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Geophysical investigation of underground water content zones using electrical resistivity tomography and ground penetrating radar: A case study in Hesarak-Karaj, Iran

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ABSTRACT

This paper describes the successful application of an integrated geophysical survey to investigate the depth of underground water table and the location of probable cavity occurrences at a developing residential area to design the foundation of under constructing urban buildings located at Hesarak-Karaj, Alborz province of Iran. The integrated shallow and non-invasive geophysical survey consists of Electrical Resistivity Tomography (ERT) and Ground Penetrating Radar (GPR). These methods could appropriately indicate the existence of the water table at a depth of approximately 12 m while processed GPR radargrams localized no cavity occurrences in the studied site. A 100-MHz shielded GPR antenna has been used to conduct a high resolution shallow subsurface survey in order to delineate probable cavities of the area, and two electrical arrays of gradient and Wenner have been used as well to image resistivity variations of subsurface layers especially for prospecting water saturated zone. The acquired results which were in good accordance with the reality of the studied area at locating water table and cavity occurrences could effectively provide guidance to builders in order to tackle water flow issue and not to concern about filling cavities during constructing any building in the site.

1. Introduction

Shallow subsurface geophysical tools provide quick and relatively inexpensive alternatives for collecting continuous information from near surface of the prospected area. The geophysical mapping of subsurface features can provide information about the spatial distribution of physical properties, such as electrical conductivity (or resistivity), dielectric permittivity, magnetic permeability, density and velocity. Among all geophysical techniques, electrical and electromagnetic methods are undoubtedly the leading ones in exploration and management of groundwater in engineering studies (Goldman and Kafri, 2006; Attwa et al., 2011). Two prevalent techniques in groundwater exploration are the methods of ground penetrating radar (GPR) and electrical resistivity tomography (ERT).

GPR could image with high resolution near surface cavities (even small ones) that are important for builders before constructing any buildings. But transmitted waves of GPR would be strongly attenuated in a partially water content zones and could not penetrate at greater depth in order to detect probable cavities in the region of interest. In addition to conducting a GPR survey, ERT could be an appropriate technique in such cases and attempts to image electrical properties of the subsurface features. Since soil moisture and ground water are mostly electrically conductive, the measured resistivity by ERT method is predominantly controlled by the amount of water content and the concentration of dissolved solids (salts) within the soil and rock at porous media. ERT in spite of a lower resolution is able to image cavities (as a resistive media, e.g. Cardarelli et al., 2006; Ezersky, 2008; Martínez-Pagán et al., 2013) located at greater depths than GPR in conductive environments. Therefore, an integrated survey of GPR and ERT can simultaneously localize shallow or deep cavities along with delineate water table at area of prospect. A combination of ERT and GPR has been used worldwide during the last decade to localize water content zones or cavity occurrences in engineering studies (Bowling et al., 2005; Pellicer and Gibson, 2011; Gómez-Ortiz and Martín-Crespo, 2012; Mahmoudzadeh et al., 2012; Carbonel et al., 2014; Sonkamble et al., 2014). GPR can be an appropriate geophysical method in these cases, especially groundwater and cavity detection, to visualize the desired underground features. The technique is used to detect changes in subsurface electromagnetic impedance of diverse targets via the propagation and reflection at impedance boundaries of an electromagnetic wave generated by a transmitter deployed at the surface or, less commonly, within a borehole (Everett, 2013). This method is particularly successful at detecting changes in pore fluid content related to the appearance of water and/or contaminant

