Journal of Applied Geophysics 128 (2016) 179–190

Contents lists available at ScienceDirect

Journal of Applied Geophysics

journal homepage: www.elsevier.com/locate/jappgeo

Comparison of various dimensionality methods on the Sabalan megnetotelluric data

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ARTICLE INFO

Article history:
Received 9 June 2015
Received in revised form 17 February 2016
Accepted 23 March 2016
Available online 29 March 2016

Keywords:
Magnetotelluric
Sabalan
geoelectrical dimensionality
galvanic distortion
Iran

ABSTRACT

Dimensionality of MT data is a powerful tool that selects which type of approach is more suitable to accomplish the modeling, or interpretation: one dimensionality, two dimensionality or three dimensionality. Moreover dimensionality analysis can be a tool to determine whether data are affected or not by local heterogeneities. In this paper, a part of the Sabalan geothermal field in the NW of Iran was selected as a test area to determine the dimensionality models. Different methods were used to assess the structural dimensionality of the electrical conductivity of the earth and identify distortions from observed data. A comparison has been made between the results of the methods and the main limitations existing in dimensionality characterization were discussed. The analysis of all sites in the Sabalan area using various methods indicates the electrical conductivity structure is less complex at the shallowest depths, with mixed 1D and 2D cases that are affected by galvanic distortion, whereas at middle and lower depths, dimensionality is mainly 3D. The dimensionality of the underlying conductivity distribution coincide with the known geological evaluations in the study area.

Contents

1. Introduction

The spatial distribution of the electrical conductivity known as geoelectric dimensionality, which can be organized as 1D, 2D and 3D structures. In a 1D Earth, the conductivity varies only with depth. In a 2D Earth, the conductivity is fixed along one horizontal direction (this direction is strike) while altering along the other horizontal directions and the vertical direction and in a 3D Earth, the conductivity distribution differs along all directions (Marti, 2006).

The common representation of the magnetotelluric impedance tensor (z) is denoted as follows (Cantwell, 1960):

$$\mathbf{z} = \begin{pmatrix} \mathbf{z_{xx}} & \mathbf{z_{xy}} \\ \mathbf{z_{yx}} & \mathbf{z_{yy}} \end{pmatrix} \quad (1)$$

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http://dx.doi.org/10.1016/j.jappgeo.2016.03.020
0926-9851/

The diagonal components of the impedance contain the information on lateral conductivity while its off-diagonal components indicate mainly the vertical conductivity effects (Berdichevskey, 1999). For all horizontal rotations of the coordinate system, in a 1D Earth the diagonal components of impedance tensor are zero, while the non-diagonal components are equal in modulus but with opposite signs. When one of the measurement axes coincides with the strike direction of structure, in a 2D Earth, the diagonal components of impedance vanish to zero, while the non-diagonal components differ. There is no strike direction for a 3D Earth, Nevertheless it has become customary to assess the direction that minimizes the diagonal components and maximizes the non-diagonal components of impedance tensor. In a 3D Earth, all the components of impedance tensor never vanish for any direction (Dobrin and Savit, 1988). In nature, because of distortions or 3D induction, diagonal components of impedance tensor are not zero. Thus, it is not possible to discriminate the type of the regional structure and to determine whether data are affected by galvanic distortion or not. The dimensionality analysis should be carried out to obtain such information (Naidu, 2012).

Most of the dimensionality methods are based on the rotational invariants of impedance tensor and different collections of rotational invariants have been introduced to assert specific categories of the dimensionality (Marti, 2006). Many authors have used the rotational invariants of impedance tensor to obtain information about the geoelectrical structures (Swift, 1967; Bahr, 1991; Szarka and Menvielle, 1997; Weaver et al., 2000). Other authors have introduced the graphical representations of function of components for a dimensionality interpretation (Berdichevsky, 1968; Sims and Bostic, 1969, Lilley, 1976). In some methods, the geomagnetic transfer function was utilized to characterize the dimensionality of the Earth (Parkinson, 1962; Romo et al., 1999) and more recently, Caldwell et al. (2004) suggested the phase tensor to acquire information about the dimensionality of the regional structures, because it is unaffected by local heterogeneities.

In this paper we applied different methods for dimensionality analysis of the Sabalan area in NW of Iran. The choice of the several methods is due to the fact that they use all the information from the MT data and provide a dimensionality description not limited to a particular model. Examples from four sites of the Sabalan area (sites 111, 203, 210 and 211) is presented (Fig. 1) and discussed.

