# THE ELECTRICAL RESISTIVITY SURVEY AT THE EB IV - MB II CEMETERY NEAR TELL EL-‘UMEIRI

by
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## Introduction

In the mid-20th century, some archaeologists tried to adopt means of surface detection (metal detectors) with the aim of discovering buried archaeological sites, but since it is not possible to detect hidden sites by such traditional methods, geo-archaeological studies have concentrated on developing new techniques for detecting sub-surface structures. The earliest techniques used was the excavation of bore holes to follow cavities, walls and also to get soil specimens (Lerici 1959). The technique succeeded in locating some tombs in Italy. It was improved on by using photographic equipment. This improvement was tried at the Pyramid of Khofo (Cheops) in Egypt (Kerisel 1988).

Another method depends on soil magnetism by using a magnetometer. In addition, geochemical techniques have been tried (Clark 1968). Echo-sounding methods succeeded in discovering tombs in the Valley of the Kings in Egypt (Bassa 1988). Geophysical remote sensing added new positive results in this field (Clark 1977). Since 1946, Atkinson tried to adopt the resistivity method in his excavation in Dorchester, Oxfordshire. He obtained promising results (Atkinson 1952: 63). Aitken discussed in some details the “Galvanometer” that he used in a resistivity experiment (Aitken 1961).

In Jordan, archaeologists tried to use such methods in their excavations at Bab edh-Dhra‘. The EM-31 electronic conductivity meter was used to identify and locate shaft tombs electronically so that time consuming test excavations could be avoided (Fröhlich and Ortner 1982: 251-253).

A resistivity survey was conducted in the Baq‘ah Valley, where a number of fairly large diffuse areas of higher resistivity were located on all sides of Rujm el-Ḥenu, revealing a large area of settlement (McGovern 1979:114; 1983: 87-105). A Cesium Magnetometer Survey was also conducted in the same area (McGovern 1981: 39-41).

At Tell el-‘Umeiri, the team attempted to assess the feasibility of using ground-penetrating radar to locate sub-surface archaeological features (Herr *et al.* 1991: 173). In this article, the resistivity experiment at ‘Umeiri East will be discussed. The area is located southwest of Amman, on the northern edge of the Madaba Plains and along the Airport Highway, at Palestine Grid coordinates 234.7-1441.6 (K737 map 3153.1. SE) to the east of the major archaeological site of Tell el-‘Umeiri, under investigation by an American team (Geraty *et al.* 1989; 1991; Herr *et al.* 1991).

## Principles of the Resistivity Method

The method depends on applying an electrical current to the ground between two poles and measuring the resistance and the natural potential field between other two poles. Repeating this process along the line (profile) measures the electrical properties and ultimately calculates the resistivity distribution beneath this profile down to a depth of 1/5 to 1/4 of the current electrode separation. Thus, increasing and decreasing the current electrode separation allows the study of the rock resistivity and other electrical properties down to any desired depth.

The electrical properties of rocks depends on their type, mineral composition, compaction, porosity, and water content. The last two are the most important factors. If the pores are filled with moisture or water, resistivity may decrease sharply depending on the type of water, particularly if the salt content is high. Thus, sub-surface cavities effect the resistivity of a rock, depending mainly on its volume. Empty cavities may result in an increase in resistivity on the order of a few tens to a few hundreds of ohm-meters or more, depending on the rock-type and the size of such cavities. When these are filled with earth, resistivity may vary according to the type of the material, its compaction, and other factors.

Local geological conditions also affect the resistivity distribution, mostly due to lithological variations, either horizontal or vertical. Thus, fracture and fault zones may also be located successfully, particularly if these effects result in lithological and porosity variations, as is usually the case.

### The Resistivity Experiment

Twelve electrical trenching profiles were conducted at the study site utilizing the Wenner configuration (see Fig. 1). The profiles were run in a north-south direction and were extended or shortened to cover the reservoir area and the neighbouring proposed constructions. Thus, their lengths varied in the range of 52 to 80m. For the reservoir area, the profiles were run along the lines of foundations.[1] Thus the spacing between profiles is in the order of 5-5.1m. For the area west of the reservoir, three profiles were run along the three north-south foundation lines.

For the profiles of the reservoir area (profiles 1-9 and 12), electrical measurements were made with electrode separations of a=2m, 4m and 8m, thus allowing a depth penetration of about 1.2-1.5m, 2.4-3m and 4.8-6m respectively. An extra electrode spacing (a=10m) was also tried for the first profile, thus allowing greater depth penetration.

