

## Cesium Magnetometer and Electrical Resistivity Surveying in Search of Late Bronze Age Remains in the Baq<sup>ḥ</sup>ah Valley, Jordan

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*Grants 1930, 2141, and 2320:* For an archeological survey using geophysical instruments (cesium magnetometer and electrical resistometer)—and follow-up excavations—in the Umm ad-Danānīr region of the Baq<sup>ḥ</sup>ah Valley, Jordan.

### BACKGROUND

In June 1977, the grant recipient co-directed the salvage excavation of a partially robbed-out Late Bronze Age burial cave (Cave A2) on Jebel al-Hawāyah in the Umm ad-Danānīr region of the northwestern Baq<sup>ḥ</sup>ah Valley (Figure 1). In contrast to earlier surveys that had found no evidence for the Late Bronze Age in the valley (Glueck, 1939; de Vaux, 1938), a very extensive and representative collection of Late Bronze (LB) local and imported pottery (over 90% datable to LB I, ca. 1600-1400 B.C., and including Chocolate-on-White, local bichrome, Cypriote Base-Ring II, and Mycenaean IIIB wares) were recovered from two strata, along with accompanying grave goods (scarabs, cylinder seals, toggle-pins, many types of beads, etc.). The quantity of exceptionally well-made pottery and small artifacts (about 10,000 sherds, 52 whole vessels, and 290 small finds) from a sounding limited to less than a quarter of the cave, coupled with clear evidence of foreign contacts to the north, south, and west, could hardly be explained as the work of nomads or "semi-nomads" (Glueck, 1940, later modified, 1970), and strongly suggested that LB people(s) were well established and probably settled somewhere in the Umm ad-Danānīr region.

A limited search in the vicinity of Cave A2 confirmed the existence of at least three more robbed-out burial caves, which appeared to be part of larger series along the northwestern slopes of the valley, where the strata of limestone and sandstone is easily eroded. It also seemed likely that

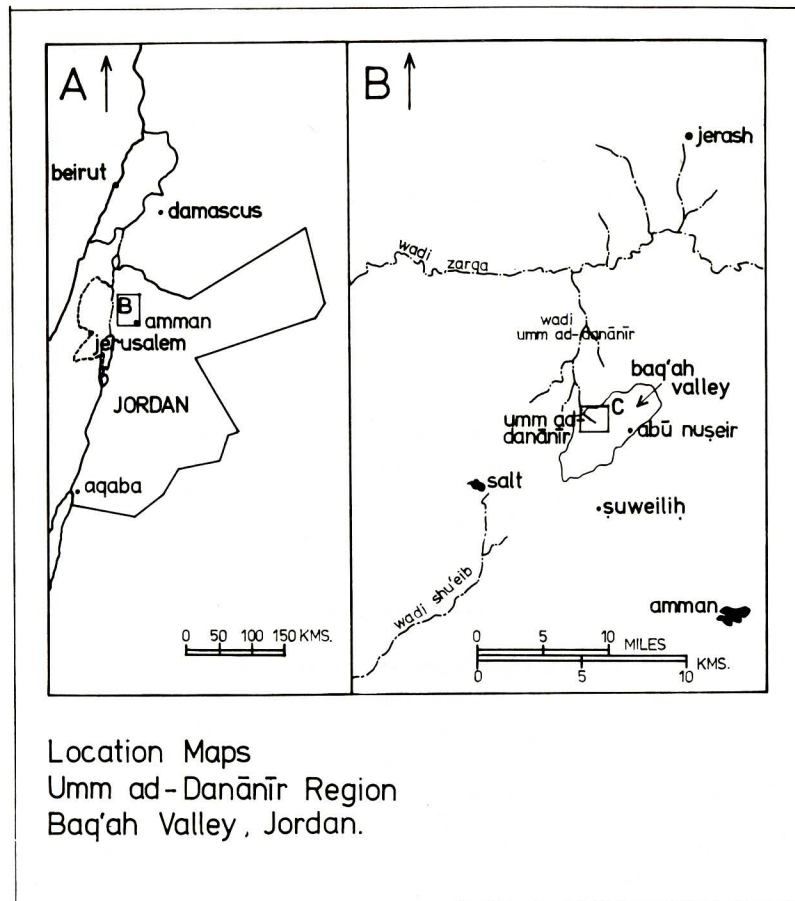


FIGURE 1. Baq'ah Valley, Jordan.

some of the many "megalithic" buildings found within a kilometer of the caves were connected with LB settlement. A prime candidate was Rujm al-Ḥenū, 650 m southeast of the Jebel al-Hawāyah caves, whose easternmost building (Figure 2) is architecturally very similar to the LB Amman Airport Building 15 km southeast of Baq'ah which produced a surprisingly large number of Egyptian and Aegean imports (Hankey, 1974). The latter building is the prime example of the *quadratbau* architectural type on the East Bank of the Jordan so-called because of its square layout with

a central unit ("courtyard") surrounded by outer rooms. Since there was little evidence for permanent settlement in the immediate vicinity of the structure (Hennessy, 1966; Herr, 1983), it was proposed that the building might have been a tribal shrine, possibly a temple or mortuary cult structure related to biblical traditions about the early Israelites (Campbell and Wright, 1969).

#### WORK IN 1978

Because of the high probability of finding more LB burial caves with an associated settlement, a thorough archeological survey using geophysical instruments was needed. This was carried out between October 19 and November 12, 1978 with the support of the National Geographic Society, the Jordanian Department of Antiquities, the University Museum of the University of Pennsylvania, and the Museum Applied Science Center for Archaeology (MASCA), and was affiliated with the American Schools of Oriental Research (ASOR) and its Center in Amman (ACOR). Five-man teams were involved in each aspect of the work: a cesium magnetometer survey to locate LB burial caves, particularly those that had been filled in and were less likely to have been disturbed by tomb robbers; an electrical resistivity survey near Rujm al-Ḥenū to determine the nature and size of any buried occupational remains; and a general archeological survey using standard techniques to locate all potential LB sites within a kilometer of the caves.

#### CESIUM MAGNETOMETER SURVEY

The cesium magnetometer is the most sensitive magnetic prospecting instrument presently available; MASCA pioneered, and has continued to be in the forefront of, research involving its application to archeology (Ralph, 1969, summarizes MASCA instrument surveys to 1969; another 20 magnetometer surveys were carried out in the next decade). For the Baq'ah Valley survey, a Precision Portable Cesium Magnetometer Model 49-544, specially manufactured by Varian Associates, was used. Its basic components include a readout and cesium sensor powered by a 30-v battery (Ralph et al., 1968).

Since earlier magnetometer surveys had been successful in detecting graves at Forts Louisbourg and Lennox in Canada (MASCA, 1965), it appeared possible that the cesium magnetometer could be similarly employed to locate much larger, filled-in burial caves in the Umm ad-Danānīr region. To test this possibility, the magnetic susceptibilities of stone and soil samples from the 1977 cave sounding were measured with a single sensor in a magnetically quiet area, with frequent checks on the background field intensity (about 56,000 nT; 1 nanotesla = 1 gamma).

The difference in average magnetic susceptibility between the cave fill ( $0.005 \text{ nT m}^3/\text{kg}$ ) and the sandstone and limestone bedrock (only a very slight susceptibility) was statistically significant according to the Student's *t*-test. Assuming a range of 8 to  $40 \text{ m}^3$  for the volume of filled-in caves, magnetic anomalies between 5 and 25 nT could then be expected. The cesium magnetometer (0.1-nT sensitivity with a single sensor) should detect the complete range of projected anomalies.

