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Mapping of Manganese Ore Deposits by Using Geomagnetic Method in Aceh Jaya District, Nangro Aceh Darussalam Province, Indonesia

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Abstract:- The Manganese ore deposits in Aceh Jaya District, Aceh Province, Indonesia have been known for a long time for their commercial importance and academic interest. However, until now there is no study or exploration process included the manganese exploration for industry. In this study, we explore the manganese ore body deposits in Aceh Jaya using geophysical method, in this case using geomagnetic method. Geomagnetic data were collected by using a Precision Proton Magnetometer (PPM) with coverage study area about 3000 meter x 1500 meter and there are 1600 measurement points and 50 meters spacing between each points. IGRF and diurnal correction were calculated in order to obtain the total-field geomagnetic anomaly, then upward continuation to separate the local and regional anomalies. The magnetic anomaly agree well with geological information, in which a strong magnetic suseptibility (~105.4 to 165.4 nT) in southern and eastern part interpreted as a group of limestone and medium magnetic suseptibility (~25.4 to 105.4 nT) around the manganese outcrop and spread from east to west associated with manganese mineralisaton itself may be due to either Pirolusit (MnO_2) and Manganit MnO(OH). Whereas, weak magnetic suseptibility (~ -54.6 to 25.4 nT) in northern part which indicated the presence of another mineral deposits and interpreted as nonmagnetic mineral such as gold, copper, silver, alluvium, and or clay. These evidences show that the geomagnetic method was successfully locate minerals particularly for the manganese ore deposits in study area.

Keywords:- Manganese, geomagnetic, Aceh Jaya**.**

I. INTRODUCTION

Manganese ore body in Aceh Jaya District, Aceh Province, Indonesia has great prospect for exploitation because the result of geological mapping shows that the high reserve of manganese ore body. Figure 1 shows the outcrop of manganese ore body deposits in Aceh Jaya.

However, until now there is no exploiration process in Aceh Jaya, included the manganese exploration for industry. In this study, we explore the manganese ore body deposite in Aceh Jaya using geophysical method, in this case using geomagnetic method. This method measures magnetic field variation on the earth surface due to the magnetized thing below the earth surface. The measurement data can inform the physical properties of rock, the geometry of rock below the surface, and the magnetic anomaly position in depth. These informations will be useful for us to understand the relationship between the physical properties of rock and observation of geomagnetic data then correlate with geological information to get high quality interpretation of manganese ore deposite in study area.

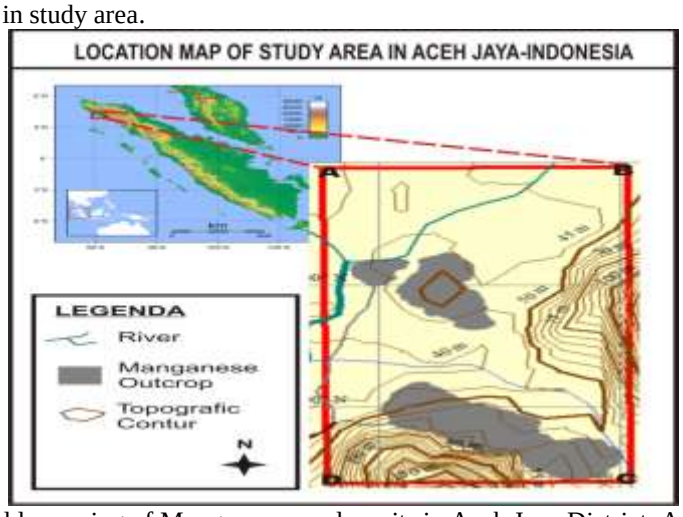

Figure 1 Geological field mapping of Manganese ore deposits in Aceh Jaya District, Aceh Province,Indonesia.

II. GEOLOGICAL SETTING AND MINERALISATION

The geology, resources, and tectonic evolution of Sumatra have been extensively discussed in [1]. A general discussion of regional plate tectonics and magmatic arc formation can be found, for example, in [2]. [3] has recently summarized the regional geology of Sumatra. Sumatra forms the southwestern margin of Sundaland, which is an extension of the Eurasian continental plate. Sumatra is considered to be composed of fragments of continental plates and volcanic arcs which were derived from the breakup of Gondwana during the Late Palaeozoic and Mesozoic. On going phases of subduction in the Mesozoic, Tertiary and Quaternary have resulted in the formation of magmatic arcs along the length of Sumatra.

