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RESEARCH ARTICLE

A Geophysical Survey with Magnetic Method for Interpretation of Iron Ore Deposits in the Eastern Nusawungu Coastal, Cilacap Regency, Central Java, Indonesia

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Abstract

Geophysical survey with magnetic method to interpret the iron ore deposits in the Eastern Nusawungu Coastal, Cilacap Regency, Central Java, Indonesia was carried out during six month, i.e. March –August 2017, covering the area in the geographical position of 109.3462° – 109.3718° E and 7.6958° – 7.7098° S. This survey has produced total magnetic field strength data at each measuring point in the research area. The magnetic field strength data which have been obtained, then be processed, corrected, and mapped so that the local magnetic anomaly contour map can be obtained. The local magnetic anomaly contour map shows the distribution of magnetic anomalous sources in the subsurface of research area. The 2D-modeling of magnetic anomalies data has been carried out along the AB trajectory extending on the local magnetic anomaly contour map from the position of A(109.3463°E and 7.7023°S) to B (109.3688°E and 7.7053°S), so that some subsurface anomalous objects is obtained. The modelling results of magnetic anomalies data show that the research area is estimated to have the potential of iron ore deposits. The subsurface rocks deposits containing iron ore are estimated to be located below the AB trajectory with a length about of 164.85 meters, a depth ranging of 1.709 – 31.909 meters, and a magnetic susceptibility value of 0.0122 cgs unit. These rocks are interpreted as sand deposits which coexists with silt and clay containing iron ore grains from the alluvium formation. Further, iron ore is also estimated to be present in the rocks deposits below the AB trajectory which have a depth of 24.405 – 49.809 meters and 3.989 – 11.111 meters, with the magnetic susceptibility values of 0.0093 and 0.0073 cgs units.

Keywords: Geophysical Survey, Magnetic Method, Iron Ore, Eastern Nusawungu, Cilacap Regency

1. Introduction

1.1 Background of Research

Along with the increasing human needs, currently the exploration technology of natural resources to be developed, especially the subsurface natural resources. One method that is quite well used for exploration of subsurface natural resources is the magnetic method. This method is suitable used for exploration, especially for metallic ores and minerals (Ahnin et.al. 2013 and Ba Dai et.al., 2014). The basic of the magnetic method is to utilize the variation of the subsurface rocks magnetic susceptibility thatmeasured on the earth's surface to interpret the geological structure or subsurface rocks physical model thatbe the target of the research. Some types of subsurface rocks or geological structures that can be interpreted using the magnetic method are fold, fault,igneous rock intrusion, metallicores, geothermal reservoir,and others. One type of metallicoreswhich is commonly explored using the magnetic method is iron ore(Amigun e.al., 2012 and Vincent et.al., 2013).

The coastal of Cilacap Regency have the potential of abundant iron ores. The mining activity in this area (i.e. the Western Coastal of Cilacap Regency) have produced about of 300,000 tons of iron ore concentrates per year (Herman, 2005). Iron ore mining which carried out over several years has resulted in decline in iron ore reserves along the coastal of Cilacap Regency. According to the Mining and Energy Office of Cilacap Regency, currently the remaining iron ore reserves are estimated to be only 600,000 tons with iron (Fe) content is less than 50%, sothat less prospect. Although the large-scale mining has been closed and the former mining area was reclaimed, but the minings in small-scale still continueto this now time (Antaranews.com, 2007).

One area which is estimated still to store iron ores reserves is the EasternCilacap Regency Coastal. This area include of Binangun and Nusawungu Coastal. Iron ores reserves in these areas have not been mined,with thetotal areas of more than 500 hectares, degree of magnetism is about of 12.2% and the iron (Fe) content is more than 53%. Overall, the iron ore reserves which have not been mined in these coastal are spreading from the Welahan Wetan Village in Binangun District to the Jetis Village in Nusawungu District, with estimation are about 744,678.85 tons of reserves (Anonim, 2015). The magnetic survey has been conducted in these coastal areas, including the Widarapayung Coastal (Sehah et.al., 2016), the Eastern Coastal of Binangun (Sehah et.al., 2017), the Western coastal of Nusawungu (Raharjo and Sehah, 2017), and Eastern Coastal of Nusawungu. This paper is focused to publish the results of the magnetic survey in the Eastern Coastal of Nusawungu only.

Iron metal is an important raw material which has been used by almost all industries for centuries to the present.

Some of the uses of ferrous metal is materials for concrete construction, bridges, transportation such as trains, cars, motorbikes, and so on. Aside from being a raw material for the steel industry, the nano-sized iron sand is also used as a mixture of cement, laser printer, and dry ink (toner). Given the importance of the iron sand contribution in the industrial world, so necessary to investigate the potential and distribution of the iron ores which is buried in the Coastal of Cilacap Regency, especially the areas which have not been exploitedlike the Eastern Coastal of Nusawungu (Anonim, 2015).

