Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

OPEN ACCESS Journal of Applied Sciences

ISSN 1812-5654
DOI: 10.3923/jas.2017.41.47

Research Article
Using 2D and 3D CVES in Archaeology at Umm Qais, Jordan

[1]Abd El-Rahman Abueladas, [1]Emad Akawwi, [2]Rami Al-Ruzouq and [1]Abdallah Alzoubi

[1]Department of Surveying and Geomatics, Al-Balqa Applied University, 19117 Al-Salt, Jordan
[2]Department of Civil and Environmental Engineering, University of Sharjah, Sharjah, UAE

Abstract

Background and Objective: Geophysical prospecting involving the use of 2D and 3D electrical resistivity imaging techniques have been carried out in order to study and investigate the archeological features at Umm Qais area. **Materials and Methods:** That used in this study is a Wenner-Schulmberge array configuration using a multielectrode system, with 48 electrodes equally spaced was carried out in the study area, which represents a complex collection of landscape elements from a number of historic periods: Roman, Byzantine and Islamic. This array configuration is moderately sensitive to both horizontal and vertical structures. The 2D resistivity data were collated and inverted into 3D images. The interpreted resistivity data shows the existence of anomalies. **Results:** Results of this study show that the maximum depth of investigation survey is 43 and 14 m for the 2D and 3D resistivity, respectively. Seven meters deep high resistive discontinuous layer beneath profile 1 may represent buried wall. The location and the depth of the ancient pool can be easy determined using the 3D continuous vertical electrical sounding. **Conclusion:** The using of 2D inverted to 3D imaging of the electrical resistivity is very useful for investigating the archeological features.

Key words: 2D and 3D inversion, electrical sounding, resistivity, imaging, archaeology

Received: September 17, 2016 Accepted: November 04, 2016 Published: December 15, 2016

Citation: Abd El-Rahman Abueladas, Emad Akawwi, Rami Al-Ruzouq and Abdallah Alzoubi, 2017. Using 2D and 3D CVES in archaeology at Umm Qais, Jordan. J. Applied Sci., 17: 41-47.

Corresponding Author: Abd El-Rahman Abueladas, Department of Surveying and Geomatics, Al-Balqa Applied University, 19117 Al-Salt, Jordan

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

It is a familiar that subsurface investigations involving the use of geophysical techniques are very useful for several fields as subsurface geological structure, groundwater and archeology. One of these geophysical techniques is the continuous electrical sounding (CVES).

The CVES has been widely applied in environmental and engineering geophysics to obtain 2D and 3D high resolution images of the resistivity at shallow depths targets and this method is very popular in archaeological investigations[1-3]. This geoelectrical method offers quick and cost-effective imaging of subsurface resistivity pattern to a depth of several tens of meters. The success of the method depends on the difference between the resistivity properties of the potential archaeological targets (walls, roads, buildings, etc.) and the host environment[4].

Recent advances in hardware and software allow acquiring resistivity information of the investigated body. This technique furnishes detailed two (2D) and three (3D) dimensional models of electrical resistivity distribution of the portion of the subsurface being investigated[5].

The current town of Umm Qais is the site of ancient Greco-Roman city of Gadara, one of the cities of the Decapolis. The Greeks were the first to marvel at the breathtaking view and established their acropolis there. Later, Romans, Byzantines and Ottomans left their own marks on this site. Gadara was mentioned in the late 16th century in the Ottoman tax records as mkes, which means in Arabic a frontier station for gathering taxes[6]. Gadara is the ancient semitic name of modern Umm Qais. It means a wall as an indication of its highland topography, which makes it seem like a fortification or fortress[7].

The city has witnessed natural crises in which earthquakes destroyed many buildings during the early islamic period from 661 AD until 799 AD[8]. After that, the city declined and Gadara soon became just another village. Later, it was reoccupied during the Ottoman period and recovered its significance as a major town.

Today, the region of Umm Qais as a whole can be divided into two main parts: the ancient city of Umm Qais including the Greco-Roman, Byzantine and Ottoman occupation levels, the modern village of Umm Qais and the rural landscape including farms and green spaces within the region[9]. The Greco-Roman remains are of great importance and are especially interesting in that they show the main features of an integrated Roman city in terms of city planning, monuments and artistic works, as well as its distinctive type of basalt stone[10].

