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Landscape Resources and Human Occupation of Ancient Jordan : A Perspective From Subsurface Mapping Techniques Utilized by the Mādabā Plains Project

The Mādabā Plains Project (MPP) research design has for two-and-one-half decades guided exploration of portions of the region encompassed by the Mādabā Plains in central Jordan (FIG. 1), paying particular attention to food systems and broad occupational patterns. Major talls (Ḥisbān, al-'Umayrī, Jāwā, Jalūl), forts, farmsteads, cemeteries, and other hinterland sites and features constitute a rich database for investigating and understanding in an integrated fashion landscape resources and human occupation in ancient Jordan.

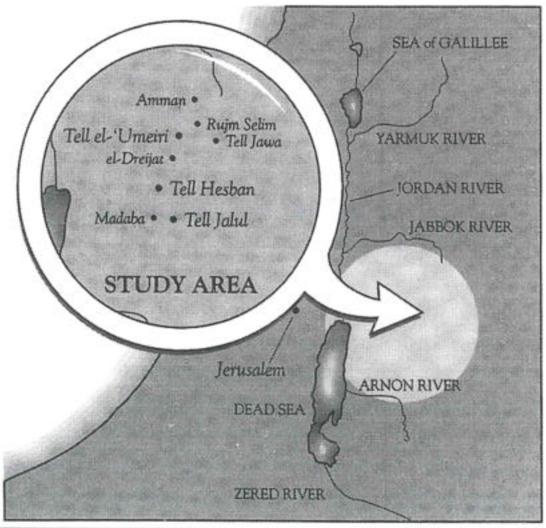
One emerging scientific endeavor which has contributed significantly to our research in the Mādabā Plains is the use of geophysical survey methods to perform subsurface mapping. In the context of the objectives of this conference and of the research design of the Mādabā Plains Project, this presentation initially summarizes the geophysical subsurface mapping techniques the Mādabā Plains Project has utilized since beginning excavations and surveys at and around Tall al-'Umayrī in 1984. It then focuses on the varied sites investigated and results obtained from subsurface mapping endeavors to this point in time at those locations. Of the techniques described below, ground-penetrating radar receives the greatest attention, especially its use in conjunction with the Iron Age excavations at Tall al-'Umayrī. Finally, we explore the implications of subsurface mapping investigations for the– continued study of natural and human resources in the Mādabā Plains region.

Development of Subsurface Mapping by the Mādabā Plains Project

Geophysical techniques used in subsurface mapping have included seismic refraction (SR –1984, 1987 and 1989 seasons), ground-penetrating radar (GPR –1989, 1992 and 1994) and electromagnetic induction (EMI –1992). GPR potentially provides the highest resolution of the three techniques, hence the greatest emphasis on its use by MPP. Seismic refraction does not reveal subsurface features to the same level of resolution as GPR, but it is not limited by a high soil conductivity as is GPR. EMI also provides subsurface detail to a much lower resolution than GPR, but more land area can be explored in the same period of time, with the potential of following with GPR for higher resolution where features indicate the need. All three techniques are non-invasive and non-destructive of the site.

Seismic refraction. In the course of developing subsurface mapping techniques for MPP, we began with SR because of its relatively inexpensive equipment. With it we investigated several sites. Our approach to SR employs a 4-pound hammer on a steel plate for signal production. Vertically oriented geophones receive the refracted sound waves, convert them to electrical signals and send them to a single-channel enhancement seismograph for display. Subsequently, the signals are digitized and recorded on a portable computer. We have used SR successfully at locations where GPR results were seriously limited by soil type. The technique shows promise for greater depth penetration, although, as noted above, resolution of the results is significantly lower than with GPR, making interpretation of the results more difficult.

Ground-penetrating radar. Thus far, we have collect-



1. Mādabā Plains Project Study Area Map.

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ed data at six different sites which have a variety of soil types and potential subsurface features. These include two rural areas and four ancient urban sites within the Mādabā Plains. The hinterland areas are Wādī al-Bishārāt, located approximately 2 km southwest of Tall al-'Umayrī, and a Bronze Age cemetery (Boot Hill) on property belonging to the al-Bishārāt family about 2 km south of the tall. The urban sites include Mādabā, Jāwā, Jalūl, and al-'Umayrī. A Geophysical Survey Systems, Inc., GPR controller and antennas transmitted and received broad-band signals centered at 300 and 500 megahertz (MHz). The reflected wave forms were recorded by a personal computer (PC) on removable hard disks. We used survey grids with intervals of 0.5, 0.6 and 1.0 m, as appropriate to the area, to determine the location of subsurface structural features. The radar data were subsequently analyzed as transect profiles using a 486 PC. Computer software enhanced the data and interpolated between radar profiles, when appropriate, to produce two-dimensional maps of the subsurface features.