The objective of this geophysical survey is to model the subsurface anomalies sources which are thought to contain iron ore in the NusawunguEastern Coastal area. One of method in the geophysical survey which suitable for exploration of anomalies sources which are thought to contain iron ore is magnetic method. The magnetic method is a geophysical exploration methodbased on the measurements of magnetic field variations on the earth surface which arise due to the distribution of non-homogeneous magnetized rocks andminerals in the subsurface (Adagunodo et.al. 2015; Waswa et.al. 2015). The basic principle of the magneticmethod is to utilizevariation of measurable magnetic field valueto model subsurface anomalous objects based on their magnetic susceptibilities values. The magnetic method is suitable be used for the iron oreexploration and other metallic ore, because their magnetic susceptibilityare generally very large, so that it can be detected easily (Grandis and Sumintadireja, 2018).

1.2. Basic Theory

A volume of objects such as subsurface rocks that consist of magnetic materials or magnetic minerals can be considered as magnetic dipoles as shown in Figure 1 (Telford et.al., 1990). The magnetization that occurs on the object depends on its track record as long as it is in the main magnetic field of the earth, or in other words depends on the magnetic induction that received from the main magnetic field of the earth. The magnitude of the magnetic potential contained at a point in the rock can be written with the equation (Telford et.al., 1990).

$$V = -C_m \vec{m} \bullet \nabla \left[\frac{1}{r} \right] = C_m \frac{m \cos\theta}{r^2} \tag{1}$$

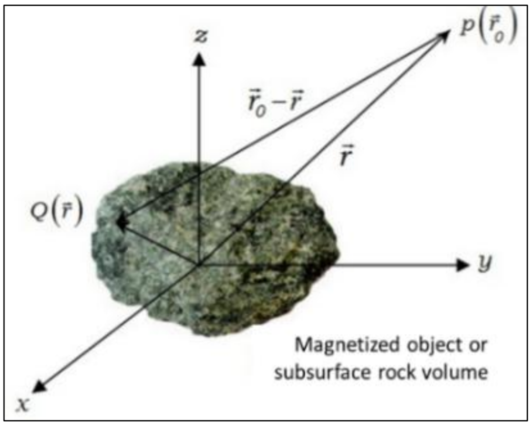

Fig. 1. Magnetic anomalies from rocks or magnetized objects in the subsurface of the Earth.

By integrating the equation (1) and changing the variables slightly, the magnetic potential quantity of all rock volumes can be calculated using the equation

$$V(\vec{r}_0) = -C_m \int \vec{M}(\vec{r}) \bullet \nabla \left[\frac{1}{|\vec{r}_0 - \vec{r}|} \right] dv \tag{2}$$

where $\vec{M}(\vec{r})$ in equation (2) is the dipole moment per unit volume and C_m is a constant. If $\vec{M}(\vec{r})$ is fixed and has a fixed direction, then the magnetic induction of all rock volumes can be calculated through an integration process which can be expressed by the equation

$$\vec{B}(\vec{r}_0) = C_m \nabla \int_V \vec{M}(\vec{r}) \bullet \nabla \left[\frac{1}{|\vec{r}_0 - \vec{r}|} \right] dV \tag{3}$$

The magnetic induction field such as equation (3) is referred to as magnetic anomaly that superposed with the earth's main magnetic field (B_0) at all points on the surface. Thus, the total magnetic field value recorded in the magnetometer apparatus at a point on the surface is combination of the main magnetic field and magnetic anomaly (B_{r0}), with assuming that the external magnetic field is ignored. This formulation can be expressed with simple equations

$$\vec{B}_T = \vec{B}_0 + \vec{B}(\vec{r}_0) \tag{4}$$

But in reality to get the total magnetic anomaly, it is necessary to correct to the total magnetic field data that measured at each point on the surface, which includes daily correction (B_D), topographic correction (B_{To}), and main magnetic field or IGRF correction (B_0). If the total magnetic anomaly is denoted as ΔB, the equation of the correction can be expressed by (Stella et.al., 2015)

$$\Delta B = B_T - B_D - B_0 \tag{5}$$

IGRF is stands for the-International Geomagnetic Reference Field which is the main magnetic field of the earth. The IGRF value on the surface is not constant, but changes according to latitude position and time. The effect of magnetic value variation in IGRF is anticipated by updating and setting IGRF values regularly, i.e. every five years (Macmillan and Maus, 2005).

2. Research Method

Magnetic survey for exploration of buried iron ore deposits in the Eastern Nusawungu Coastal area of Cilacap Regency has been carried out in March - August 2017 with the location as shown in Figure 2. Magnetic data acquisition has been conducted covering the area in the geographical position of 109.3462° – 109.3718°E and 7.6958° – 7.7098°S. Then processing, modeling, and interpretation of obtained magnetic anomaly data have been carried out at the Geophysical Laboratory, Faculty of Mathematics and Natural Sciences (MIPA), Jenderal Sudirman University, Purwokerto. Several equipment which is used for magnetic surveying consists of Proton Precession Magnetometer, Global Positioning System, Compass, Surfer 7, Mag2DC 2.11 for Windows software, and several other supporting equipment.

