THE 2011 EDOM LOWLANDS REGIONAL ARCHAEOLOGY PROJECT (ELRAP): EXCAVATIONS AND SURVEYS IN THE FAYNĀN COPPER ORE DISTRICT, JORDAN

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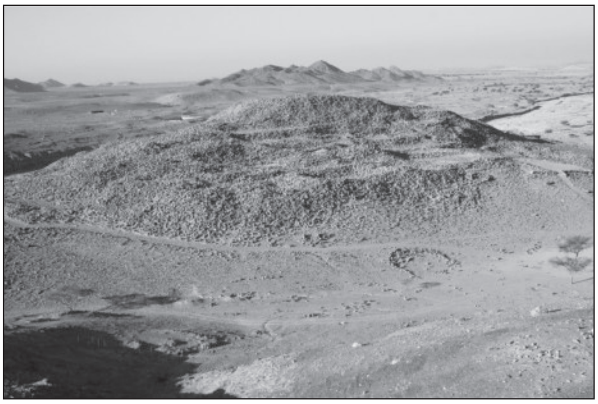
Introduction

The Edom Lowlands Regional Archaeology Project (ELRAP) is a deep-time investigation of the role of mining and metallurgy on the evolution of societies in the copper ore rich Faynān district in southern Jordan, directed by T.E. Levy and M. Najjar. From 2002 to 2009, research focused primarily on the Iron Age (*ca.* 1200-500 BC), one of the most intensive periods of copper production in the ‘Arabah valley that separates modern Israel and Jordan. In addition to the ELRAP, there have been three other recent, large-scale research projects in the Faynān region: (1) the Deutches Bergbau Museum’s (DBM) archaeometallurgy project, directed by Andreas Hauptmann (Hauptmann 2007), (2) the Council for British Research in the Levant (CBRL) Wādī Faynān Landscape Survey, directed by Graeme Barker, David Gilbertson and David Mattingly (Barker *et al*. 2007b) and (3) the Early Prehistory of Faynān Project, directed by Bill Finlayson, Steven Mithen and Mohammad Najjar (Finlayson *et al*. 2011). What distinguishes the ELRAP from other projects is our application of new digital technologies for archaeological research to carry out large scale excavations in order to contextualize the socio-cultural context of ancient mining and metallurgy (Levy 2010; Levy *et al.* 2008; Levy and Najjar 2008).

The main focus of the ELRAP has been the investigation of mining and metallurgy during the Iron Age (Ben-Yosef *et al*. 2009a; Ben-Yosef *et al*. 2010; Ben-Yosef *et al*. 2009b; Levy *et al*. 2012; Levy and Najjar 2007; Levy *et al*. under review). Additionally, over the past eight years our team has carried out excavations at a Pre-Pottery Neolithic B site (Levy in prep.) Early Bronze Age sites (Levy *et al*. 2002; Muniz 2007) and sites of other periods. One of the main aims of the new 2011 ELRAP expedition in Faynān was to investigate Khirbat Faynān (KF, Biblical Punon, Roman / Byzantine Phaino; 30° 37.6’ N, 35° 30’ E) as the possible social and economic center of copper production during the 10th and 9th centuries BC. Large-scale excavations at Khirbat an-Nuḥās demonstrated that it was the primary center of smelting and processing in the region (Ben-Yosef 2010; Levy *et al*. 2012; Levy and Najjar 2008; Smith 2009). However, the logistical and political center of copper production during these key centuries has eluded researchers. In addition, we wish to expand our research to explore the potential socio-economic role of Khirbat Faynān in copper production during other periods, such as the Early Bronze Age, and Nabatean / Roman periods. Furthermore, we wish to clarify how socio-political organization changed during when the region fell under Byzantine and Islamic control.

To complement the deep-time research goals of our new project at Khirbat Faynān (Levy and Najjar 2007) (**Fig. 1**), in 2011 we also carried out ten soundings of agricultural terrace walls in the immediate vicinity of the site, a pedestrian survey of the Buwayridah springs in the southernmost part of our research area and small probes at the Early Bronze Age copper manufactory at Khirbat Ḥamrat Ifdān and the Middle Islamic copper production village of Khirbat Nuqayb al-Asaymir. Here we present the first preliminary report on these research efforts.

In addition to an overview of notable discov-

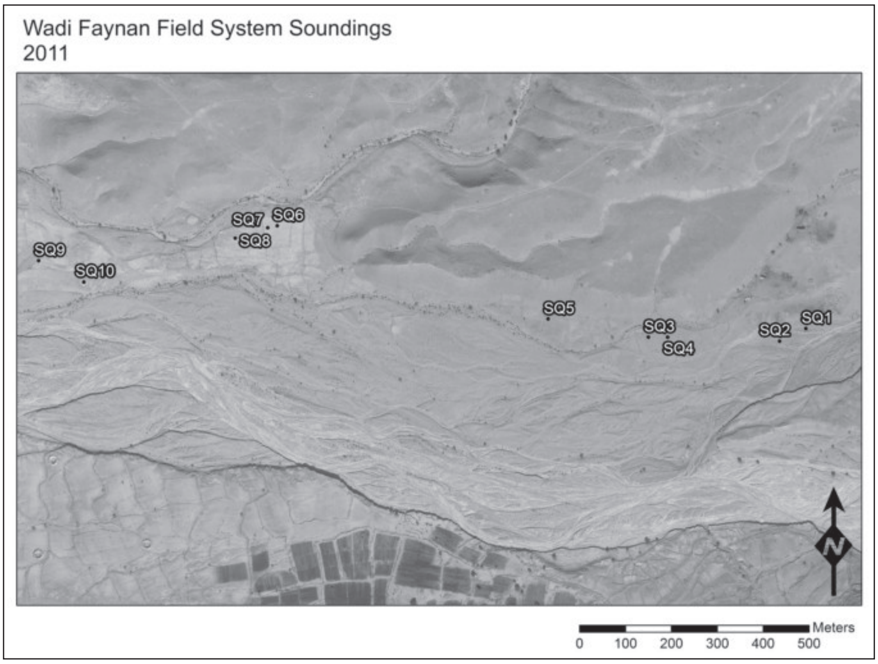


1. Khirbat Faynān (Biblical Punon) seen from the helium balloon photographic system designed by UC San Diego undergraduate students for this project, November 2011.

eries from our excavations and surveys, an extensive discussion of how three novel techniques complemented the ELRAP is presented. First, a geophysical survey elucidated potential excavation obstacles. Second, a digital chemistry unit consisting of X-Ray Fluorescence and Fourier Transform Infra-red Spectroscopy units yielded important data with which to form conclusions in the field regarding excavated contexts. Third, a Light Detection and Ranging unit provided a high-resolution point cloud for scanning the different sites.

