, data collection point, coordinates, and magnetic field.

The data from measurements in the field was then processed by making corrections to the IGRF (International GeomagneticReferee Field) and daily corrections until a total magnetic anomaly map was obtained. At the data processing stage, this magnetic field anomaly was still mixed with other magnetic fields, so the total magnetic anomaly data obtained needed to be separated between regional anomalies and residual anomalies so that regional and residual anomaly maps were obtained. Next, the residual anomaly was reduced to the poles using an RTP filter (reduction to the poles), and the reduction to the poles produced a contour map which was then used to model the magnetic field to produce a residual anomaly map. which had reduced to the poles. The next step was the forward 2D modeling process of the RTP map (reduction to the poles) which was sliced into 3 parts, where this modeling was based on geological intuition and magnetic anomalies and was carried out using a trial and error process, aimed to be obtained the shape of the 2D model and the depth of the anomaly which was used as an objected from beneath the earth's surface. The data processing flowchart can be seen in Figure 2 below.

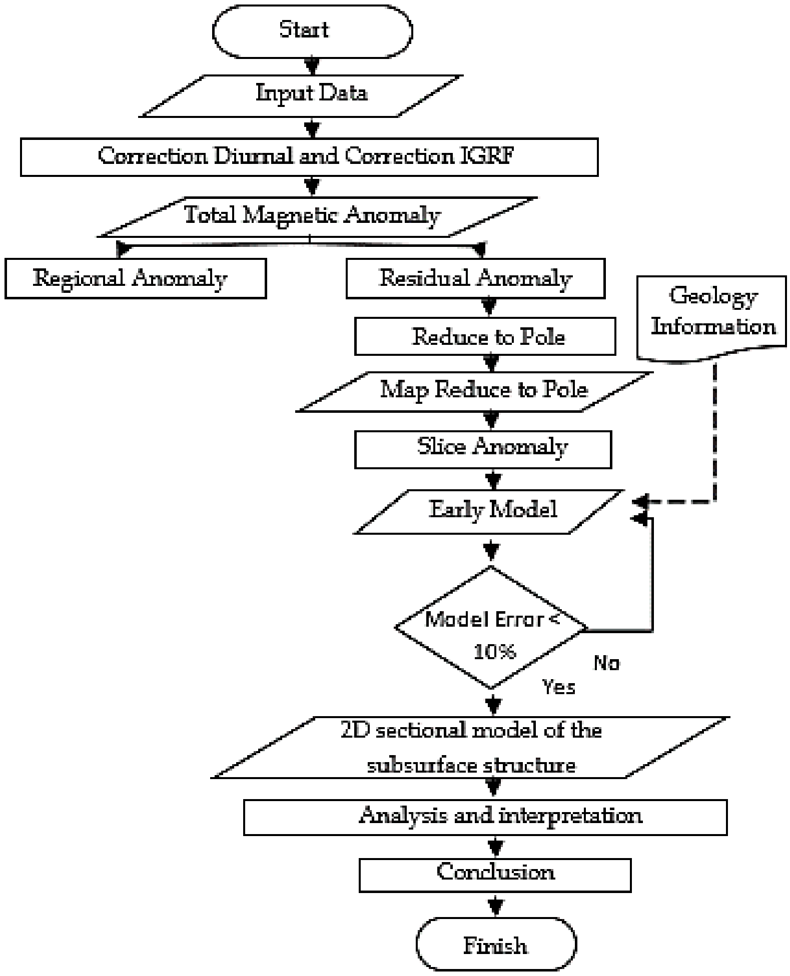

Figure 2. Data Processing Flowchart

III. RESULT AND DISCUSSION

3.1 Qualittative Interpretation

Data from field measurements was a distribution of total magnetic field values which was still influenced by components of the external magnetic field, so the magnetic field obtained must corrected for daily variations and IGRF. The magnetic data processing and anomaly map can be seen in Table 1 and Figure 3.