Whereas, The general geology of Nothern Sumatra particularly in Aceh Jaya was first described by [4] and [5]. More recently it has been summarised and further described by [6], [3] and [7].

Figure 2 shows the simple geological setting of the Aceh Jaya. The mangnese, pyrite, and gold deposit is hosted in a sequence of Plio-Pleistocene andesitic volcanic rocks located on the southern flank of the Sague Volcanic Centre. [4] described the host rocks as shallow dipping andesitic to dacitic lavas, tuffs, and agglomerates of the Leuping Volcanics. The lowest exposed unit is a rather monotonous andsite unit, overlain by a unit of intertonguing andesite and dacitic to andsitic agglomerate which is the main host to manganese, pyrite, and gold mineralisation.

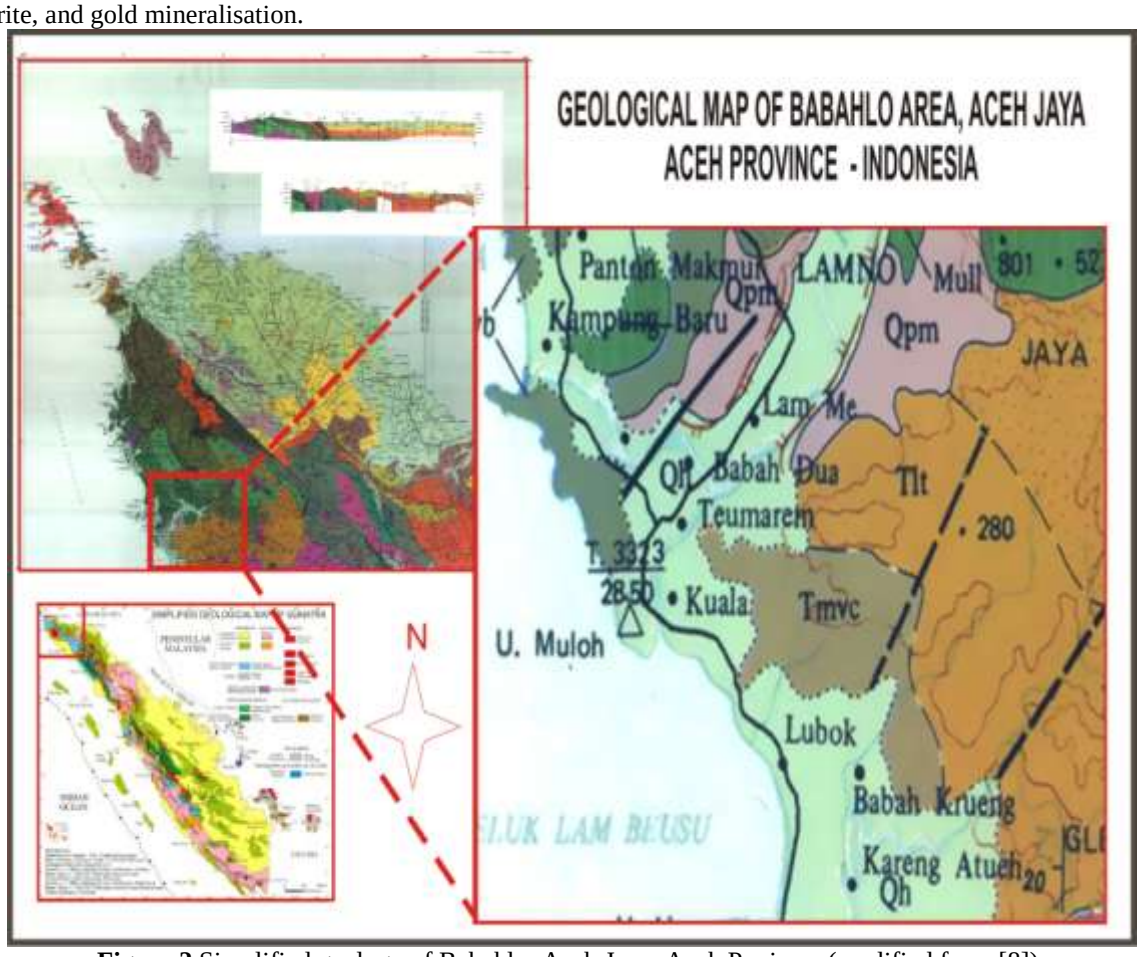

Figure 2 Simplified geology of Babahlo, Aceh Jaya, Aceh Povince (modified from [8]).