As Umm Qais is on the road from Damascus to Tiberias and hence to the Palestinian seaports, overlooking lake Tiberias and the Golan Heights, it attracted people during the Ottoman period to construct the village (Fig. 1). However, the modern human interventions including archaeological excavations and restoration conducted within the site in the last decades have disturbed the cultural landscape and caused the destruction of some buildings as a result of the wrong policies[11].

MATERIALS AND METHODS

Study area: Umm Qais, situated 110 km North of Amman. The strategic location of Umm Qais was an important factor in its settlement[6]. The site of Umm Qais is situated 378 m a.s.l., with a magnificent view over the Yarmouk river, the Golan heights and lake Tiberias, this town was known as Gadara, one of the most brilliant ancient Greco-Roman cities of the Decapolis (Fig. 1).

The 2D and 3D electrical imaging of subsurface resistivity distribution are generated. Using this method, features with contrasting electrical properties to that of surrounding material may be located and characterized in terms of resistivity, geometry and depth of burial (Resistivity data used in the electrical imaging are typically collected using computer controlled measurement system connected to surface multi-electrode arrays. The field data are inverted to produce models of subsurface electrical properties. Inversion algorithms used to generate 2D and 3D resistivity models have been available for many years and consequently 2D and 3D imaging has regularly been applied to geological, engineering and hydro-geological problems.

The 2D imaging used the Wenner-Schlumberger, the electrode array arrangement is a mixture between Wenner and Schlumberger arrays by which the resistivity changes in both the vertical as well as horizontal direction can be detected along the survey profiles. The above electrode arrangement array combines the advantages of the two separated arrays. The apparent resistivity for Wenner-Schlumberger array:

$$\rho = pi\ n\ (n+1)\ a\ R$$

where, R is the measured resistance, a is the spacing between the P1 and P2 electrodes and n is the ratio of the distance between C1-P1 and P1-P2 electrodes. The depth of investigation increased as the spacing between the potential electrodes P1-P2 is increased 2a, the measurements are