Table 1. Magnetic Data Processing

			IGRF
			43899,3
Station	Magnetic Value (nT)	H Base (nT)	Diurnal Correction (nT)
1	43499.4	43772.2	0
2	43414.1	43779.5	7.2
3	43140.2	43775.4	3.1

4	43500.8	43768.5	-3,7
5	43487.7	43760.5	-11.7
6	43780.8	43767.2	-5
7	43673.9	43776	3.7
8	43567.1	43774.3	2.1
9	43668.3	43771.2	-1
10	43873.6	43767.4	-4.8

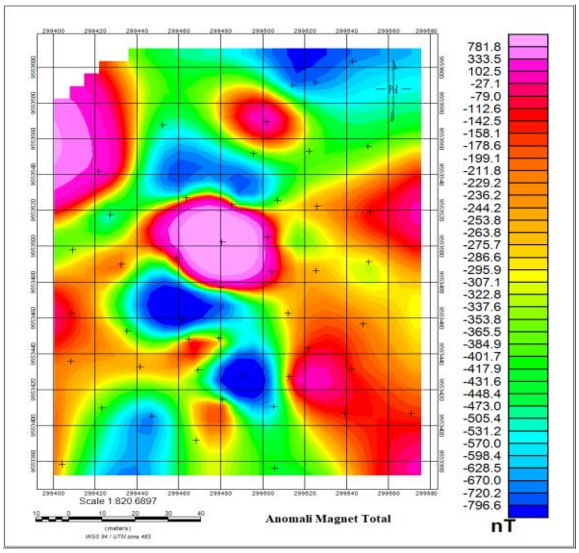

Figure 3. Total Magnetic anomaly

The magnetic field value originating from subsurface rock was a total magnetic anomaly. The results of the total magnetic anomaly value could have been seen in Figure 3 above which had been diurnal corrected and IGRF corrected. Based on the total magnetic anomaly map, the highest and lowest magnetic anomaly values were determined, the highest magnetic anomaly was 781.8 nT, and the lowest magnetic anomaly was -796.6 nT. A high magnetic anomaly indicates that the point had a large magnetic intensity value, while a low magnetic anomaly indicates that the area or point has a small magnetic intensity value. This negative or low value anomaly was influenced by the presence of subsurface rock around the measurement area. Parjuangan (18) conducted similar research regarding a magnetic surveyed in the Geothermal Prospect Kepahiang, from the researched results it was founded the highest magnetic anomaly value was 1500 nT, while the lowest anomaly was -1500 nT, which showed that the area was influenced by geothermal heated.

Separation of magnetic anomalies was aimed to separate regional anomalies and residual anomalies because for further processing the residual anomalies that would have been interpreted had information on the total magnetic field closed to the surface. Separation of magnetic anomalies was carried out using a bandpass filter. In the bandpass filter process, a frequency range of 2 Hz to 14 Hz was used because regional anomalies passed through low frequencies with larger wavelengths, while to obtain residual anomalies a frequency range of 14 Hz to 26 Hz was used because residual anomalies passed through high frequencies, with a smaller wavelength.