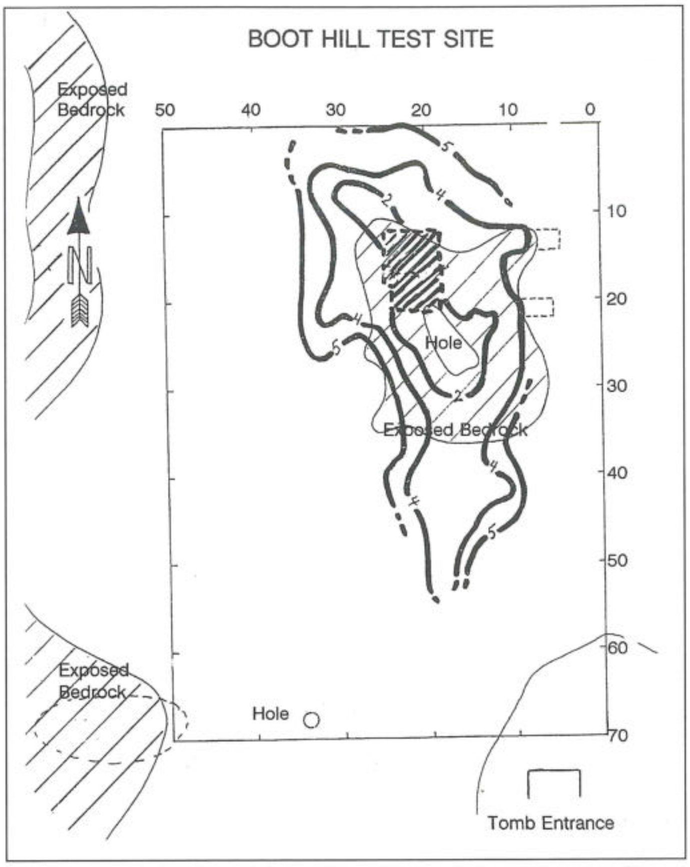
Electromagnetic induction: We explored the use of a Geonics EM -31 Ground Conductivity Meter as a means of locating large caves, caverns and tombs. The sensor consists of a horizontally held boom, 0.10 m in diameter and 4 m long, containing transmitting and receiving coils at opposite ends of the boom. Data were recorded by a battery-powered digital data logger, and were transferred in the field onto floppy disks for storage and transport using a notebook computer. Post-season signal processing used MATLAB, in addition to lab-developed software, on 386 and–486 PCs. The EM-31 transmits a time-varying magnetic field that induces electrical current in the ground. The associated induced magnetic field can be measured at the ground surface. The amplitude of the induced signal is recorded at regular intervals as the investigator carries the sensor along a predetermined track. The orientation of the coil, whether parallel or perpendicular to the direction of motion, will also impact the strength of field reading. We compared the results of EMI with those of GPR in a 30 x 30 m area of the al-Bishārāt Bronze Age cemetery.

MPP Sites Investigated by Subsurface Mapping Techniques and Results

Boot Hill

The detection and analysis of tombs are important to any investigation of ancient human occupation. On the site of this Bronze Age cemetery, we employed GPR to identify the shape of a large known cave and to detect previously unknown tombs . A 30 x 30 m area of the cemetery was mapped using 300- and 500-MHz antennas with 0.5 m transect separation. We also mapped this site with an EM-31 ground conductivity meter, basing a grid on transects 1 m apart.

Our analysis of the GPR data proved our ability to identify the depth and shape of caves and tombs. As (FIG. 2) demonstrates, GPR results confirmed a correlation with surface features and indicated the contours of a subterranean cave. Comparing tombs located by GPR, but otherwise unknown in the current era, with those which had been found and robbed, provided an opportunity to develop EMI and GPR siting techniques. The strategy of locating tombs with large-scale EMI surveys, leading to more specific GPR mapping, receives our continued attention in Wādī al-Bishārāt as well as in the vicinity of al-'Umayrī. In addition , these non-intrusive technologies allow us time to plan excavations without revealing tomb locations to potential grave robbers.



