Joint interpretation Versus joint inversion of DC resistivity and magnetometry data

Ramin. Varfinezhad[1], Behrooz. Oskooi[2]

[1]*PhD student of geophysics, Institute of Geophysics, University of Tehran, ramin.varfi@ut.ac.ir*
[2]*Associate professor, Institute of Geophysics, University of Tehran, boskooi@ut.ac.ir*

ABSTRACT

Separate inversions of DC resistivity and magnetometry methods are diagnostic tools for recovering subsurface anomalies but their integration can lead to more consistent interpretation with real subsurface. This integration may be carried out through joint interpretation, cooperative inversion and joint inversion. In this paper we want to compare joint interpretation and joint inversion of DC resistivity and magnetometry data. A linear approximated forward problem of the DC resistivity is used so that both the resistivity and magnetic inverse problems are expressed as a linear integral equation under the form of a Fredholm integral of 1st kind. At first, a synthetic case of a cavity above a conductor is considered indicating of the geophysical data integration importance. Finally, two data sets of DC resistivity and magnetometry collected on a profile of archeological area of old Pompeii city near Naples in Italy. For the both synthetic and real cases, interpretation elicited from joint inversion is superior to the joint interpretation.

Keywords: DC resistivity, joint interpretation, joint inversion, magnetometry.

INTRODUCTION

Separate inversion of DC resistivity (e.g., Günther et al., 2006; Gündoğdu and Candansayar, 2018) and magnetic data (e.g., Fedi and Rapolla, 1999; Cella and Fedi, 2012; Paoletti et al, 2013) are tools leading to realistic models of the related physical parameters: electrical resistivity and magnetic susceptibility, respectively. In order to build a valid geological model of the subsurface, it could be useful to integrate the information from different geophysical methods. This task may be fulfilled by joint interpretation (f.i., Ogaya et al., 2016), cooperative inversion (e.g., Le et al., 2016) and joint inversion (e.g., Gallardo and Meju, 2011). In joint interpretation, models are recovered for both methods by separate inversions and then correlated on each other. In cooperative inversion, one of the inverted models is considered as the initial model for the other one. Joint inversion is instead based on inverting different geophysical data sets together.
In this paper, comparing of joint interpretation and joint inversion of DC resistivity and magnetic methods are investigated. At first, a model of a cavity above a conductor is considered as a synthetic case and ultimately joint inversion and joint interpretation procedures of DC resistivity and magnetometry methods are applied on archeological area collected on an area of old Pompeii city near Naples in Italy.

Methodology and results

DC resistivity modeling is nonlinear, but here a linear modeling method proposed by Perez-Flores et.al, (2001) is utilized. For 2-D modeling, considering the subsurface of the interested area is discretized into a lot of prisms with rectangular cross-sections and assuming constant parameter value (resistivity for DC resistivity and susceptibility contrast for magnetometry) for each cell (Fig. 1), forward response of the anomaly can be computed by the following formula:

$$\boldsymbol{d} = \boldsymbol{A}\boldsymbol{m} + \boldsymbol{e} \qquad (1)$$

$\boldsymbol{d}$ is data vector, $\boldsymbol{A}$ is the kernel matrix (forward operator) data, $\boldsymbol{m}$ is model parameters vector and $\boldsymbol{e}$ is the added noise vector to the data.

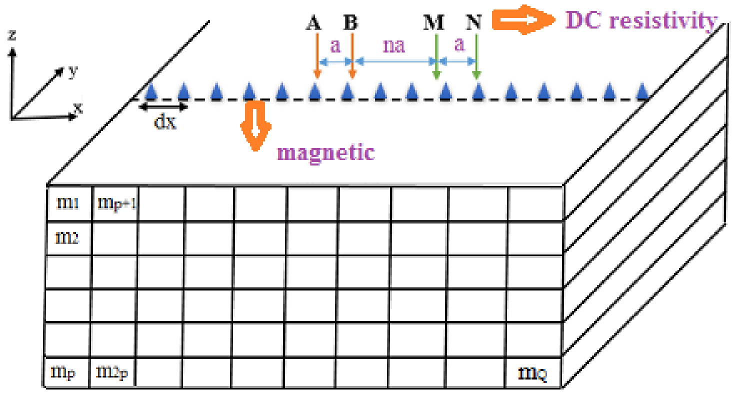

Figure 1. Subsurface discretization into a lot of prisms which are elongated along strike direction.

Joint interpretation needs only to the separate inversions of both methods, therefore, readers are referred to Gallardo and Meju (2004) in order to find the required formulas for simultaneous separate and joint inversions of DC resistivity and magnetometry data. However, this paper is dealing with cross-gradient based joint inversion of DC resistivity and seismic methods.