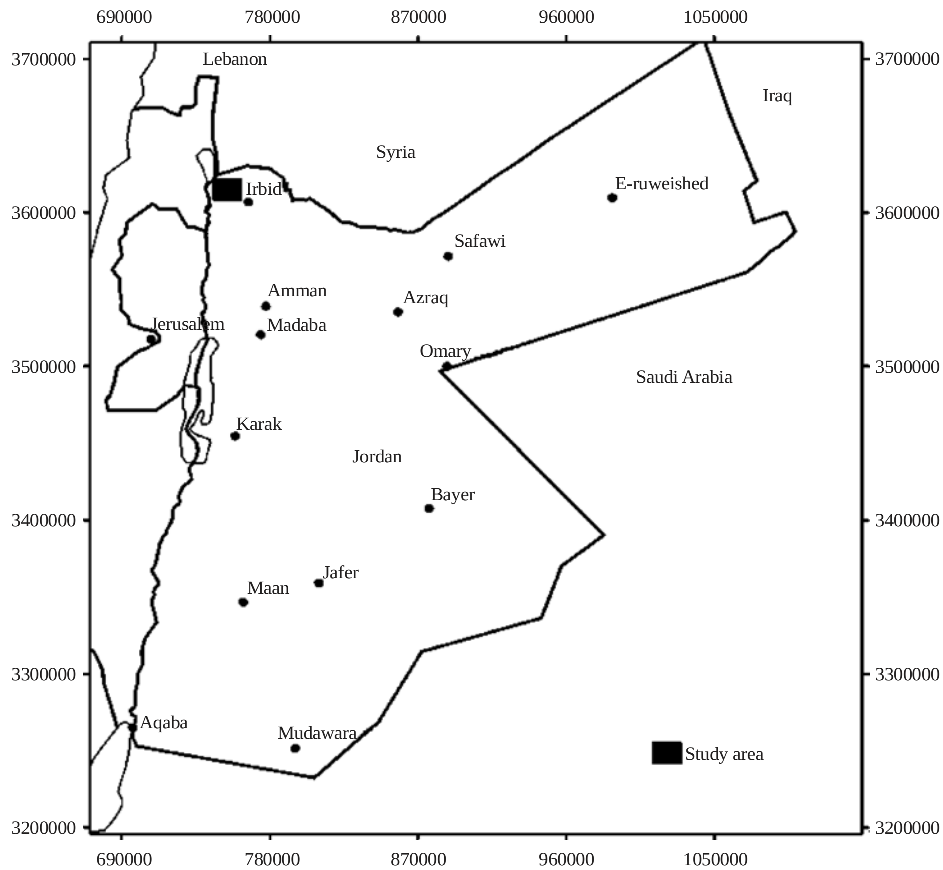

Fig. 1: Location map of the study area

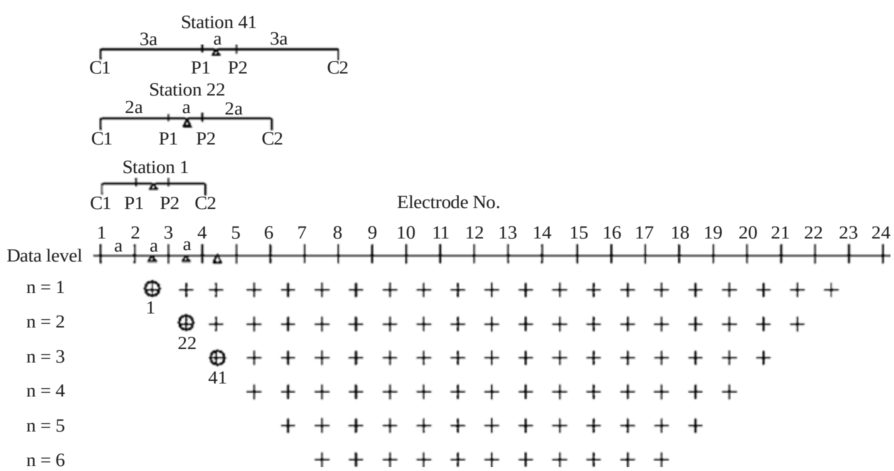

Fig. 2: Arrangement of electrode for a 2D electrical survey and pseudosection data pattern for the Wenner-Schlumberger arrays

repeated for n equals to 1-6. The P1-P2 spacing is increased and the same sequence measurement repeated (Fig. 2).

The 3D Wenner-Schlumberger resistivity field data were collected in a rectangular area of 15 by 55 m, along 5 m spaced parallel profiles (Fig. 3).

The data collected using Syscal-pro system (IRIS instruments) with 48 multi-electrodes system with two 24 electrodes cables and 5 m electrode spacing. The electrodes location and elevation were measured by Global Position System (GPS). The location map of the lines is shown in Fig. 4.

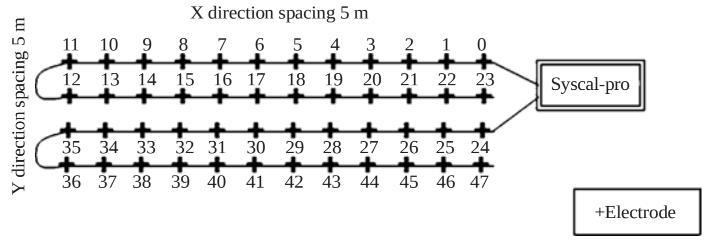

Fig. 3: Arrangement of potential electrodes for the 3D Wenner-Schlumberger electrical survey

