

Ground Penetrating Radar Survey Report:

Tel Es-Safi, Israel

Data Acquired June 15-17, 2003

Report compiled August 4, 2003

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Introduction

Tel es-Safi is a site located on the border between Philistia and the Judean Shephelah in Central Israel. The entire site is over 40 hectares (~100 acres) and is commonly believed to be the site of *Gath of the Philistines*, from the well known Bible story David and Goliath. It was a continuously settled Bronze and Iron Age site, where the latest phase so far excavated dates to the Iron Age, around late 8th century BCE.

Headed by Dr. Aren Maeir of Bar-Ilan University, survey and excavation seasons for the Tel es-Safi Archaeological Project have been undertaken every year since 1996. Given the discoveries to date and the size of the site, Dr. Maeir enlisted the support of Mnemotrix Systems, Inc. for GPR (Ground Penetrating Radar) studies to be done to augment the existing archaeological record, and to assist in decision making for future seasons. Therefore, under the guidance of Head Archaeologist, Dr. Aren Maeir, this geophysical survey was conducted in June of 2003 in association with Geomorphologist, Dr. Oren Ackerman, also of Bar-Ilan University.



As shown below, Tel es-Safi is named for its white cliffs which can be seen clearly from afar. Until now most of the serious excavation studies have been done closer to the top of the tel, focusing around Area A which is referred to in many of the papers discussing the site's excavations. The lower areas have had less attention, so GPR sub-surface studies have an appeal towards choosing which lower areas should be taken up next, holding an important role in future planning.



Actions Taken

After discussions with both Dr. Maeir and Dr. Ackerman, two main areas (GPR

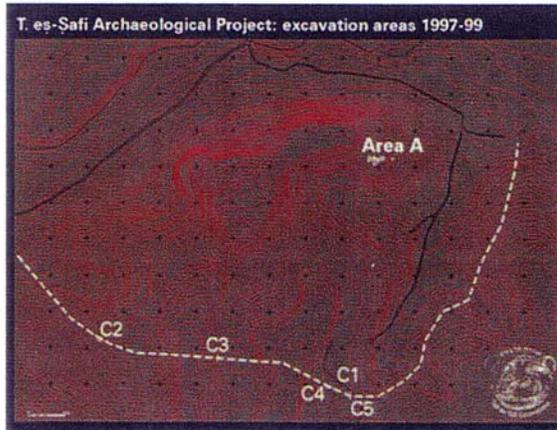


Study Areas 1 and 2) were chosen for current study.

On June 15th, 2003, test drags east of the tel were performed in Study Area 1 in order to determine the location of features of potential interest. On June 16th, a subset of this area was marked out, and an intensive GPR survey was conducted.

This intensive grid was labeled Study Area 1 and was chosen for its size (a large area not previously excavated), its accessibility, and towards the goal of confirming some informal and undocumented reports by Israeli General Moshe Dayan, as to the appearance of coffins in this general area in the 1950's.

It is planned that a more complete geological mapping survey will be done later this year to map our Study Area 1 to the overall mapping of the Tel es-Safi site for future excavation work.

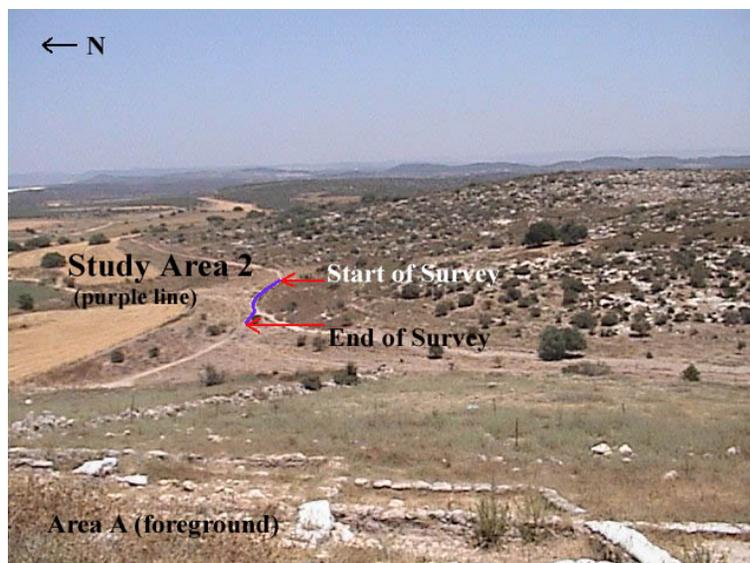


General plan of T. es-Safi and environs. Notice the man-made trench surrounding the site (dotted line)