The porphyritic andesite host rock in Aceh Jaya is an easily recognizable unit, irrespective of the degree of alteration and may be a useful marker unit within the stratigraphic package. The rock has a porphyritic texture made up of approximately 25% phenocrysts, many of them plagioclase crystals. It is interpreted to be a lava flow

III. LITERATURE REVIEW

1. Earth's Magnetic Field

The Earth possesses a magnetic field caused primarily by sources in the core. The form of the field is roughly the same as would be caused by a dipole or bar magnet located near the Earth's center and aligned sub parallel to the geographic axis. The intensity of the Earth's field is customarily expressed in S.I. units as nanoteslas (nT) or in an older unit, gamma (γ): 1 γ = 1 nT = 10^{-3} μT [12].

The Earth's magnetic field dominates most magnetic measurements made at or near the surface of the Earth. The Earth's total field intensity varies considerably by location over the surface of the Earth. Most materials except for permanent magnets, exhibit an induced magnetic field due to the behavior of the material when the material is in a strong field such as the Earth's. Induced magnetization (sometimes called magnetic polarization) refers to the action of the field on the material wherein the ambient field is enhanced causing the material itself to act as a magnet. The field caused by such a material is directly proportional to the intensity of the ambient field and to the ability of the material to enhance the local field a property called magnetic susceptibility [9].

Magnetic susceptibility is the degree of magnetization of a material in response to an applied magnetic field [10]. The volume magnetic susceptibility, represented by the symbol *K* is defined by the relationship

$$\boldsymbol{M} = K\,\boldsymbol{H} \quad \text{..... (3.1)}$$

where, $\boldsymbol{M}$ is the magnetization of the material (the magnetic dipole moment perunit volume), measured in amperes per meter, and $\boldsymbol{H}$ is the applied field, also measured in amperes per meter. Both quantities are measured in SI units The magnetic induction $\boldsymbol{B}$ is related to $\boldsymbol{H}$ by the relationship

$$\boldsymbol{B} = \mu_0(\boldsymbol{H} + \boldsymbol{M}) = \mu_0(\mathbf{1} + K)\boldsymbol{H} = \mu\boldsymbol{H} \quad \text{.....(3.2)}$$

where μ_0 is the permeability of free space (4π x 10^{-7} Henry/m), and is the relative permeability of the material [11].

If *K* is positive, then (1+*K*) greater than 1 and the material is called paramagnetic. In this case, the magnetic field is strengthened by the presence of the material. Alternatively, if *K* is negative, then (1+*K*) less than 1, and the material is diamagnetic. As a result, the magnetic field is weakened in the presence of the material. The contributions at low field to magnetic susceptibility are summed up as shown [9].

2. Intensity of the Geomagnetism

The Earth magnetic field is characterized by physic parameters, which are also called as the element of earth magnetic field (Figure 3) [12]. These are measured by direction and intensity of magnetization. These physic parameters are:

a. Declination (D), which is the angle between magnetic north and horizontal component, as counted from north toward east.

b. Inclination (I), which is the angle between total magnetic field and horizontal plane, counted from horizontal plane toward vertical plane at the below.

c. Horizontal Intensity (H), which is the rate of total magnetic field on the horizontal plane.

d. Total Magnetic Field (F), which is the rate of total magnetic field vector.

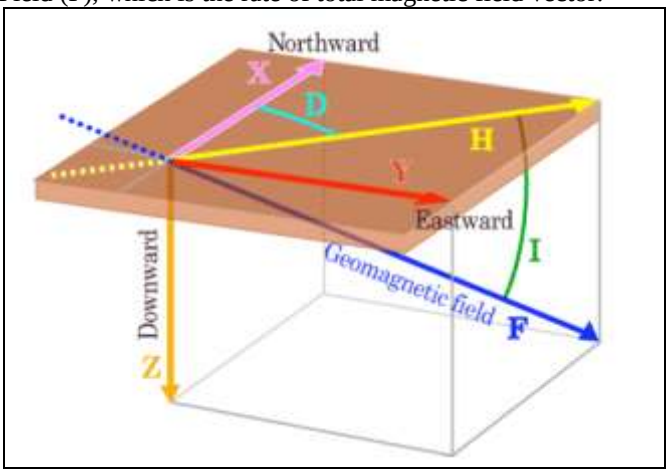

Figure 3 Resolution of the Earth's magnetic field into the various geomagnetic elements.