For profiles 10 and 11, electrode spacing of a=2m and 4m were tried, i.e. down to a depth of not less than 3m. For each profile, electrodes were planted every 2m all along the profile. The electrical measurements for resistance (ohm) and self potential (volts) that represent the average for the centre of the configuration were made. After measuring the first point, all connections were moved to the next four electrodes, i.e. in

1. Resistivity experiment in the cemetery area.

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[1] Thanks to Prof. Z. Isa and Dr. F. Kaddoumi for their efforts in the interpretation of the resistivity data.

steps of 2m for all electrode separations. The same process was repeated to the end of each profile.

The resistivity meter used in the experiment is the Atlas Copco SAS-300, a digital signal-enhancement device that allows the recycling of the applied electrical current some 64 times to the ground if the electrical background noise is higher than normal. It thus permits more accurate measurements. The electrical background noise at the study site is quite normal and thus for all measurements only four recyclings were made for the resistivity readings and usually only one for the self-potential reading.

Through an internal microprocessor, the device measures, calculates, and displays both the resistance (in ohms, milli-ohms and micro-ohms) and the potential down to a micro-volt.

## Analysis and Interpretation of the Resistivity Data

Utilizing available software for the analysis of such electrical data, corrected apparent resistivities were calculated for all profiles and electrode separations.[2] These were later plotted against the horizontal distance between the start of the profile and the centre of the configuration. These analyses revealed a large number of resistivity anomalies of variable amplitudes, wave lengths, and signs. These are believed to be caused by one or more of the following:

1. The presence of subsurface cavities of variable size, depth, and shape, e.g. anomalies 1, 2 and 3 of profile 1. Anomaly 3 is located over a cavity that has been detected by excavation while anomaly 1 indicates the presence of a much larger and deeper cavity. The nature of some of the observed anomalies along some profiles indicate that some cavities are partially or almost totally filled with earth or some other conductive material.

2. Local geological irregularities, such as cracking, fracturing, and local faulting, can produce similar anomalies with comparable amplitudes, mainly due to an increase in porosity.

3. Horizontal lithological variations may also cause such anomalies, such as anomaly 2 of profile 3. Such variations are quite common in marly limestone and other rocks. Large nodules that may be present in softer limestone and/or buried man-made constructions may produce such anomalies.

*Profile 1.* The resistivity distribution beneath this profile is presented in Fig. 2. Three major positive anomalies and two smaller negative anomalies were observed:

Anomaly 1 revealed tombs 1 and 2.
Anomaly 2 revealed cistern 12.
Anomaly 3 revealed tombs 13 and15, and cisterns 14 and 23.
Anomaly 5 revealed tomb 30.

*Profile 2.* Four anomalies were observed along this profile:

Anomaly 1 revealed tomb 16.
Anomaly 3 revealed cistern 31.

*Profile 3.* Although two major anomalies were considered of prime concern, neither tombs nor cisterns were found.

*Profile 4.* Three anomalies were observed, but no archaeological remains were found.

*Profile 5.* One anomaly was observed, but no archaeological remains were found.

*Profile 6.* Two anomalies were observed along this profile, but no archaeological remains were found.

*Profile 7.* Only one negative anomaly was observed, but no archaeological remains were found.