Study Area 2 was chosen for the work done on June 17th. In previous excavation seasons a trench approximately 2.5 km long was seen to circle the site on the eastern, southern, and western sides (see figure to left). It is surmised that this feature may be the remains of an ancient siege moat. There is both archaeological evidence and Biblical reference as to the veracity of this hypothesis. A part of this trench was excavated during the 2000 field season on the eastern side of the

trench (Area C6 not on map).

On June 17th, 2003, surveys were taken on the northern slope of the valley on a road that extends to the summit of the tel. This can be seen in the figure below labeled as Study Area 2. The object of the GPR survey acquired here was to locate a possible continuation of the excavated trench. It was suggested that a survey perpendicular to the supposed location of the trench along the road would be best, as can be seen in the figure below.



Observations and Post-Processing

Many things were observed in the acquired data from both Study Areas 1 and 2. First, a significant amount of background interference was removed by applying a Horizontal Background Removal FIR filter to both datasets. Issues regarding signal interference were studied in post-processing which will allow for follow-on GPR studies to be done taking these issues into account more effectively. Nevertheless, much useful information was gleaned.

Study Area 1: A grid was marked out in the dimensions of 11 meters by 20 meters within the overall area called Study Area 1. GPR Signal Data was acquired in a tight set of overlapping parallel lines taken first Southwest to Northeast, and then transected in a perpendicular direction Southeast to Northwest. These sets of data were put together into a 3D cube for follow-up study in a lab environment.

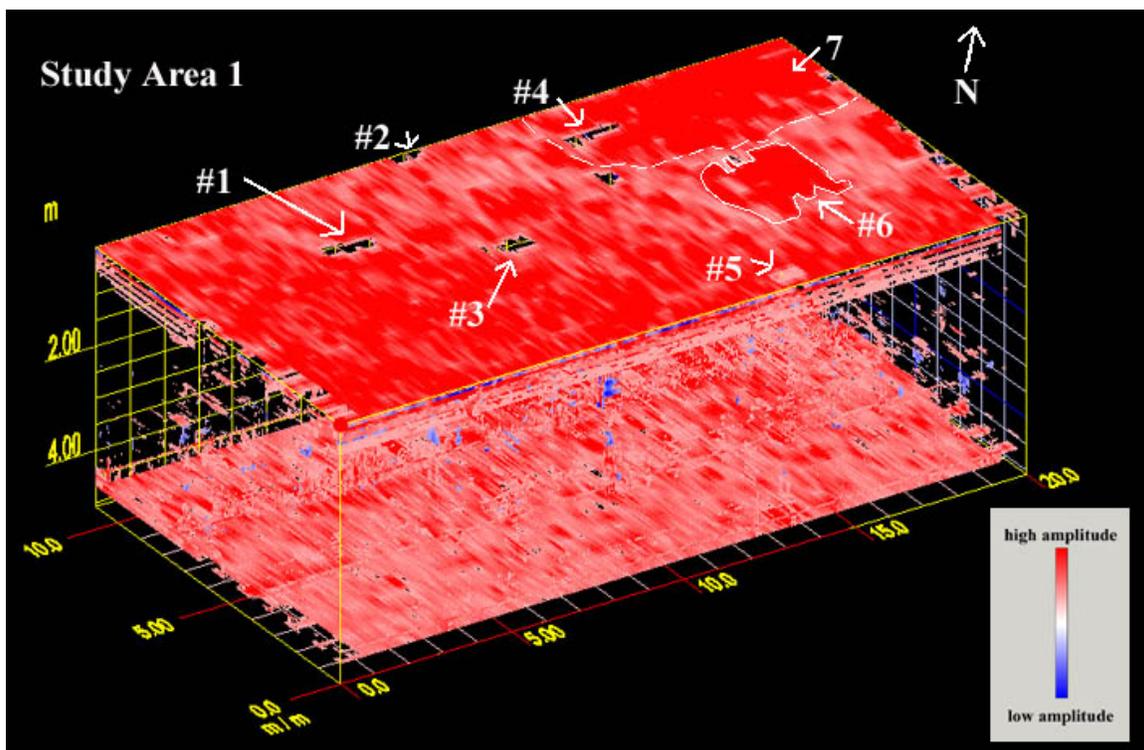
Area 1 was analyzed closely as to depth (vertical axis) and movement along the horizontal axis in a 3D cube. A velocity analysis shows that the estimated signal depth of useful data was approximately 5 meters, traveling through hard ground made up primarily of limestone.