*Findings.* Our expectations appear to have been justified. Another 32 partially or fully robbed-out burial caves have been located on Jebel al-Hawāyah and Jebel al-Qešir. Of the 23 caves whose robbers' dumps could be surface-sherded, 19 were LB in date (5 Middle Bronze [MB] III/LB IA, 3 LB IA, 3 LB II, 7 LB, and 1 LB II/Iron IA), 3 were Byzantine, and 1 was Mamlūk. No less than 39 significant anomalies in the 10- to 25-nT range were located and mapped near the robbed-out caves and in the same soft limestone/sandstone strata; some undoubtedly represented filled-in LB burial caves.

On Jebel al-Qešir, the robbed-out burial caves and the anomalies run in lines along several tiers. Since in some places large boulders appear to have been intentionally positioned, the tiers may have been cut as roads or terraces. Natural processes can hollow out soft limestone and sandstone, but smoothed-off walls, a two-chambered cave, and well-cut elliptical, square, or rectangular entrances (occasionally recessed, perhaps to hold a blocking stone) argue for human agency, or at least adaptation, in the formation of the caves.

Two thirds of the caves had been extensively robbed out, so a good idea could be gained of the sizes and shapes of caves from the various periods represented. The maximum dimension of LB caves varied from about 10 m to 1 m; and the caves were circular, elliptical (both horizontally along the hill and vertically into the hill), or two-chambered in shape. Robbers' dumps associated with many of these caves had large quantities of pottery and bones, probably attesting to multiple burials over several generations. From the more than 270 diagnostic sherds collected from the robbers' dumps came some remarkable finds, including complete profiles of LB I and II vessels, an MB IIC black cylindrical juglet, and 3 sherds of at least two more Mycenaean IIIB stirrup jars, similar in type to that found in excavated Cave A2.

In contrast, the three Byzantine caves and one Mamlūk cave produced only 18 diagnostic sherds, and only one of these caves (Byzantine) had a considerable number of bones in its robbers' dump. While the Mamlūk cave was large (maximum dimension, 4.5 m) and irregularly shaped, the Byzantine caves varied in shape (circular and irregular elliptical) and were quite small (average dimension, about 2 m), which suggests their use for a single burial.

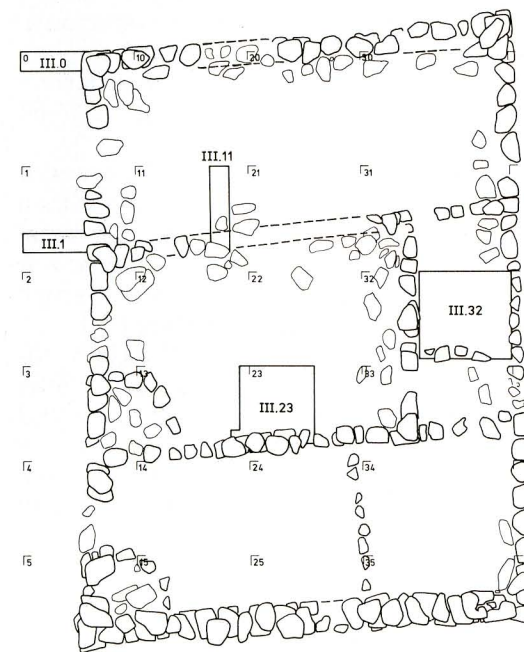


FIGURE 2. *Top:* Aerial view of Rujm al-Henū. *Bottom:* Plan of the eastern building at Rujm al-Henū (Site 1), scale, 1:100.

Since Early Bronze Age, Iron Age, and Roman remains are also known to exist in the region, cemeteries for these periods should be close by. However, nothing to date has been found of them.

**Survey Methods and Data.** The logistics of the survey involved laying out grids (usually  $50 \times 100$  m) with a transit and optical square in relation to the permanent bench marks on the 1 : 10,000 Zarqa Basin Map, Sheet 27/64 (Department of Lands and Surveys of Jordan, 1950), and making magnetometer measurements at 2-m spacings with the sensor 0.7 m above the ground. Magnetic intensity contour maps were quickly drawn up, and areas of promising magnetic activity were then explored with a high-resolution, 1-m sensor spacing. Eleven grids, covering a total of 3.38 ha at the 2-m spacing and 0.24 ha at the 1-m spacing, were surveyed.

Grid 11 (Figure 3) on Jebel al-Qeşir provides a good example of the type of data we obtained. As is readily apparent, there is a great deal more magnetic activity on the lower part of the hill than farther up. Robbers' dumps, downhill from the robbed-out caves' entrances, show up as magnetic highs (X14, Y0; X10, Y16; X8, Y24; X9, Y32; X9, Y10). The robbed-out caves themselves show up either as lows (B3 and B30) or blend in with the background intensity (B27, B5, and B6), depending upon the amount of magnetic soil fill that has been removed and the size of the air cavity (with no magnetic susceptibility) thus created.

Other magnetic highs of 15 nT (X14, Y7) and 10 nT (X14, Y40), both  $2 \times 4$  m in area, are equivalent in size and located on the same line as robbed-out caves B27, B5, and B6. They are probably best explained as silted-up features, either burial caves or naturally formed depressions.

A 15-nT high (X17, Y22),  $4 \times 6$  m in area, with a 10-nT reverse anomaly to the north, may represent an extension of Cave B3, since this cave appears to have been only partially robbed out. Other highs occur farther downhill along another line of robbed-out burial caves, e.g., a 15-nT anomaly at X1, Y27, and a 10-nT one at X-6, Y32.

Magnetic lows are of potential importance; they could be caves or parts of caves with large air voids, and, therefore, easier to excavate than filled-in caves. For example, a 10-nT anomaly at X22, Y20,  $2 \times 2$  m in area, could be a further extension of Cave B3. The 20-nT low at X-5, Y16 may be a large unfilled cave with only its mouth covered over; however the high gradient dipole, even clearer on the 1-m grid, suggests surface iron.

The average intensity of the Earth's magnetic field for the Umm ad-Danānir region was about 43,850 nT, which normally decreased slightly during the morning hours. Since the variation was always quite slow and did not show any major disturbances, a single sensor in its absolute mode was used for the survey. This speeded up operation over difficult terrain; however two sensors in the differential mode would have eliminated all variations, including the diurnal one.