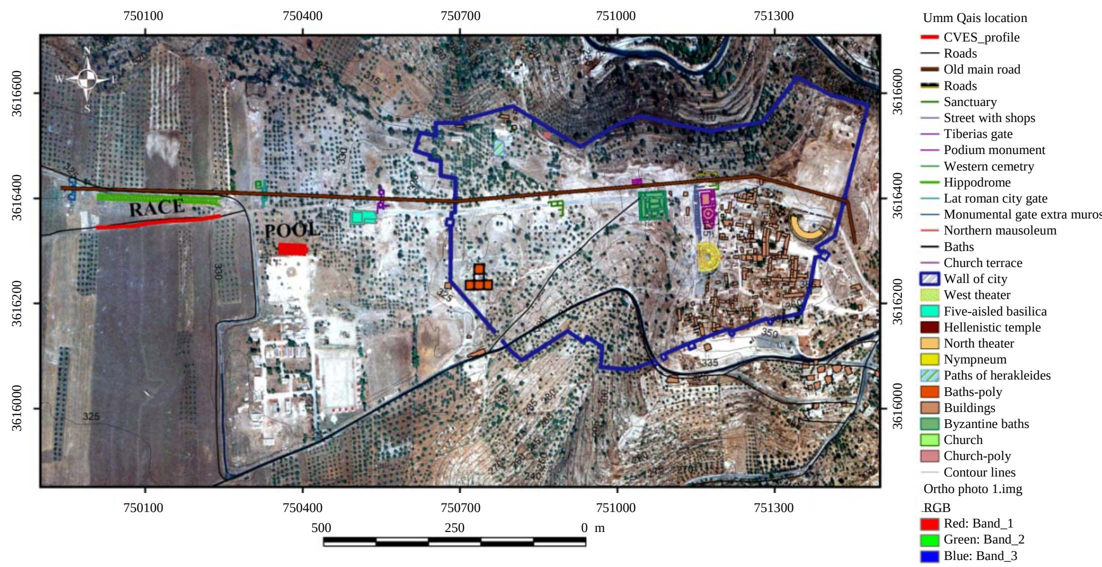

Fig. 4: Satellite image shows the location of Umm Qais archaeological site and the location of the resistivity lines

The measured data were processed using 2D and 3D inverse modeling software (RES2DINV and RES3DINV) applying Loke and Barker inversion methods[12-15]. The program can large data sets collected with large number of electrodes and can account the topographical effect along the survey lines. The Root Mean Square (RMS) error quantifies the different between the measured resistivity values and the calculated from true resistivity model. The average RMS error of the profiles was less than 10%.

RESULTS AND DISCUSSION

A two-dimension multi-electrodes resistivity profile and another 3D profile were conducted at the study area (Fig. 4). The 2D multi-electrodes resistivity profile 1 was laid parallel to the racetrack and trends W-E direction to a length of 235 m and imaging depth of 43.1 m. The measured apparent resistivity pseudo-section and the inverse model are shown in Fig. 5.

The upper low resistance layer less than 20 Ωm along most of the profile represents plowed agricultural soil with moisture. The discontinuous high resistive layer between 100 and 250 Ωm at 7 m depth may represents buried wall or foundations. The moderate resistive layer between 20 and 100 Ωm dominated most of the profile and extended to the bottom of it (Fig. 5).

The 3D profile was laid at an ancient pool (Fig. 4). The acquired data were combined to produce three-dimensional depth slices of the resistivity beneath the profile.

Figure 6 shows five horizontal cross-sections slices at depth intervals 0-2.5, 2.5-5.38, 5.38-8.68, 8.68, -12.5 and 12.5-16.9 m that resulted from the 3D inversion.

The low resistivity values (less than 15 Ωm) could correspond to a very damp zone and the closed geometry may represent the pool location. The resistivity variations over short distances between the materials contained inside the pool and surrounding area and the shape of these anomalies confirm the location of the ancient pool The low resistivity anomaly appears in the horizontal cross-sections slices at depth intervals 0-2.5, 2.5-5.38 and 5.38-8.68 (Fig. 6).

The vertical cross-sections of the model obtained from the inversion of 3D data at y intervals 0-5, 5-10 and 15-15

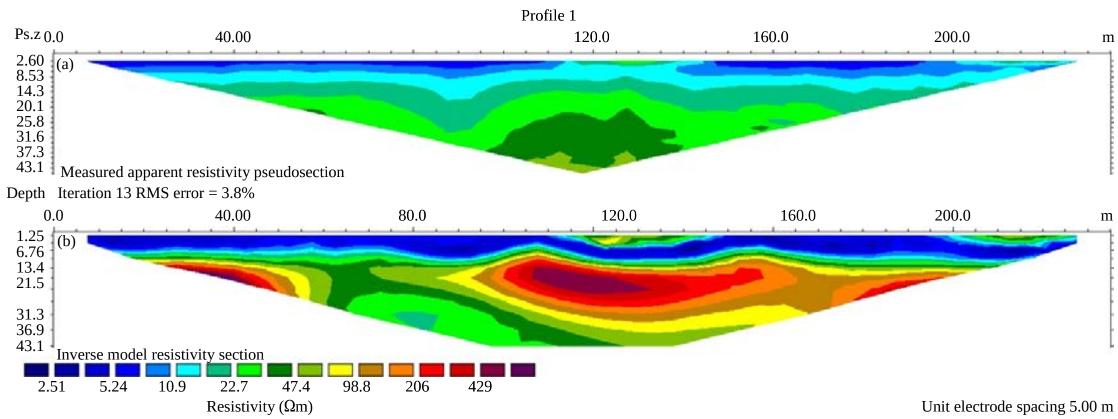

Fig. 5(a-b): (a) Two-dimensional electrical profile with apparent resistivity pseudosection and (b) Interpreted resistivity model

