Geoelectrical prospecting for detection qanat in Kerman province, southern Iran

Saeed. Parnow[1], Sadegh, Moghaddam[2], Sajjad Ebrahim Nejad[3] and Asghar Azadi[4]

[1]*Ph.D. Student, Institute of Geophysics, University of Tehran, Iran, saeed.parnow@ut.ac.ir*
2Ph.D. Student, Institute of Geophysics, University of Tehran, Iran, sadegh136789@yahoo.com
[3]*zamin physic company, Tehran,, Iran, S.ebrahimnajad@yahoo.com*
[4]*Professor, Payame Noor University, Department of Education, Tehran, Iran, Asghar_azadi_2007@yahoo.com*

ABSTRACT

In most of Iran areas, especially dry areas, there are no lakes or rivers on the surface. So, in the past, the water of cities and towns had been supplied by underground water channel systems that are called qanat. Most of these old channels were abounded and collapsed. Following collapsing of the qanat walls, a very important matter is the detection of these man-made structures to prevent them from possible destruction to surrounding buildings and lifelines. This paper deals with a geophysical survey carried out in a critical urban area of Kerman, southern Iran. Kerman has a very complex shallow qanats. Here, we present the results of a near-surface survey carried out by the Electrical Resistivity Tomography (ERT) method. In this work, we show that inverse modeling of ERT data can give us information about the location of the ganat. In addition, 3-D presentation of the ER data is very useful in the 3-D visualization of the subsurface, and thus, can indicate the ganats more precisely.

Keywords: Electrical Resistivity Tomography (ERT), qanat, Kerman

INTRODUCTION

The main source of fresh water in the dry area of Iran for drinking and agriculture in the past was underground channels which are known as qanats. Some of these qanats systems are still in use and others were abandoned and their locations are now unknown. Some of the qanats of Kerman province have been damaged due to the collapse of their tunnel walls. During the time these underground man-made tunnels have lost their stability and collapsed. The collapse usually leads to land subsidence, which is often manifested in the form of sinkholes that occur on the ground surface (Rayhani and El Naggar, 2007).

These destructions that can occur due to the collapse of the qanats can cause considerable financial losses and also irreparable injuries to life. In this regard, geophysical methods can be used for delineation and elimination the risks of these structures. Often there is sufficient physical contrast between qanats and their surrounding media. Thus, these structures are suitable targets for detection by the ERT method.

In this method, DC currents are used for detection, demonstration, and investigation of shallow subsurface structures. The most important advantage of this method over other geophysical methods is conceptual simplicity, low equipment cost, and ease of use.

ERT surveys have been used for many decades in hydrogeological, mining, environmental and geotechnical investigation (Moghaddam *et al.*, 2017, Rucker *et al.*, 2009, Cheng *et al.*, 2019).

In this paper, we presented the results of ERT to determine qanats and their collapse of tunnel walls in Kerman, Iran.

Survey area

In general, Kerman and its surrounding towns consist of a flat alluvial plain of fine silt and clay materials. In morphological aspects, these sediments have a very gentle slope with the main infrastructure of the city built on them (Aghamolaie *et al.*, 2018).

Land and road subsidence depending on the quant wall collapses led to the manmade subsidence problems, so the probability of damages on the above structures cannot be overlooked without any knowledge of underground tunnel lines. Figure 1 shows some of the damages to road and surface resulted from the collapse of qantas in the investigated site.

Figure 1: Qanat collapse and its damage to the surface in the investigated site.

In this work, the DC resistivity method was employed by the electrical resistivity technique in Dipole-Dipole array. The geophysical data were acquired through seven lines with 130 m, tow lines with 120 m, and one line with 105 m long and 5 m spacing between electrodes (**Error! Reference source not found.**). The selected electrode separation is a tradeoff between resolution and investigation depth. The lines were arranged in a regular grid, according to the structural criteria established in previous works which consider the crossing of major regional structures. The equipment used for the acquisition of apparent electrical resistivity measurements was the ABEMSAS1000, manufactured by ABEM Instrument (Sweden). This equipment consists of a single module for transmitting and receiving automated signals from the previous programming, with 100W, resolution of 30 nV, and a maximum current of 1000 mA (ABEM, 2012).