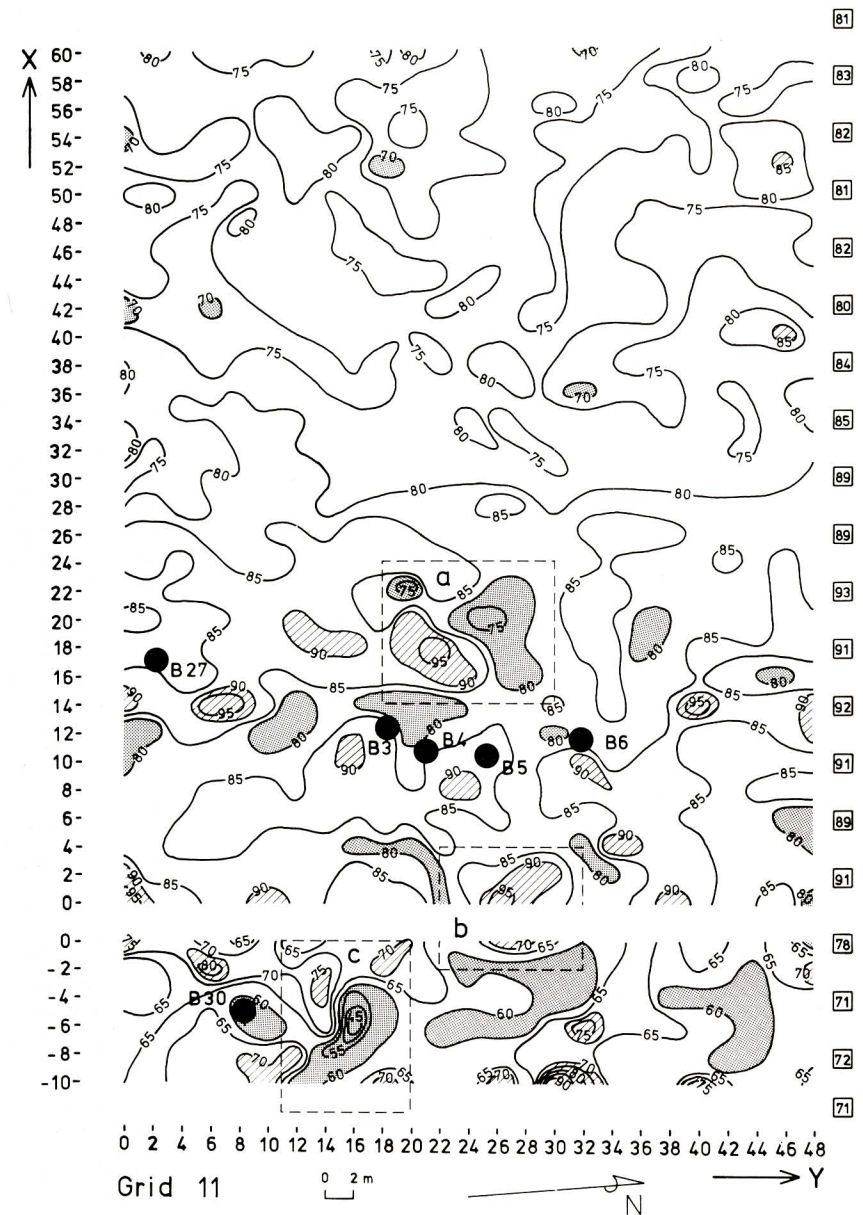


FIGURE 3. Magnetic contour map of Grid 11, based on 2-m-spaced magnetometer readings. Only the final two numbers of the magnetic intensity are recorded (i.e., 85 should be read as 43,885 nT). A slow diurnal decrease in the background field intensity should be noted: traverses  $\times 0$  to  $\times -10$  were done in the early afternoon after completing the traverses  $\times 0$  to  $\times 60$  in the morning. Robbed-out burial caves are indicated by black dots, letter, and number; magnetic highs by diagonal hatching; lows by stippling. (Drawing by H. Schenck, MASCA.)

## GENERAL ARCHEOLOGICAL SURVEY

Approximately 2 km<sup>2</sup> were surveyed using standard archeological survey techniques of systematic surface traversing and the collection of artifacts (potsherds, flints, etc.), with the principal goal being to locate LB settlement sites. We appear to have discovered two such sites.

Khirbet Umm ad-Danānīr is a multiterraced site, 2.5 ha in area, strategically located above the strong, perennial spring of <sup>c</sup>ain Umm ad-Danānīr. It is situated on the northern side of Jebel al-Qeṣīr, and would have guarded the northwestern pass of the Baq<sup>c</sup>ah Valley. The site had previously been explored by Glueck (1939) and de Vaux (1938), who noted the ancient walls and structures still visible on the surface and assigned them mainly to the Iron Age (some Early Roman and Byzantine sherds were also found). According to our systematic surface sherding (306 diagnostics), however, LB II also turned out to have been a main period of occupation, along with Iron IA and IC, Iron IIA to C, Early Roman III, Early Byzantine, and Mamlūk. Thus, Khirbet Umm ad-Danānīr could be a very important transitional site from LB II to Iron IA, a period of major cultural change in Transjordan with the presumed arrival of the Ammonites, Israelites, and other peoples.

The other potential LB site, Rujm al-Ḥenū, is comprised of two buildings with very clear surface ground plans (dated by Glueck to the Iron Age). The eastern rectangular building (about 25 × 30 m), with a central courtyard surrounded by other rooms, is similar in structure to the LB Amman Airport Building. Besides Iron IIC, Late Roman/Early Byzantine, Umayyad, Mamlūk, and modern sherds from the various rooms, MB III/LB IA sherds were discovered in the central courtyard of the building. Since no MB III/LB IA sherds were found within 500 m of the structure, it is probably another example of a characteristic MB-LB architectural type, which also occurs west of the Jordan River. Now that the Amman Airport Building is covered by a runway, the Rujm al-Ḥenū structure provided another opportunity for testing hypotheses about the function of this type of building and its association with nomads or semi-nomads.

Surface sherding of the western building of Rujm al-Ḥenū, which rises about 3 m high above nearby bedrock outcrops, points to Iron IIC as the main period of occupation. It is of the *gasr* (fortress) architectural type (Glueck, 1939), and has a circular tower (*rujm malfūf*) and square bastion incorporated into its perimeter wall.

The most impressive of the sites connected with other periods is the large Early Bronze II to IV site of al-Qeṣīr (Site 7), which covers the entire top of Jebel al-Qeṣīr and has many structures and an encircling defensive wall still visible on the surface.

Two of the three Iron II sites investigated had been almost totally de-

stroyed by modern earth-moving. Rujm <sup>c</sup>ain Umm ad-Danānīr (Site 6), located about 100 m northeast of the spring, may have been a megalithic building—sherds were found within a 20-m-diameter area and a 5-m line of limestone and sandstone boulders could be an ancient wall. Only Iron IIB-C sherds were found, suggesting that the site was an offshoot of Khirbet Umm ad-Danānīr during prosperous times. Rujm al-Hawāyāh (Site 4), located up a side valley behind Jebel al-Hawāyāh, was possibly another satellite settlement of Khirbet Umm ad-Danānīr, with its main period of occupation being Iron IIC.

The third Iron II site, Rujm al-Ḥawī (Site 5), is a large (about 50 × 30 m) *gasr*-type building rising 5 m above the surrounding fields, with two circular towers located to the south and one to the west of the main structure and separated from it. Surface sherding indicates an Iron IIC date for construction and later uses in the Early Byzantine and modern periods. Rujm al-Ḥawī and the western building of Rujm al-Ḥenū (Site 2), about 350 m apart and equal distance from the road, could be viewed as Iron Age forts in advanced positions guarding routes to Amman. Rujm al-Ḥawī is virtually the mirror-image of the Rujm al-Ḥenū West architectural layout; a circular tower and a square bastion are incorporated into the main walls directly opposite those of Rujm al-Ḥenū West, facing the road and the northwestern pass. Many other Iron Age forts of similar type exist in the Baq<sup>c</sup>ah Valley, including Khirbet al-Muḍmār (Glueck, 1939), only 0.5 km to the south, large and well preserved, with standing walls up to 5.5 m in places.

A collection of 250 lithic artifacts concentrated in 9 of the magnetometer grids on Jebel al-Hawāyah and Jebel al-Qeṣīr includes 17 implement and 5 core types, dating to the later Middle Paleolithic (ca. 45,000 B.C.), Upper Paleolithic, Epi-Paleolithic, and Neolithic periods. The flints greatly push back man's earliest presence in the valley and may have been deposited on the lower slopes of the hills as colluvium, or alternatively, they may mark sites of encampments along the shore of a lake that filled the valley in the Pleistocene and immediately post-Pleistocene periods.