Faynān Agricultural Terrace Excavations

As part of our comparative study of differences in subsistence strategies used in the lowlands and highlands of Edom, test excavations were carried out on ten terraces around Khirbat Faynān (**Fig. 2**). The landscape of Wādī Faynān has been extensively modified with agricultural field systems and terraces for managing floodwaters and erosion. Recently, the Council for British Research in the Levant (CBRL) completed a systematic survey of the field systems and noted concentrations of ceramics from the Early Bronze Age to Islamic periods (Mattingly *et al*. 2007). Agricultural terraces have also been recorded in the highlands of Edom. However, like the Faynān field systems, it is difficult to determine the date of use and construction of these features based on concentrations of ceramics alone owing to complications in site formation processes. Dating methods generally involve indirect dating by systematic surface collection of ceramics that may have been deposited during episodes of manuring (Given 2004; Wilkinson 1989). Direct dating is not usually possible because of the paucity of radiocarbon samples associated with terrace walls and the difficulty in finding a chronologically constrained sample. However, recent applications of Optically Stimulated Luminescence (OSL) methods (Avni *et al*. 2006; Bishop *et al*. 2004; Porat *et al*. 2006, 2012) to date archaeological features have been used as a successful alternative to traditional



2. Overview Google Earth satellite image of Wādī Faynān field systems WF442 and WF443.

dating methods. Thus, ten test excavations were carried out that complement previous systematic surface collection in the area and the trench excavation at Khirbat Faynān described below.

The ten excavated trenches will contribute to our explanation of the history of farming on the Faynān agricultural terraces (**Fig. 3**). The primary goal of our excavations was to collect samples for Optically Stimulated Luminescence (OSL) dating of agricultural terraces and to that end we were successful. A total of 28 OSL samples were collected. In addition, we collected sediment samples for analysis of pollen, grain size and phytolyths. These future analyses will contribute to our understanding of ancient paleoclimate and subsistence practices, especially when combined with the existing survey and excavation record.

Buwayridah Springs Survey

The Buwayridah Springs Survey focused on an area in the southernmost portion of the Faynān district that has received little attention, despite its potential for long term human occupation. Our working hypothesis is that the Buwayridah springs played an important role in ancient trade routes in the area. The springs are part of the Wādī al-Fayḍ catchment area that begins in the highlands and empties into the ʻArabah valley. This survey is a continuation of the Wādī al-Fayḍ Survey begun in 2009. Wādī al-Fayḍ flows from the highland plateau in a westward direction for approximately 20 km, eventually reaching the Buwayridah spring zone situated in an area dense with sand dunes on the eastern margin of the Wādī ʻArabah valley. The survey of the Buwayridah spring zone will yield an important data set for testing the relationship between regional-scale economic processes and small-scale economies, because this area is also part of ancient Iron Age Edom – and the core settlement area of the later Nabataean kingdom – as well as an important part of the Roman / Byzantine periphery (el-Khouri 2008).

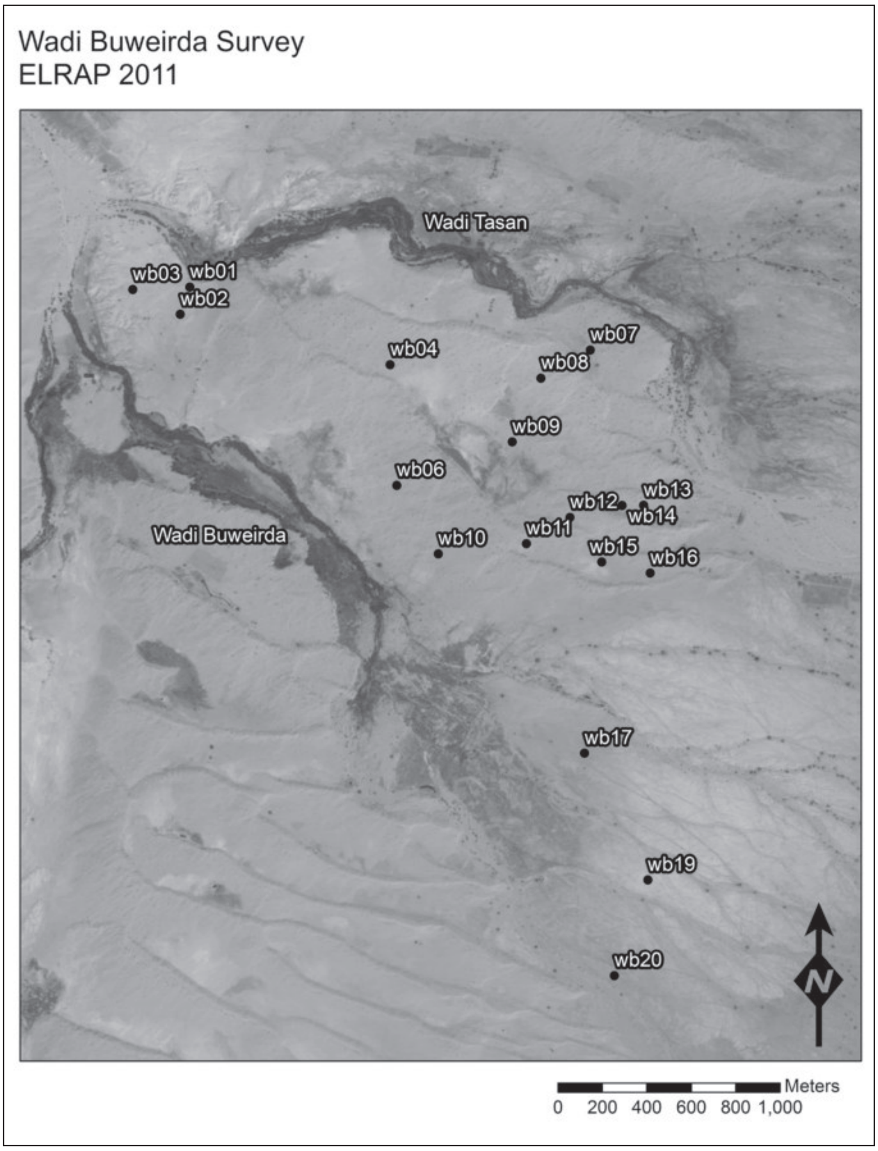
3. Ancient terrace wall uncovered below the modern surface, WF 442 (Trench 7).