Synthetic case

The assumed synthetic example is composed of a cavity with resistivity of 100 kΩm placed above a conductor with resistivity of 20 Ωm (Fig. 2). In this case, the magnetic method is sensitive to the conductor only, because the susceptibility of the cavity has a negligible discrepancy with the scarcely magnetized material surrounding it, while the conductor susceptibility contrast with a nonmagnetic background is 0.1 (SI). From separate inversions of both methods, DC resistivity is not able to retrieve the conductor, while the magnetic senses just the conductor, which is well reproduced in the susceptibility inverse section. One possible interpretation from separate inversions is a magnetized and resistive anomaly which its depth ranges in both sections are absolutely different. Therefore, joint interpretation can lead to a wrong interpretation from subsurface. Under the joint inversion, the magnetic model helps to recover the conductor in the resistivity model but DC resistivity is not able to improve the magnetic model in such a way to reconstruct the cavity (Fig. 3). Now we can have an appropriate interpretation: there is a resistive but non magnetized anomaly above a conductive and magnetized body and this joint sections solve our ambiguities about true subsurface.

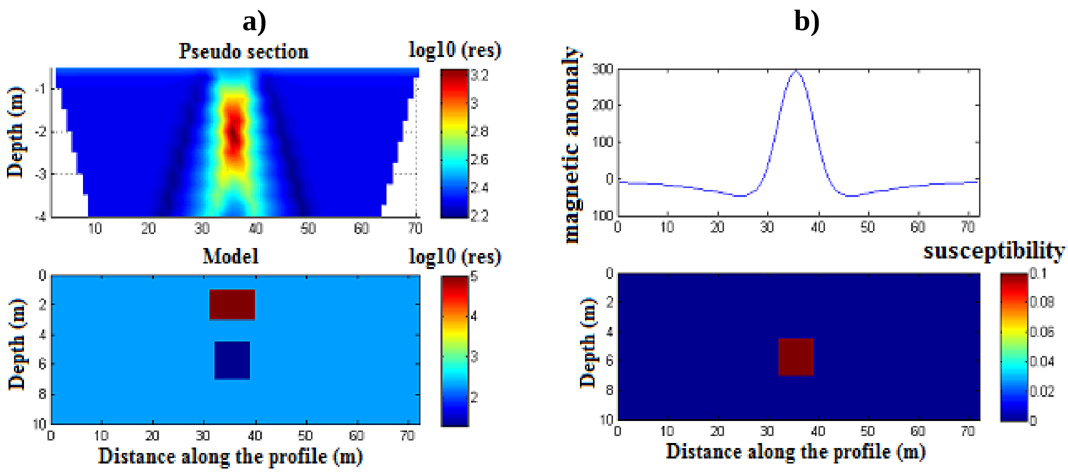

Figure 2. a) apparent resistivity values (top) produced by the resistivity model shown below. b) total intensity magnetic anomaly (top) caused by the susceptibility model shown below. Inclination: 90°, Declination: 0° for both total magnetization and inducing field. The inducing field intensity is assumed to be 47000 nT.

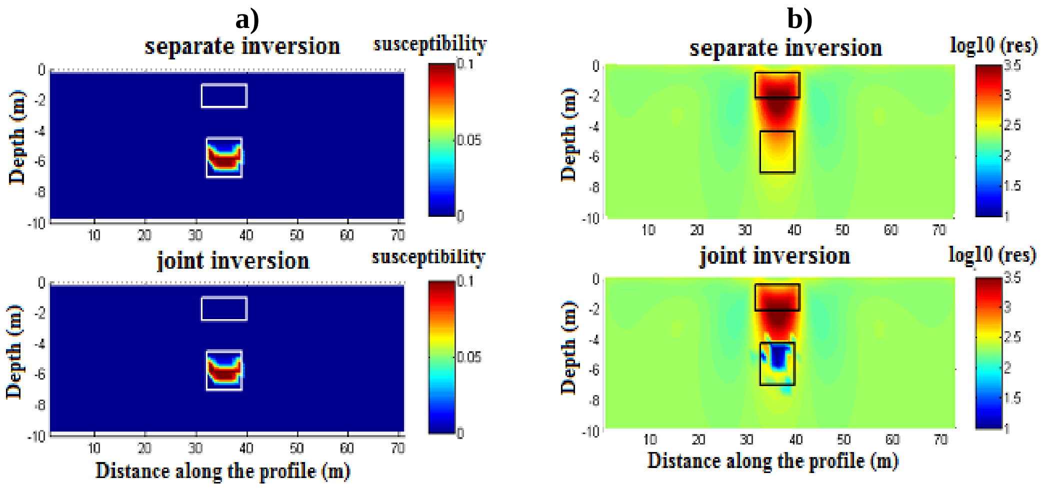

Figure 3. a) Magnetic model after separate (top) and joint (bottom) inversions of the data due to the thick dyke. b) Resistivity model after separate (top) and joint (bottom) inversions of the data due to a cavity-conductor source model.

Real case

We here examine the resistivity and magnetic data sets of two profiles in the archeological area of Pompeii (Southern Italy). The investigated area is located in Via Nolana, adjacent to the cemetery of Pompeii. The interested profile is over three known walls at 11-13 m, 16-19 m and 33-34 m. The resistivity interpreted section consists of a resistivity anomaly extended from 13 to 19 m, while we know that there are two walls at 11-13 m and 16-19 m. So, the information deducible from resistivity data is not clearly defined with respect to the known position of the walls. Instead, magnetic separate inversion recovers both the walls with a better definition. After joint inversion, the resistivity section allows a better retrieval of the two walls, in good agreement with the known wall positions. It should be said that there is also another wall at the end of the profile, which was however poorly recovered by both resistivity and magnetic methods. Again it can be said better interpretation can be made from joint inversion result.