## ELECTRICAL RESISTIVITY SURVEY

The location of buried occupational remains required different methods because stone walls and structures would not produce large enough anomalies to be detected by the magnetometer. Since electrical resistivity techniques have been successfully used to detect stone features and to obtain plans of buried structures (Clark, 1970), soil samples from the valley were tested using MASCA's Gossen Geohm resistivity instrument. The specific resistivity of the soil was found to vary between 20 and 60 ohm-m, depending mainly upon the water content. This was much lower than the specific resistivity values for limestone and sandstone (~ 5000

ohm-m) used in the construction of the buildings.

After experimenting with various probe spacings, it was decided that the conventional 4-probe Wenner configuration with a 1-m probe separation would be best for detecting near-subsurface remains. As with the magnetometer survey, grids were precisely laid out in relation to the Zarqa Basin Map, and contour maps were prepared at 5- or 10-ohm intervals, so that interesting anomalies could be thoroughly tested with the Gossen Geohm. Seven grids were run on each side and also inside the eastern building of Rujm al-Henū, covering a 0.62-ha area. Because of the closer spacing of measurements and time required for setting up, even though two instruments were sometimes used simultaneously, only about 17% of the area covered by the magnetometer could be checked for resistivity.

The resistivity survey revealed a number of fairly large, diffuse areas of higher resistivity located on all sides of the Rujm al-Henū structure, suggestive of a larger area of settlement. For example, Grid 9 (Figure 4), covering the area between the two buildings at Rujm al-Henū, has generally higher resistivity values in the area between X0-18 and Y17-47 than in the surrounding regions. These higher values could represent the foundation of another building, a room attached to the eastern building, a rock tumble from the latter building, or possibly only bedrock irregularities. Although possible "M" patterns, which typically result from running a linear array of electrodes perpendicularly to a wall were noted (X8-9.5, Y30-33), there was no consistent overall pattern. However, on the assumption of a simplified two-phase system, measurements at the same midpoint using probe separations fit best a theoretical model of a thin (about 5 cm) soil layer lying directly over bedrock. Unexpectedly, the results from the grids inside the eastern building (Grids 12, 17, and 18) indicated no crosswalls other than those visible on the surface.

#### WORK IN 1980 AND 1981

Work conducted from May 15 to June 30, 1980 and May 25 to June 30, 1981, provided a detailed understanding of our geophysical survey data and a fuller picture of archeological remains in the Umm ad-Danānīr region of the Baq'ah Valley. Because of the immediate threat of bulldozing and house construction on Jebel al-Hawāyah, accompanied by renewed robbing, the 1981 season was conducted only 10 months after the 1980 campaign.

#### TEST SOUNDINGS OF CESIUM MAGNETOMETER ANOMALIES

Even before any test excavations were carried out, it was clear that the magnetometer had located lines of significant anomalies, coincident

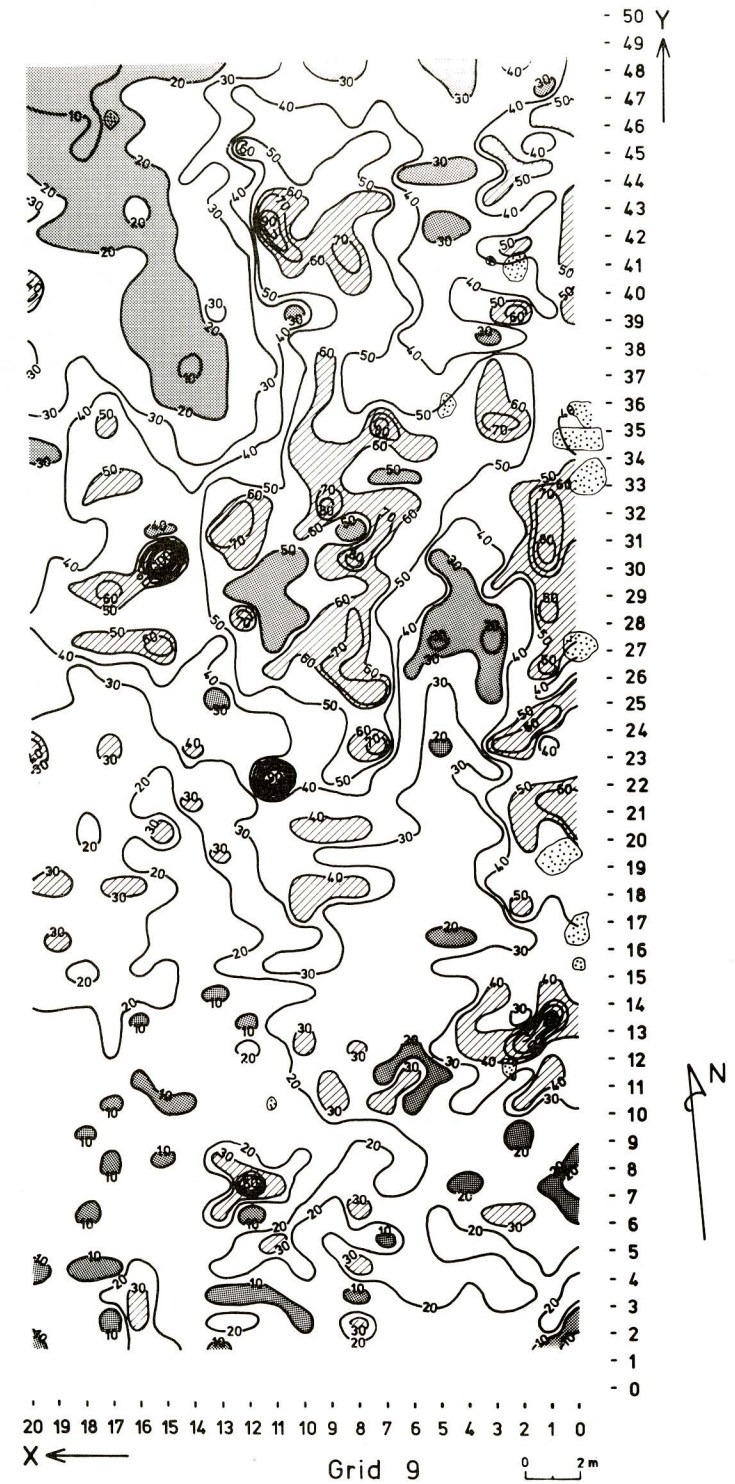


FIGURE 4. Resistivity contour map (10-ohm interval) of Grid 9, located between the two buildings at Rujm al-Henū (Sites 1 and 2). Measurements were recorded at the midpoint of a Wenner array with 1-m probe separation, oriented in an approximately north-south direction. Resistivity highs are indicated by diagonal hatching, lows by fine stippling, and boulders by less fine stippling.

with the lines of robbed-out caves. Archeological test soundings were required to define the distinctive magnetic patterns ("signatures") of the hypothesized caves. From a priority list of 39 significant anomalies—by definition having intensities of at least 10 nT and containing more than one datum point—a 7- × 11-m area with 5- to 15-nT-high readings in Grid 7 (Figure 5) on Jebel al-Hawāyah was chosen for the initial test excavation in 1980. Its large size and shape (deep elliptical) were comparable to the nearby LB Caves A1 and A2 (McGovern, 1980). Two low anomalies to the north could be tested concurrently.