2. Boot Hill GPR Top Plan.

Wādī al-Bishārāt

SR has been used in Wādī al-Bishārāt to define one of several ancient stone-core earth dams which help control erosion and retain water for soil moisture build-up during winter rains. Such ancient dams, which are without question extremely significant for exploiting landscape resources, abound in wadis of the hilly region on the northern fringe of the Mādabā Plains. Many are successfully operating today, while erosion has exposed the retention structures in isolated instances. We used SR in 1987 and GPR in 1989 to gain a better understanding of their size and nature. The SR effort was partially successful in producing a low-resolution description of one dam. Clays mixed with other fine-grained soils, typical of those deposited in wadi bottoms, proved impenetrable to GPR signals. Thus, the higher resolution GPR technique was unsuccessful in this location.

We have also initiated an EMI project in Wādī al-Bishārāt to locate shallow subsurface caverns that could be opened to the surface and used as cisterns for supplying water for agricultural purposes during the summer growing period. Prime candidate locations include areas not far above fertile wadi bottoms with exposed bedrock or shallow soil coverage. Directing runoff water toward an open cistern with rock channels or barriers or shaping the surface to funnel runoff water toward a cistern opening was a common method in antiquity and is still used in some places today.

The loss of valuable surface water through runoff carries significant implications for land use. Efforts at renovating and maintaining water retention structures for use in the present era have already begun. And combining the results of geophysical exploration with our current knowledge of ancient cistern use for agricultural purposes could be the basis for more extensive modern local projects to retain seasonal runoff water for enhancement of summer crop production.

Mādabā GPR was also employed in the modern city of Mādabā to search for a cistern donated to the city by the Emperor Justinian. We were unsuccessful in these GPR investigations due to electromagnetic interference and reflections from a variety of above-surface structures. Additional software development for signal enhancement may be helpful in clarifying subsurface reflectors.

Jāwā

In considering a variety of sites and conditions during our 1989 GPR feasibility survey, we investigated three areas on tall Jāwā. In that first season of GPR use by MPP, we recorded the radar reflections on audio cassette tapes. Unfortunately, although observations at the time of data collection indicated significant subsurface features, the tapes for Jāwā were later damaged and provided no useful information when we sought to retrieve and analyze the data on our return to the United States. Subsequently, we have recorded all of our geophysical data exclusively on digital media with more reliable backups.

Tall Jalūl

Occupying a prominent position in the center of the Mādabā Plains, Tall Jalūl must have played a significant role in the region in antiquity. The site is large (19 acres) and, although excavations have only begun at this point, it is clear the site had major economic and political status. Archaeological interpretations of a large surface feature just inside the apparent south gate at Tall Jalūl indicate the possible presence of a water structure. A south-to-north transect passing through this feature and extending nearly 200 m in length was outlined, starting midway up the south gateway ramp and extending down the north slope nearly to a cistern at the bottom. As a result of clay-rich soil, GPR penetration at Tall Jalūl was limited to about 0.5 m in depth along this transect for the 500 MHz antenna. Radar penetration by the 300 MHz antenna over the southern 95 m of this line was only slightly greater.

We obtained good GPR reflections at depths greater than 1m adjacent to Field B excavations near the east gate using the 300-MHz antenna. While it was possible to observe structural features in the GPR profiles, the penetration depth was only slightly greater than the depth of overlying wind-blown deposits, limiting the usefulness of GPR in describing the location of subsurface features at this site. We anticipate the need for further improvements in sensor capability before we employ GPR extensively at Tall Jalūl.