The research begin with magnetic data acquisition. After the total magnetic field strength dataare obtained, then several corrections which include daily and IGRF corrections are applied, so that the total magneticfield anomalies data can be obtained. The total magnetic field anomalies data is spreaded on the topographic surface, so must be reducedto horizontal surface. It is because those magnetic anomalies data cannot be processed in the next, if not distributed on the horizontal surface (Blakely, 1995). Then the magnetic anomalies data are corrected from the effects of regional magnetic anomaly so that the local magnetic field anomalies data can be obtained (Telford et.al, 1990; Mariita, 2008).

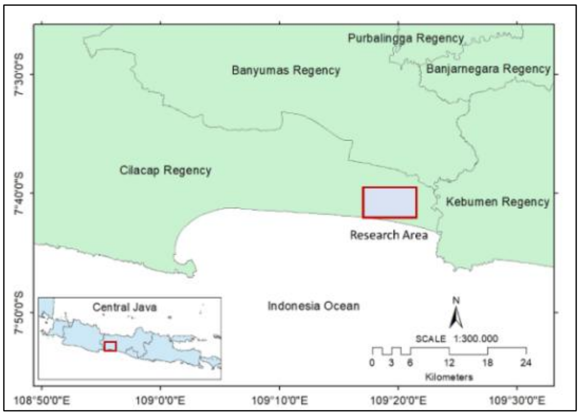

Fig. 2. The research location; The Eastern Nusawungu Coastal in Cilacap Regency.

The total magnetic anomalies data in equation (5) are still spreaded on the topographicsurface, so that it is a function of longitude (x), latitude (y), and altitude (h). Further, the anomalies data is reduced to horizontal surface (h_0) from topographic using the Taylor series approximation, which can be written as equation (6). Equation (6) can be written in an iterative form, where $\Delta B(x,y,h_0)$that is a magnetic anomalies data distributed in a flat surface an be estimated through an approach;ΔB (x,y,h_0) obtained from i-thiterations can be used to obtain the value of ΔB (x,y,h_0) in the $(i+1)$-thiteration. The iteration process is done sufficiently, so that the value of $\Delta B(x,y,h_0)$which obtained shows convergence (Blakely, 1995).

$$\Delta B(x,y,h_0)^{[i+1]} = \Delta B(x,y,h) - \sum_{n=0}^{\infty}\frac{(h-h_0)^n}{n!}\frac{\partial^n}{\partial z^n}\Delta B(x,y,h_0)^{[i]} \qquad (6)$$

The magnetic anomalies data that have been spread in the horizontal surface is still affected by the effects of the regional magnetic anomalies. Therefore the regional magnetic anomalies data must be reduced because the target of this research is a local geological structurelike iron ore deposits. The regional magnetic anomalies data is obtained through upward continuation of magnetic anomalies data which have distributed in the horizontal surface to a certain height ($h_0 + \Delta h$), so that changing in anomalous data show a subtle trend. The equation of upward continuation for anomalies data is taken from the 2ndidentity of Green theorems (Blakely, 1995), whose formulation can be expressed asequation (7)

$$\Delta B(x',y',h_0+\Delta h) = \frac{\Delta h}{2\pi}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\frac{\Delta B(x,y,h_0)}{\sqrt{\left((x'-x)^2+(y'-y)^2+\Delta h^2\right)^{3/2}}}\,dx\,dy \qquad (7)$$

ΔB $(x',y',h_0+\Delta h)$ is a regional magnetic anomalies data, which is then corrected to the total magnetic anomalies data which have distributed in the horizontal surface, using the following equation (8) (Stella et.al., 2013)

$$\Delta B_{Local} = \Delta B(x,y,h_0) - \Delta B(x',y',h_0+\Delta h) \qquad (8)$$

The local magnetic anomalies data which obtained are magnetic anomalies data that represents the subsurface conditions that are shallow (in the crust near surface).

3. Results and Discussion

The results which obtained in this research include the results of data acquisition, the results of magnetic anomalies data processing, and the results of modeling and interpretation.

3.1. Results of Data Acquisition and Processing

Acquisition of the total magnetic field data has been carried out in the Eastern Nusawungu Coastal area of Cilacap, covering the area in the geographical position of 109,3462°E – 109,3718°E and 7,6958°S – 7,7098°S, with the location map as shown in Figure 3. The results whichobtained are total magnetic field data (B_T) at each measurement point with values ranging of 44,384.28 – 45,291.84 nT. To get the total magnetic anomaly data, thenseveral corrections and reduction were carried out as explained in the Research Method section. The data corrections which has been performed including of the daily correction and the IGRF correction.