It was as much a goal of this project to discover exactly how GPR signal data can be aligned to subsequent archaeological discoveries, as to find definite answers regarding Study Area 1. Since there is little known hard data as to what the GPR signal data in this terrain actually represents, any correlative information as to pattern recognition of geologic and archaeological features will be extremely useful in a broader scope for the future excavation of this and similar sites. This study is a work in progress, and these

preliminary findings represent the beginning rather than the end of what is hoped will be a continued study.

High amplitude colors signify a strong reflection of the material, while low amplitude colors signify a weak reflection in the surrounding material or matrix. Therefore where the reddest hue is present, there exists a strong difference between layers of sub-surface material, which can be viewed as an anomaly.

In this view of Study Area 1, several anomalies can be seen throughout the data and are shown in the figure below. These anomalies are labeled 1-7, respectively.



A more in-depth visualization of these anomalies is shown in a set of animations which can be seen on the Mnemotrix website, at this address:

<http://www.mnemotrix.com/geo/essafi.doc>. If you are connected to the Internet while reading this report, you can view these animations by clicking below. You will see that as the vertical depth slices proceed from the surface down to a depth of approximately 5

meters, you can trace the presence of these anomalies, and then when animated, this view becomes quite interesting and potentially revealing as to where areas of features of interest might be located. Future studies conducted with less interference in the signal data should prove to be even more revealing.

[Click here to view the Vertical Depth Profile Animation](#)

http://www.mnemotrix.com/geo/es_1b_z.gif

[Click here to view the Horizontal Axis Profile Animation](#)

http://www.mnemotrix.com/geo/es_1b_y.gif

Anomalies 1-5 seem to be of a similar type in that as each is seen in depth, they become distinct, vertically oriented lines. Although their true identification is unknown at this time, they are intriguing in that they are significantly different from their surrounding geological matrix (amplitude levels are very high).

Anomalies 6 and 7 are interesting in that they are relatively large (about 3-4 meters wide and about 10 meters long, respectively), and roughly rectangular in shape. It can be assumed that anomaly 7 extends past the grid area shown, so its true dimensions are unknown. Of note is that during the survey, it was mentioned that many years ago a large metal cattle feeder which had gone missing from a local farm, perhaps about 20 feet long (6-7 meters), may have been buried in this general area. It could be speculated that this is the source of these anomalies, though only further study can prove this hypothesis.

An intentionally shallow profile was used for the collection of the data in Study Area 1, since the major focus of interest was a few meters down. Therefore a 400 MHz antenna was selected for the project. In future studies this same area could be viewed with a 200 MHz antenna which potentially can be aimed at 10-15 meters deep. This would allow for a more thorough study of geologic or deeper habitation layers in this area if this was of interest.

Study Area 2: Selecting the portion of the road for Study Area 2 was a vastly different project than Study Area 1. In the first case, a thorough grid of a specified area was relatively easy to accomplish. In the case of the search for the continuation of the siege moat, a much wider area of possible locations existed, in terrain which was not quite as accessible as in Area 1.