Our survey methodology consisted of systematic, intensive surveying of 100 % of the area within the survey boundaries, as well as systematic surface collection and mapping at sites and other features. The survey boundaries included an area of five square kilometers between Wādī Buwayridah and Wādī Tasān (**Fig. 4**). Surveyors recorded site locations using a handheld Garmin Oregon 450 GPS. Digital photos were taken of all sites and features; attributes were recorded on a standardized data form developed in 2009. Information was recorded on the size, site type, geomorphology and environmental surroundings of the site. The survey team used a combination of systematic surface collection and targeted collection strategies, depending on the terrain, size, density, time constraints and other factors.

18 sites were recorded during the archaeological survey of Buwayridah springs (**Table 1**). Because the area is extensively covered by sand dunes, the sites consisted mostly of artifact scatters located near the dune margins. Poor visibility was the most influential variable in our ability to locate sites. Thus, it is quite possible that many more sites are covered by the Buwayridah sand dunes, some of which are upwards of 10-15 meters high (**Fig. 5**).

Summary

The Buwayridah Springs Survey was the first systematic archaeological survey of the Buwayridah springs zone. There is great potential for future discoveries in the Buwayridah springs area. Because



4. Map of survey area showing the sites recorded. Wādī Tasān (northern wadi) marks the northern boundary of the survey area, while Wādī Buwayridah (southern wadi) represents the southern boundary. The survey area = ca. 5km2.

the current survey only covered a small area between Wādī Buwayridah and Wādī Tasān, a larger survey will likely find more sites. The periods most represented in the Buwayridah springs area are the Late Prehistoric, Early Bronze Age and Roman / Byzantine periods. Further analysis of the artifacts collected will be required to better understand the occupation history in the survey area, as well as to interpret site function and how each site relates to the regional settlement pattern in Faynān.

Khirbat Nuqayb al-Asaymir - A Middle Islamic Period Copper Production Village

Area X: Major Building Complex

Introduction

The 2011 season marks the beginning of ELRAP's investigation of the final phase of copper production in Faynān at Khirbat Nuqayb al-Asaymir (KNA; 30°40'31" N, 35°26'48" E), a copper-smelting site of the Middle Islamic Period (*ca.* 1000-1400 AD). A probe was made in Area X, a building and its associated slag heaps that made up the center of copper production at the site. Area X consists primarily of a single five-room building and adjacent mounds of copper slag to the east, just outside the entrances to the building. The excavation area was in the north-western portion of the building and was bounded by two walls, Wall 105 and Wall 108. The walls are built out of local dolomite, with chinking stones inserted at semi-regular intervals. Although visually striking (**Figs. 6**-7), the

Table 1: Sites recorded in the 2011 survey near the junction of the Wādī Tasān and Wādī Buwayridah.

Site Number	Northing	Easting	Site Size (m^2)	Periods	Site Type
WB001	723267	3383372	18000	Early Roman, Islamic	Artifact scatter, Campsite
WB002	723226	3383253	11000	Neolithic, Roman, Islamic	Lithic scatter (production site?)
WB003	723031	3383365	3100	Prehistoric, Roman/ Byzantine	Artifact scatter (pottery and flint tools, debitage)
WB004	724051	3383048	175	Early Bronze	Artifact scatter, possible hearth
WB006	724099	3382509	900	Roman/Byzantine +	Pot Drop
WB007	724843	3383140	1300	Neolithic	Artifact scatter, small settlement
WB008	724629	3382976	1100	unknown	artifact scatter
WB009	724528	3382702	1900	Early Prehistoric	lithic scatter
WB010	724257	3382217	7500	Early Bronze	Artifact scatter, small settlement
WB011	724592	3382269	500	Classical	Sherd scatter
WB012	724758	3382395	600	Classical	Artifact scatter (ceramics and ground stone)
WB013	725060	3382450	1700	Classical	Artifact scatter (ceramics, glass, ground stone)
WB014	724988	3382441	2500	Classical	Artifact scatter (ceramics, glass, ground stone)
WB015	724927	3382144	3500	unknown	Artifact scatter (lithics, ceramics, ground stone)
WB016	725113	3382133	2600	Classical	Artifact scatter (ceramics, lithics, ground stone)
WB017	724839	3381340	2	late Classical +	Pot Drop
WB019	725100	3380786	350	Early Prehistoric	lithic scatter
WB020	724985	3380387	2400	unknown	sherd scatter

construction of the walls shows the importance of practical over aesthetic concerns in the construction of the building.

The probe was conducted to answer several questions. Initially, we wished to test a hypothesis put forward by Hauptmann (2007: 126-127) that the Area X building may have housed a mineshaft. We also wanted to better understand both the nature and chronology of metal production at KNA. Over the course of nine days working at KNA, we excavated an area of 7x3m to a maximum depth of *ca.* 1.2m. All loci, including topsoil loci, were completely sieved through a ¼" mesh to retrieve as much excavated material as possible.

In terms of chronology, the excavations revealed – as we had suspected – that copper production at KNA occurred during a single phase, local Stratum X2, after which the site seems to have been abandoned. Although datable artifacts

5. Overview of WB07, showing the large sand dunes that surround the site.

6. KNA Furnace 120, showing the slag pit (front) and replaceable granite facing, as well as the red mortar fill.

from the Area X probe were scarce and radiocarbon dating has not yet been performed, we suggest, based on earlier analyses of ceramics from survey (Jones *et al*. in press) that Stratum X2 should be dated to the Middle Islamic IIa period, or the first half of the 13th century AD.

The Shaft Furnace

Rather than a mineshaft, the Area X excavation revealed something much more exciting: the remains of a copper-smelting workshop, complete with a well-preserved, stone-built shaft furnace (L. 120) abutting Wall 108 (**Fig. 6**). The dimensions of the furnace itself are roughly 1x1.6m, with a slag pit *ca.* 0.75m in diameter to the east. The western, permanent portion of the furnace is constructed of local dolomite, the same material as the walls of the Area X building, with a replaceable facing made primarily of granite, now very decayed. Between the permanent structure and the replaceable facing is a layer of red, iron-rich sediment. FTIR analyses revealed this to be iron-rich loess with relatively high clay content, which was used as mortar between the two parts of the furnace. This layer is now very decayed and the mortar has run off in large quantities into the slag pit. The plan of the furnace is similar to Early Islamic II (800-1000 AD) shaft furnaces at ‘Arja in Oman, specifically from Site 103 (Weisgerber 1987: 155), which suggests that this type of furnace was both widespread in the Islamic world and also long-lived. It is also interesting to note the superficial similarities between this furnace and the stone-built, mortar lined furnaces at Timna 2, dated by Rothenberg (Rothenberg 1990: 16-35) to the Late Bronze Age, but which yielded Early Islamic period radiocarbon dates (Rothenberg 1990: 71; Ben-Yosef 2010: 671).