Each of these vectors and angles is called a geomagnetic element, and the follow the relationships exist between them.

$$H = F\cos I \quad \text{..... (3.4)}$$

$$Z = F\sin I \quad \text{..... (3.5)}$$

$$Z/H = \tan I \quad \text{..... (3.6)}$$

$$F = (H^2 + Z^2)^{1/2} = (X^2 + Y^2 + Z^2)^{1/2} \quad \text{..... (3.7)}$$

In spherical coordinates, the vertical, horizontal and total field intensities are given by the following formulae:

$$Z = Br = 2M \cos\theta / r^3 \quad \text{(3.8)}$$

$$H = B_\theta = M \sin\theta / r^3 \quad \text{(3.9)}$$

$$F = B = M\,(1 + 3\cos^2\theta)\,/r^3 \quad \text{(3.10)}$$

where M, the magnetic moment defined as:

$$M = \frac{4}{3\pi} r^3 \mathrm{I} \quad \text{(3.11)}$$

I is defined as the intensity of magnetization.

IV. DATA COLLECTION AND PROCESSING

The study area is located in Babahlo area, IE Jeurengeh village, Aceh Jaya district, southwestern of Aceh province (Figure 1) at longitude and latitude position 95° 30'49.74" E and 4° 56'59.26" N. The acquisition of geomagnetic method for manganese ore body in in Babahlo area, Aceh Jaya was done on 15-21st July 2011 with covers an area about 3000 m x 1500 m.

The instruments for geomagnetic acquisition using Proton Precision Magnetometer (PPM) and Global Positioning System (GPS) Type 60 CSx. The PPM originally aligned with natural field. External coil is energized with a DC current resulting in a strong B field that aligns protons. While, GPS is used to measure the position of measuring points involving longitude, latitude, and altitude.

To gethigh quality data, the magnetic surveys are designed to reveal the magnetic anomalies originated from very localized, near-surface sources. Magnetic surveys are based on the premise that a target is limited in space and has a different physical property (e.g., magnetic susceptibility), from the surrounding formation. In our study, whave create geomagnetc survey design which shows in Figure 4.

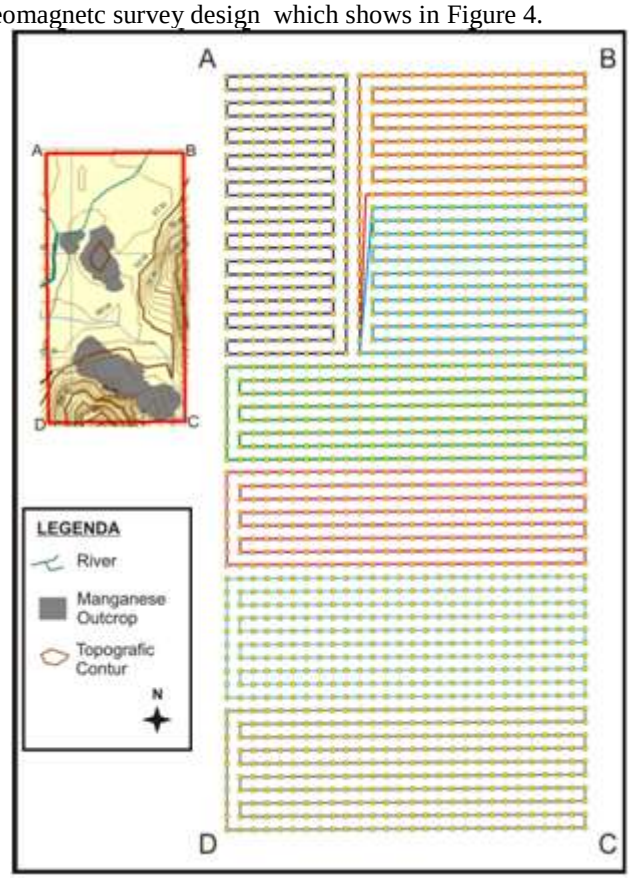

Figure 4 Survey Design to investigate manganese ore deposite in Aceh Jaya District, Aceh Province.