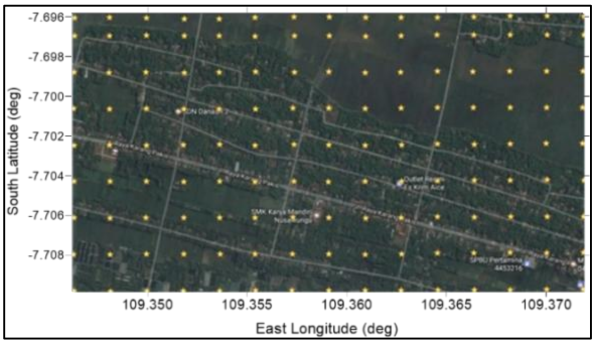

Fig. 3. The location map from google earth of research area (Eastern Nusawungu Coastal area) which completed with the measurement points position.

The daily correction is performed using the looping technique, where looping is done every two hours. And IGRF correction is done using online calculations from services provided by National Geophysical Data Center (https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml). The results of online calculation show that the IGRF value for this area is 44,998.5 nT. After apply several corrections, then the total magnetic anomalies data are obtained. These anomalies data is distributed on the topography with values ranging from -612.55 – 296.29 nT, as shown in Figure 4.

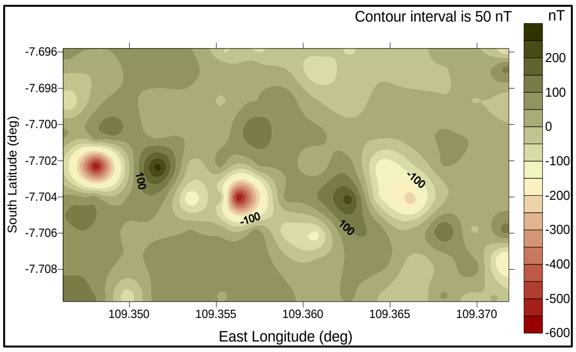

Fig. 4. The total magnetic anomaly contour map; distributed above the topographic surface.

Then the total magnetic anomalies data are reduced from the topographic surface to the horizontal surface using Taylor Series approximation like equation (6), so the anomalies data can be processed in the next stage. The horizontal surface has been chosen at the height of average topographic,i.e. 25.63 meters above a reference spheroid, so that the iteration process to calculate the magnetic anomalies value sreach convergence quickly (Blakely, 1995). The magnetic anomalies data obtained from this calculation process have ranging of -478.77 – 221.62 nT with a contour map is shown in Figure 5. The ranging between maximum and minimum anomalies data is relatively smaller than the ranging of anomalies data when still above the topography. This shows that the iteration process in the Taylor Series calculations has reached convergent, so that anomalies data which obtained is considered to have been distributed on the horizontal surface (Blakely, 1995).

The research target is near surface objects, i.e. iron sand deposits, so magnetic effects from deep and wide sources must be reduced. This magnetic effect is called as regional magnetic anomaly. Those regional magnetic anomalies data were found through process of upward continuation of the total magnetic anomalies data which distributed on the horizontal surface to a certain height, so the ranging of anomalies data has shown a very small value and its contour map tends to remain (Mastellone et.al., 2013). Upward continuation process of anomalies data is done step by step; where for each upward step is equipped with anomaly contour image, as can be seen in Appendix 1. Visual observation is done to determine; whether anomaly contour pattern has shown regional anomaly pattern. Based on this criteria,the anomaly contour as show in Figure 6 isdesignated as the regional magnetic anomaly contour map, because it has shows regional pattern (Ganiyu et.al., 2013). This contour has been obtained from upward continuation process at height of 2,250 meters above the reference spheroid.

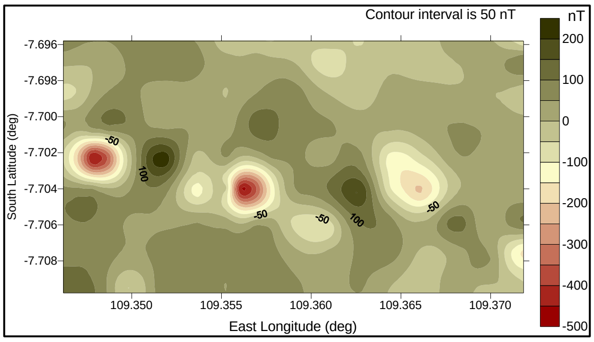

Fig. 5. The total magnetic anomaly contour map; distributed above the horizontal surface (average topographic).

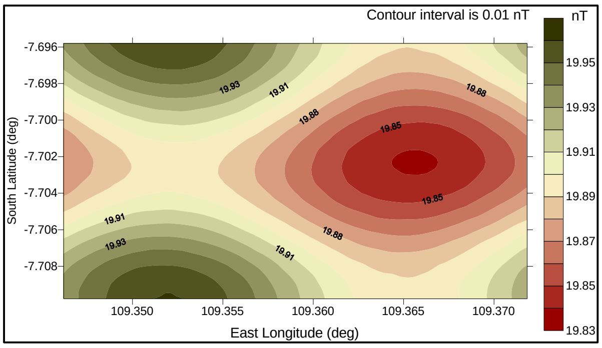

Fig. 6. The regional magnetic anomaly contour map which has beenupwarded to a height of 2,250 metersabove the references pheroid.