2. Sabalan geothermal field

The area of study lies at the NW of Mt. Sabalan in Ardabil province at the NorthWest of Iran. The Sabalan area is the most interesting location of Iran for Geothermal activities due to occurrence of hot spring. The area has been extensively studied since 1978. Fig. 1 shows the geological map of the Northwest of Sabalan and the location of selected MT sites. Mt. Sabalan is underlain mostly by intrusive and effusive volcanic rocks. In relation to the original geological evolution, the Northwest of Sabalan has been divided into four major units: Lacustrine, fan and terrace deposits related to Quaternary age, post-caldera trachy-andesitic flows related to Pleistocene age, Pleistocene syn-caldera trachy-dacitic to trachy-andesitic domes and Pliocene pre-caldera trachy-andesitic pyroclastic, tuffs and lavas (SKM, 2005; Noorollahi et al., 2008; Ghaedrahmati et al., 2013).

MT survey was carried out by the EDC at 78 sites in 2007 and 2009 to identify probable center of the resource and to determine drilling targets for the development of geothermal energy purposes. Final analysis of MT data sets shows a hot zone, east of Well Pad D (Fig. 1), postulated to be the heat source for the Northwest of the Sabalan area (Ghaedrahmati et al., 2013).

3. Traditional parameters

Different Sets of dimensionality parameters can be defined as a function of traditional parameters of impedance tensor. Traditional parameters in terms of trace, determinant and non-diagonal components of impedance can be obtained (Vozoff, 1991; Szarka and Menvielle, 1997):

$$z_1 = \frac{Z_{xy} - Z_{yx}}{2} = \frac{Z'_{xx}(\theta) - Z'_{yx}(\theta)}{2} \quad (1)$$

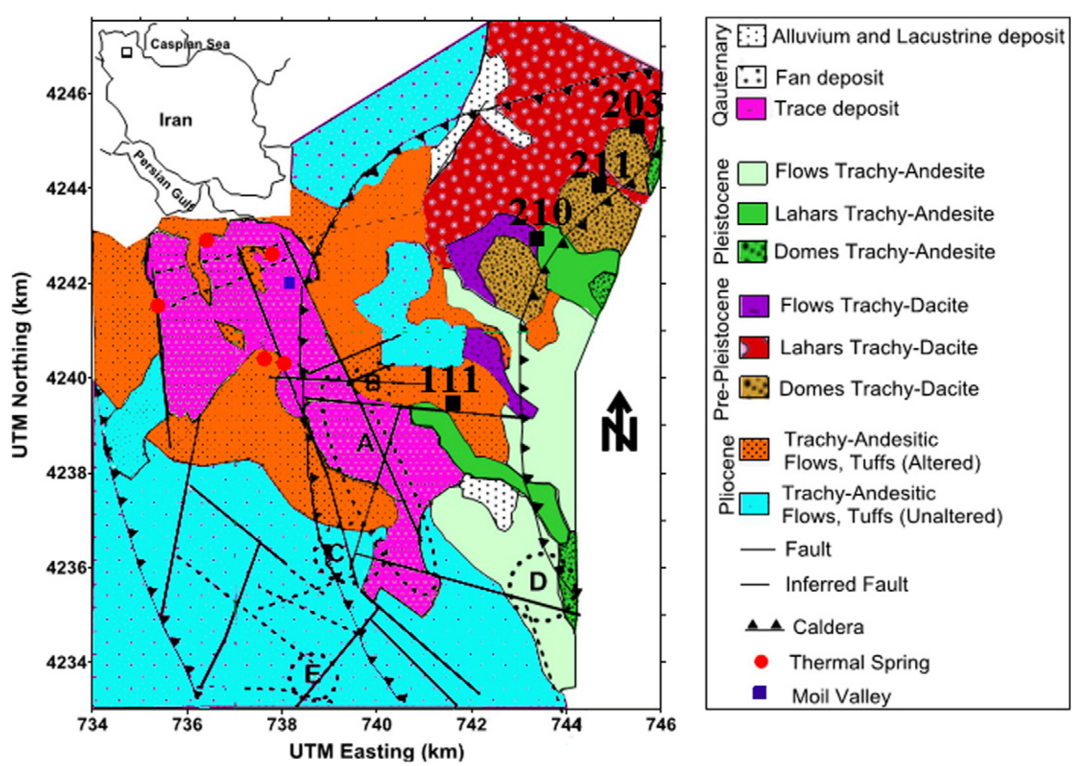

Fig. 1. A geological map of the NW of Sabalan geothermal field in Iran. Station numbers are shown for selected sites