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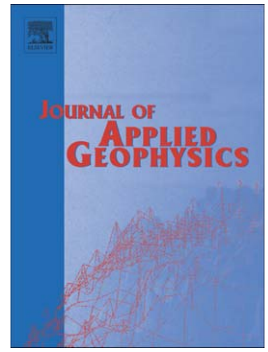

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Offset-electrode profile acquisition strategy for electrical resistivity tomography

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Abstract

We present an electrode layout strategy that allows electrical resistivity profiles to image the third dimension close to the profile plane. This "offset-electrode profile" approach involves laterally displacing electrodes away from the profile line in an alternating fashion and then inverting the resulting data using three-dimensional electrical resistivity tomography software. In our synthetic and field surveys, the offset-electrode method succeeds in revealing three-dimensional structures in the vicinity of the profile plane, which we could not achieve using three-dimensional inversions of linear profiles. We confirm and explain the limits of linear electrode profiles through a discussion of the three-dimensional sensitivity patterns: For a homogeneous starting model together with a linear electrode layout, all sensitivities remain symmetric with respect to the profile plane through each inversion step. This limitation can be overcome with offset-electrode layouts by breaking the symmetry pattern among the sensitivities. Thanks to freely available powerful three-dimensional resistivity tomography software and cheap modern computing power, the requirement for full three-dimensional calculations does not create a significant burden and renders the offset-electrode approach a cost-effective method. By offsetting the electrodes in an alternating pattern, as opposed to laying the profile out in a U-shape, we minimize shortening the profile length.

Keywords: Electrical resistivity tomography; 2-D profiles; 3-D inversion; Sensitivity pattern; Field method

1. Introduction

Over the past few decades, electrical resistivity tomography (ERT) has been among the most popular geophysical methods for imaging the shallow subsurface. Its versatility has made it a viable technique for applications as diverse as aquifer characterization (e.g. Slater et al., 2000; Kemna et al., 2002; Coscia et al., 2011, 2012; Doetsch et al., 2010, 2012; Yeh et al., 2015), contamination monitoring (e.g. Ogilvy et al., 2003; Olofsson et al., 2006; Genelle et al., 2012; Bichet et al., 2016; Maurya et al., 2017), bedrock mapping (e.g. Cardarelli & De Donno, 2017; Chambers et al., 2012, 2013), soil science (see Samouëlian et al., 2005, for an overview), subsurface cavity detection (Leucci, 2006; Lazzari et al., 2010; Martínez-Pagán et al., 2013; Park et al., 2014; Bharti et al., 2016), landslide (e.g. Ling et al., 2016; Wilkinson et al., 2016) and rock avalanche investigations (e.g. Socco et al., 2010), studies of saline intrusion (Martínez et al., 2009; Goebel et al., 2017), volcanology (Revil, 2008; Barde-Cabusson et al., 2013; Brothelande et al., 2014), and archaeology (Astin et al., 2007; Ullrich et al., 2007; Negri et al., 2008; Himi et al., 2016; Nero et al., 2016). Loke et al. (2013) provide an overview covering recent electrical resistivity tomography developments.

Freely available high-performance software packages for electrical resistivity tomography such as BERT (Günther et al., 2006; Rücker et al., 2006) and E4D (Johnson et al., 2010), cheap computing power, and improvements in algorithm design (e.g. Blome et al., 2009; Papadopoulos et al., 2011; Plattner et al., 2010, 2012) have made three-dimensional electrical resistivity data inversions cheaper than ever. Nevertheless, two-dimensional investigations imaging resistivity at depth along profile lines remain the most widely used electrical resistivity applications (Loke et al., 2013). The popularity of two-dimensional over three-dimensional surveys is likely a consequence of reduced equipment requirements and lower cost of work in the field. Developments in data acquisition strategies (e.g. Blome et al., 2011; Hoorde et al., 2017) and of the equipment itself (e.g. Stummer et al., 2002; Blome et al., 2011) help offset some of the extra cost of three-dimensional surveys in the field, but are unlikely to bridge the vast gap between the simplicity of two-dimensional profiles and the time required to set up and run a full 3-D array. To obtain subsurface resistivity models along profile lines, investigators typically make use of a "2.5-D" inversion procedure (Dey & Morrison, 1979), which implements a three-dimensional current source but assumes that subsurface resistivities only vary within the profile plane and infinitely extend perpendicular to the plane. These 2.5-D inversions allow for a quick imaging of the subsurface along profile lines but are prone to artifacts and unable to image resistivity variations beyond the profile plane.

We propose a cost-effective profile approach that has the capability of imaging the third dimension close to the profile plane. As we show in Section 3, simply inverting linear profile data using three-dimensional software does not suffice. Our approach involves staggering the electrodes on the surface sur-

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