The regional magnetic anomalies data that obtained then corrected to the total magnetic anomalies data that has been spread above the horizontal surface, so that the local magnetic anomalies data are obtained. Thes edata have values ranging of -498.66 – 201.73 nT. The local magnetic anomaly contour map completely can be seen in Figure 7. The local magnetic anomaly contour represents a geological condition near surface including the iron ore deposits in the research area. Based on the results of previous research (Sehah et.al., 2017) and the geological information (Herman, 2005), that the Cilacap Regency Coastal is dominated by iron sand, including the Nusawungu Coastal area. Therefore, the magnetic anomaly contour pattern which resulted has a strong correlation with the content of iron ore in it.

The local magnetic anomaly contour map obtained show several pairs of magnetic dipoles which located in the middle relatively towards the west. The objects that are sources of magnetic anomalies are estimated to be located below this zone, one of which is iron ore. This coastal area is the most eastern area of the whole area that have prospect of iron sand in Cilacap Regency. It is based on the geophysical survey results using magnetic method (Sehah and Raharjo, 2017). The research result shows that the Binangun and Nusawungu Coastal areas are iron ore prospective areas, especially the Eastern Binangun and the Western Nusawungu Coastal. While the potential of iron ore in the Eastern Nusawungu Coastal is estimated not be as large as both areas.

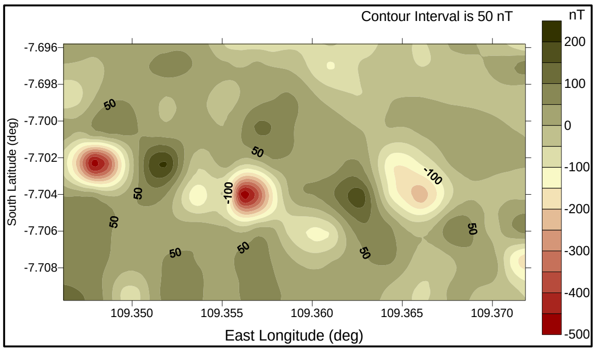

Fig. 7. The local magnetic anomaly contour map at theaverage topographic height of research area.

3.2. Results of Modeling and Interpretation

To explore the distribution of iron ore deposits in the Eastern Nusawungu Coastal area, anomalous object modeling has been carried out in two dimension (2D). The 2D-modeling begins by making the trajectory above the local anomaly contour through several anomalous closures which indicate dipoles pairs (Lino et.al., 2018). This area is estimated to contain iron ore deposits. The 2D-modeling is done on the local magnetic anomalies data which extracted from the AB trajectory, as can be shown in Figure 8.

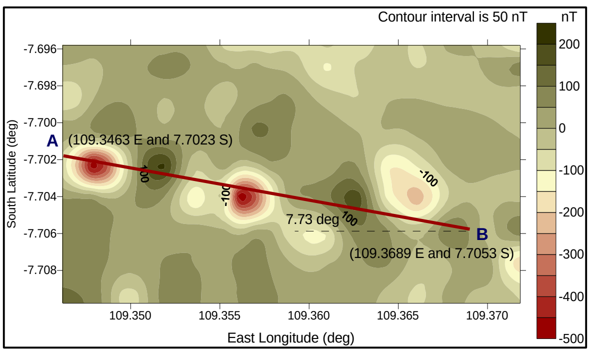

Fig. 8. The AB trajectory which is placed on the local magnetic anomaly contour map with a direction of 7.73° N-W.

The AB trajectory has a length about of 2,345.10 meters and stretching from position of 109.3463°E and 7.7023°S to

109.3689°E and 7,7053°S. The magnetic anomalies data which extracted from the AB trajectory, then referred to as observation anomalies data in the form of a curve.

The modeling on the local magnetic anomalies data is done using the curve matching techniques between the observation anomaly curve versus the calculation anomaly curve. The observation anomaly curve is taken from the local anomalies data that extracted along the AB trajectory. After two curves reach a match, then eight anomalous objects are obtained in the subsurface. All objects can be interpreted as the subsurface rocks of the research area as can be shown in Figure 9, including the iron ore deposits. Before 2D-modeling is done, several model parameters are needed. Several parameters that used in the modeling are IGRF values, inclination angle, and declination angle of the research area as can be seen in Table 1. The parameter values can be accessed online easily and completely through the website at: https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml

Table 1. The parameters which used in the 2D-modeling of the local magnetic anomalies data

No	Parameter	Value
1	Main Magnetic Field (IGRF)	44.996,30 nT
2	Inclination angle	-32,441°
3	Declination angle	0,853°