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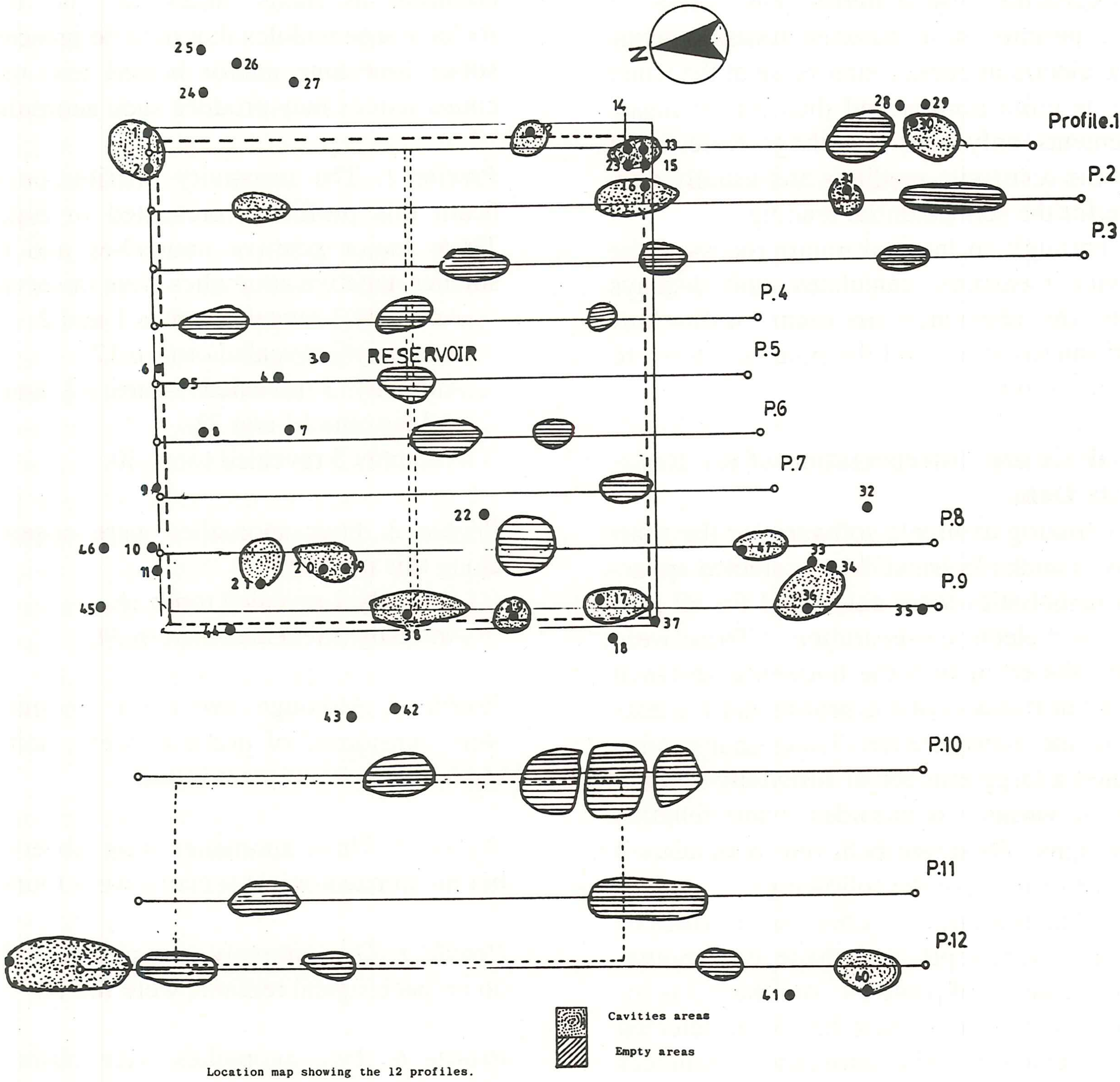
[2] A more complete report on this survey will appear in a forthcoming publication of the Madaba Plains Project.



Location map showing the 12 profiles.

2. Location map showing the 12 profiles.

*Profile 8.* Four anomalies were observed:
Anomaly 1 revealed cistern 21.
Anomaly 2 revealed cisterns 19 and 20.
Anomaly 3 revealed cistern 47.

*Profile 9.* Four anomalies were observed:
Anomaly 1 revealed cistern 38.
Anomaly 2 revealed cistern 39.
Anomaly 3 revealed cisterns 17 and 37.
Anomaly 4 revealed shafts 33 and 34, and cistern 36.

*Profile 10.* Four anomalies were observed, but no archaeological features were revealed.

*Profile 11.* One major anomaly was observed, but no archaeological features were observed.

*Profile 12.* Five anomalies were observed:
Anomaly 1 revealed cistern 48.
Anomaly 5 revealed cistern 40.

The resistivity anomalies observed at this site are believed to result from one or more of the following:

1. Some sub-surface irregularities brought about by local fracturing and faulting. The associated fractures may greatly increase porosity, thus causing excessive resistivity. Also local lithological variations, particularly horizontal variations, do cause similar anomalies, like anomalies of profiles 4, 5, 6, 7, 10, and 11.

2. The presence of sub-surface cavities of variable depth, width, and shape, well represented in profiles 1, 2, 8, 9, and 12. It is worth mentioning that tomb 13 (Profile 1, anomaly 3) revealed the richest grave assemblage dated to the EB IV ever found so far in the Southern Levant (Waheeb and Palumbo 1993).

It is clear that the area of the reservoir contained an extensive cemetery, rather than just a few isolated tombs and cisterns. The boundaries of the cemetery are still undetermined, since much of the area is under cultivation, but the activities of robbers and agricultural bulldozing on the upper slopes of the hill revealed the presence of more cavities. Given the small budget available, however, the resistivity survey concentrated on the construction area of the reservoir.

In conclusion, the newly discovered EB IV and Middle Bronze Age cemetery at 'Umeiri East is an important addition to the archaeological evidence already coming to light in the Tell el-'Umeiri excavations. Hopefully more resistivity experiments will be considered in order to further develop geo-archaeological research in Jordan.

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