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Inversion of geophysical data of Hafthar Pb-Zn deposit

Hamid Bizhani[1], Abolghasem Kamkar-Rouhani[2], Ali Reza Arab-Amiri[3], Saeed Parnow[4]

[1]*MSc, Shahrood University of Technology,* hamidbizhani1992@gmail.com
[2]*Associate Professor, Shahrood University of Technology,* kamkar@shahroodut.ac.ir
[3]*Associate Professor, Shahrood University of Technology,* alirezaarabamiri@yahoo.com
[4]*Ph.D. Student, Institute of Geophysics, University of Tehran,* saeed.parnow@ut.ir

ABSTRACT

In the recent decades, in order to detect the vein and disseminated mineral deposits, electrical resistivity and induced polarization (IP) methods have been widely utilized as powerful exploratory tools. The process of inverting collected data is one of the key steps in the demonstration of electrical resistivity and induced polarization images in the subsurface. In this paper, the results obtained from two widely used software named Res2dinv and Zondres2d are compared. For this purpose, the data surveyed in lead and zinc deposit in Hafthar area located at 32 km west of Aghda are used. The survey of data has been carried out by utilizing rectangular arrangement for prospecting and dipole-dipole arrangement to investigate the depth expansion and lateral changes. Also, in order to compare and validate the models obtained, Zondres2d software is applied with different algorithms including Smoothness constrained, Occam, and Marquardt-Levenberg for inversion. Finally, considering the best algorithms, which have the best adaption with the results of drilling and the information of geology, the best model is proposed.

Keywords: Electrical resistivity, induced polarization (IP), rectangular array, dipole-dipole array, lead and zinc, Hafthar

INTRODUCTION

Electrical resistivity and induced polarization methods are among the geophysical methods that are being able to assist in the mineral exploration especially vein and disseminated mineral such as lead and zinc over the years [Telford, 1990]. Many studies based on these methods have been carried out for the base metals exploration in which in the most of cases, the results obtained were satisfying. Among the previous studies accomplished for geophysical exploration in different regions with these two well-known methods, geophysical investigation of Pb-Zn deposit of Lontzen-Poppelsberg, Belgium [Maxime et all, 2018], and characterization of a mine waste rock pile with the direct current resistivity and induced polarization method [Power, 2019] can be mentioned. Hafthar area is located about 130 km northwest of the city of Yazd in the central Iran. The main mineralization in this area is a massive sulfide type and containing lead, zinc, and iron within the shale formation of the area. The main reason for high potential of this area for geophysical investigation is the presence of various lead and zinc mineralization outcrops. According to the surface outcrops and the expansion of obtained electrical anomalies by the rectangular arrangement, the survey of electrical resistivity and induced polarization data is accomplished with the dipole-dipole arrangement. The collected data are processed and modeled using Res2dinv software to identify the lead and zinc mineralization areas. Then, using three inverting algorithms available in Zondres2d software, the best model in terms of location and depth of anomalies with the main model is proposed.

METHODOLGY

The presence of various lead and zinc mineralization outcrops in the area caused to carry out a geophysical investigation in the area. Previous investigation of mineralization in under study area has proven an economic potential of lead and zinc deposits in different parts of the area. To recognize these deposits using resistivity and induced polarization methods, in the prospecting step, an area surface of over 128,000 square meters was investigated by a rectangular electrode arrangement in order to identify the promising mineralization zones in the area. In the next step, to investigate these zones more accurately and determine the size and depth of the probable lead and zinc deposits, resistivity and induced polarization surveys were carried out along three lines using the dipole-dipole arrangement (in this paper one line has been provided). Then, the collected data are processed and modeled using Res2dinv and Zondres2d software packages. Finally, in order to acquire the best adoption between the models obtained from Res2dinv as main model and Zondres2d, three algorithms including Smoothness constrained, Occam and Marquardt-Levenberg available in Zondres2d applied, and the best model is accordingly suggested.