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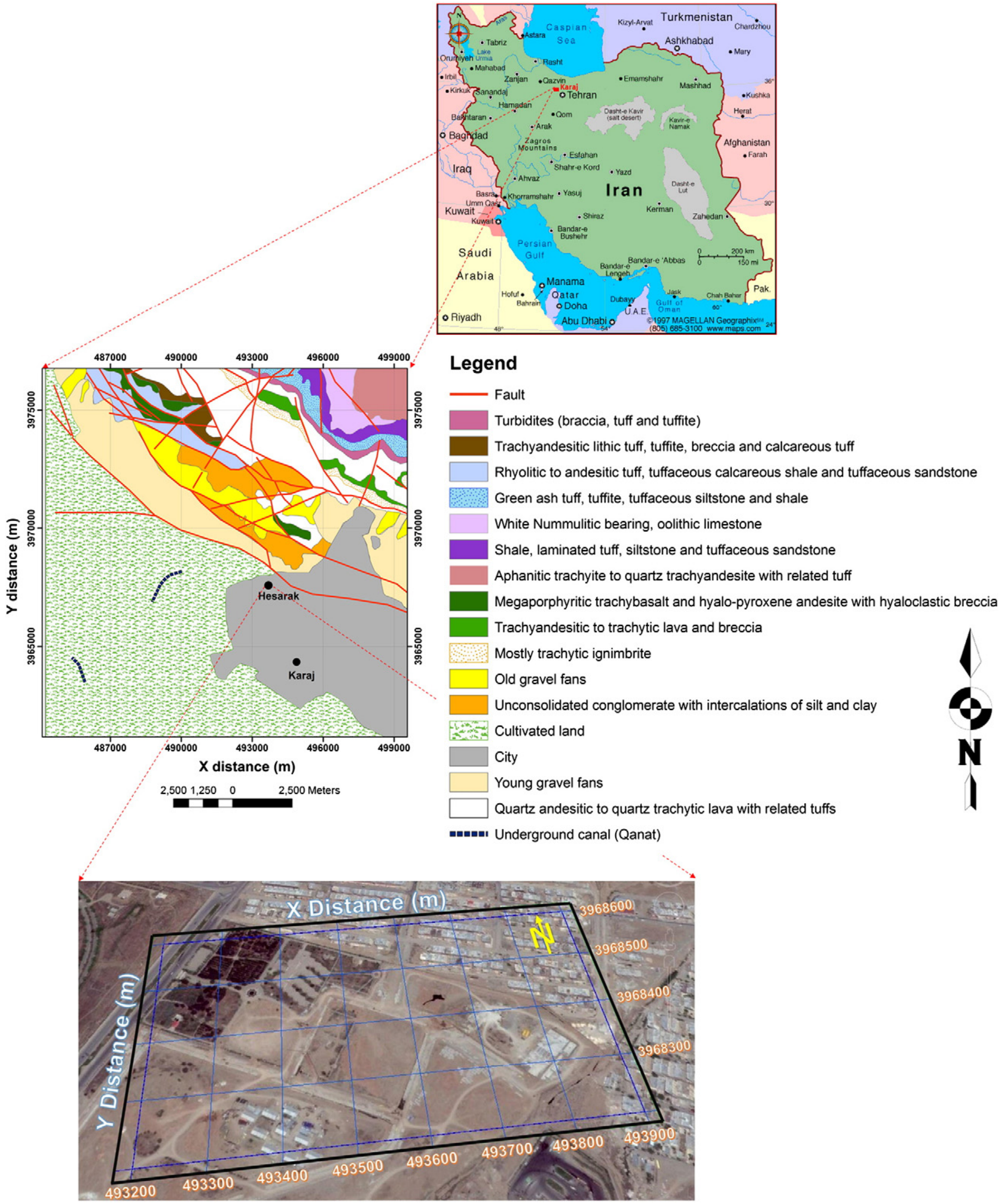

Fig. 1. Location and geology maps of the study area in Iran map and in Hesarak-Karaj, reproduced from National Geoscience Database of Iran, http://www.ngdir.ir.

plumes and can be used to map relatively expansive areas to a depth of 10 m or more proportional to the antenna used (Cassidy, 2007).

GPR has a wide range of applications for shallow subsurface investigations in engineering geophysics, such as mineral exploration, geological, geotechnical, hydrogeological, environmental, and archeological studies (Porsani and Sauck, 2007). Of particular usage of GPR is for geologic characterization of the subsurface materials as well as for mapping of non-geologic objects. The technique is successfully found to be applicable in stratigraphic studies of sedimentary formation (Bristow and Jol, 2003), outlining the foundation of building and other engineering structures (Abbas et al., 2009), archeological investigation (Oveisy Moakhar, 2008; Negri et al., 2008), mineral exploration (Gómez-Ortiz et al., 2007; El Assel et al., 2011; Francke, 2012), location of water table, and characterization of subsurface contamination (de Menezes Travassos and de Tarso Luiz Menezes, 2004; Hamzah et al., 2009; Win et al., 2011), geomorphic studies and surface subsidence (Poole et al.,