In figure 4, there are 1600 points and spacing between each point are 50 m. The yellow point shows the geomagnetic measurement station. The colour lines shows the route of geomagnetic measurement with looping method. Left figure shows the topographic map of survey area.

After we have finished geomagnetic measurement and get field data such as magnetic field data, position (latitude, longitude, and elevation), and time recording then we continue to process all those magnetic data set. All magnetic data sets contain element of noise and will require some form of correction to the raw data to remove all contributions to the observed magnetic field other than those caused by sub-surface magnetic

source. The correction were applied to the raw geomagnetic data are diurnal correction, IGRF correction, upward continuation, and reduction to pole

V. RESULT AND DISCUSSIONS

1.Geological Field Mapping

1.1 Morpology of Babahlo Area in Aceh Jaya

The greater part of the Babahlo area is very hilly (Figure 5). Extending northeast and southeast through the center of the Babahlo is a mountainous " backbone" (Figure 6), which in the nortthern part, with its foothills that reach almost to the water's edge, forms a trackless wilderness. Toward the southwest end this ridge approaches the coast and becomes lower, finally merging with the upland plateau north of Lanmo (see figure 2).

Figure 5 Morpology of Babahlo Area, Aceh Jaya, Aceh Province.

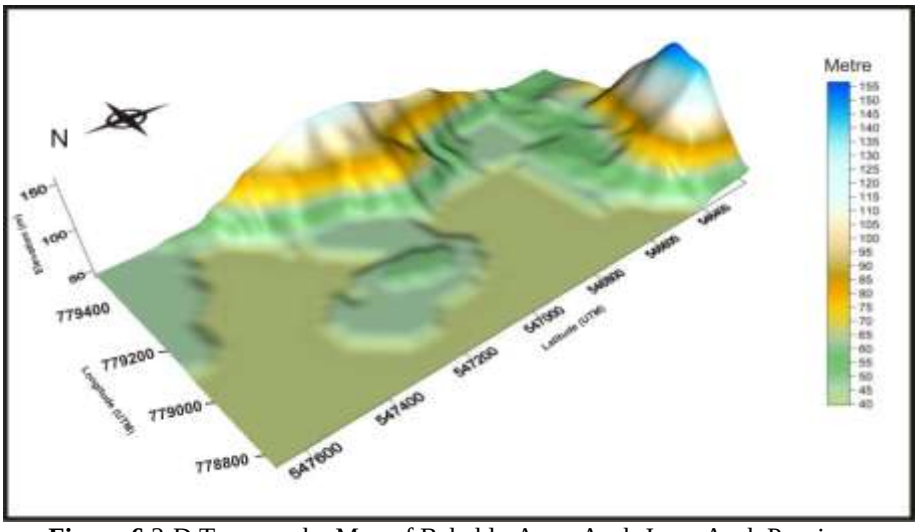

Figure 6 3-D Topography Map of Babahlo Area, Aceh Jaya, Aceh Province.

In Figure 5, along the head of the river on the west side the narrow strip of lowland increases to a belt several km wide fringed by dense mangrove swamps. Across these swamps run long winding estuaries, dry at low tide but forming deep channels at flood tide.

In Figure 6, the deposits of manganese minerals occur in the rim rocks which mark the western and southern boundaries of a basin, and in steeply folded rocks in the eastern part of the basin. The floor of the basin is about 40 m in altitude, and the highest point on the eastern rim is about 155 m. The eastern rim is lower than the southern and in the southeastern part two places branches of a gulch have eroded channels through it and find outlet to Disappointment Creek.

1.2 Manganese Outcrop in Babahlo Area

Deposits of manganese minerals occur in the western part of Aceh Jaya, in a basin at the IE Jeureungeh village near the Lamno. The principal outcrops of manganese minerals in the survey area have been included in a three group of manganese ore deposite (Figure 7).