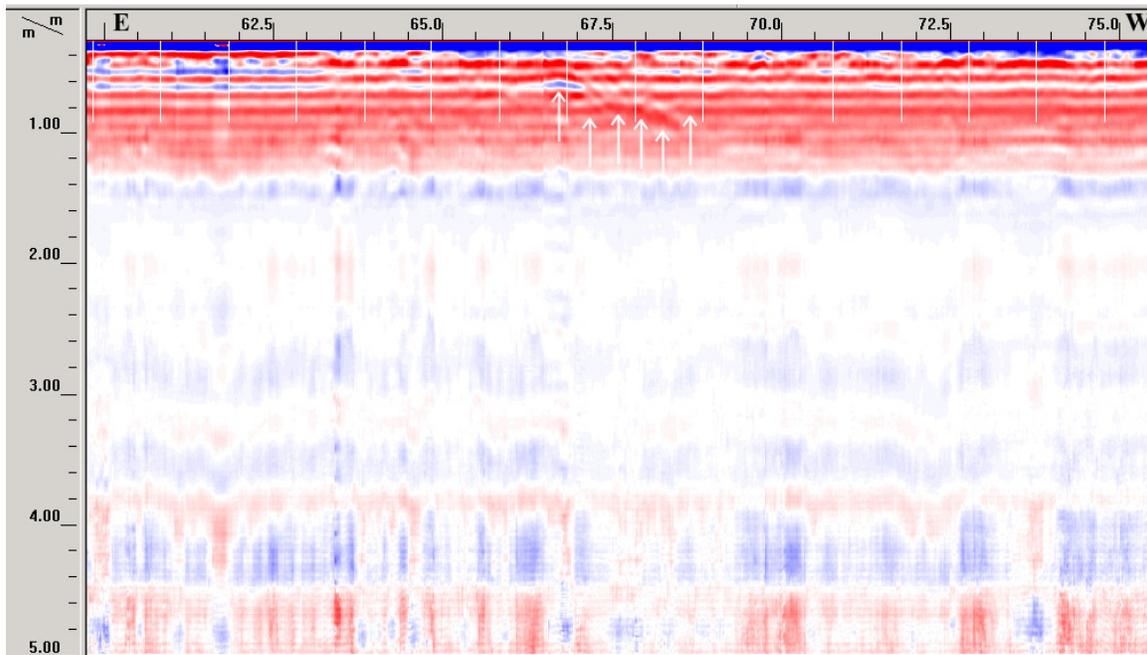
Area 2 was chosen by surmising where the old riverbed would meet the old trench near the cliff, to see if we could find the meeting point of the old siege moat and the old riverbed. Therefore we did very long test drags along the present road area rather than attempting to create a 3D study of a whole area. The test area surveyed was about 102 meters in an East/West direction along the road, covering about 1-2 meters across. (See photo of Study Area 2 on page 4 of this report.)

Both a 400 MHz antenna and a 200 MHz antenna were used, and it seemed that the 200 MHz data where the signal was focused deeper was potentially more reliable. Upon re-examination of the data from Study Area 2, it was clear that due to interference beyond our control (perhaps from “over the horizon” radar following IAF pilot training missions throughout much of the day), we were unable to remove all background

interference. In any event, time did not allow for as full a study of this area as could be useful in the future.

Although the results of this second study could not be called definitive, some areas of the road appeared to show anomalies where others did not. Below is shown a portion of the GPR signal data where it would appear some anomalies could be seen.

A mid-strength reflection can be seen in the figure below (curving red line with white arrows pointing up from below). The blue appears to be the beginning of the anomaly causing this reflection.



This reflection is located approximately 67.5 m from the eastern starting point of the GPR survey. There is another similar reflection located at 26 m. Both reflections are considerably subtle, yet given the above-mentioned characteristics of the site, this at least gives some suggested points at which to begin a more focused excavation, and also

shows where a follow-up survey focused at these locations would yield more relevant information.

Summary and Recommendations

These preliminary results may disclose anomalies which are consistent with archaeological predictions based on prior excavations and a general understanding of the site. While it cannot be stated definitively whether the anomalies shown denote archaeological discoveries to be made, or merely denote extant geologic features, it will be of great interest towards the correlation of pattern recognition in signal data with the actuality of the site, to discover what these areas of anomaly turn out to be in strictly archaeological excavation terms.

This study was vastly useful in terms of gaining experience as to how GPR operates in this kind of environment, and with the post-processing and study of the results, more acumen can be applied to future GPR surveys that may be undertaken on this site and surrounding areas.

It is recommended that a more in-depth GPR survey be conducted utilizing a more concentrated grid analysis possibly to be done during a period of time when there is less environmental interference from surrounding radar systems, and the outdoor temperature is cooler.

Given that Study Areas 1 and 2 are the subject of subsequent excavation plans, the areas of noted anomaly can be used to assist in entry points to begin work. In lieu of a follow-up GPR survey, this data may be helpful in determining the archaeological strategy for the 2004 field season.