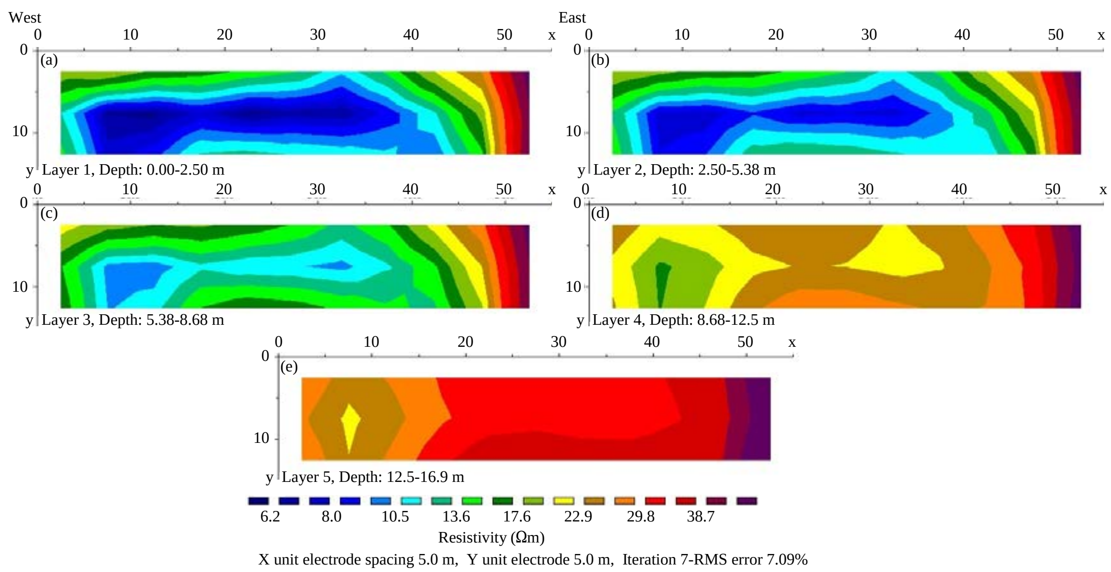

Fig. 6(a-e): Horizontal cross-sections depth slices of increasing depth that resulted from the 3D inversion. Low resistivity anomalies indicate probable conductive filling materials, (a) Layer 1, (b) Layer 2, (c) Layer 3, (d) Layer 4 and (e) Layer 5

shows the thickness of the filling materials which is about 8 m (Fig. 7). The resistivity of the filling materials decreases toward the center of the pool.

The results of this study was compared with other researchers used the same methods as electrical surveys was used by Leucci and Greco[16]. They found that the effectively visualized as iso-resistivity surfaces, allow the localization of anomalies leading to buried archaeological remains beneath the ruins of the church. A joint interpretation of the gradient and pole-pole data using the probability tomography method was used by Matias *et al.*[17]. The results in that study show high resistivity anomalies and high resistivity anomaly occurrence probability contrasts that were assigned to the presence of the walls of the tomb. Ekinci and Kaya[18] used a geoelectrical survey by using Wenner-Schlumberger array along several parallel profiles. They found that the detection of high resistivity anomalies indicated that using this method is suitable for searching tombs. The 2D and 3D resistivity imaging was used by Abdelwahab[19]. He found that the dipole-dipole array cannot be used for 2D and 3D imaging in his study area. The Wenner-Schlumberger array is more suitable for his study area. On the Other Hand he found that the Wenner array is a good choice if a fast work speed or many lines are required in the target area. In general, as he said the Wenner array is the most suitable array in his study area examined for 2D and 3D electrical resistivity mapping. Drahor *et al.*[20] used both the magnetic imaging and electrical resistivity tomography for investigate an archeological site.