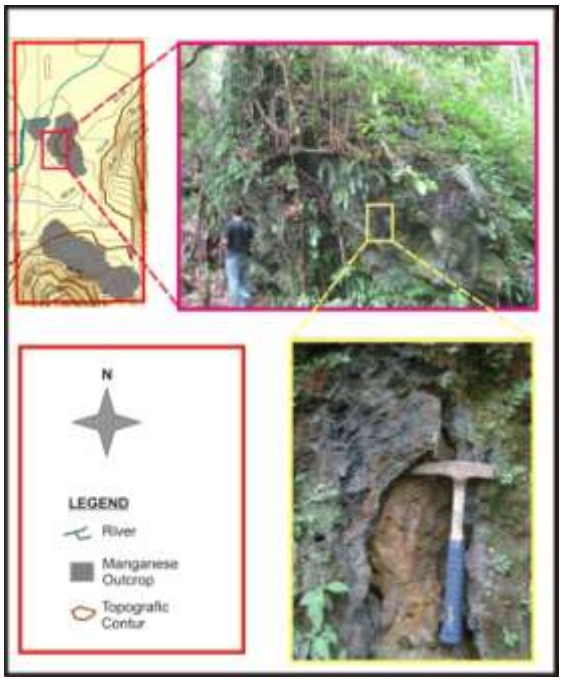

Figure 7 Manganese Outcrop in Babahlo Area, Aceh Jaya, Aceh Province.

The outcrop were located in southern part of survey area and two outcrop located in central part of the survey area.The rocks in the vicinity of the manganese deposits are all sedimentary and consist of gray, black, and brown sandstone, with interbedded red and green shale, which overlie fossiliferous limestone and shale exposed in the upper of the basin. A maximum thickness of about 10 m of manganese sediments is exposed in the western rim of the basin. The series of rocks is known as the Meulaboh formation, which is of Pleistocene age.

2.Geomagnetic Anomaly Associated with Manganese Deposite

2.1. **Interpretation of Total-Field Geomagnetic Anomaly**

To investigate the manganese ore deposit in Babahlo area, Aceh Jaya we was applied geomagnetic method. The geomagnetic data were collected using a Proton-Precession Magnetometer with 0.01 nT accuracy. Geomagnetic measured points were selected on a 50 m grid. The data were collected on the base of land survey corrected for diurnal variations. Totally, 1600 data points with covarage area about 3000 m x 1500 m. Regional geomagnetic field was removed using IGRF model. The average of inclination and declination of geomagnetic field due to studied area are -5°34’ and -1° respectively. Finally, after raw magnetic data correction we get the total-field magnetic anomaly. The total-field magnetic anomaly of area under study has been shown in Fig 8 .

Figure 8 shows the total-field geomagnetic anomaly map of manganese deposit in Babahlo Area, Aceh Jaya. Base on these maps, geomagnetic contour anomaly (green colour closure) with magnetic suseptibility about 25.4 nT-105.4 nT associated with manganese mineralisaton itself may be due to either Pirolusit (MnO_2) and Manganit MnO(OH).

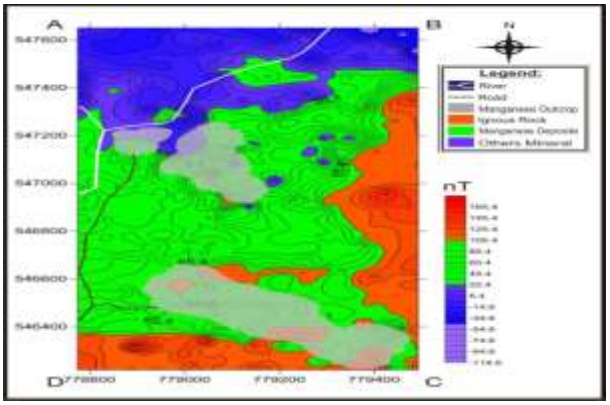

Figure 8 2D Total-Field Geomagnetic Anomaly Map of Manganese Deposit in Babahlo Area, Aceh Jaya, Aceh Province.

The manganese ore body have paramagnetic characteristic that mean the magnetic respon is lower than ferromagnetic mineral such as iron ore or others ferromagnetic mineral. The manganese ore deposite dominant in southern part and spread from the East to the West with the group bounded by limestone rocks that form steep hills. In general, Manganese Ore body found in hilly landscape with slope ranging 20^o to 30^o. Manganese Ore is generally formed simultaneously with overlapping limestone that form nodules Polymetal and bedding are limited and there are several points in the rocks encountered meta sediment that limit contact with limestone areas.

In Figure 8, in the southern part and eastern part are a strong magnetic suseptibility about 105.4 nT to 165.4 nT are interpreted as a group of limestone. This prediction was reinforced by observations in the field during geomagnetic survey. While to the north of the area survey found weak magnetic suseptibility about -54.6 nT to 25.4 nT which indicated the presence of another mineral deposits and interpreted as nonmagnetic mineral (diamagnetic) such as gold, copper, silver, mineral sedimentary rocks (alluvium), weathered rock or rock is unchangeable such as clay, silt, sand and gravel that have a small susceptibility.