Air seems to have been provided to the furnace in two ways. First, from the outside of the building a small, built opening is visible at the bottom of Wall 108 (**Fig. 7**), in the section of this wall opposite the furnace. This is likely intended to take advantage of the winds blowing into the site from Wādī Nuqayb al-Asaymir to the west; both this and the proximity of sources of copper ore in this *wadi* (WAG 56 and 57 [see Levy *et al.* 2003]) help to explain the placement of the Area X building. Second, a partial bellows tube was found *in situ* in locus 131, to the north-east of the furnace, and this would have provided more direct air from the front. Textile and rope finds in L. 119 and L. 130 respectively may represent the very fragmentary remains of cloth bellows attached to these ceramic bel-

7. An aerial view of KNA Area X taken from the ELRAP balloon aerial photography platform, with rooms labelled. The slag heaps east of the Area X building are visible in the photo. The 2011 probe was carried out in Room 3.

lows tubes. Although no tuyère fragments were found during the excavation in Area X, a single example was surface collected from the slag heaps outside the building (**Fig. 7**). It is wheel-turned and fired to buff, with large, rocky inclusions throughout.

The placement of the furnace and the finds nearby clarify how the Area X building was used. The fact that the furnace is located on the west wall of the building, away from the entrances at the east, suggests that the building was at least partially open. The eastern portion of the building – Rooms 1 and 4 – may have been roofed, but the western portion could not have been. Likewise, the relatively low density of slag in the excavated part of Area X, as well as the almost complete lack of technological ceramics other than the bellows tube in L. 131, suggest that waste from the furnace was removed from the building and dumped on the slag heaps outside. Considering this, it is somewhat surprising that a large lump of partially processed copper was found discarded in the north-western corner of the building. It is not clear if this was awaiting reprocessing at the time the site was abandoned, or was hastily discarded after a failed smelt close to the time the building went out of use.

Summary

Based on the evidence outlined above, it is certain that the Area X building was devoted primarily to copper smelting, which to our surprise took place in the building itself. Based on the way the shaft furnace appeared before excavation, it is likely that the other piles of rock collapse along the walls of the building are the remains of metallurgical installations, and it is even possible that another furnace is present in Room 2. It cannot be entirely ruled out that some mining activities took place in Room 5, but this is an unlikely function for that room and we would suggest that most, if not all, ore for the site came from the mines of Wādī Nuqayb al-Asaymir. Given the intensity of copper production in Room 3, it is unlikely that it was roofed. In fact, most of the Area X building was probably unroofed. Currently, we place the copper production in Area X in the first half of the 13th century A D, following analyses of our previous survey data.

Khirbat Ḥamrat Ifdān

Area Q

Large-scale excavations were carried out at Khirbat Ḥamrat Ifdān (KHI; 30°39'41" N, 35°23'33" E) in 1999 and 2000 (Levy *et al*. 2002; Muniz 2006). These excavations revealed the best-preserved Early Bronze Age III - IV (EB III-IV; *ca*. 2500-2000 BC) copper manufactories in the ancient Near East. Thousands of casting moulds (final product and ingot), copper objects, ceramic vessels and artifacts related to EBA metallurgical process came to light. Sometime after the EB III occupation at the site, but before the EB IV period (*ca*. 2300 BC), the site suffered a massive earthquake that effectively sealed over 70 rooms, courtyards and other architectural features at the site. This 'Pompeii effect' has made KHI a unique site in the history of Old World metallurgy and the archaeology of the southern Levant.

The 2011 excavation at KHI had two primary objectives. First, we wanted to further clarify the stratigraphy from past seasons at KHI. Second, we sought to provide a basis for the regeneration and new geo-referencing of the spatial data collected during past seasons. In order to meet our first objective we planned a small probe with a 1 meter wide baulk adjacent to what was identified as Area H in the 1999 and 2000 seasons (**Fig. 9**). Based on the results of this season's excavation, we confirmed the division of the site into four strata. Stratum I represents occupations from the Iron Age to Islamic periods. Stratum II dates to the Early Bronze IV occupation. Stratum III represents the primary occupation of the site during the Early Bronze III. Stratum IV represents the first use of the site with a mixture of pottery from the Early Bronze I and, possibly, Early Bronze II. The second objective was initiated using our aerial photography system, coupled with GPS and Total Station readings at the site. Once all of the spatial data has been integrated with aerial imagery taken during the 2011 season, the complete KHI dataset will be ready for more detailed spatial analysis.