To interpret the subsurface anomalous objects that obtained, the average magnetic susceptibility value for the rocks in the research area must be estimated firstly based on the geological information. Geologically, this research area is composed of alluvium formations and coastal sand deposits. The alluvium is composed of silt, clay, sand, and gravel containing iron ore grains;while the coastal sand deposits consist of loose sand grains which intersect with iron ore (Herman, 2005). Below the two rock formations is the Halang formation which is composed of claystone, sandstone, marl, and tuff with breccia inserts (Asikin et.al., 1992). The geological map of the research area is shown in Figure 10. Based on the geological information supported by simple calculation, the average magnetic susceptibility value of rocks in the research area is estimated as0.0080 cgs unit (Sehah et.al., 2017). While the magnetic susceptibility value of each subsurface object can be obtained by summing the average magnetic susceptibility values of rocks to the magnetic susceptibility contrast value of each anomaly object, as be shown in Table 2. Based on the magnetic susceptibility values of each subsurface object which supported by the geological information of the research area, then lithological interpretation can be conducted. The results of interpretation for each anomaly object has been shown in Table 2. Generally, the iron ore are thought to occur in the alluvium rocks deposits near the surface (Hikmatyar, 2016) such as object 1, object 2, and object 3.

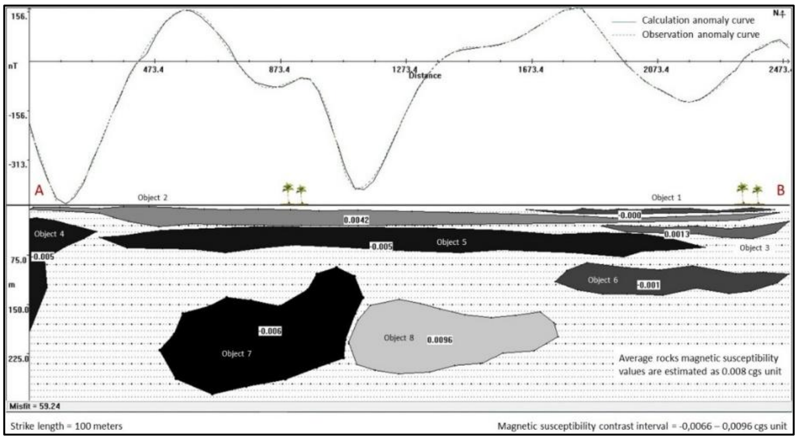

Fig. 9. The result of 2D-modeling on the local magnetic anomalies data along the AB trajectory using the Mag2DC for Windows.

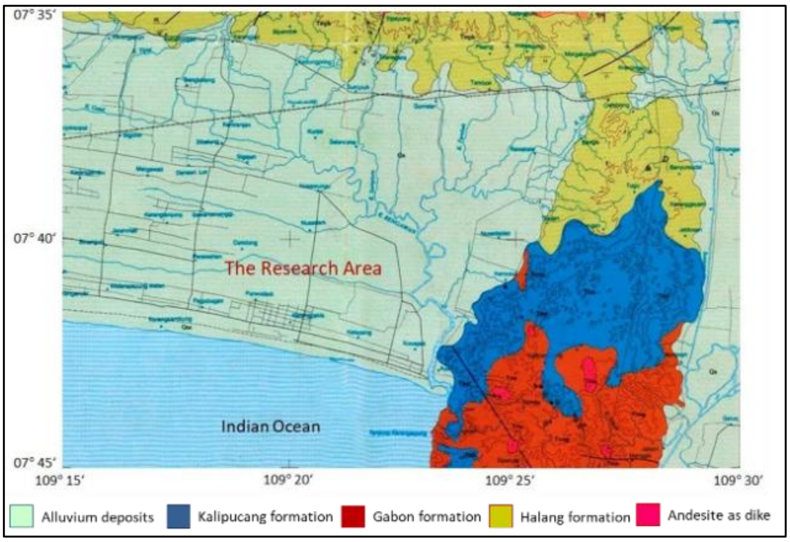

Fig. 10. The geological map of the research area which is part of Geological Map – Sheet of Banyumas Central Java Indonesia. This research area are covered by alluvium deposits which is composed of silt, clay, sand, gravel; and coastal sand deposits consisting of loose sand grains which intersect with iron ore grains (Asikin et.al., 1992).

Table 2. The results of the calculation of the magnetic susceptibility value of each anomalous object and its interpretation

No.	Anomaly Object	Depth (meter) Top	Depth (meter) Bottom	Magnetic Susceptibility (cgs) $\Delta\chi$	Magnetic Susceptibility (cgs) χ	Results of Interpretation
1	Object 1	3.989	11.111	-0.0007	0.0073	Alluvium deposits; composed of sand, silt, clay, and gravel containing iron ore grains
2	Object 2	1.709	31.909	0.0042	0.0122	Alluvium deposits; sand inserted with silt and clay containing iron ore grains significantly
3	Object 3	24.405	49.809	0.0013	0.0093	Alluvium deposits; composed of sand, silt, clay, and gravel containing iron ore grains
4	Object 4	19.140	193.477	-0.0050	0.0030	The rocks from Halang formation; composed of sandstone, claystone, marl, tuff, and other
5	Object 5	32.289	77.842	-0.0050	0.0030	
6	Object 6	87.179	134.188	-0.0014	0.0066	
7	Object 7	94.017	285.470	-0.0066	0.0014	
8	Object 8	142.735	255.556	0.0096	0.0176	The rocks from Halang formation; composed of sandstone, claystone, marl, tuff and other with inserted by breccia