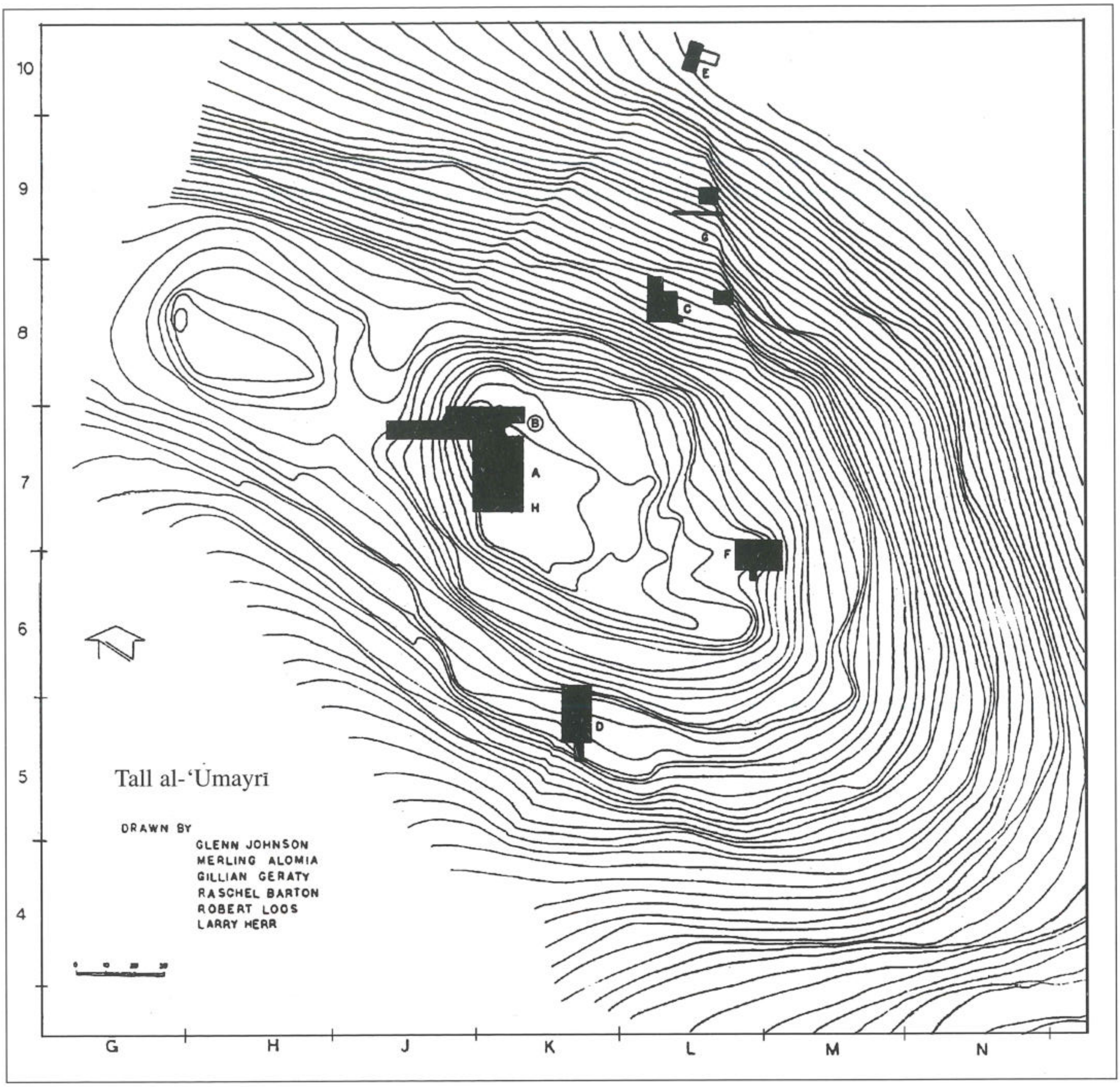
We also used SR on the southern 70 m of the south-north transect. More data will be necessary in order to make definitive interpretations of the results, but significant subsurface information is apparent to depths well below the radar penetration. The success of SR investigations indicated promise for further exploration by this technique.

Tall al-'Umayrī (FIG. 3)

The region of Tall al-'Umayrī has received the greatest attention in terms of geophysical investigation by MPP. Starting with the 1984 season, SR provided low-resolution descriptions of the subsurface structure of three apparently agricultural terraces on the southwest flank of the tall. It also revealed the probable depth of human occupational debris to limestone bedrock in the region east of Field A to be in excess of 8 m. The knowledge gained by correlating EMI and GPR signals at Boot Hill has also been put to use in searching for possible tombs along the hillside south of the tall below the 'Ammān National Park. Further analysis of recorded data is necessary to assess the results.

