Bulletin of Scientific Contribution GEOLOGY

Fakultas Teknik Geologi
UNIVERSITAS PADJADJARAN
homepage: http://jurnal.unpad.ac.id/bsc
p-ISSN: 1693-4873; e-ISSN: 2541-514X

Volume 16, No.3
Desember 2018

MANGANESE PROSPECT IDENTIFICATION USING MAGNETIC AND INDUCED POLARIZATION METHODS

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ABSTRACT

Surveys have been carried out using Magnetic and Induced Polarization methods over area dominated by Bobonaro complex formation. This survey was conducted with the purpose to identify a mineral source using data of magnetic, conductivity and resistivity of rock. Data acquisition applied 5 m dipole space with 50 m maximal depth coverage.

The interpretation was conducted by analyzing 2D and 3D sections of resistivity inversion, subsurface Induced Polarization, and geomagnetic anomaly. The interpretation result of chargeability anomaly indicates that mineral source occurred as a mineral of manganese with thin layer spreading in complex structural sediment. As is shown from IP anomaly supported by magnetic data obtained, the anomaly has a spread of 3 m to 10 m depth from the surface. The trend of anomaly has a continuity at other locations where is predicted as the manganese mineralization source.

***Keywords**: Induced Polarization, geomagnetic, manganese*

INTRODUCTION

Timor Island and some other islands are at the nonvolcanic Outer Banda Arc of negative gravity anomaly and shallow seismic zone (depth of earthquake fossil less than 100 km). Geology as well as its structure is very complicated due to which this island has come to the object of study by domestic as well as foreign earth science experts during the last 50 years. Geologic and structural complications are manifested by:

1. The presence of various kinds of rocks of different ages many of which are in structural contact.
2. The occurrence of chaotic rock which covers about 40% of the island.

There are still two different conceptions about this chaotic rock. On one hand, it is believed that this chaotic rock was of sedimentary origin (olistostrome) whilst on the other, it is suggested that it is of tectonic origin (melange).

Manganese

Bollenhagen (2004) described briefly about manganese as follow. Manganese is the fourth most used metal in terms of tonnage, being ranked behind iron, aluminum, and copper, within the order of 40 million tons of ore being mined annually. The main manganese minerals are pyrolusite (MnO_2), rhodochrosite($MnCO_3$), manganite($MnO(OH)$) and psilomelane($(BaH_2O)_2Mn_5O_{10}$). He wrote further about manganese deposits:

- ☐ Chemical sedimentary – Clastic sediments of varying composition to iron formations and carbonate rocks in either a geosynclinals or stable platform structural setting.
- ☐ Residual – Formed near the surface by the supergene processes of leaching and residual enrichment of either existing manganese deposits or low-grade manganese-bearing proctor.
- ☐ Hydrothermal – Emplaced by rising thermal waters.
- ☐ Metamorphosed – Thermal and/or dynamic metamorphism.

METHODS

The use of magnetic methods are based upon the concept of Coulomb's law of magnetic force generated by two separate poles at a distance r with its cargo of each and, as given by the equation:

$$\overline{F} = \left(\frac{q_1 \cdot q_2}{\pi \cdot r^2} \right) \hat{r}_1 \quad (1)$$

with :
μ = magnetic permeability, which shows the

properties of a medium

$\overline{F}$ = magnetic force (dynes) $q_1 q_2$

r = distance between the two magnetic pole

$\hat{r}_1$ = unit vector directed from the $q_1 q_2$

q = particle charge (Coulomb)

Magnetic Field Intensity in the MKS system can be expressed:

$$\overline{H} = \left(\frac{q_1}{\pi_0 \cdot r^2} \right) \hat{r}_1 \quad (2)$$

If an object is in a strong field H, the object will undergo magnetic polarization, given by:

$$\overline{M} = k \cdot \overline{H} \quad (3)$$

Magnetic polarization M usually called Magnetic Intensity and k is the magnetic susceptibility that reflects the nature of magnetism of rock. The magnitude is in SI units scale and emu, given by:

$k = 4\pi k'$ (= emu dan k = SI) (4)

The value of k and the geometry of the object is the main target in magnetic exploration.
In the measurements, the magnetic field measured is the induction of magnetic field included magnetization effect by ignoring the effects of the remanent magnetic field which in MKS system is given by:

$$\overline{B} = \mu_0 \left(\overline{H} + \overline{M} \right) = \mu_0 (1 + k) \overline{H} = \mu \cdot \mu_0 \overline{H} \quad (5)$$

with :

$\overline{B}$ = magnetic induction (Tesla)

μ_0 = magnetic permeability of free space ($4\pi 10^{-7}$)

Theory of Resistivity method

Resistivity is measured in ohm-m or ohm-ft and is the reciprocal of the conductivity of the material.