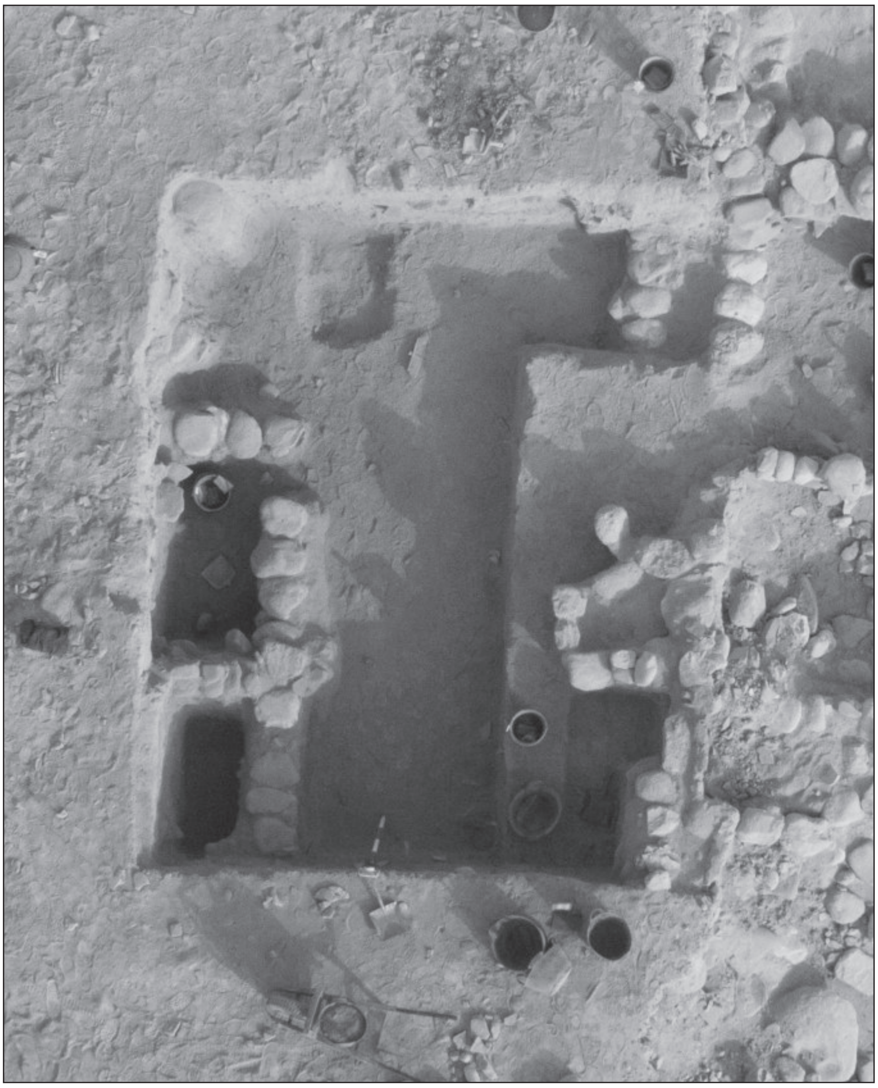
The 2011 excavations at KHI took place over nine days of work at the site using the ELRAP recording system (Levy and Smith 2007). Unlike the earlier large-scale excavation, every locus was sieved completely so as to try to retrieve as much excavated material as possible, especially lithics. One artifact of particular note was a copper axe found sealed under the upper layer of mud-brick collapse (**Fig. 8**). Below the collapse were layers that contained large amounts of ash. The collapse provides further evidence for the earthquake identified in previous excavation seasons (Levy 2002: 425) (**Fig. 9**). The copper axe is very similar in form to one of the Khirbat al-Batrāwī copper axes described by L. Nigro (Nigro 2010) and other axes found in past seasons at KHI (Levy *et al*. 2002). The formal similarity between the axes suggests that KHI was the production site for these axes before distribution to other EB III settlements.

8. Copper axe head with parallels to Khirbat al-Batrāwī.

Khirbat Faynān

Area 16

The 2011 season was designed to give us an introduction to the challenges and stratigraphy of Khirbat Faynān (Biblical Punon, Roman / Byzantine Phaino; 30°37.6' N, 35°30' E) as the beginning of a planned, long-term excavation



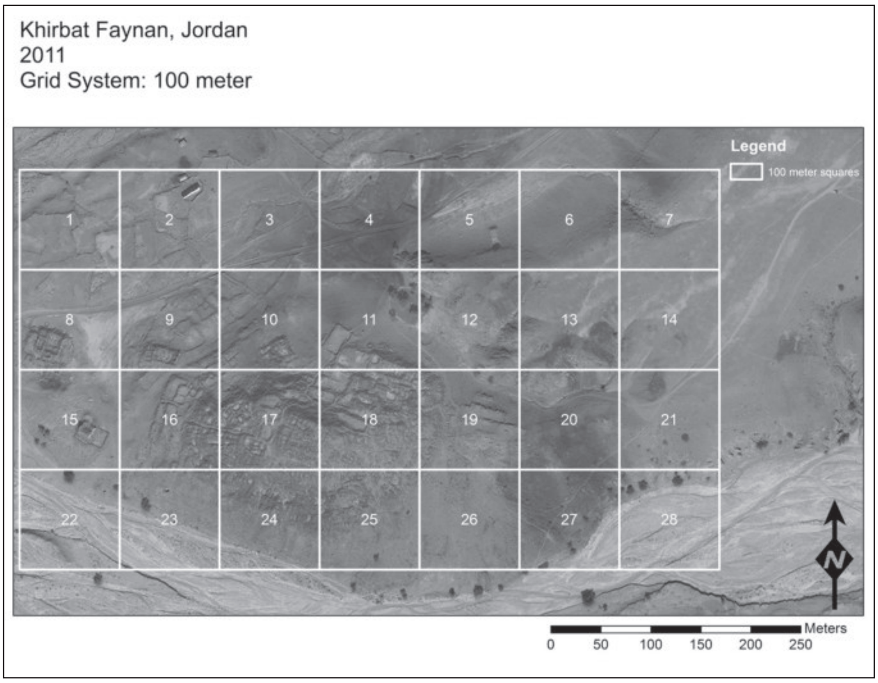
9. Aerial Photograph of 2011 probe (Area Q) at Khirbat Ḥamrat Ifdān close to completion of excavation. All the walls seen here date to the EBA.

project. To begin the project, we decided it best to open a 5x40 meter trench on the west side of the *tall* (**Figs. 10-11**). The trench started at the base of the *tall*, below the first surface architecture on the *tall* proper and ended before the obvious, dense later occupation higher up on the *tall*. For three weeks before excavation began, a geophysical survey was conducted to provide a preview of what to expect in some of the excavated areas and to test the feasibility and practicality of continued geophysical survey in the future. Depending on the archaeological context, we employed four different sieving strategies. For the uppermost layers of fill we did not sieve at all. In contexts without any clear occupational definition we used a one to five sieving strategy. As we approached floors we would sieve every other *quffa* (Ar. "rubber bucket"). All excavated sediment associated with floors and living surfaces was sieved through ¼ mesh. The allocation of stratigraphic units is still in a very preliminary stage as 2011 represents the first excavation season at KF. Owing to the steep western slope in Area 16, the focus of our excavation, deeper and more extensive exposure will be required to establish a unified stratigraphic sequence of the mound. Here a relative stratigraphic system, based on separate 5x5m units is utilized.

Geophysical Survey at Khirbat Faynān

Full characterization of archaeological sites by conventional archaeological methods can take years. Furthermore, coring and excavations, the most common methods for archaeological assessment, are intrusive. Therefore, non-intrusive geophysical techniques are used to map the

10. Oblique aerial view of excavation Area 16 in relation to the rest of Khirbat Faynān mound.



11. Grid system employed at the new excavations at Khirbat Faynān superimposed on Bing satellite image.

shallow subsurface of smaller zones of interest for subsequent detailed excavations. Among these techniques – based on previous results in the same area (Witten 2000) – we decided to use EMI (Electromagnetic Induction) and ERT (Electrical Resistivity Tomography).