MODELING OF THE SURVEYED DATA WITH RES2DINV

As mentioned earlier, the modeling of the data measured in this paper is accomplished using Res2dinv. Also, in order to comparison and validation of the resulting models, Zondres2d software is utilized. In general, the two-dimensional model used in both software divides the subsurface into a number of rectangular blocks, and its purpose is to specify the resistivity of the rectangular blocks that cause to generate an apparent resistivity pseudosection that equals with the actual measurements in terms of conformity. In addition, for decreasing the discrepancy between the calculated and measured apparent resistivity values an optimization method, which adjusts the resistivity of the model blocks, is applied in both software. A measure of this discrepancy is given by the root-mean-squared (RMS) error [Loke, 2004]. Res2dinv will automatically specify a two-dimensional (2-D) resistivity model for the subsurface for the data measured from electrical imaging surveys [Griffits and Barker, 1993], and also for acquiring the apparent resistivity values a forward modeling is utilized, and finally a non-linear least-squares optimization technique is employed for the inversion routine [deGroot-Hedlin and Constable, 1990]. Inverse modeling of the collected data for a line was accomplished using Res2dinv software, and the results are illustrated in figures 1 and 2.

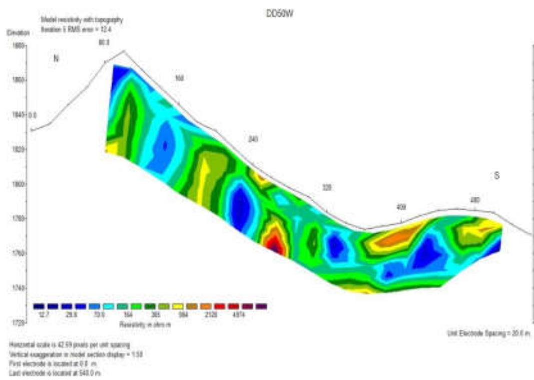

Figure 1. Resistivity inverse modelling for the survey line.

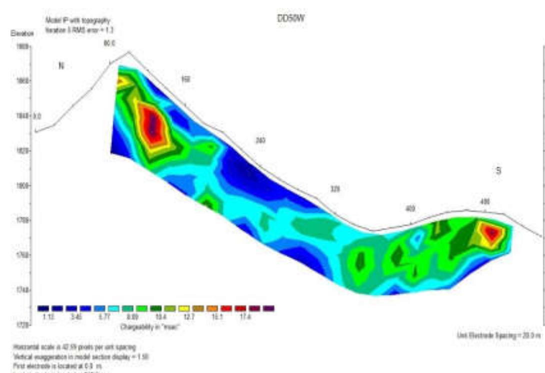

Figure 2. Induced polarization inverse modelling for the survey line.

MODELING OF THE SURVEYED DATA WITH ZONDRE2D

After inverse modeling the survey line by res2dinv software, the survey line is modeled using Zondres2d. Zondres2d is similar to Res2dinv in terms of the operation. However, in Zondres2d, finite-element method as a mathematical tool, is utilized to obtain a solution for the forward and inverse problems. It provides the best outcomes in contrast with mesh methods [Dey and Morrison, 1979]. In addition, the least squares method with regularization is applied for inverse problem solution. Regularization enhances solution constancy and enables obtaining the smoother resistivity and potential distribution [Constable, 1987]. In this paper, three algorithms including Smoothness constrained, Occam, and Marquardt-Levenberg available in Zondres2d software are utilized for acquiring the best model in terms of the adoption of anomalies with the main model. The details about these algorithms are summarized as follows.

- **Smoothness constrained** is the first algorithm available in Zondres2d. In this algorithm, the least-square method is used for inversion using a smoothing operator. As a result of using this algorithm, the smooth (without sharp boundaries), steady parameter distribution, and the minimum misfit value are obtained. The matrix equation for this kind of inversion can be expressed as follows [Kaminsky, 2013]:

$$\left(A^T W^T W A + \mu C^T C\right)\Delta m = A^T W^T \Delta f \tag{1}$$

Where A – the Jacobian matrix of partial derivatives, C – smoothing operator, W – relative error, m – section parameters vector, μ - regularizing parameter, Δf - discrepancy vector between observed and calculated values, R – focusing operator.
Inversion of the data surveyed in Zondres2d software by utilizing this algorithms is illustrated in figure 3.