Water source: It is likely that the water source at the northern base of the tall has been a major reason for long-term occupation of the site. We have mapped a portion of the area around this facility using GPR and SR. In seven GPR profiles of the vicinity, radar penetration obtained reflections indicating the presence of subsurface features. These included probable piping or channels adjacent to the existing opening, which might otherwise have been located only with extensive excavation. Features up to 2-3 m deep were detected by radar, clay deposition not presenting the serious limitation we feared. Additional transects, possibly combined with further excavation, would be helpful in describing more completely subsurface features in the area surrounding the water source.

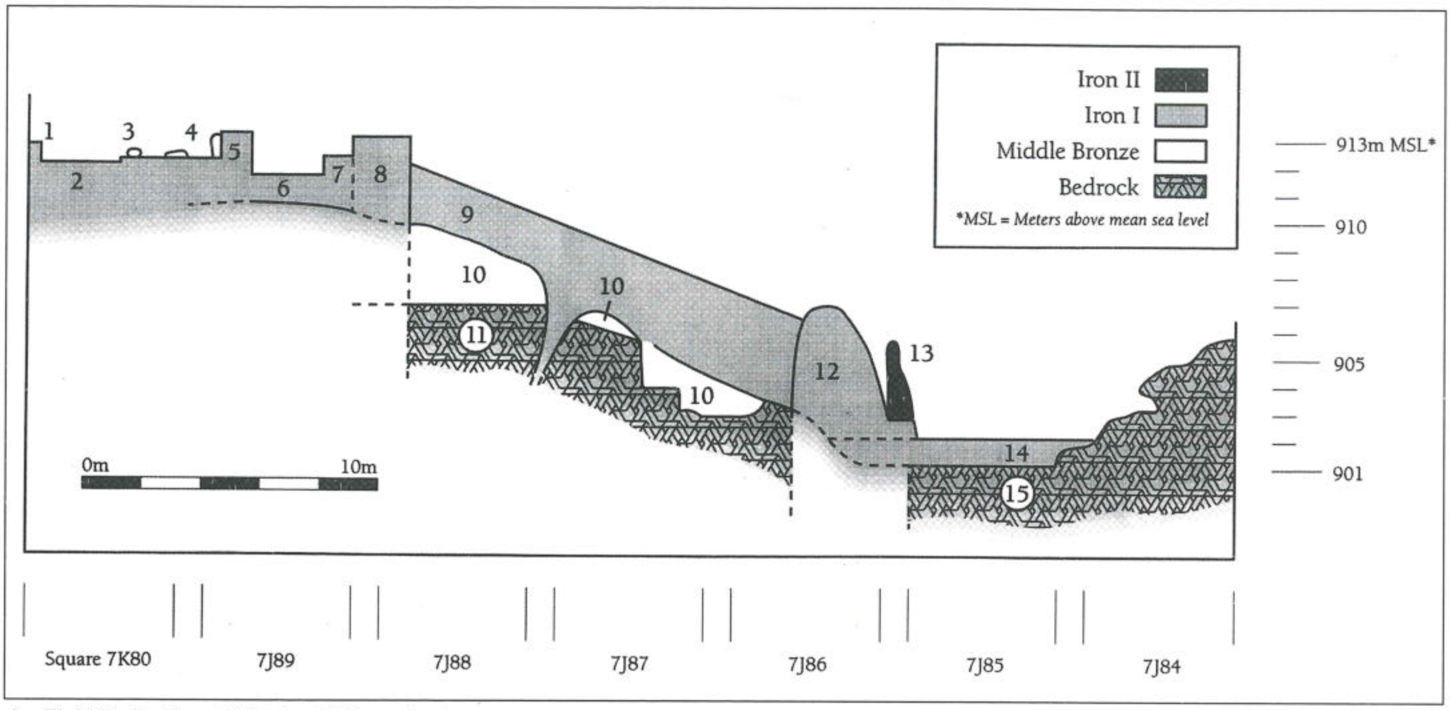
Western defenses: Perhaps the most intriguing use of GPR at al-'Umayrī is tied to the western defense system (Field B). It dates to the early Iron I period and represents one of the earliest and best preserved casemate wall sys-