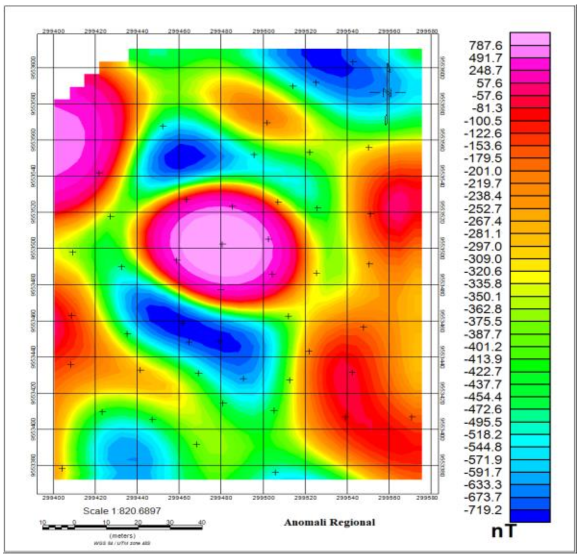

Figure 4. Regional Magnetic Anomaly

Then regional and residual anomalies were obtained. Based on the bandpass filter results in Figure 4, regional anomalies showed that magnetic anomaly values in the Dempo Magnet area range from the highest of -787.6 nT to the lowest of 719.2 nT. In the magnetic surveyed method, the focus or target of measurement in this research was variations in the magnetic field on the surface, namely residual anomalies which can be seen in Figure 5. These residual anomalies showed magnetic anomaly values ranging between the highest 732.0 nT and the lowest 560.2 nT, The magnetic intensity in the residual anomaly was produced by local magnetic rock.

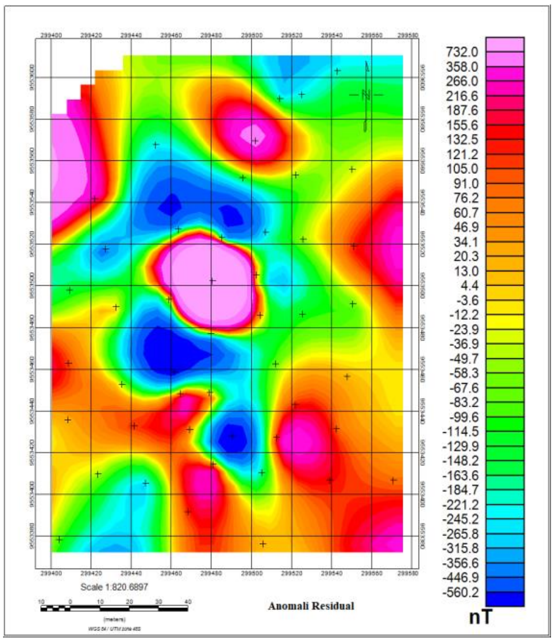

Figure 5. Residual Magnetic Anomaly

Earth's magnetic field always varies with a timed or natural dipole, therefore an advanced process was needed to change the magnetic field in the residual anomaly into a monopole. The process was called reduction to the poles (reduced to pole). This Reduction to the Pole changed the parameters in the researched area which had a declination valued of 0.183° and an inclination of -25.329° to conditions at the poles with a value of 0° declination and an inclination of 90°. Reduced to the pole produced a contour map can be seen in Figure 6.

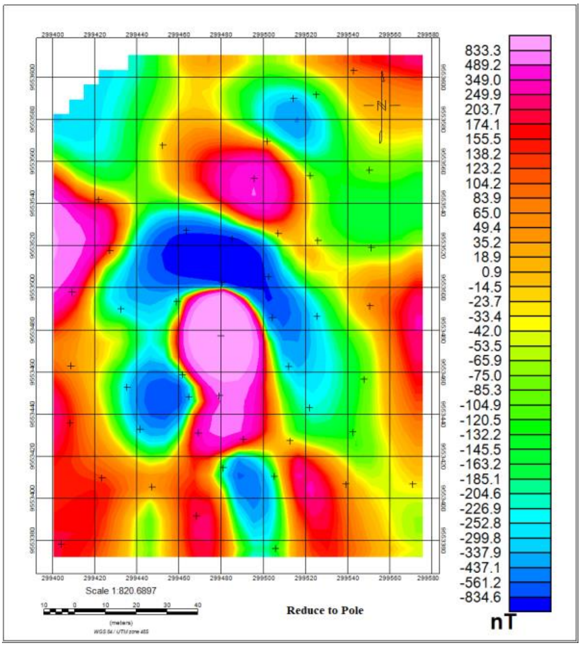

Figure 6. Reduce to Pole

Based on Figure 6, it could have been seen the difference between the residual anomaly before and after the reduction process to the poles. The reduction to the pole showed anomaly values ranging from the highest of 833.3 nT to the lowest of -834.6 nT. Quantitative Interpretation after reduction to the poles, then proceed with making a model and the depth or geological structure of the measurement results. The modeling was based on the qualitative interpretation results that had been obtained, namely residual contour maps and reduction maps to the poles. Slice on reduction to the poles as Figure 7 below.