Among many applications, electromagnetic induction instruments are used for near-surface archaeological investigations and the detection of buried structures such as building foundations, as well as for the detection of highly conductive metallic objects. The system used in this campaign is a Profiler EMP-400 (GSSI, USA), which is a digital, portable, multi-frequency electromagnetic induction sensor. The system bandwidth extends from 1 kHz to 16 kHz.

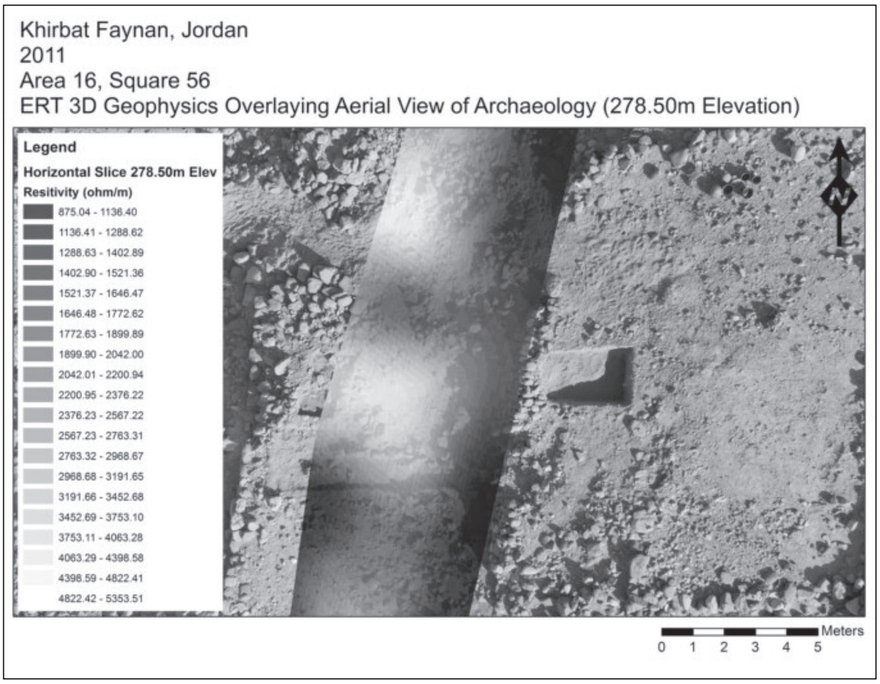
ERT is very popular in archaeological investigations and was also employed. The success of the method depends on the difference between the resistivity properties of the potential archaeological targets (walls, roads, buildings etc.) and the surrounding environment (Leucci and Negri 2008). We used the Syscal Pro resistivity meter (Iris Instruments, France) with 48 electrodes spaced at 0.5 meter.

Three different sets of 2D ERT lines (24 electrodes at 1 meter separation each) were collected over three sides (north, east and west) of the Khirbat Faynān mound (**Fig. 12**). The main objective was to obtain vertical sections up to 6 meters along the mound in order to investigate the different layers and hopefully distinguish cultural from natural layers. The position of every electrode was measured with a total station in order to correct the ERT lines for topography. On the other hand, a small 3D ERT survey was collected over a grid to be excavated. The 3D ERT survey used a set of parallel 2D profiles with a separation of 0.5 meter between electrodes. After collection, data were sent to Geostudi Astier (Livorno, Italy) for inversion and generation of final maps. The main purpose of the 3D ERT survey was to direct the excavation and give as much information as possible beforehand. **Fig. 12** (below) illustrates some of the ERT results.

Snap-Shot of Key Excavation Areas and Finds from Khirbat Faynān

Early Bronze Age Settlement (Square 16-57)

One of the most exciting discoveries in 2011 was a large number of well-built foundation walls dating to the Early Bronze III in the upper portion of the excavation (**Fig. 13**). It can be divided both vertically into building phases based on architecture and horizontally according to activity areas based on artifact distributions. Three building phases were recorded: a more recent *ad hoc* enclosure visible on the surface and two distinct building phases that date to the Early Bronze Age. Two distinct construction phases are visible in the structure of the walls running north to south, allowing for the division of the middle section into two sub-strata for the Early Bronze occupation. The local stratigraphy for the area of Square 57 with the EBA buildings contains Strata 16-57-1, 16-57-3a, 16-57-3b and 16-57-4. Three definite rooms were identified with potential rooms existing to the north and south of the excavation area. The rooms were numbered from north to south: Rooms 4, 5 and 6. The middle section is best defined as the area between Walls 1129 and 1135. In the west, abutting Wall 1049 – that forms the boundary between Squares 56 and 57 – is another fill, but much deeper. The western fill contained a mixture of material with ceramics ranging from the Iron Age to Byzantine periods in a mixed context. Interestingly, in this fill, the Early Bronze Age is nearly completely absent until just above the basal layer. Between the early and later fills is a sterile fill. The eastern portion of Square 57 includes Strata 16-57-1, 16-57-2a, 16-57-2b, 16-57-2c and 16-57-4. The western portion of the



12. *Geophysical ERT data superimposed on aerial photograph taken with the ELRAP balloon system. Ground truth excavations revealed a small room, with a range of Byzantine artifacts.*

square is best defined as the area between Walls 1049 and 1129.

The square was excavated piecemeal in fragments over the course of the excavation, which led to confusing descriptions of the archaeological record. The fragmentary nature of the excavation in Square 57 was the result of trying to excavate around the only superficial architecture at the site, consisting of Walls 1127 and 1130. Excavation in the square began with a roughly 1 x 1 meter probe in the north-west corner of the square into Stratum 16-57-4. Next, the eastern portion of the square was excavated to the basal gravel layer. In neither of these probes was subsurface architecture detected. Eventually, the area over the rectilinear Early Bronze structure was excavated as a single unit, leaving space between the different probes for small baulks. It was decided to extend the excavation to include the full extent of the 10 x 10 meter square in order to clarify fully the extent of the EB settlement area. Owing to logistical reasons, we did not finish excavating the northern half of the square until the southern half was finished. Initially, the southern half of the square was divided into sections informed by our observations of the horizontal stratigraphy in Square 57. Other than Early Bronze III pottery, few finds were identified. The discovery of well-preserved buildings dating to the EB III is especially important at KF because it provides evidence for a large settlement in the main Faynān valley during the area's first peak in copper production (**Fig. 13**). While the site of Wādī Faynān 100 was initially thought to be an EBA settlement over 11 hectares in size (Wright *et al*. 1998), definitive evidence for the site being a large habitation site did not come to light. According to a British team (Barker *et al*. 2007a: 237-238), the main exposure of EBA structures at WF 100 was in Operation 4 and even there no single structure could be defined. The recently discovered well-constructed room complex and *in situ* ceramic assemblage from KF both point to the importance of this site as the potential settlement center in the Faynān valley during the 3rd millennium BC.