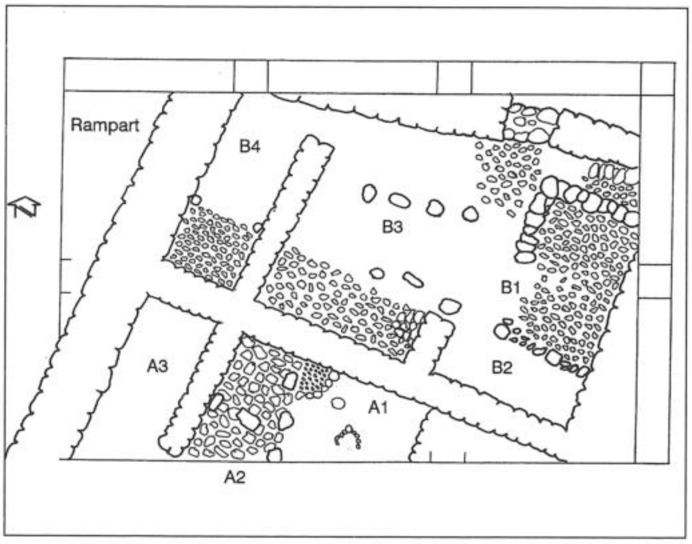
3. Topographic Map of Tall al -'Umayrī.

tems extant anywhere in Palestine. Its construction following an earthquake around 1200 BCE included a casemate wall, a beaten-earth rampart which incorporated a lateral pyramidal row of revetment stones embedded into and across the surface of the glacis, a large retaining wall at the base of the rampart, and a dry moat (FIG. 4). A massive and fiery destruction a few decades later preserved the system and adjoining buildings inside the wall.

Given the nature of the transition between the Late Bronze Age and the early Iron I period in the hill country of Palestine, characterized predominantly by the establishment of small agrarian settlements, a site with defense expenditures of this magnitude signals tremendous economic and political significance. Two buildings thus far excavated inside the wall (FIG. 5) significantly enhance our understanding of resource exploitation and human occupation at the site. Building A encompassed a domestic food-preparation area (A1), separated in antiquity by posts and (likely) a curtain wall from a room with religious significance (A2), and a casemate storeroom (A3)



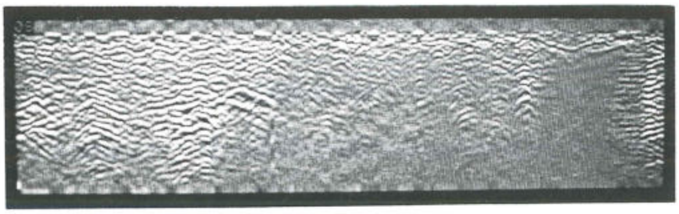
4. Field B: Section of Western Defense System.
Key:
(1) Eastern wall of building.
(2) Beaten-earth surface of food-preparation area.
(3) One of three post-bases (perpendicular to the section), likely supporting a curtain wall between food-preparation area and cultic room .
(4) Flat stone (altar?) on pavement facing standing stone against inner casemate wall.
(5) Inner casemate wall.
(6) Beaten-earth surface of casemate storeroom.
(7) Ladder platform for access to upper story.
(8) Outer casemate wall.
(9) Iron I rampart.
(10) Middle Bronze rampart (fractured by earthquake).
(11) Bedrock .
(12) Iron I defense / retaining wall .
(13) Iron II defense / retaining wall.
(14) Iron I moat base .
(15) Bedrock beneath Middle Bronze moat base.



5. Field B: Western Perimeter Early Iron I Buildings A and B .

containing 12-15 collared pithoi used for grain storage. Building B, adjacent to Building A on the north, incorporated additional rooms, including a large pillared room (B3) and an additional casemate storeroom (B4) holding over 30 pithoi.

The western defense system provided a ready test case for evaluating the usefulness of GPR at al-'Umayrī. In 1992 we made a GPR transect along the south balk of the already exposed defenses (casemate wall, rampart, revetment row of stones, retaining wall, but not the dry moat, which was not yet excavated). This process allowed us the opportunity to correlate GPR results with what we knew from excavation. Twenty additional 30 to 40 m transects were run up the western slope and radially from the northwest corner of the acropolis. Not only did the findings correlate positively (FIG. 6), they also provided the basis for adjustments to the GPR profiles which has helped us calibrate subsequent results. In addition, GPR