The modelling result of the local magnetic anomaly data indicate the presence of anomalous objects in the subsurface which estimated to have iron ore prospects. The anomaly object is interpreted as sand that inserted with silt and clay containing iron ore from the alluvium formation (object 2). This rock deposit has a length of about 164.850 meters, a depth of 1.709 – 31.909 meters, and the magnetic susceptibility value of 0.0122 cgs unit. This rock is located below the largest magnetic dipole pair, which indicates the large magnetic susceptibility value such as iron ore (Siregar & Budiman, 2015; Joshua et.al., 2017). Iron ore is also estimated be present in other anomaly object, that interpreted as alluvium deposit consisting of sand, clay, and gravel containing of iron ore grains (object 3). This rock deposit has length about of 376.281 meters, depth ranging of 24.405 – 49.809 meters, and susceptibility is 0.0093 cgs unit. The Iron ore grains are also estimated to be found near the surface although not dominant, that are interpreted as clay, sand, silt, and gravel containing iron ore granules (object 1). This interpretation is based on its magnetic susceptibility value which relatively large (i.e. 0.0073 cgs unit) and supported by direct observation in the field. This rock stretches below the AB trajectory with a depth of 3,989 – 11,111 meters and have an important role as a buffer rocks in the coastal area.

The modelling results show that the iron ore which be estimated to be present in the rocks (object 2) has formed a elongated deposits. Generally iron ore grains are found along the coastal, which be formed due to the destruction of the host rock from volcanic eruptions by weather and water in the surface. The destruction rock process occurs due to heat and rain, resulting in iron mineral granules detached from the rock. Furthermore, iron ore and other materials from the destruction are transported and deposited along the coastal. Certain waves of sea water have sorted and accumulated these deposits into iron ore grains. Most iron ore which has a large density will be deposited over the coastal, while iron ore which has a light density will be carried back by waves into the sea. This happens continuously so as to form iron sand deposits in the coastal (Kurnio, 2007 and Hilman et.al., 2014) as results which obtained from the modeling in this research. Figure 11 shows the iron ore grains which spread unevenly in the alluvium deposits on the research area surface.

Most of the iron ore mineral resources in coastal are from volcanic rocks, namely andesite and basaltic rocks. Geographically the research area is about 60 kilometers from Slamet Volcano Central Java, Indonesia. Possibility of the material from volcanic eruptions containing iron ore minerals carried by the river flows to this coastal areas, as explained before. In addition, there is a Gabon formation in the eastern research area, which is often found volcanics rocks intrusion as can be shown in the geological map in Figure 10. The intrusion rock material that eroded and carried by river water flow in this area is also estimated to contribute to the formation of iron ore deposits. This Gabon formation is located in the Karangbolong Mountains which is thought to be an ancient volcano that has been lost. Geographically, this area is located in Kebumen District, Central Java.

Fig. 11. Iron ore grains which spreaded in the alluvium deposits on the surface of the research area unevenly (source: personal documentation).

Exploitation of iron sand which is likely to be carried out in this research area is feared to cause rock or sand material to be reduced, so that the surface will decrease. The surface decrease results in environmental damage and increases the potential for sea water intrusion. The seawater which have large density and higher pressure becomes easier push groundwater and interface zones in the aquifer, so that intrusion can occur. In addition, the exploitation of iron sand in the coastal is also feared to result in abrasion. Moreover, naturally abrasion has occurred in this region, as shown in Figure 12.

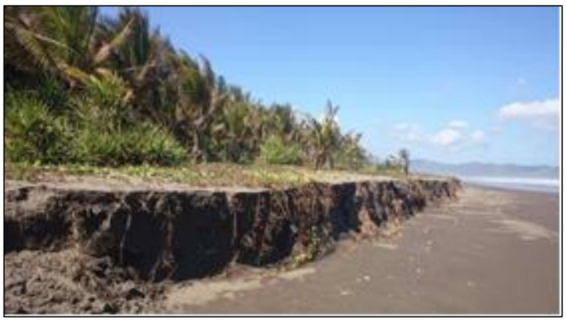

Fig. 12. Abrasion of the alluvium deposits in the Nusawungu Coastal Area which has occurred due to the sea water waves (source: personal documentation).

4. Conclusion

Geophysical exploration with a magnetic method to investigate the iron ore deposits in the Eastern Coastal Area of Nusawungu, Cilacap Regency, Central Java has been carried out. Based on the results of research which has been obtained can be concluded:

a. The research area has the iron ore potential which is estimated to be localized below the AB trajectory with a length of 164.85 meters, a depth ranging of 1.709 - 31.909 meters, and magnetic susceptibility value of 0.0122 cgs unit which interpreted as sand inserted with silt and clay containing iron ore grains significantly from the formation alluvium.
b. Iron ore deposits are also estimated to be found in the alluvium at a depth of 24.405 – 49.809 meters with magnetic susceptibility value of 0.0093 cgs and at a depth of 3.989 – 11.111 meters with magnetic susceptibility value of 0.0073 cgs unit.
c. In addition to alluvium formation, other rocks that obtained from modeling are subsurface rocks from the Halang formation, with magnetic susceptibility value ranging of 0.0014 – 0.0176 cgs unit, which is composed of sandstone, claystone, marl, tuff, and other with inserted by breccia.

