EAGE

VOLUMETRIC CALCULATION BASED ON COMPARATIVE RESISTIVITY IMAGING ANALYSIS BETWEEN MARQUADT AND OCCAM INVERSION: AN ANDESITE QUARRY CASE STUDY

Aditya Aries Furkhan, Agra Adipta, Wrego Seno Giamboro, Yatini
Universitas Pembangunan Nasional "Veteran" Yogyakarta, Jl. SWK 104 (Ring Road Utara) Condongcatur, Yogyakarta, 55283

Summary

Volumetric determining in mining prospect encounters certain biases. Resistivity imaging was comprehended to determine the resistivity distribution of the andesite body. Inversion is used to characterize a subsurface property upon the geological condition. Inversion data are transformed into model parameters which could explain the possible subsurface properties that may cause the data be obtained based on the acceptable forward formulation (Martakusumah and Srigutomo, 2015). Marquadt and Occam inversion are non-linear inversions with a linear approximation. Both of inversions are used on the resistivity data resulting a comparative resistivity model. The result from Marquadt inversion suites more with the geological condition, in contrary with Occam inversion. Andesite body identified as a high resistivity value ranging 400 – 2000 Ω.m. Marquadt inversion portray intrusion shaped andesite with a volumetric reaching 9,987 x 10^6 m^3.

Keyword: Volumetric Calculation, Resistivity, Marquadt Inversion

Introduction

Mining industry in Indonesia need a breakthrough on determining prospects reserves. Volumetric calculation on most cases has been done by estimating the bulk volume of determined areas based on geological and topography map. This "conventional" method increases the uncertainty and mining risk of the mine reserve. Whereas overburden and rock bodies ratio is not well defined.

In this research, resistivity data was used as an analytical method to determine the andesite body. Geoelectric is an active geophysical method that aims to obtain resistivity parameters. The measured field data is an apparent resistivity due to the geoelectric assumption of homogeneous isotropy, while the real earth conditions is heterogeneous anisotropy. Inversion was needed to transform the apparent resistivity into true resistivity. Inversion data are transformed into model parameters which could explain the possible subsurface properties that may cause the data be obtained based on the acceptable forward formulation (Martakusumah and Srigutomo 2015).

In the inversion of resistivity data there are two inversions that are often in use, namely Marquadt and Occam inversion. The equations of both inversions are both using the concept of nonlinear inversion with linear approximation. On the basis of its inversion Marquadt and Occam are similar, but the difference lies in the Occam inversion which adds delta parameters to avoid overparameterized cases in the model. The purpose of this study was to compare the model of Marquadt and Occam inversion on the resistivity data and determine which model fits the best with the geological conditions. Based on the best inversion, the model will be used to estimate the volumetric rock body. In this case, the methodology is applied for calculating the andesite quarry volume.

Method and Theory

1. Geoelectric Method

The resistivity of a material is a quantity that indicates the level of resistance to electric current, the greater the resistance or the resistivity, the less current will propagate within the material (Hartyanto and Waluyo 2002). The geoelectric resistivity method is a method that applies artificial sources in the form of electric currents through the surface. The concept is to measure the potential of the surrounding electric current. Based on the measured electrical current, it is possible to know the sub-surface pseudo resistivity (Telford et al, 1990). Resistivity is the level of electrical resistance to an object symbolized by rho (ρ). Electrical resistance is proportional to the length (L) and inversely proportional to the area (A).

The equation can be formulated as follows:

$$R = \rho \frac{L}{A} \quad \text{......} \quad 1$$

Dengan,
R: Resistance (Ω)
ρ: Resistivity (Ω.m)
L: Length (m)
A: Area (m^2)

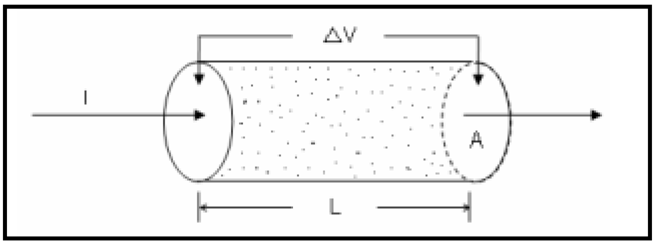

Figure 1. *Injected current on a homogenous medium (Zohdy et al, 1980)*

2. Lavenberg-Marquadt Inversion

The non-linier inversion sees the relation between data and parameter as,

$$G(m) = d \quad (1)$$

Here, the objective is to find values of the parameters that best fit the data. By assuming the measurements errors are normally distributed, we minimize the sum squared error that normalized by their standard deviations (Martakusumah and Srigutomo 2015).