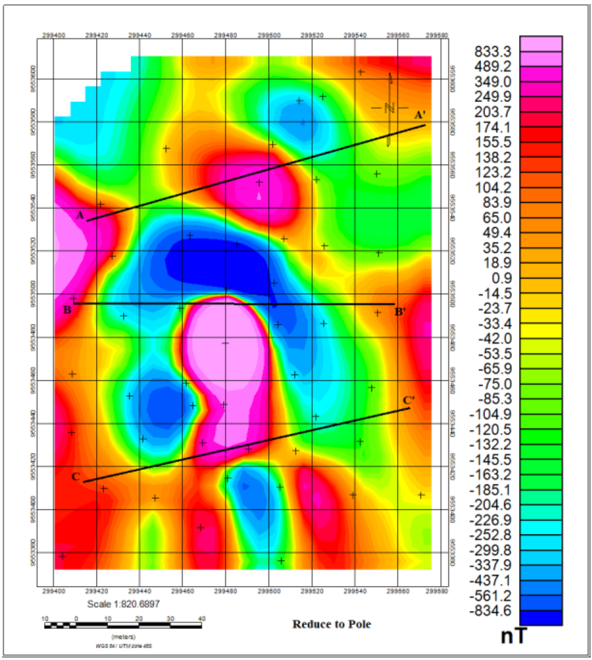

Figure 7. Determination Slice Anomaly on the Reduction to Pole

There were 3 slice anomalies performed on the polar reduction map in Figure 7 which was made to cut low anomaly and high anomaly values, aimed to be able to covered the entire researched area and be able to described the structure below the surface. In this 2D modeling, 4 layers of rock were made as a possible rock structure beneath the surface of the studied area. After modeling, The susceptibility value of each rock would be determined from a 2D section of the subsurface structure, and after modeling had been corrected, it would be determined whether the model matched the structural geological information about the studied area's rock formations. Generates a cross-sectional model of the 2D model of the results shown in Figure 8, Figure 9, and 10.

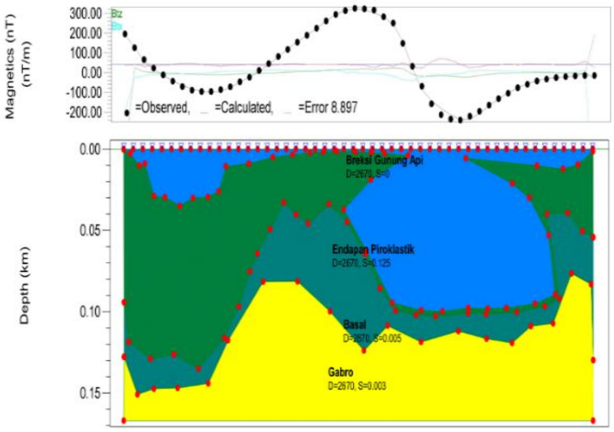

Figure 8. Model slice A-A' from Slice Map Reduction to Pole

The subsurface structure slice a-A' from the reduced to pole map was represented as a 2D cross-sectional model based on Figure 8. Slice transverse from west to east intersecting between positive anomaly and negative anomaly. on modeling slice A-A' had a valued error of 8.897, and the lithological arrangement of layers obtained 4 rocked layers in the subsurface model with a depth of 165 meters from the topography. The first layer of rock had a susceptibility value of 0.00001257 SI, interpreted as volcanic breccia rock, the second layer of rock had a susceptibility value of 0.2503541 SI, interpreted as this pyroclastic sedimentary rock, the third layer of rock had a susceptibility value of 0.00503912 SI, interpreted as basalt rock; and the fourth and final layer has a susceptibility value of 0.0030285 SI interpreted as gabbro rock.