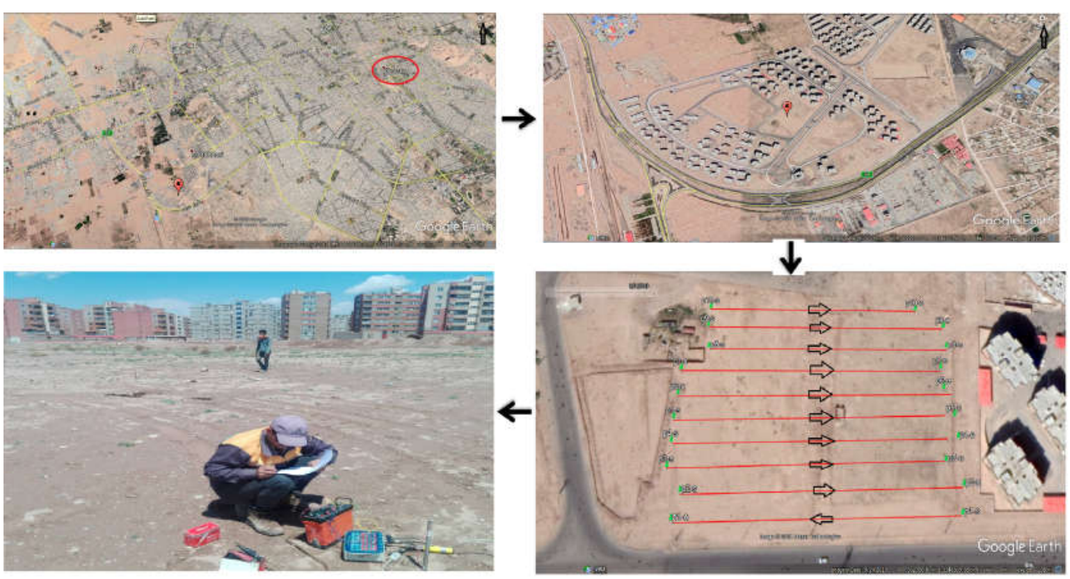

Figure 2: Study area, including the location of ER profiles and data acquisition.

Inversion and interpretation of data

The raw data from the ERT survey are processed using ZondRes2d software. Five inversion methods are available in the software package: Smoothness constrained, Occam, Marquardt, Blocks, and Focused. The models of resistivity values are applied with the smoothness constrained inversion is presented in Figure 2. The software generates a calculated model of the pseudo-section from the inverted model, the Root Mean Square (RMS) error between the calculated and the measured pseudo-section is computed. A least-squares algorithm is used to reduce the RMS error between the measured and the calculated apparent resistivity in an iterative mode. The final RMS error, which is the difference between the successive 2D model inversions and the measured data, was less than 5% for the measured data. Here, the interpretation of the geophysical results is made based on field observations and geological aspects. Within the area of exploration, the resistivity anomalies can be divided into two categories. The first zone that can be seen in the middle of profiles and very close to the surface can be classified as dry qanat with a resistivity range value of 20 to 77 Ω.m (red to pink colors in color-bar of **Error! Reference source not found.**). The second domain is the water-filled part of the ganat or collapsed tunnel walls that have a resistivity range value of 1 to 4 Ω.m (Blue color in **Error! Reference source not found.**). Figure 4 shows these parts of the ten profiles are shown in Figure 3, where it clearly shows the location and extension of the dry and wet parts of gnats. The results proved with confidence that ER is capable of discriminating between dry ganat, which yields resistive anomalies and those filled with other water or sediments yielding lower resistivity anomalies.