<ins>Iron Age Finds (Square 16-54)</ins>

It is difficult to make generalizations about the stratigraphic development of the entire site because the slope of the excavation trench is considerable. Here we focus on one square to characterize the topsoil because of a single outstanding artifact that came to light. The finds from the topsoil of Square 16-54 were a mix of material assumed to have washed down the *tall* over time. Notably, in the surface finds / scrape from Locus 1001 we found a remarkable ceramic Iron Age head / mask figurine with some parallels to a 9th century BC final product casting mould found at Khirbat an-Nuḥās (Levy 2008: 249-251) (**Fig. 14**). It is also similar to anthropomorphic figurines found at the late Iron Age 'Edomite' site of Horvat Qitmit (Beit-Arieh 1995). While a good stylistic parallel exists, the lack of a good context for the KF find does not allow for a definitive temporal assignment.

13. Early Bronze Age (III) room complex found at Khirbat Faynān. This is the first major EB (ca. 3,400 - 2,000 BC) settlement evidence found at this large settlement.

14. 'Edomite' figurine head removed during the topsoil scrape in Square 16:54.

<u>Nabataean to Byzantine Settlement (Square 16-56, Room 3)</u>

The relatively flat surface behind a terrace wall half way up the excavation trench made it conducive to the detailed ERT survey briefly described above. Indications of a small walled enclosure were seen with this geophysical investigation. At a depth of *ca.* 50cm, excavations in this area revealed a room is in the north-western corner of Square 16-56, between Walls 1031 and 1032, and the well-built terrace wall, Wall 1048. Both Wall 1031 and 1032 are two row walls preserved to a height of two to four courses, made primarily of limestone, basalt and granite in a boulder and chink construction. Terrace Wall 1048 is of similar construction, but is much deeper and preserved to a height of seven to 12 courses. It is possible that, like Wall 1124, this wall belongs to an earlier construction phase and was reused as part of the later Room 3.

The primary occupation of Room 3 belongs to Stratum 56b-3. After clearing the Stratum 56b-3a fill, the edges of a *ṭābūn*, L. 1103, emerged. This installation takes up almost half of the excavated portion of the room and is constructed of buff clay. The *ṭābūn* belongs to Stratum 56b-3b, as do the foundations of Walls 1031 and 1032. The occupation of Room 3 seems to belong entirely to this stratum, which is tentatively dated to the late Roman and early Byzantine periods (**Fig. 15**).

Below the foundations of the walls and the Stratum 56b-3b surface is another potential surface belonging to Stratum 56b-3c. This stratum contains a single course wall constructed entirely of a line of standing stones, Wall 1126, which is likely connected to Wall 1125, although as Wall 1032 was not removed this is not certain. *ṭābūn* 1103 is dug into the surface of Stratum 56b-3c and is built around the pre-existing line of Wall 1126. This stratum, tentatively dated to the Nabataean and earlier Roman periods, was rich in copper finds and contained three copper bracelets, as well as a leaf-shaped pin or pendant bearing the image of a woman (**Fig. 16**).

15. Room 3, Area 16-56 with ṭābūn still filled with ash.

Chemistry Lab Studies in the Field

The ability to carry out micro-archaeological analyses of excavated material is rapidly becoming a key element of the 21st century archaeological tool box (Weiner 2010). During the 2011 field season, we used a digital chemistry lab to conduct in-field analyses of several types of material. This method yielded data that could improve the site supervisors' understanding of the sediments and anthropogenic and cultural materials being excavated. Chemical analysis helped guide aspects of the excavations and enhance our interpretations of those data. The ELRAP chemistry lab made use of two techniques for chemical characterization of samples. These included: (1) a Bruker Tracer III-V Portable Handheld

16. Copper pendant depicting a standing woman. As it was associated with a clasp-pin, it seems to have been a broach.

XRF (X-Ray Florescence) Spectroscope, which allows researchers to gather data on the elemental composition of a sample. The Bruker Tracer III-V can be set up using different combinations of filters, voltage (KeV) and amperage (micro-amps) in order to optimize the instrument to read elements within different ranges of atomic mass. Where applicable, the instrument settings used are noted in this report. (2) Chemical analysis of samples in the field was augmented with the addition of a technique previously untested by the ELRAP, *viz*. infrared spectroscopy. We used a Thermo-Nicolet iS5 FTIR (Fourier-Transform Infrared) Spectroscope, which allows researchers to examine chemical bonds and compounds within a sample. All FTIR samples were tested using FTIR-grade Potassium Bromide (KBr) as a matrix to form pellets. The ELRAP team gathered and analyzed samples of sediment, rocks, cultural deposits, slag, lithics, ceramic objects and metal artifacts during the 2011 season. Here we summarize the 2011 applications at several metal production sites, the study of toxic metals found in sediment samples obtained in the surveys described above and characterization of a systematic geological collection from the study area.

Khirbat Nuqayb al-Asaymir Chemistry

13 sediment samples from Khirbat Nuqayb al-Asaymir were analyzed during the 2011 season, along with 16 samples of slag. Sediment samples were collected specifically from excavation loci and unusual deposits, while slag samples were picked randomly out of all the slag collected from the site. All sediment samples were analyzed by FTIR, while only half of them were analyzed using XRF. The majority of the sediment samples proved to be typical loess soils, with higher relative amounts of quartz and calcite and lower relative amounts of clay than the loess standard provided by the Weizmann Institute. One sediment sample proved to be almost entirely composed of quartz sand, and one sample could not be identified. Most of the sediment samples analyzed with XRF contained relatively high levels of iron, which is consistent with (1) the fact that comparatively iron-rich copper ores were smelted at KNA (Hauptmann 2007: 183) and (2) the run-off from the iron-rich mortar used in the shaft furnace. Most sediment also contained small amounts of copper, manganese and strontium; trace amounts of lead were identified in all but one sample.