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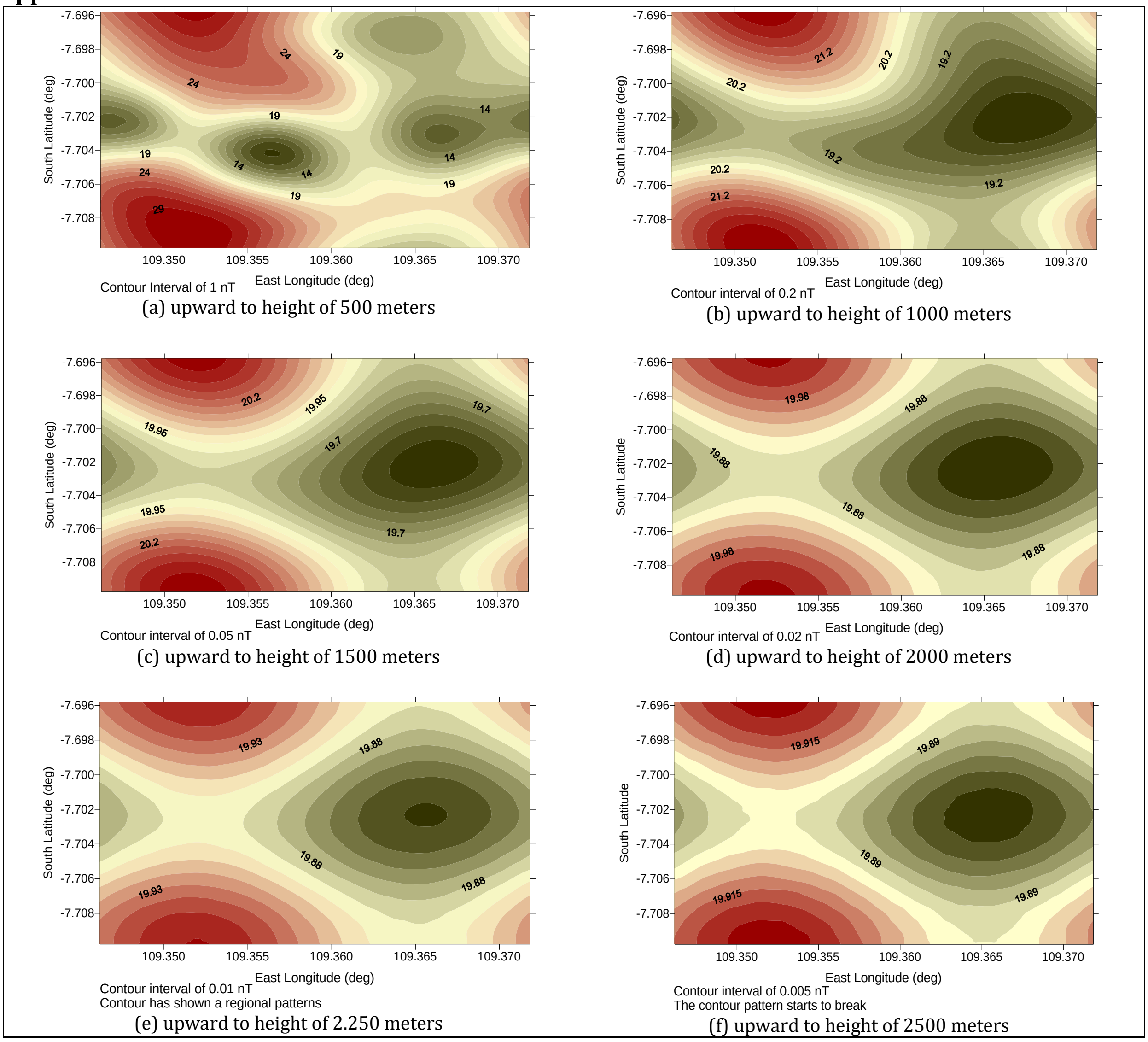
Appendix 1



Appendix 1. Several magnetic anomaly contour resulted from upward continuation process of the total magnetic anomalies data. The magnetic anomalies data is upwarded from a height of 500 meters up to 2500 meters above the reference spheroid. Initially upward continuation process of the total magnetic anomalies data is carried out every 500 meters. However, after approaching regional conditions, the upward process is carried out every 50 meters to reach a certain height which shows a fixed contour pattern with interval anomalies values is very small. This contour map is considered to have shown regional magnetic anomalies (Ganiyu et.al., 2013), as shown in part (e).

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