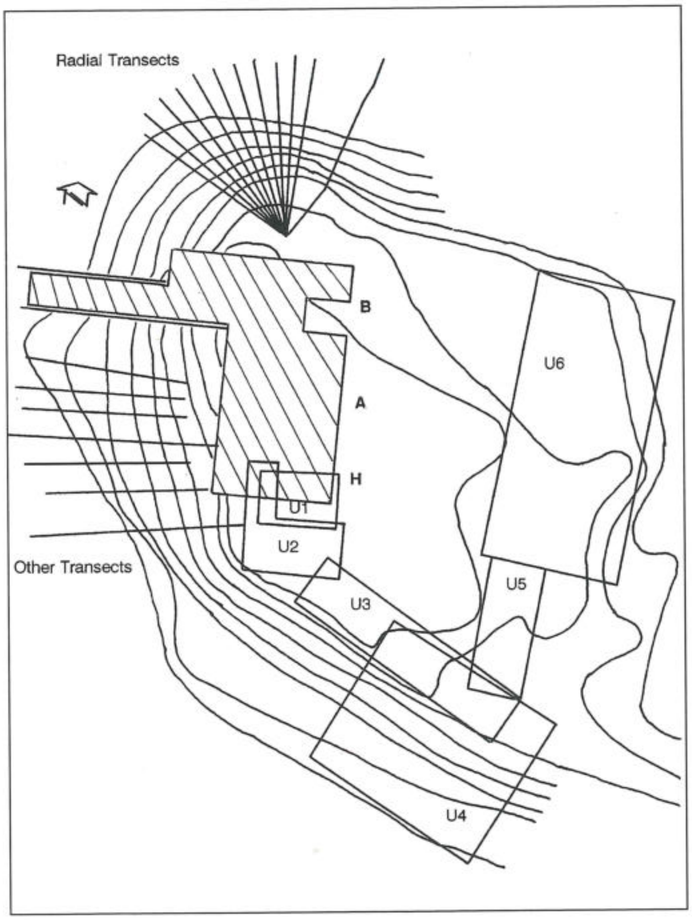


6. Field B: GPR Section of Defense System.

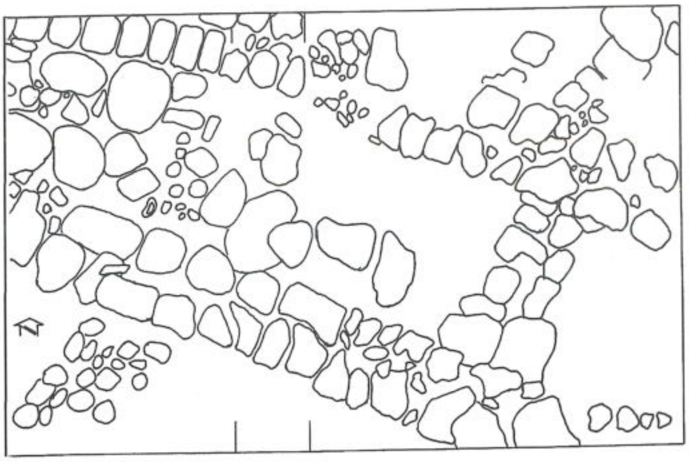
indicated the presence of a deep structure at the base of the defenses, a structure that, when excavated, proved to be the massive dry moat.

Ammonite Citadel: Two areas (U1, 10 x 15 m and U2, 18 x 20 m) adjacent to Field A on the south (covering part of what was later excavated as Field H), were criss-crossed with GPR transects in a grid on 0.6 m centers (see FIG. 7). Analysis of the GPR data for the area and production of a resultant map revealed subsurface walls similar in width and orientation to those excavated in Field A. Subsequent excavations in the newly opened Field H in this area have confirmed the presence, size and location of the walls (FIGS. 8 and 9).

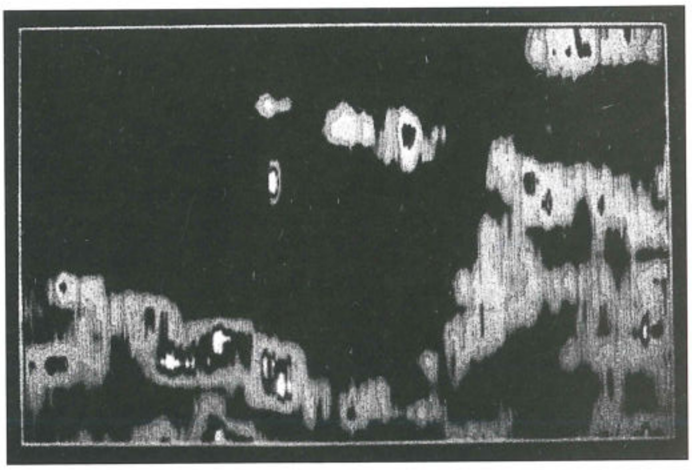
Southern Perimeter: A 10 x 44 m area (U3) on a 0.5 m grid along the south rim of the tall (FIG. 10) tied together the region south of Field A and a 30 x 35 m pattern (U4) on the upper south slope. The U3 pattern has shown that