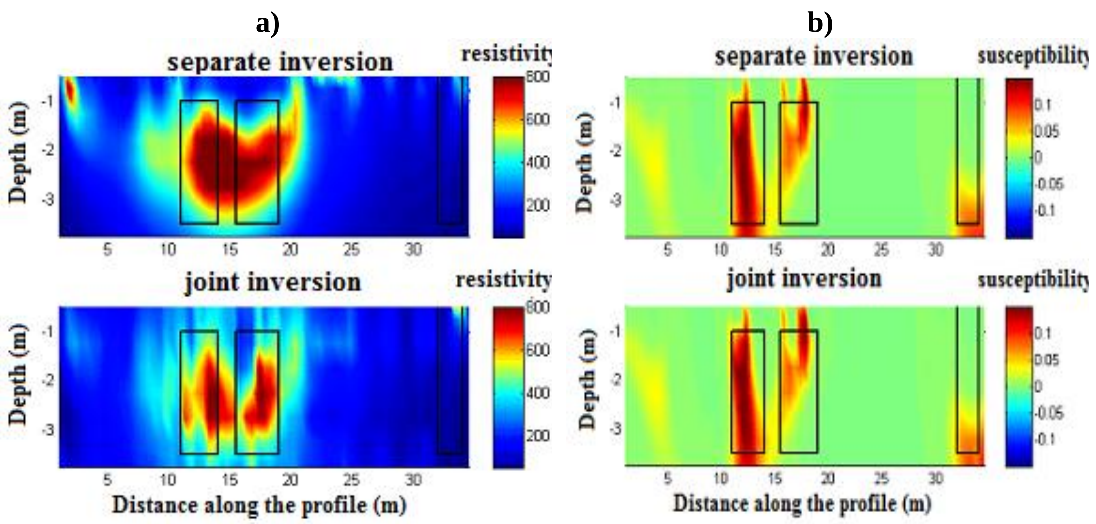

Figure 4. Inversion sections of Pompeii archeological data after separate and joint inversions for a) DC resistivity and b) magnetometry methods.

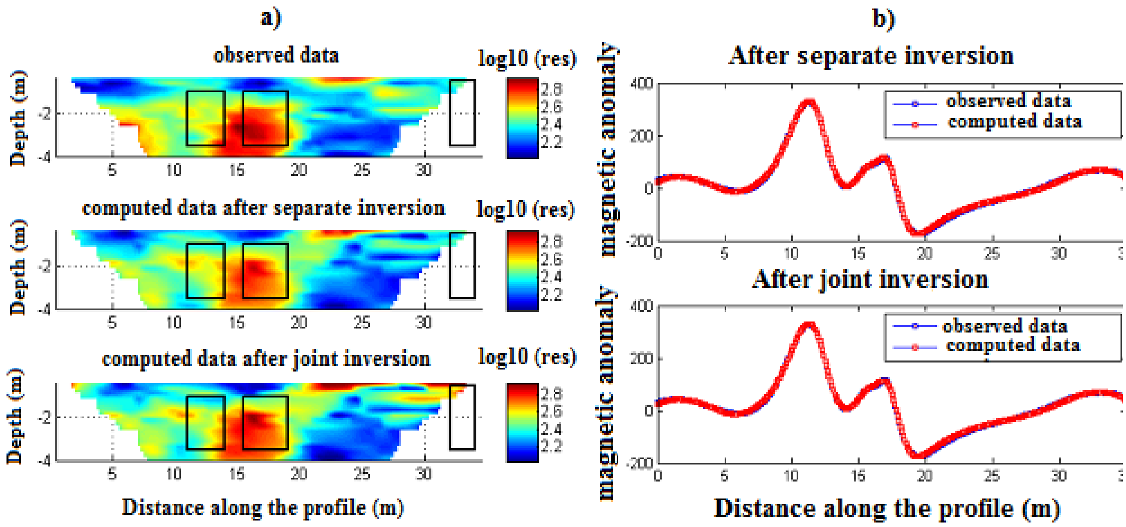

Figure 5. a) Resistivity pseudo-sections of observed data (top), calculated data after separate inversion (middle) and after joint inversion (bottom). b) Observed and calculated magnetic data after separate and joint inversions.

CONCLUSION

DC resistivity and magnetometry methods can solitarily be efficient tools for recovering of the subsurface anomalies, but their integration in terms of joint interpretation, cooperative inversion and joint inversion can decrease our ambiguities about geological targets giving rise to the measured anomalies at the surface of the earth. In this research, joint interpretation of DC resistivity and magnetometry methods was scrutinized versus their joint inversion. Linearized form of DC resistivity inverse problem was manipulated to express both modeling methods as the Fredholm integral equation of the first kind. For investigation of the performance of joint interpretation and joint inversion, synthetic and real cases were employed. The results indicated that joint inversion is superior to joint interpretation.

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