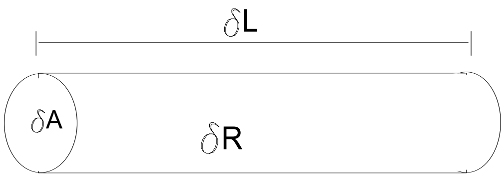

Figure 1: Resistivity is defined based on the change in resistance for a given change in length δL and cross- sectional area of material. δA

IP Survey Configuration Wenner Array

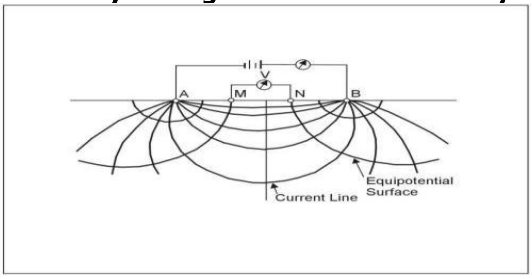

Figure 2: Equipotential and current lines for a pair of current electrodes A and B on a homogeneous half-space, AM=MN=NB= *a*.

The data from resistivity surveys are customarily presented and interpreted in the form of values of apparent resistivity $\rho\alpha$.
The effect of an electrode pair (or any other combination) can be found by superposition. Consider a single point electrode, located on the boundary of a semi-infinite, electrically homogeneous medium, which represents a fictitious homogeneous earth. If the electrode carries a current I, measured in amperes (a), the potential at any point in the medium or on the boundary is given by:

$$U = \rho \frac{I}{2\pi r}, \quad (6)$$

The mathematical demonstration for the derivation of the equation may be found in textbooks on geophysics, such as Keller and Frischknecht (1966). For an electrode pair with current I at electrode A, and -I at electrode B (figure 1), the potential at a point is given by the algebraic sum of the individual contributions:

$$U = \frac{\rho I}{2\pi r_A} - \frac{\rho I}{2\pi r_B} = \frac{\rho I}{2\pi} \left[\frac{1}{r_A} - \frac{1}{r_B} \right], \quad (7)$$

where;
rA and *rB* = distances from the point to electrodes *A* and *B*
Wenner array consists of four electrodes in line, separated by equal intervals, denoted *a*. Applying equation 2, the user will find that the geometric factor K is equal to *a*, so the apparent resistivity is given by:

$$\rho_a = \pi \left[\frac{s^2}{a} - \frac{a}{4} \right] \frac{V}{I} = \pi a \left[\left(\frac{s}{a} \right)^2 - \frac{1}{4} \right] \frac{V}{I}, \quad (8)$$

Wenner array is moved between successive observations. On the other hand, the Wenner array demands less instrument sensitivity, and reduction of data is marginally easier.

DATA ACQUISITION

Data acquisition for the magnetic method used three magnetometers. The first magnetometer was used as a base station while the others were measuring observation points, which reads the magnetic intensity values at the point of observation in the field with a fixed sampling time. Therefore, data of the base station measurement will correct the field measurement data. The measurements are advised to avoid any equipment made of metal and avoid measuring around outcrops, border because it will affect the readings. Readings of the Base station were set of *5 minutes time interval*. The amount of data is 120 daily variation data. The distance between the points of acquisition field magnetometer is *5 meters* so that distribution quite details to cover the survey area. The magnetometer read 3 (three) data for each measurement points, then data with optimal value for each point would be taken. The number of paths was measured in southern-block of survey area includes *11 lines* with each of the line length is about 600m. The data is very important to note the magnetic measurements, include:

- ☐ The value of magnetometer readings in the field, a minimum of three times measurements at each measurement station to reduce noise.
- ☐ The value in the base magnetometer readings also called daily variation.
- ☐ Major field of Earth, literature (IGRF 11, 2011).
- ☐ Time include day, time, and date.
- ☐ The position of the observation points was taken from GPS coordinates and field topography.