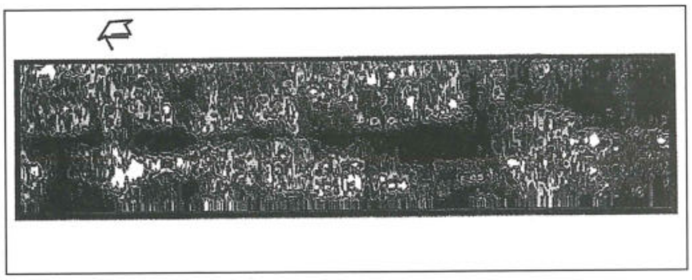
7. Al-ʿUmayrī Topographic Map With GPR Grids.



8. Field H (eastern half): Architectural Top Plan.



9. Field H: GPR Top Plan.



10. Al-ʿUmayrī South Rim GPR Top Plan (U3).

the excavated walls in Fields A and H are parallel to an apparent casemate wall extending east along the south rim of the acropolis. A possible gate post appears at the east end of U3 and in the U4 upper south slope area of GPR investigation.

Trans-acropolis Area: North from the east end of U3, a 10 x 24 m (U5) and a subsequent 25 x 53 m pattern (U6) traversed the central portion of the acropolis and the upper north rim using a 0.5 m grid. Thus, we have mapped several portions across the acropolis of the tall (north-south), including some parts of the southern and northern perimeter defenses. Although preliminary findings are tentative, expansion of the use of GPR and improvements in GPR technology and computer software have drastically enhanced detail and have cleared "noise" from the readings, allowing us a much more accurate picture of subsurface architectural structures. Initial assessments of collected data for this part of al-'Umayrī are extremely promising, but demand more time for analysis.

In the future we plan to examine more of the acropolis of the tall, paying particular attention to perimeter walls and other major observable features and focusing on Iron I structures if possible. It appears that only the southern half of the acropolis was occupied to any significant extent with buildings following the destruction of the Iron I site, leaving virtually untouched the northern half of the tall. This factor will be extremely helpful as we attempt to map out the Iron I settlement.

Implications of Subsurface Mapping for Understanding Landscape Resources and Human Occupation in Ancient Jordan

Traditional methods of excavation and survey will continue to serve archaeologists well in their attempts to explore landscape resources and human occupation in ancient Jordan. Each year, field projects yield new insights into agricultural practices, hydrological exploitation of annual rainfall, pastoral strategies, and other economic structures of subsistence and marketing. These all have to do with the utilization of landscape resources. The Mādabā Plains Project has added the technology of subsurface mapping in its endeavor to reconstruct a picture of ancient resource management. Thus, in a non-destructive fashion, one can examine data which will contribute to our understanding and assessment of water and land management. In the process, areas deserving excavation can be identified with greater certainty and more efficiently than by means of traditional methods alone.

Subsurface mapping technology has also supplemented our knowledge of human occupation in both rural and urban contexts. Although no substitute for careful excavation, these techniques can extend the range and scope of our awareness of occupational features such as architecture, defenses, and cemeteries in minimal time, with little or no disruption of existing conditions, and in a fashion consistently growing more reliable.

Acknowledgements

The Mādabā Plains Project is a joint endeavor sponsored by Andrews University in consortium with Canadian Union College, La Sierra University, Levant Foundation Poland, The University of Eastern Africa Baraton, and Walla Walla College with support from Cincinnati Theological Seminary, Dubuque Theological Seminary, and Zaokski Theological Seminary in Russia in cooperation with the Jordanian Department of Antiquities, the American Center of Oriental Research (ACOR), the Amman Training Center, and Dr. Raouf Abujaber. The GPR and EMI equipment was on loan to Walla Walla College from the U.S. Department of Energy, Pacific Northwest Laboratory, operated by Battelle Memorial Institute. Partial funding has come from faculty research grants at Walla Walla College.

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