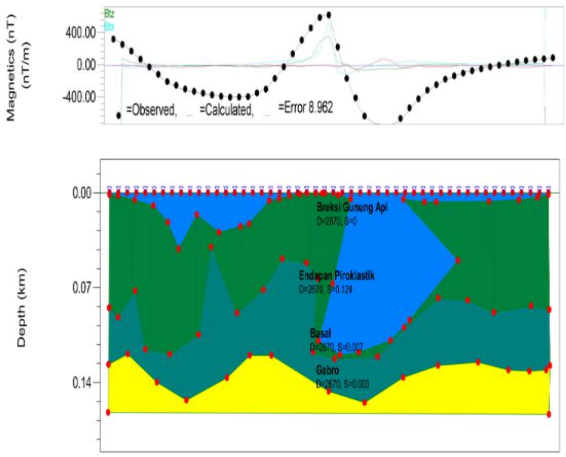

Figure 9. Model slice B-B' from Slice Map Reduction to Pole

The modeling results in Figure 9 showed the results of the 2D cross-sectional model of the subsurface structure in slice B-B' from the reduced map to the poles. Cross-section models B-B' across from the west to the east intersecting the positive anomaly with the low anomaly transverse from the southwest to the northeast had a valued error was 8.962, and the composition of the subsurface structure obtained 4 subsurface model rocked layers with a depth of 163 meters from the topography. The first layer of rock had a susceptibility value of 0.00001257 SI, interpreted as volcanic breccia rock, the second layer of rock had a susceptibility value of 0.1245869 SI, interpreted as pyroclastic sedimentary rock, the third layer of rock had a susceptibility value of 0.00692343 SI, interpreted as basalt rock, and the fourth and final layer has a susceptibility value 0.00293897 SI interpreted as gabbro rock.

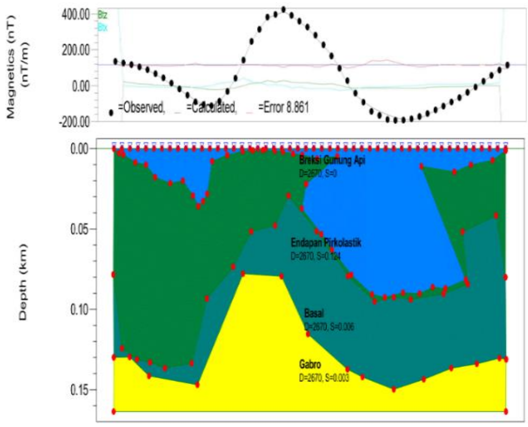

Figure 10. Model slice C-C' from Slice Map Reduction to Pole

The subsurface structure slice a-A' from the reduced to pole map was represented as a 2D cross-sectional model based on Figure 10. Slice transverse from west to east intersecting between positive anomaly and negative anomaly. A modeling had a valued error was 8.861, and the lithology arrangement obtained 4 subsurface model rocked layers with a depth of 164 meters from the topography. The first layer of rock had a susceptibility value of 0.00001257 SI, interpreted as volcanic breccia rock, the second layer of rock had a susceptibility value of 0.12440709 SI, interpreted as this pyroclastic sedimentary rock, the third layer of rock had a susceptibility value of 0.00566743 SI, interpreted as basalt rock, and the fourth and final layer has a susceptibility value 0.00292796 SI interpreted as gabbro rock.

IV. CONCLUSION

Based on the results of data processing that was carried out, the distribution of magnetic anomaly valued at the studied site had a value of 781.8 nT from the highest anomaly to the lowest anomaly with a value of -796.6 nT. The subsurface structure was displayed by 2D modeling of subsurface cross-sections. Each cross-section consisted of layers of rocked model shapes accompanied by information on the susceptibility value of each rock below the surface of the Dempo Magnet area and its surroundings. The condition of the subsurface structure based on the results of 2D modeling that has been carried out based on the magnetic anomaly reduced polar distribution results in a subsurface structure consisting of 4 layers. The first layer was volcanic breccia rock, the second layer was pyroclastic sedimentary rock, the third layer was basalt rock, and the fourth layer is the fourth layer also gabbro rock.

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