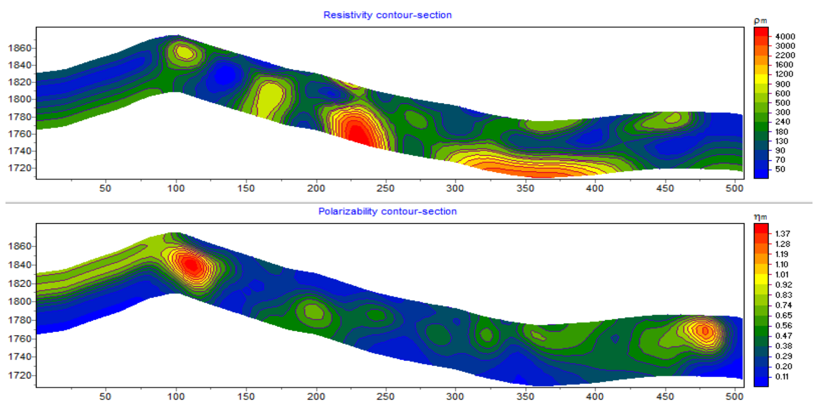

Figure 3. The results of inverting resistivity and induced polarization data in Zondres2d software considering Smoothness constrained algorithm.

- Occam is the second algorithm available in Zondres2d software. In this algorithm, the least-square method based on a smoothing operator and an additional contrast minimization is used for inversion [Constable, 1987]. The smoothest parameter distribution is obtained by using this algorithm. The matrix equation for this kind of inversion is as follows**:**

$$\left(A^T W^T W A + \mu C^T C\right)\Delta m = A^T W^T \Delta f - \mu C^T C m \tag{2}$$

Inversion of the data surveyed in Zondres2d software considering this algorithm is illustrated in figure 4.

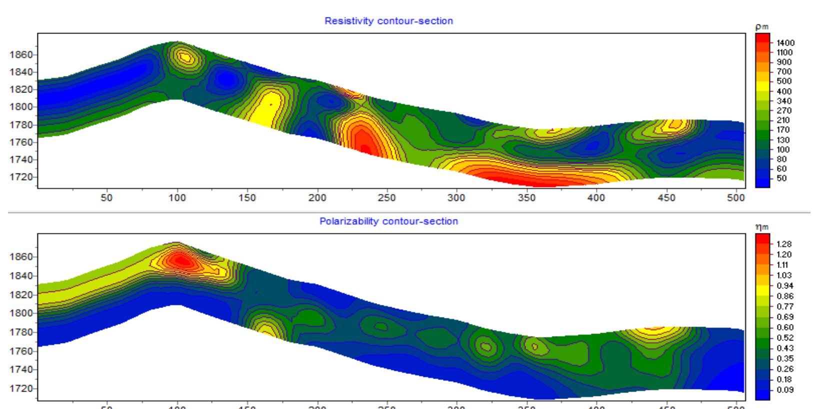

Figure 4. The results of inverting resistivity and induced polarization data in Zondres2d software considering Occam algorithm.

- Marquardt-Levenberg is the third algorithm available in Zondres2d software. In this algorithm, the lease square method with regularization based on the damping parameter (Ridge regression) is used for inversion [Marquardt, 1963]. In case of little quantity of section parameters, this algorithm enables obtaining contrast subsurface model. Matrix equation for this kind of inversion can be written as follows**:**

$$\left(A^T W^T W A + \mu I\right) \Delta m = A^T W^T \Delta f \quad (3)$$

Inversion of the data surveyed in Zondres2d considering this algorithm is shown in figure 5.