*Cave A4.* In this instance, theory was so fully borne out by the exca-

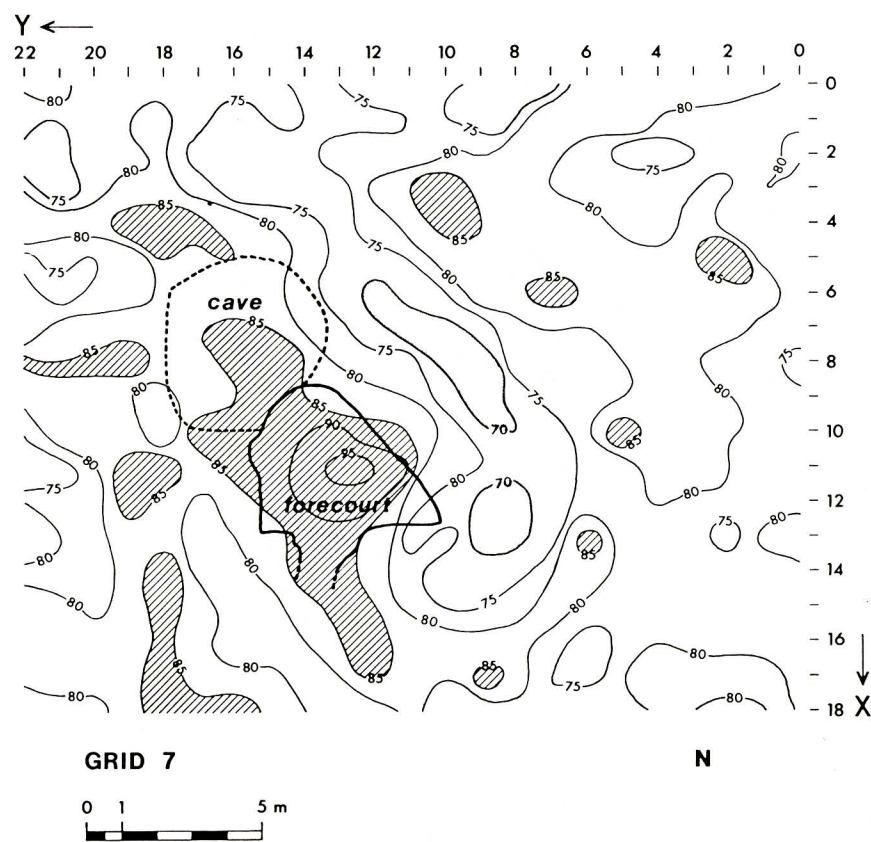


FIGURE 5. Overlay of Cave A4 onto Grid 7. High magnetic anomaly shown in diagonal hatching; lows in magnetic intensity are indicated by stippling. (Drawing by H. Schenck, MASCA.)

vation results that additional test soundings had to be delayed until 1981. An undisturbed Iron IA (ca. 1200 to 1050 B.C.) burial cave (A4) was uncovered in the area of the magnetic high. When excavation began, only an outcrop of bedrock beneath heavy vegetation was visible on the surface.

The circularly shaped cave, some 4.5 m in diameter and 2 m high, had been completely silted up and six large boulders (each about 1.5 m long) blocked the entrance; a single large boulder was wedged into a secondary entrance in the back roof. The cave faced due east onto a 20-m<sup>2</sup> "forecourt," entered by ramp on the southeast (Figure 6). The forecourt was filled in with soil, in places to a depth of 2.5 m.

With the ground plan of the cave and forecourt superimposed over the magnetometer grid, the fit between the two can be seen to be quite close. The 85 (43,885-nT) contour line follows the general external configuration of the cave, forecourt, and ramp. The area of the greatest colluvial buildup in the forecourt shows up as a 15-nT high at X11, Y12.5, dropping off to 5 nT on the periphery. Using a simplified equation



FIGURE 6. Cave A4 after excavation. (Photograph by N. Hartmann, MASCA.)

( $H = Mm/2R^3$ ; where  $M$  is the specific magnetization,  $m$  mass, and  $R$  the sensor to dipole distance) for a point dipole of a spherical feature (Lington, 1964, 1972-73) and allowing for geometric and random variations (e.g., diurnal drift and soil noise), the range of magnetic values from the survey corresponds very closely to the calculated theoretical intensities of the soil volumes of the cave and forecourt. For the 39,000-kg soil mass of the forecourt, an anomaly of  $\sim 12$  nT would be expected, nearly exactly the result obtained in the field. The burial cave itself had a somewhat smaller mass ( $\sim 23,600$  kg), and the 1-m-thick bedrock between the cave and the outside surface somewhat modifies the calculations. For an  $R$  of 2 m, a 7-nT high can be projected. However, the lack of soil cover above the cave, exposing bedrock with a lower magnetic susceptibility, would reduce the anomaly by several nanotesla and bring the theoretical calculation in line with the survey result, viz. a net moment of 5 nT. The ramp with a shallow fill also showed up as a 5-nT high.

The lows to the north are some 4 m from the midpoint of the high, the expected distance for a reverse anomaly effect (Aitken, 1974). They do not blend in with the 0- to 5-nT background variation, because the exposed bedrock serves to reinforce the lows. Since the cleared cave and forecourt showed no sign of entrances to other chambers, these lows do not represent air voids.

Although groundwater percolation may have eroded away some of the softer bedding planes in the initial stages of cave formation, the final form of the relatively symmetrical cave A4, forecourt, and ramp were most probably man made. Compared with nearby LB caves A1 and A2, both about 10 m in diameter, Cave A4 is small; uniquely, it has a forecourt and ramp. However, into its 20-m<sup>2</sup> area, 227 burials had been deposited, the majority in two secondary heaps—twice as many adult men as women in the pile to the north, and approximately equal numbers in the one to the south. Fifty subadults were evenly distributed between the piles.

Rather than dating to the Late Bronze Age, as might have been anticipated, the burial cave belonged to an equally enigmatic period—Iron IA—and represented one of the largest tombs for this period in Palestine. A unique assemblage of whole vessels, including bowls, lamps, jugs, juglets, kraters, "beer-strainers," basalt mortars, etc., were recovered. Neutron activation analysis of the pottery has confirmed that they were locally manufactured (McGovern et al., 1982). The clay came from a bed near the perennial spring of <sup>c</sup>ain Umm ad-Danānīr, immediately below the settlement site of Khirbet Umm ad-Danānīr, where other essential materials for pottery manufacture, water and sand or limestone (for temper), are available. Kilns were probably located in the same area. Since the LB I local wares from Cave A2 derive from the same clay deposit, a continuous tradition of about 500 years for the initial step in potmaking—

gathering the clay—is attested to. Petrographic studies revealed, however, a marked technological drop off in other respects. Whereas the LB I wares were tempered only with quartz (5 to 8%), and well fired, the Iron IA pottery has considerable amounts of calcite and was fired only to about 600°C (perhaps to prevent the "blowing out" of calcites). Further, the slips and painted decoration that characterize the LB pottery are virtually nonexistent in the Iron IA corpus. Radiographic studies revealed that the LB pottery was wheel-made in contrast to the coil construction of the early Iron vessels.

A lower technological level is not evidenced in the metal artifacts from Cave A4. The bronze jewelry recovered—open-ended and overlapping-ended anklets and bracelets, rings, earrings, toggle-pins, and beads—exhibits uniform levels of tin (10 to 15%). This points to excellent control of the production process. If the tin trade routes were indeed cut off about 1200 B.C. (Maddin et al., 1977), the melting down of old bronzes would be the most probable explanation of consistent alloying. Analysis of copper/bronze artifacts from the Baq<sup>c</sup>ah, however, indicated that widely varying amounts of tin (0 to 15%) and occasionally lead were used, so local recycling seems unlikely.