Data acquisition using Wenner Resistivity methods used one set of ARES multichannel model G-5A. For the first, used as a starting point while used as a Wenner Resistivity observation, which reads the voltage, apparent resistivity, and chargeability values at the between of points of observation in the field. The distance between the points of acquisition field Wenner Resistivity is every *5 meters*. The number of lines measured in South block includes *11 lines* with each of the line length is about *600m* and also taken the data along the baseline.

It is very important to note that the Resistivity data measurements with Wenner array include:

- ☐ The value of voltage readings in the field, a minimum of one or two times measurements at each measurement station to reduce noise.
- ☐ The value of resistivity and chargeability in the field, a minimum of one or two times measurements at each measurement station to reduce noise.

The position of observation point obtained from GPS geodetic coordinates and field topography.

RESULTS AND DISCUSSION

The area mineralization is generally associated with some of the rocks that have high-magnetic content but there is also that contain the relatively low-magnetic field. Base on total magnetic intensity, rocks containing low magnetic and the area mineralization was trapped in a vein system where the rock is relatively low resistivity, then a low magnetic response of the rock is necessary. Thus, the resistivity and magnetic responses are an important parameter for understanding the physical configuration of the rocks under the surface at the location.

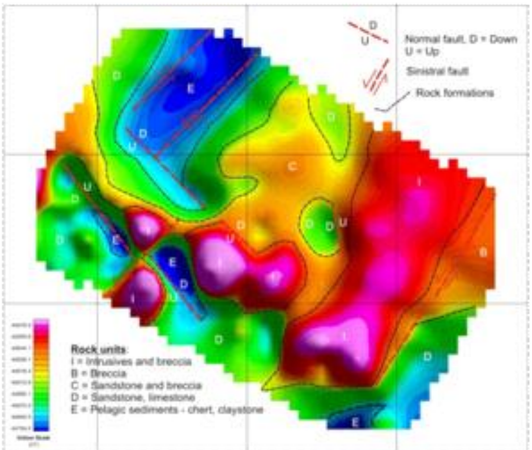

Figure 3. Interpretation of total magnetic intensity map in survey area consists of (I) intrusion (gabbro, diorite, and lava) and breccia, (B) breccia, (C) sandstone and limestone and (D) is pelagic sediment (claystone, chert). The structure consists of the northeast-southwest sinistral fault and northwest-southeast normal fault.

Reduced To the Pole (RTP)

The ground magnetics TMI contour have been advanced processed to give a Reduce to the Pole (RTP). This places the magnetic high close to the position of the magnetic source. An Interpretation of these results is presented as a figure: 4, there is no change to support the area of mineralization in the southern area; although there is intrusion there. Concerned with support data field, there is found manganese mineral in the northern area; associated to the northwest – southwest dextral fault in northern part.

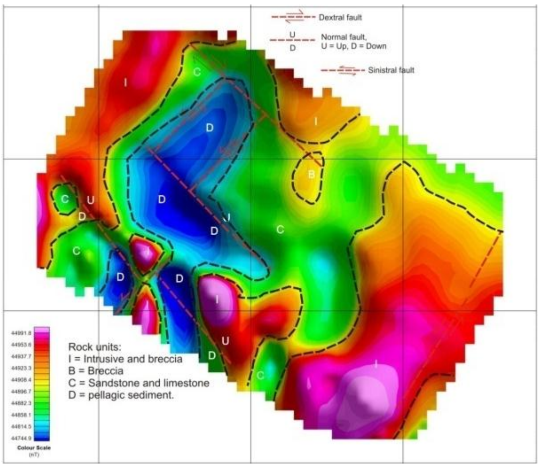

Figure 4. Interpretation of Reduced To the Pole magnetic anomaly map in survey area consists of (I) intrusion (gabbro, diorite, and lava) and breccia, (B) breccia, (C) sandstone and limestone and (D) is pelagic sediment - claystone, chert. The structure consists of northeast-southwest and northwest-southeast sinistral faults and northwest-southeast normal fault.