2.2 Interpretation of Local-Regional Geomagnetic Anomaly

To get a local anomaly data from regional effect, the total-field geomagnetic data was filtering using upward continuation method. On geomagnetic data processing, this process can serve as a filter as low pass filter, which is to eliminate or reduce the effects of local magnetic origin from various sources of magnetic objects scattered on the surface that is not associated with the survey target. The Filtering process is done 3 times with continuation upward of 100 meters, 500 meters, and 1000 meters above sea level. The Map results after upward continuation to 1000 m above sea level can be seen in Figure 9.

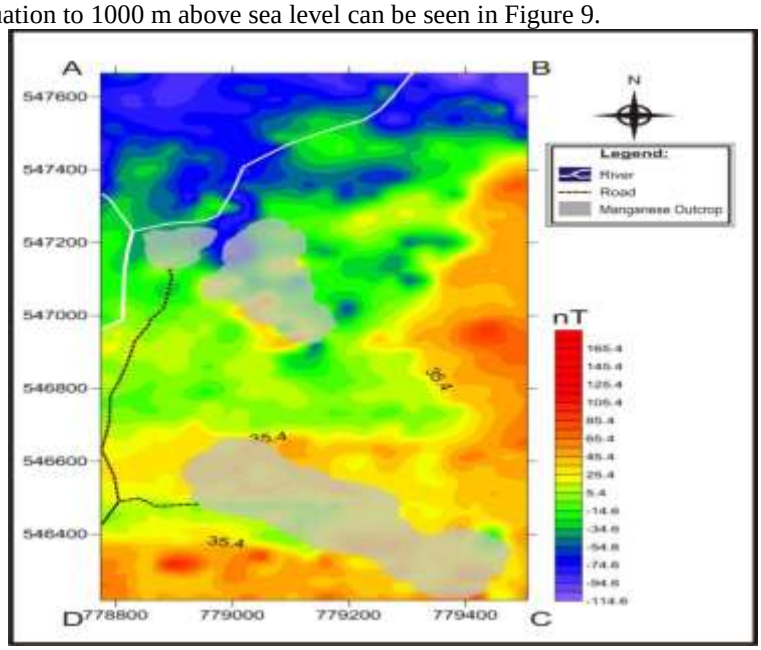

Figure 9 Regional Magnetic Map anomalies after upward continuation process to 1000 meter.

Figure 9 is final magnetic map anomalies after some upward continuation in different height, then the value obtained for the most stable continuation to above 1000 meters above sea level. These results are used as a deduction of the Total Magnetic Field Anomaly in Figure 8. With this process, often referred to as 'Separation of Local-Regional Effects', so that would be obtained anomalous magnetic field is relatively free from the influence of diurnal, IGRF, regional topography and terrain. Result of the reduction is called the Local Anomaly. Local anomaly is expected to further demonstrate local effects caused by the distribution of manganese rocks close to the surface.

Figure 10 shows the regional magnetic field anomaly. In these magnetic anomaly map, each rock type have been cluster depend on magnetic suseptibility. The green closure show the location of manganese ore deposite, a red closure show the group of limestone, and blue closure a suspected location there are other minerals such as gold, quartz, rocks and clay sediments.

In local regional magnetic field anomalies, shows that the range value of the local magnetic field between -114.6 nT to 165.4 nT. The variations value of the local magnetic field is divided into a negative magnetic anomaly ($\leq$ 0 nT) and positive anomalies (> 0 nT). Positive magnetic anomalies (green closure), related to the estimated relative paramagnetic (Manganese Ore) and red closure related to ferromagnetic rocks (limestone) and Those minerals resulted from the volcanic rocks like igneous rocks that have undergone

weathering or alteration moderate to high levels, such as volcanic breccia rocks that have undergone the process of mineralization that contains minerals like manganese Pirolusit (MnO2) and Manganit MnO (OH) and then with water borne transport medium and sedimented to form sedimentary rocks containing manganese minerals such as Pirolusit (MnO2) and Manganit MnO (OH).