On the other hand, the iron pieces, including eight anklets/bracelets and three rings of basically the same types (Figure 7) as those in bronze, strongly suggest a nearby production center, and are probably the most important discovery from the tomb. Metallographic examination and elemental analysis (Pigott and McGovern, 1982) was facilitated by the substantial amounts of uncorroded metal retained. The iron is in fact a mild steel, with an even distribution of about 0.5% carbon. It is the earliest verified instance of steel from the Transjordanian plateau, and joins a small group of the earliest dated steel from the eastern Mediterranean. Why only jewelry should be manufactured in steel is unclear; one would have anticipated also finding weapons, particularly for a period that is usually depicted as one of war and disruption. Perhaps the goal of the steeling process was to produce an aesthetically pleasing metal coloration and texture. This effect, which can be achieved by slowly cooling iron in the presence of charcoal, may have been accidentally discovered by the metalsmiths.

Significantly, one of the few sources of iron ore in the Levant is located in the Wadi Zarqa/Ajlun region; the closest known mine is only 10 km north of the Baq<sup>c</sup>ah (Abū Thawab). Limited archeological investigation (Coughenour, 1976) in the area has thus far only substantiated medieval Islamic smelting operations; but sherding evidence from the Roman-Byzantine and Early Iron periods points to earlier activity.

The hypothesis that the steel jewelry is of Transjordanian origin fits with the general lack of foreign imports in Cave A4. Only four special



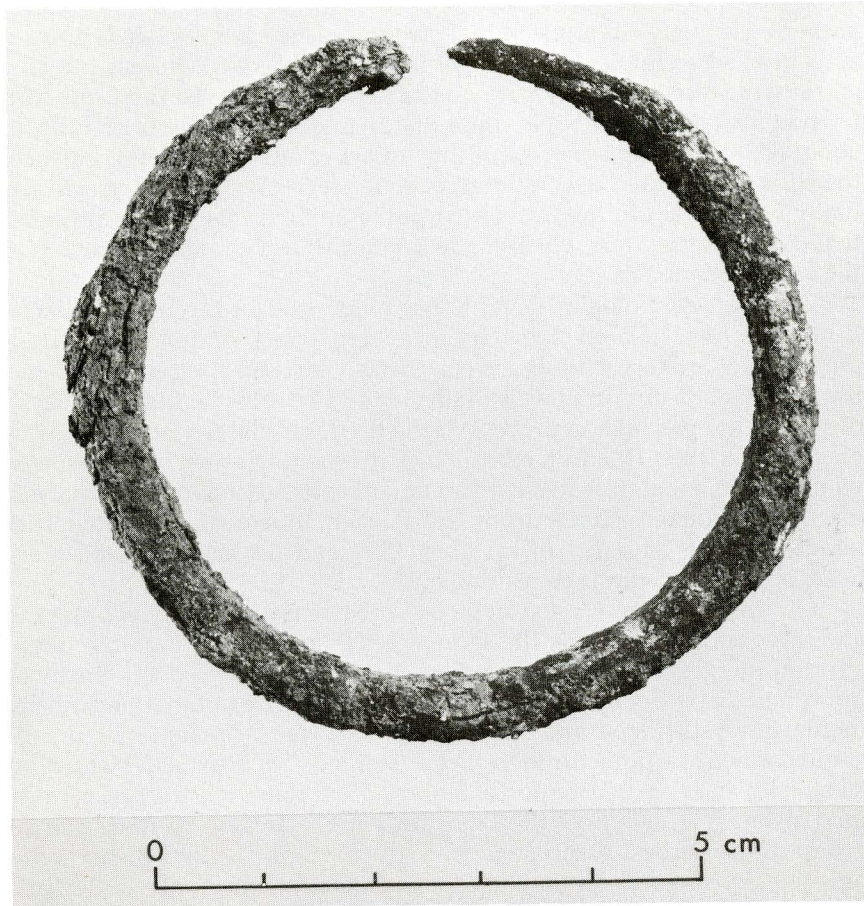


FIGURE 7. Mild-steel anklet of open-ended type from Cave A4. (Photograph by N. Hartmann.)

finds were found, two of which were standard Syro-Palestinian types—an elongated drop pendant (McGovern, 1984b) and a conical stamp seal. A Ramesside-type scarab also appeared to be a Palestinian product, and a Mitannian Common Style cylinder seal was most likely an heirloom from the LB. Semiprecious stone beads in a wide range of colors are primarily quartz species that could have been gathered in the Eastern Desert. Small numbers of red glass beads have extremely high iron levels (up to 50% by weight of the oxide), and possibly represent reworked slag, a by-product of the contemporary iron and steel industry. Perforated cowrie shells and

other marine mollusk species (*Murex trunculus*, *Nassarius gibbosulus*, and *Monodonta turbinata*) are the most unequivocal evidence for long-range trade during the period.

Preliminary analysis of the human skeletal material, being followed by more detailed osteometric and genetic studies, suggests continuity of population in the Umm ad-Danānir region. For example, all ages of both sexes are represented in the various burial groups, and pathologies common among agricultural peoples (arthritis, excessive tooth wear, and dental caries) were observed. This research ultimately bears upon the question of how the relatively advanced LB culture developed into or was displaced by the emerging kingdoms of the Israelites and Ammonites. Military causation is belied by the general lack of weaponry and the absence of traumatic injuries. Environmental factors, such as decreased precipitation (Horowitz, 1978), may have been more important reasons for cultural change.

*Other Excavations in 1981.* During the 1981 season, an additional nine magnetic anomalies on Jebel al-Hawāyah were tested by excavation. The highs coincided with excess soil deposition, and the field data matched calculated values. However, since the magnetometer cannot distinguish between filled-in features used for burials and those that were not (tests demonstrated negligible magnetic enhancement from decomposition and fermentation), the highs in these instances represented geological depressions (sinkholes, solution pits, and caves). Lows correlated with bedrock outcrops. Within the area surveyed, most of the significant high anomalies are likely caused by variously sized, silted-up natural features at the back of terraces. This interpretation is supported by the examination of what appeared to be cave mouths, with blocking stones or soil plugs, along terraces that had been cleared by bulldozing; test excavation of the most likely candidates showed them to be natural. Thus, the burial ground on Jebel al-Hawāyah appears to have been confined to the fully examined cluster of LB and Early Iron Age caves.

Test soundings of magnetic anomalies on Jebel al-Qeşir reinforced the interpretation outlined above. Three highs correlated with filled-in features—a natural cave, an artificial niche, possibly used for burial rites, and an undisturbed section of a partly robbed-out burial cave (B3).

Cave B3 in Grid 11 was the only known cave dating to LB II (ca. 1400 to 1200 B.C.) in the region. Excavation of a 15-nT high, 4 × 6 m in area and located 4 m from the entrance (X17, Y22), showed it to be an extension of the cave, making this the largest burial cave on Jebel al-Qeşir. The high had been caused by a large accumulation of stones and soil that washed in through a hole at the back of the cave, and covered two undisturbed burial layers.

In the topmost layer, three skeletons were clustered around an in-

verted bowl. The upper parts of these bodies were reasonably intact; but each individual, as well as another three nearby, lacked legs. Articulated legs and long bones laid out in the same direction were found elsewhere in the cave—a hitherto undocumented burial practice of uncertain significance. Intermingled with the remains were pieces of charcoal and completely charred bones. The latter are possibly cremation remains, unless a blackened cooking pot from the same context points to a more mundane explanation.