Induced Polarization Interpretation

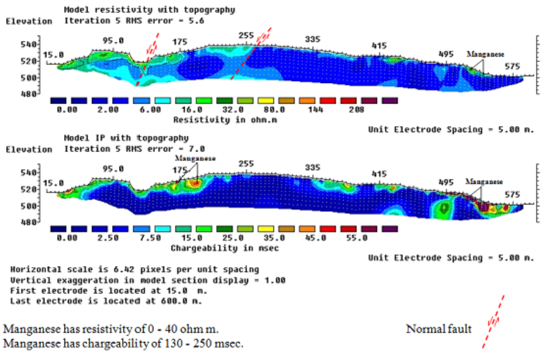

Figure 5. Line-X1 of resistivity and chargeability of Survey area; in resistivity cross-section interpreted to be a normal fault; there indicates low resistivity (blue and green). In chargeability cross-section, there indicates low anomaly (dominant blue), in the right side, there is green, yellow and brown-red colour as an indication there is manganese deposit.

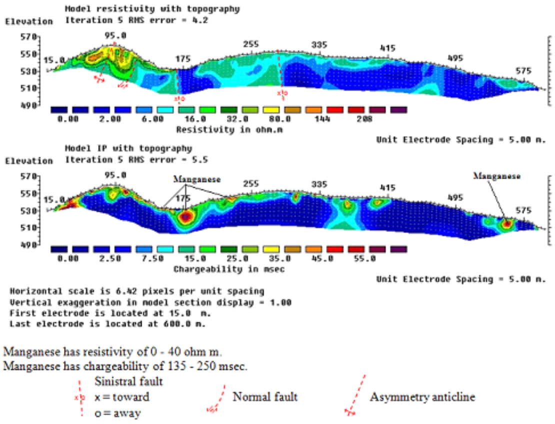

Figure 6. Line-X2 of resistivity and chargeability cross-section; in resistivity cross-section interpreted to be sinistral and normal faults; and asymmetrical anticline; there indicates low resistivity (blue and green in right side), the high resistivity in the left side (yellow colour). In chargeability cross-section, low anomaly indicates by dominant blue.

Generally, there are found rock units have low resistivity with blue to green colour in deepness 0 – 6 m. Lineaments of faults are directed to northwest-southeast(Figure 7 and 8).

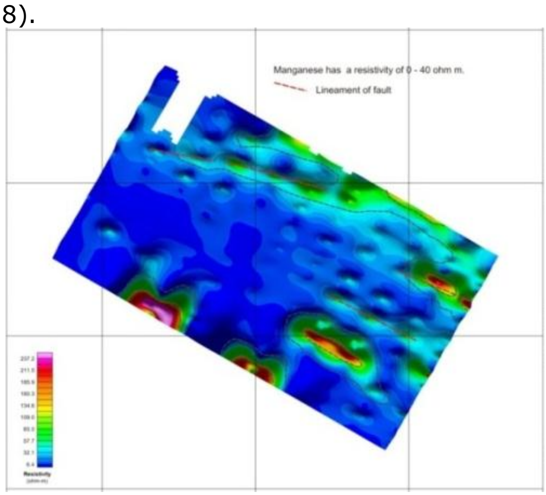

Figure 7. Map of resistivity anomaly in survey location. Deepness is 0 – 3 m. Generally, there are found rock unit has low resistivity (blue), green. High resistivity related to block of intrusion and breccia (red). Lineaments of fault directed northwest-southeast.

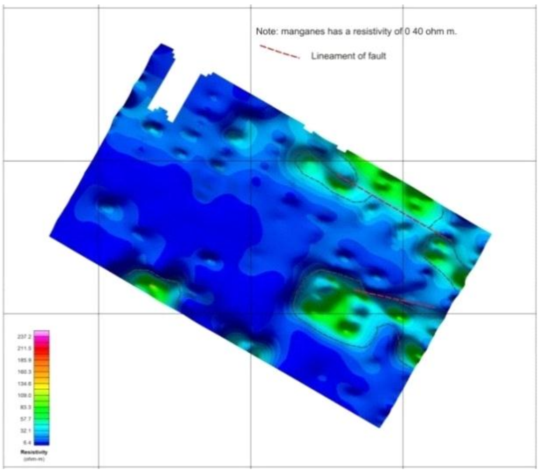

Figure 8. Map of resistivity anomaly in survey location. Deepness is 3 – 6 m. Generally, there are found rock unit has low resistivity (blue and green). Lineaments of fault directed northwest-southeast.