While in the north indicated the distribution of other metals mineralization (blue closure) which has a negative value and interpreted as diamagnetic mineral such as gold, copper, silver, mineral sedimentary rocks (alluvium), weathered rock or rock unchangeable such as clay, silt, sand and gravel that has little susceptibility. Negative magnetic anomaly in the eastern part was estimated as gold and copper content in the sediment of clay and rock quartz inserts.

2.3 Magnetic Profile Across Manganese Ore Deposite

Many occurence of manganese sulphides are associated with disrcrete anomalies, some or all of which may be caused by the mineralisation itself. The magnetisation of the ore and hanging-wall ultramafic units, the most likely causes of the magnetic anomalies, was affected by their metamorphic or alteration history. This study try to create subsurface structure of manganese ore deposite base on rock properties and geological information in study area.

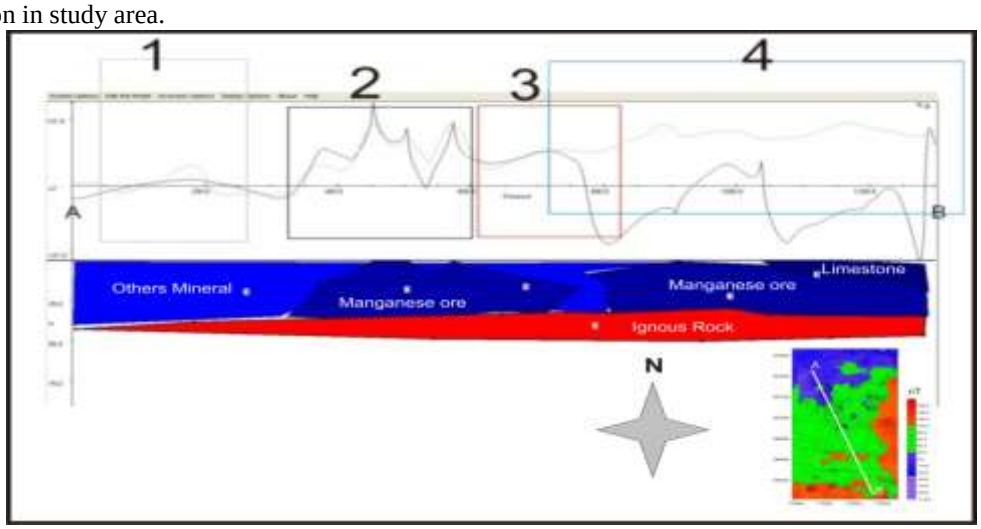

Figure 10 Interpretation magnetic profile over the manganese ore deposite in Babahlo area. The interpretation base on rock properties and geological information.

Figure 10 shows the cross-setion and corresponding to magnetic profile A-B accros deposits from local magnetic field in Babahlo area, Aceh Jaya. Modeling results showed that the subsurface rock manganese ore deposits formed bolder with a large size. Base on the model, was predicted manganese ore deposits spread below the surface at a depth of 5 meters to 40 meter with an average thickness of 30-35 meter and spread from east to west. If we make group (1 to 4) then group 1 is group with low magnetic (diamagnetic mineral) are suspected as the other mineralized zones. Group 2 and 3 have a medium magnetic value (Paramagnetic) and interpreted as manganese ore deposits. But in group 3 manganese ore was found below the surface at a depth of 5-10 meters because there is still soil with the thickness up to 5-10 meters. Group 4 is a contact zone between a manganese ore and limestone. In geological processes, manganese ore deposits generally mineralized rock from limestone so that in some areas where the ore manganese deposits are always followed by the appearance of limestone.

VI. CONCLUSIONS

Based on the geomagnetic study for manganese ore deposit in Babahlo area, Aceh Jaya district, Aceh province, it can be described those are:

1. The geomagnetic method can be used as a primary exploration for many mineral deposit types particularly for manganese ore deposits**.**
2. Based on geological field mapping, the manganese ore deposit was found such as boulders around the stream of Babahlo area.
3. The geomagnetic results show that the manganese is formed in sedimentary rocks. The manganese ore is dominant in the Southern part and spreads from East to West and progressively thinner towards the north.
4. In the Southern part was found the positive magnetic anomaly, which related to the ferromagnetic rocks (limestone) and also found the rocks which are paramagnetic response that indicated the Manganese Ore

deposit. While in the Northern part was found a negative magnetic anomaly values which are estimated gold and copper on the sedimentation process of clay and quartz rocks.

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