Below a 10-cm sterile layer was found a second level of burial remains, which belonged to a stratigraphically earlier phase of LB II. The partially articulated skeletons of six individuals were recovered—again without legs—including a preadolescent female with a rare condition of spinal curvature. Intriguingly, this was the most ornately decorated body in the tomb. The girl wore a double-stringed necklace of more than a hundred beads—one string solely of short cylindrical bronze beads, the other of glass beads in various colors and shapes—with a large, roughly cut carnelian barrel bead flanked by pairs of small spherical carnelian beads, at the back of the neck (Figure 8).

Many whole vessels—primarily bowls and lamps, Mycenaean and Cypriot imports—a partially decomposed calcite vessel, and fragments of a bronze bowl were discovered. Part of an iron anklet/bracelet, comparable to one found in Cave A4, suggests pre-1200 B.C. ironworking. Fish vertebrae were a new addition to the faunal collection, which is dominated by probably domesticated species (sheep, goat, dog, donkey, cow) throughout the LB and Early Iron periods. A single grain of carburized bread wheat (*Triticum durum*) was the first direct evidence of agriculture.

Cave B3 provides the all-important connection between the LB I and Iron IA remains of Caves A2 and A4. For example, the wide technological divergence between the fine wares of LB I and the coarse, badly fired products of Iron IA is bridged by evidence from LB II. The firing and tempering of the LB II wares appears to be closer to that of Iron IA than that of LB I. On the other hand, the LB II pottery types, often slipped and with painted bichrome decorations, show greater affinity with LB I types.

#### AERIAL SURVEY

In conjunction with the magnetometer work, an intensive aerial survey carried out in the 1980 season was timed to take full advantage of the differential drying out of the winter vegetation, especially abundant because of heavy rains. Natural pockets of soil, as well as those filling cave entrances and forecourts, retain greater moisture and encourage the growth of plants with extensive root systems. A series of oblique black-and-white and color shots, taken several hundred meters above ground level, revealed good correlation between excessive vegetational growth



FIGURE 8. Girl's necklace from Cave B3. This elaborate necklace, only half of which is shown, was found in situ on a skeleton.

and magnetic highs; where both coincide, the probability of finding a silted-up feature is higher than when using either indicator alone.

#### KHIRBET UMM AD-DANĀNĪR (FIELD V)

Because of the likelihood that the main settlement associated with the LB-Early Iron cemetery was located at Khirbet Umm ad-Danānīr, four 4-m areas (Figure 9) were opened here in 1981 (a trial sounding, Area V1, was carried out on a lower terrace in 1980). In square V2, a massive wall, about 1.5 m wide and composed of two lines of large, roughly shaped boulders, was discovered. It was comparable to surface traces of the proposed city wall, and lay some 3 m below the surface, beneath Early Roman III and Iron IIC/Persian levels. The wall was covered by an ashy layer that continued down alongside the wall for about a meter. At this level a clay surface was found, adjoining the wall and into which a deep pit had been cut. In the latter, beneath large carbonized timbers (*Olea*), lay a deposit of charred animal bones (cow, donkey, sheep, goat, and a carnivore), several large LB II pottery vessel pieces (cooking pot, krater,

storage jar, and lamps), and the front half of a hollow zoomorphic figurine of a bull virtually identical in style and manufacturing technique to one found in Cave A2.

The LB II pit is clear evidence for a permanent settlement at Khirbet Umm ad-Danānīr in the LB; the large vessels and the associated massive wall suggest a well-established community. The proposed city wall encloses an area of about 2.5 ha, making the site quite large by Transjordanian standards. Khirbet Umm ad-Danānīr's stratified sequence of architectural remains is also unusual for the Amman area.

#### RESISTIVITY ANOMALIES AT RUJM AL-ḤENŪ EAST (FIELD III)

The trial soundings at Rujm al-Ḥenū (E) partly resolved the ambiguity of the resistivity survey results. In the four areas (III.0, III.1, III.11, and III.23—see Figure 2, *bottom*) that overlapped with the resistivity grids (total of 20 m<sup>2</sup>), the correspondence between rises and dips in the bedrock and highs and lows in resistivity was evident (McGovern, 1983). Thus, bedrock hollows in Areas III.0 and III.11 coincided with lows in Grids 9 and 17. A possible east-west wall in Area III.1 appeared to correlate with a high in Grid 9 (X3, Y35.5).

These areas represent less than 0.5% of the total surveyed with the resistometer, but the results obtained thus far are quite consistent; and bedrock irregularities may well explain the diffuse highs and lows dominating each grid. Occasional small areas of very high resistivity can probably be attributed to isolated outcrops of bedrock. On the west in the area between the two buildings (Grid 9), high anomalies may indicate wall lines of room additions, pathway boundaries, or separate structures. Actual field measurements are modified by many factors, including soil stratigraphy and inhomogeneities, nearness of the bedrock and water table, the spacing between probes and their placement in the soil (Aitken, 1974), so results are often difficult to relate to theoretical calculations.

Excavation at Rujm al-Ḥenū (E) provided confirmatory evidence that this building had a different constructional and occupational history than the western building. While no LB pottery was found in the excavation of Rujm al-Ḥenū (W), the eastern building yielded 1 LB, 10 possible LB, and 9 transitional LB/iron diagnostics, besides the 3 MB/LB sherds from the survey. However, all the LB material came from a thin (30-cm) fill over bedrock, which included Iron Age and Byzantine pottery. Mixed loci are hardly definitive, and may only evidence robbing or dumping activity sometime between the Roman period and the present. The fact that only a few courses of the walls remained suggested that boulders from the eastern building had been reemployed at the western building, since the latter dates to the late Iron Age (below).