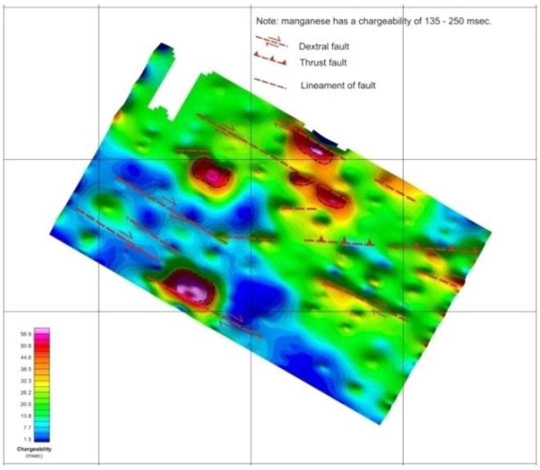

Figure 9. Map of chargeability anomaly in survey location. Deepness is 0 – 3 m. Generally, there are found rock unit has low chargeability anomaly (blue and green). High chargeability anomaly (northern and southern part) related to block of intrusion and breccia (red). Northwest-southeast dextral faults and east-west thrust fault; northwest-southeast lineaments of fault.

CONCLUSION

Base on analysis of ground magnetic data has identified of the presence of several of the possibility of mineralization zones, occurence and distribution at Southern Block of the survey area. The occurence of mineralization zones has enhancement by using advanced processing sequence such as: Total Magnetic Intensity (TMI), Reduced to the Pole (RTP).

Based on Total Magnetic Intensity (TMI) Map in Southern Block of the survey area, there are northwest-southeast normal faults and northeast-southwest sinistral faults. Rock units consist of intrusive and breccia, breccia, sandstone and limestone and pelagic sediments from the Analytical signal magnetic map in the survey area. Here, somebody of intrusions in the southern part is directed to northwest-southeast. This body of intrusion is part of Mutis Complex which consisted of gabbro, diorite. Now the area where the survey had been done is part of Bobonaro Complex. Bobonaro Complex is unit of mélange, aged Middle – Mio-Pliocene.

Base on Reduced to the Pole of magnetic map anomaly there is no change to support the area of mineralization in the southern area; although there is intrusion there. Concerned with support data field, there is found manganese mineral in the northern area; associated to the northwest – southwest dextral fault in northern part**.** The manganese deposit took place in sedimentary.

Map view of resistivity

Resistivity n1, there is northwest-southeast lineament of fault, low resistivity; n2 it contains northwest-southeast lineament low resistivity, blue-green; n3-4 n2 it contains northwest-southeast lineament low resistivity, blue-green; n5 it contains northwest-southeast and east-west lineaments, low resistivity, and n6 n2 it contains northwest-southeast lineament low resistivity, blue-green.

Map view of chargeability

In chargeability of n1, it has low chargeability of green – blue and red, northwest-southeast dextral fault, and east-west thrust fault. In chargeability of n2, it contains northwest-southeast dextral fault, east-west thrust, and low chargeability. In chargeability of n3, it contains northwest-southeast lineament and low chargeability. In chargeability of n4, it contains northwest-southeast dextral fault, east-west thrust, and low chargeability. In chargeability of n5, it contains northwest-southeast dextral fault, east-west thrust, and low chargeability. In chargeability of n6, it contains northwest-southeast dextral fault, east-west thrust, and low chargeability.

Structure in detail from a cross-section of resistivity and chargeability can be seen as follow. Symmetry and asymmetry fold which long axis of northeast-southwest have vergence from the southwest direction (3 Ma). Continued evidence of northeast-southwest thrust fault which has primary stress from the southwest; and sinistral faults have primary stress from the southwest (2 Ma – present). And sinistral, dextral and thrust faults have the primary stress of north-south when took place also on 2 Ma – present.

Fold and fault took place which is associated with the primary stress of southwest direction are older than faults which have the primary stress of north-south.

To know specifically and accurately about stratigraphy, a model of structures and manganese mineralization deposits it must be evaluated in the field.

ACKNOWLEDGMENT
The author would like to express vote of thanks to those who have helped the preparation of this article, until it can be realized.

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