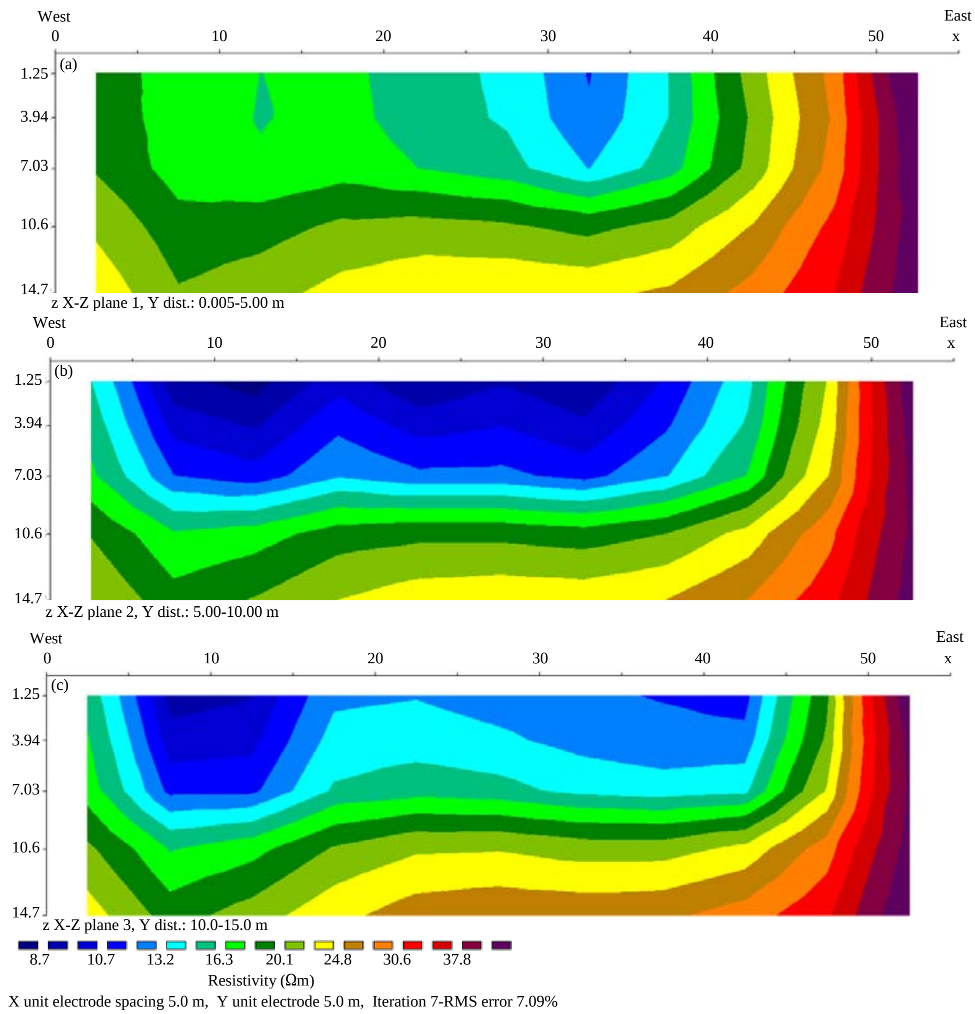

Fig. 7(a-c): Vertical cross-section depth slices of increasing depth that results from 3D inverssion

They found that the application of magnetic gradiometer imaging and 3D resistivity tomographic methods helped in visualizing of archaeological relics beneath the surface. As well they indicated that the resistivity tomography investigations were very successful in determining the main features of the archaeological remains.

CONCLUSIONS

The CVES results were differentiated between the upper layer of the study area and the lower layers. It had been showed that the upper layer is agriculture soil with water content, while the lower layer was recognized as a buried wall or other foundations. An ancient pool had been showed in one of the seismic line. Generally continuous vertical electrical sounding has better vertical and horizontal resolution than the conventional resistivity methods, but the main problem of the electrical methods is the rapid decrease of resolution with depth. The other advantage of this method is the possibility of mapping areas with complex subsurface geology. The relatively high resistivity contrast between the archaeological features and the surrounding sediments help to extract archaeological information from resistivity survey. The buried walls can be easily identified by high resistivity anomaly. To better depict the shape and the depth of the ancient pool, we reconstruct a 3D electrical resistivity model from high numbers of CVES profiles to get good resolution of the 3D image.