The combined resistivity and excavation results shed light on the

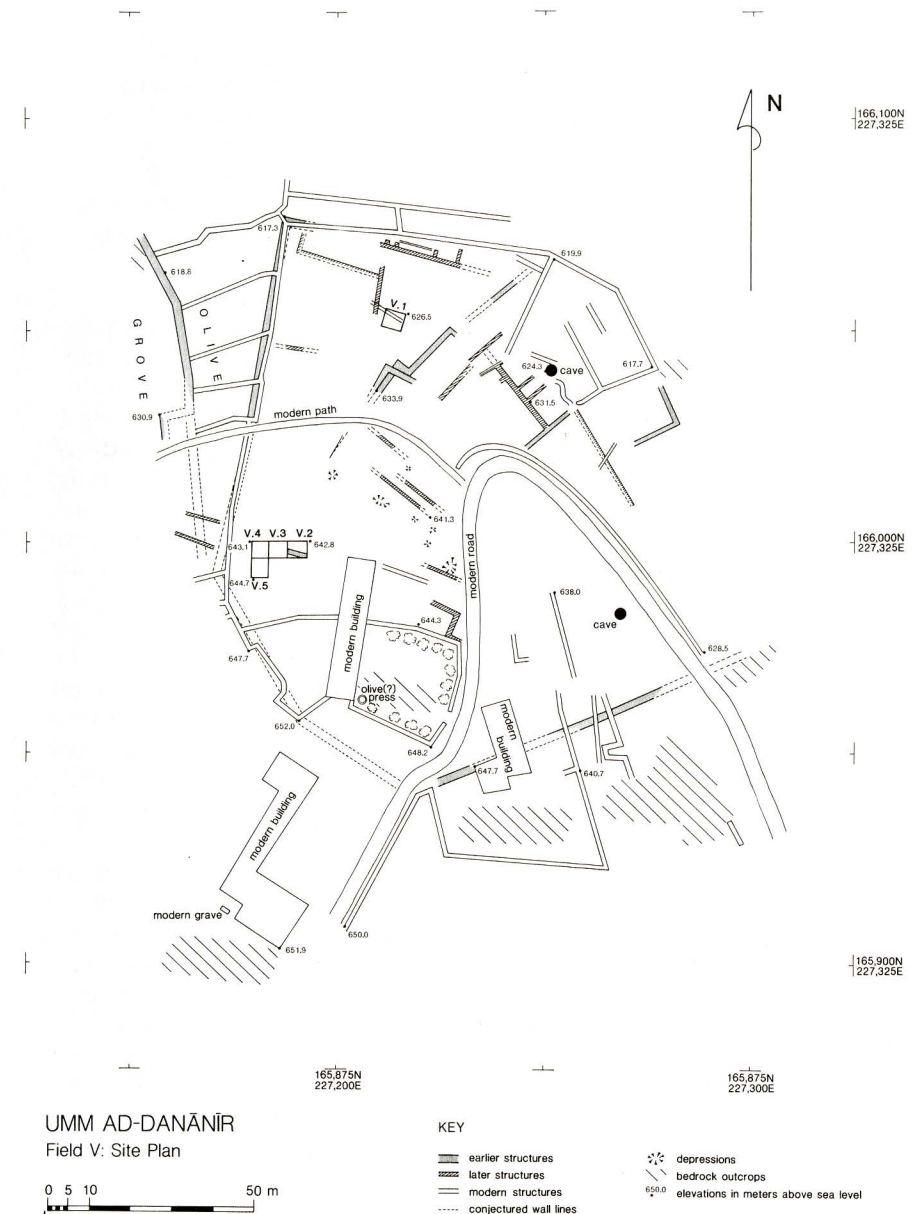


FIGURE 9. Plan of Khirbet Umm ad-Danānīr (Field V).

question of whether Rujm al-Henū (E) should be classified as a *Quadratbau* structure. No additional crosswalls, belonging to the main structure, were uncovered; and perhaps they were lacking in the original layout, a major departure from the classical architectural type. Alternatively, there might be variant traditions of the same general type, especially in the Amman area where megalithic construction was common and possibly the primary rural settlement pattern (Glueck, 1939; McGovern, 1984a).

#### RUJM AL-HENŪ WEST (FIELD IV)

In order to elucidate the structural and temporal relationship between the buildings at Rujm al-Henū, three test soundings were carried out along the western enclosure wall of Rujm al-Henū (W) (Figure 4). These showed that before the building's construction, large areas of irregular bedrock were smoothed out by laying down clay. The bedrock and/or clay then served as the foundation for interior and exterior walls, as well as the single occupational surface uncovered in the excavation. Smashed storage jars and other vessels, dating exclusively to the Iron IIC/Persian period, were found on the hard-packed clay floor. Above the floor, almost the entire accumulation inside the structure, over 1.5 m thick, was destruction debris from the collapse of upper wall courses. Thus, the building appears to have been built, occupied, and then destroyed, possibly as the result of an earthquake, within a relatively short time. The sealed Iron IIC/Persian floor provides one of the most precise datings for a *gasr*-type building (cf. the 7th to 6th century B.C. dating for Khirbet al-Hajjar and Rujm al-Malfūf South; Thompson, 1973 and 1977), which are often stripped down to bedrock or disturbed by later occupation.

Following its destruction, Rujm al-Henū (W) lay abandoned for an extended period of time. Sometime in the Islamic period, both structures at Rujm al-Henū were used as cemeteries. Burials, with heads to the west and facing south (toward Mecca), were deposited in shallow pits alongside walls; lack of associated burial goods made closer dating impossible. Among a variety of small finds from mixed contexts of the upper rockfall at Rujm al-Henū (W) came two limestone "cosmetic" dishes. These are generally Iron II in date and said to belong to upper-class Ammonite society (Thompson, 1971). If so, Rujm al-Henū (W) would appear to have been more than a border post.

#### CONCLUSIONS

Because of ongoing development and the destruction of ancient sites in the Baq'ah Valley, now virtually a suburb of Amman, the Baq'ah Valley Project from its inception has sought to recover the maximum amount

of representative archeological data with the least expenditure of time, manpower, and finances. By combining geophysical, aerial, and archeological survey techniques, a very deliberate excavation strategy was developed to test specific working hypotheses, particularly those relating to the poorly understood LB-Early Iron period. Consequently, the archeological returns from test soundings were considerable and are probably quite representative.

In addition to recovering a unique overlapping temporal sequence of LB-Early Iron burial caves, this has been tied in with stratified remains at the well-situated settlement site of Khirbet Umm ad-Danānīr. Future fieldwork may well produce a stratified sequence of archeological levels to match that of the burial caves. Iron I remains may be difficult to locate, because the presumed lower standard of living may be reflected in a contracted area of settlement.

Significant results were also achieved at Rujm al-Henū. Based on the recovered archeological materials and architectural considerations, the eastern building was probably constructed prior to the western building, perhaps in the LB. Further excavation at Rujm al-Henū (W) should yield a largely undisturbed Iron IIC/Persian level in many parts of the building. In the case of Rujm al-Henū (E), the discovery and excavation of any remaining intact loci (e.g., in corners) will have been worth the effort if the building's history is further elucidated.

Theoretical confirmation of the cesium magnetometer's utility in locating undisturbed burial caves and in clarifying erosional and depositional processes was fully demonstrated. Since the limestone/sandstone terrain of the Baq'ah is characteristic of the central Transjordanian plateau generally, the magnetometer can probably be used for exploratory work at other sites in the region; soil tests should still be routinely carried out. Despite the stony soil and the nearness of bedrock, the employment of the resistometer at Rujm al-Henū helped in reconstructing the original layout of the eastern building and in informing excavation strategy.

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As the scope and goals of the project progressively broadened, so did the size and composition of the staff. Assisting McGovern for the 1980



FIGURE 10. The outlines of a large building—probably Early Roman (first century A.D.)—are just distinguishable beneath the surface of an upper terrace at Khirbet Umm ad-Danānīr. The Wadi Umm ad-Danānīr, leading down to the Jordan Valley, is visible in the background.

season were registrar Helen R. Schenck, photographer Nicholas Hartmann, and field supervisor William D. Glanzman, of MASCA; Vincent A. Clark and David F. Graf, resident Albright and NEH fellows at ACOR; Marilyn B. Saul, osteologist; Susan M. Balderstone, architect. Ali Sa'idi and Sa'ad Hadidi, Departmental representatives, and a crew of 20 workmen aided the staff.

In 1981, the supervisory staff was particularly augmented in the areas of physical anthropology and osteology (Scott L. Rolston and Lydia P. Hume) and field archeology (Vincent Clark, William Glanzman, Cherie Lenzen, Sabah Mahmoud, and Zbigniew Fiema). Sa'ad Hadidi was again the Departmental representative; and 25 workers came from the local communities of Umm ad-Danānīr, Salt, and Suweilih. Volunteers Jean Bray and Neil Gallagher, in Amman, and Jane Evans, Martha Risser, Janice Kamrin, Pattie Walters, Patricia Cutts, Eleni Banou, and Nanita Bar-chai, in the United States, have contributed to various aspects of the field operations, registration, and the drawing and setting up of plates.

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