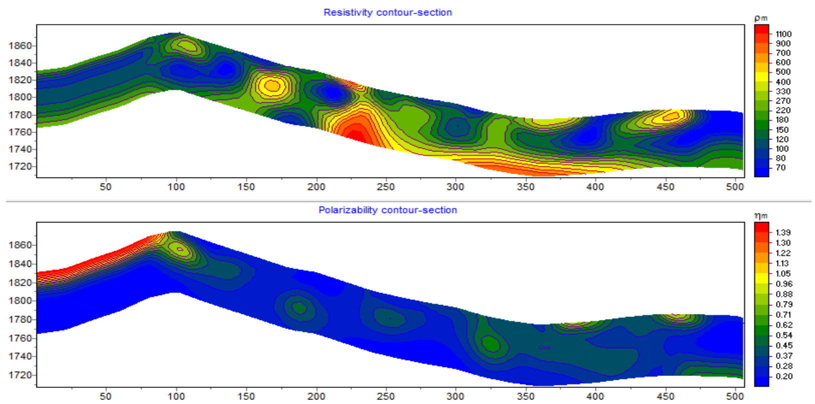

Figure 5. The results of inverting resistivity and induced polarization data in Zondres2d software considering the Marquardt-Levenberg algorithm.

CONCLUSION(S)

According to the models obtained in Res2dinv software for the line survey, two possible anomalies are observed located in 80 to 160 and 510 to 470 meter from the beginning of the line survey. In addition, the models obtained in Zondres2d considering the above-mentioned algorithms have a satisfying conformity with Res2dinv. The Smoothness constrained algorithm has the best conformity in terms of the horizontal coordination from the beginning line survey and the depth of anomalies in comparison with other algorithms (figure 3). It is worth mentioning that the degree of the smoothness in the obtained model is in the direct portion with the smoothness factor value in which the high value of this parameter can cause the misfit to be raised. Generally, it is suggested to apply the Smoothness constrained algorithm for initial cases of interpretation, and the best choice is to utilize the Marquardt method as specializing (for declining misfit) after Smoothness constrained or Occam inversion is accomplished. It is worth mentioning that any unwise usage for modifying the inversion method can cause an unsteady outcomes and increase the RMS deviation.

REFERENCES

C. Power and P. Tsourlos., (2019), "characterization of a mine waste rock pile with the direct current resistivity and induced polarization method ", 25th European Meeting of Environmental and Engineering Geophysics, Sep 2019, Volume 2019, p.1 - 5.

DeGroot-Hedlin C. and Constable S., (1990), "Occam's inversion to generate smooth, two dimensional models form magnetotelluric data", Geophysics, **55**, pp. 1613-1624.

Dey A. and Morrison H. F., (1997), "Resistivity modeling for arbitrarily shaped three-dimensional structure", Geophysics, 44(4), 753-780.

Griffiths D. H., Barker R. D., (1993), "Two-dimensional resistivity imaging and modelling in areas of complex geology", Journal of Applied Geophysics, Vol. 29, 211-226.

Kaminsky A., (2013), "program for two – dimensional interpretation of data obtained by resistivity and induced polarization methods", Saint – Petersburg.

Loke M. H., (2004a), "RES2DINV ver. 3.54 for Windows 98/Me/2000/NT/XP Rapid 2-D Resistivity & IP inversion using the least squares method".

Marquardt, D. (1963), "An Algorithm for Least-Squares Estimation of Nonlinear Parameters", SIAM Journal on Applied Mathematics, 11, 431-441.

Maxime E, Gael D, Thomas H, Michel C, and Olivier F., (2018), " Geophysical Investigation of the Pb–Zn Deposit of Lontzen–Poppelsberg, Belgium", MDPI, Vol. 8, Issue 6.

Steven C. Constable, Robert L. Parker., (1987), " GEOPHYSICS", VOL. 52, NO. 3, P 289-300.

Telford W. W. M. and Sheriff R. E., (1990), "Applied geophysics", Cambridge University Press, UK, V 1, 340-380.