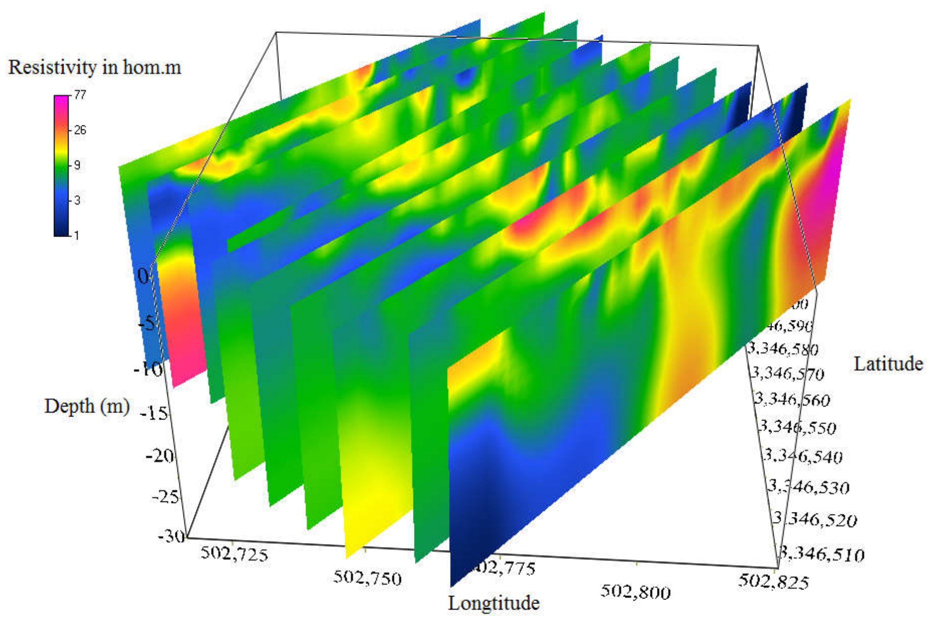

Figure 3: Inversion model results inferred from electrical resistivity profiles. RMS error fluctuates between 1.45% and 6.2%.

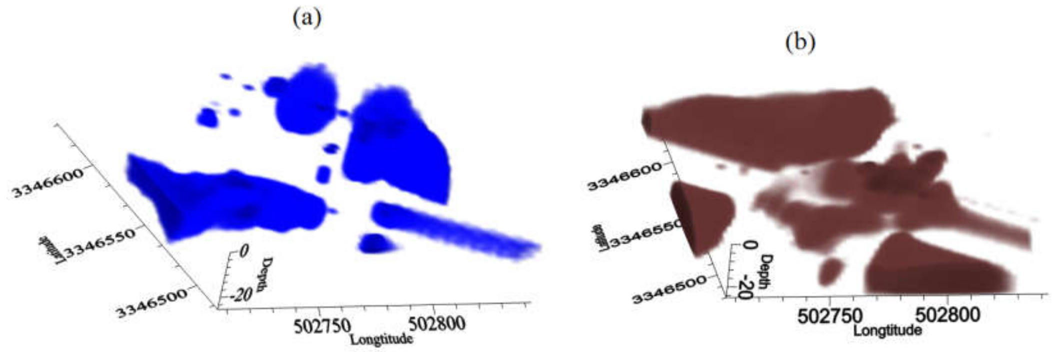

Figure 4: Isometric representation of the 3-D resistivity model. (a) Blue representing the second part (resistivity range value of 1 to 4 Ω.m). (b) Brown representing the dry ganat with resistivity range value from 20 to 77 Ω.m.

CONCLUSION(S)

The following conclusions are specific to the qantas at Kerman city but could be relevant to other qantas.

The simple information supplied by the electrical resistivity mapping is probably sufficient to guide the detection of shallow qantas. These actions are expected to mapping qantas and their connected collapse zones, thus reducing hazards associated with the unstable region.

In the unstable region, distinctly low or high resistivity material relative to background is found in the electrical imaging profiles. It may correspond to saturated collapse weathered walls or dry qantas. This work clearly shows that 3D images of subsurface acquired from inversion of ER data are useful reconnaissance tool for obtaining man-made features covered by superficial sediments.

However, the application of other geophysical methods, such as ground-penetrating radar (GPR), or excavations can aid in the diagnosis of possible structures and add greater credibility to the results.

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