$$f(\mathrm{m}) = \sum_{i=1}^{m} \left(\frac{G(m)_i - d_i}{\sigma_i} \right)^2 \quad (2)$$

And

$$F(\mathrm{m}) = \begin{bmatrix} f_1(m) \\ \vdots \\ f_m(m) \end{bmatrix} \quad (3)$$

If the $J(m)$ is the jacobian matrix,

$$J(m) = \begin{bmatrix} \frac{\partial f_i(m)}{\partial m_1} & \cdots & \frac{\partial f_i(m)}{\partial m_i} \\ \vdots & \ddots & \vdots \\ \frac{\partial f_m(m)}{\partial m_1} & \cdots & \frac{\partial f_m(m)}{\partial m_n} \end{bmatrix} \quad (4)$$

Then in the Lavenberg-Marquadt method, the inverse problem equals to finding solution of

$$\left(J(m^k)^T J(m^k) + \lambda I\right) \Delta m = -J(m^k)^T F(m^k) \quad (5)$$

Where λI is needed to ensure that the left-hand side matrix is non-singular. It denotes the identity matrix and λ is a damping parameter which is adjusted during the inversion to increase the magnitude of eigenvalues $J(m^k)^T J(m^k)$.

3. Occam Inversion

Occam inversion basically uses the discrepancy principle and seeks the solution that minimizes $\|Lm\|_2$ subject to the constraint $\|G(m) - d\|_2 \leq \delta$. The idea of Occam inversion is a local linearization which is applied iteratively as (Martakusumah and Srigutomo 2015):

$$G(m^k + \Delta m) \approx G(m^k) + J(m^k)\Delta m \quad (6)$$

Where the Jacobian Matrix $J(m)$ can be written as

$$J(m) = \begin{bmatrix} \frac{\partial G_1(m^k)}{\partial m_1} & \cdots & \frac{\partial G_1(m^k)}{\partial m_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial G_m(m^k)}{\partial m_1} & \cdots & \frac{\partial G_m(m^k)}{\partial m_n} \end{bmatrix} \quad (7)$$

By using (6), the damped Least Squares problem becomes:

$$\min \left\| G(m^k) + J(m^k)\Delta m - d \right\|_2^2 + \alpha^2 \left\| L(m^k) + \Delta m \right\|_2^2 \quad (8)$$

Where the updated model for after an iteration can be written as $m^{k+1} = m^k + \Delta m$ giving an expression to the solution in form of

$$m^{k+1} = \left(J\left(m^k\right)^T J\left(m^k\right) + \alpha^2 L^T L\right)^{-1} J\left(m^k\right)^T \hat{d}\left(m^k\right) \qquad 9$$

Where

$$\hat{d}\left(m^k\right) = d - G\left(m^k\right) + J\left(m^k\right) m^k \qquad 10$$

Conclusions

Based on the inversion result, the model generated from Marquadt inversion is more suitable with geological condition in the research area. Because the Marquadt inversion model portray the intrusion body, whereas in the Occam inversion model only portray boulders. From the inversion result the andesite body identified as a high resistivity value ranging 400 – 2000 Ω.m with a volumetric calculation of andesite reaching 9,987 x 10^6 m^3.

References

Hartyanto, Edy, and Waluyo. [2002]. Simulasi Pendugaan Kedalaman Jalur Konduktif Bawah Permukaan Dengan Probabilitas Tomografi Geolistrik. *Teknosains* v.15(No.3): 587–602.

Martakusumah, Rocky, and Wahyu Srigutomo. [2015]. Inversion Schemes Comparison of 1D Magnetotelluric Inversion Using Levenberg-Marquardt and Occam ' S Inversion Schemes. *American Institute of Physics (AIP)* :1656, 070014.

Telford, W. M., Geldart, L.P., and Sherrif, R.E., [1990]. *Applied Geophysics Second Edition*. Cambridge University Press, London.

Zohdy A.A.R., Eaton G.P. and Mabey D.R. [1980]. *Application of surface Geophysics to Groundwater Investigations: Techniques of Water Resources Investigations of the U.S Geological Survey 1-3*. U.S Geological Society (USGS), Denver.