REFERENCES

1. Aspinall, A. and C.F. Gaffney, 2001. The Schlumberger array-potential and pitfalls in archaeological prospection. Archaeol. Prospect., 8: 199-209.
2. Osella, A., M. de la Vega and E. Lascano, 2005. 3D electrical imaging of an archaeological site using electrical and electromagnetic methods. Geophysics, 70: G101-G107.

3. De Domenico, D., F. Giannino, G. Leucci and C. Bottari, 2006. Integrated geophysical surveys at the archaeological site of Tindari (Sicily, Italy). J. Archaeol. Sci., 33: 961-970.
4. Negri, S., G. Leucci and F. Mazzone, 2008. High resolution 3D ERT to help GPR data interpretation for researching archaeological items in a geologically complex subsurface. J. Applied Geophys., 65: 111-120.
5. Al-Zoubi, A.S., A.E.A. Abueladas, R.I. Al-Rzouq, C. Camerlynck and E. Akkawi *et al*., 2007. Use of 2D multi electrodes resistivity imagining for sinkholes hazard assessment along the Eastern part of the Dead Sea, Jordan. Am. J. Environ. Sci., 3: 230-234.
6. El-Khalili, M.M., 2014. Revival of cultural heritage: The case study of the Ottoman village in Umm Qais. Jordan J. History Archaeol., 8: 119-136.
7. Mershen, B., 1992. Settlement History and village space in late ottoman northern Jordan. Stud. History Archaeol. Jordan, 4: 409-416.
8. Al-Asad, M. and G. Bisheh, 2000. The Umayyads: The Rise of Islamic Art. Arab Institute for Research and Publishing, Beirut, Lebanon, ISBN-13: 9781874044352, Pages: 223.
9. Segal, A., 1988. Town Planning and Architecture in Provincia Arabia: The Cities Along the Via Traiana Nova in the 1st-3rd Centuries C.E. BAR Publishing, Oxford, UK., Pages: 127.
10. Kerner, S., 1994. The Near East in Antiquity IV. Archaeological work of National and International Institutions in Jordan. German Protestant Institute for Archaeology, USA., Pages: 92.
11. Chitty, G. and D. Baker, 1999. Managing Historic Sites and Buildings: Reconciling Presentation and Preservation. Routledge, London, UK., ISBN-13: 978-0415208154, Pages: 208.
12. Loke, M.H. and R.D. Barker, 1996. Rapid least-squares inversion of apparent resistivity pseudosections by a quasi-Newton method. Geophys. Prospect., 44: 131-152.
13. Loke, M.H., 2000. Topographic modeling in resistivity imaging inversion. Proceedings of the 62nd EAGE Conference and Technical Exhibition, May 29-June 2, 2000, Glasgow, Scotland.
14. Loke, M.H., 2001. Res2DMod ver. 3.02a. Geotomo Software. http://www.geotomosoft.com/.
15. Loke, M.H., 2004. Res3Dinv ver. 2.14. Geotomo Software. ftp://geom.geometrics.com/pub/mag/G-857_MagCD/OhmMapper/res3dinv.pdf
16. Leucci, G. and F. Greco, 2012. 3D ERT survey to reconstruct archaeological features in the subsoil of the Spirito Santo Church ruins at the site of Occhiola (Sicily, Italy). Archaeology, 1: 1-6.
17. Matias, H.C., F.A.M. Santos, F.E.R. Ferreira, C. Machado and R. Luzio, 2006. Detection of graves using the micro-resistivity method. Ann. Geophys., 49: 1235-1244.
18. Ekinci, Y.L. and M.A. Kaya, 2007. 3D resistivity imaging of buried tombs at the Parion necropolis (NW Turkey). J. Balkan Geophys. Soc., 10: 1-8.
19. Abdelwahab, H., 2013. Comparison of 2D and 3D resistivity imaging methods in the study of shallow subsurface structures. Greener J. Phys. Sci., 3: 149-158.
20. Drahor, M.G., T.O. Kurtulmus, M.A. Berge, M. Hartmann and M.A. Speidel, 2008. Magnetic imaging and electrical resistivity tomography studies in a Roman military installation found in Satala archaeological site, Northeastern Anatolia, Turkey. J. Archaeol. Sci., 35: 259-271.