Slag samples from Khirbat Nuqayb al-Asaymir were only tested with XRF. The slag samples were all tested using the machine's green filter (0.006" Cu, 0.001" Ti, 0.012" Al) at 40 KeV and 15 micro-amps, without the vacuum system. Trials were all either 180 or 300 seconds long. The majority of the samples were shown to contain high levels of both copper and iron, although three of the samples contained significantly higher amounts of copper than iron. All samples contained significant levels of manganese; small to trace amounts of calcium, lead, strontium, nickel and zirconium were also identified in numerous samples. The archaeological context of these slag samples, in addition to their chemical composition, suggests that they may be the result of an unsuccessful smelting operation. Most importantly, such high levels of copper are unexpected in slag that had been well-smelted. It is unlikely that these slag samples are particularly representative of the composition of slag after successful smelting, but this sample may be a good reference for the general elemental composition of the ores that were mined and smelted at Khirbat Nuqayb al-Asaymir.

Khirbat Ḥamrat Ifdān Chemistry

During the 2011 season, 32 sediment samples from Khirbat Ḥamrat Ifdān were analyzed in the digital chemistry lab, along with 39 slag specimens. As at KNA, sediment samples were gathered specifically to test chemical compositions of certain strata and deposits. The sediment samples from KHI were all analyzed with FTIR. The results showed that a majority of the samples were fairly typical loess soils, but that they contained very high levels of calcite relative to the other standard loess components, quartz and clay. Six of the sediment samples also contained elevated levels of quartz. Four of the samples were shown to contain a significant amount of a silicon dioxide polymorph, possibly indicating the presence of phytoliths in those areas. Two samples may contain wood ash or other burned organic material, but this was not established definitively. The nine sediment samples that were also tested with XRF contained mainly strontium and calcium, with varying amounts of iron.

Four samples had moderately high iron levels, while the other five contained small amounts of iron. Six sediment samples also contained small amounts of zirconium, copper, manganese and potassium. One sample contained small but significant amounts of sulphur and three samples contained very small to trace amounts of bromine, a poison.

Of the 39 slag samples from KHI chosen for XRF analysis, 27 were chosen at random from all the material collected during excavation. The other 12 specimens were selected specifically to give a representative sample from part of the site's stratigraphic sequence. These slag samples were all tested with the XRF using the machine's green filter (0.006" Cu, 0.001" Ti, 0.012" Al) at 40 KeV and 15 micro-amps, without the vacuum system. Trials were all either 180 or 300 seconds long. Two specimens were chosen from each of six loci and all specimens were tested non-invasively. Thus, several surface assays were collected for each specimen, but none of the specimens were crushed or homogenized. The slag from KHI was shown to contain very high levels of manganese, along with highly varied amounts of both copper and iron. Interestingly, most specimens contained either extremely high or extremely low levels of iron. This may indicate either a change in the efficiency of iron smelting over time, differential extraction of this material, or simply differential amounts of iron in ores that were smelted for copper production. Only seven specimens contained high or moderately high levels of copper, although copper was present in small to trace amounts in almost every specimen. Virtually all of the slag samples also contained strontium, zirconium and calcium in varying amounts. Very small to trace amounts of nickel, zinc, chlorine, yttrium, molybdenum and lead were also present in some samples. No samples were shown definitively to contain arsenic, as has been reported by other researchers. The confusion over this issue is most likely due to the fact that the main absorption peaks for arsenic (K shell electrons) and lead (L shell electrons) fall at the same place in the wavelength graph.

Wādī Faynān Agricultural Terrace Chemistry

38 sediment samples from the agricultural terraces at Wādī Faynān 442 were analyzed during the ELRAP 2011 season. Of these sediment samples, all 38 were tested with FTIR and six were randomly selected for analysis with XRF. The samples came from three areas: Trench 7, Trench 9 and Trench 10. FTIR analysis showed that the soil from all levels except the lowest strata of each trench was extremely similar. The sediment is very similar to the Rehovot loess standard from the Weizmann Institute standard library, except that it contains significantly less of the clay component and correspondingly higher relative amounts of both quartz and calcite. Some of the specimens had slightly higher amounts of calcite relative to quartz, or *vice versa*, and this appears to be a function of their proximity to lower sandy strata. The lowest strata in each trench contained very high levels of quartz, most likely due to quartz-rich sand prevalent in the sediment matrix. The six sediment samples tested with XRF were tested using the machine's green filter (0.006" Cu, 0.001" Ti, 0.012" Al) at 40 KeV and 15 micro-amps, without the vacuum system. All trials were 180 seconds long. These six samples contained primarily calcium, strontium, zirconium and iron. Five of the six samples contained high or moderately high amounts of iron. Other elements that were present in small to trace amounts in some samples were copper, nickel, manganese and yttrium.

Poisons Test

12 of the sediment samples from Wādī Faynān 442 were also tested using the XRF red filter (0.001" Cu, 0.001" Ti, 0.012" Al) at 40 KeV and 29 micro-amps. These trials were all 300 seconds long. These settings optimize the XRF spectroscope to excite the elements arsenic, bromine, lead and mercury, meaning that any amount of these elements that is present will be clearly visible in the spectra. These elements are poisons and their presence in agricultural soils would profoundly affect the health of both agricultural crops and the population subsisting on those products. Of the twelve samples tested for the presence of these poisons, only one contained more than a trace amount of any poison. This specimen contained a very small amount of lead. Including this specimen, five samples showed lead present in trace amounts. Eight samples contained trace amounts of bromine, six samples contained trace amounts of arsenic and

one sample contained a trace amount of mercury. One sample contained no visible amount of any poison. These results suggest that the soils of Wādī Faynān 442 do not contain poisons in any significant amount, certainly not in quantities sufficient to alter drastically the health of populations subsisting on agricultural products grown here. While these results are preliminary, they contradict assumptions that the Faynān region was polluted at levels that were detrimental to settlement in the region (cf. Pyatt *et al*. 2000).

Tabular Scrapers Experiment

Analyses of ten tabular scraper fragments collected from three sites were conducted. Four of the tabular scrapers were recovered from Wādī Buwayridah 10, one from Wādī Buwayridah 1 and five from excavations at Khirbat Ḥamrat Ifdān. These chipped stone artifacts are unifacial scrapers made on pieces of tabular flint and are especially common at Chalcolithic and Early Bronze Age sites (Fujii 2011; Rosen 1997). The scrapers were each tested with eight trials on the XRF and two trials with FTIR. Small samples were taken from the cortex and chert material of each specimen, and were then pressed into KBr pellets for FTIR analysis. Two XRF trials were made on the cortex and the chert sides of each specimen, at two machine settings. The first setting used the machine's green filter (0.006" Cu, 0.001" Ti, 0.012" Al) at 40 KeV and 15 micro-amps, without the vacuum system. This setting optimizes the machine to excite higher-mass elements, from iron to niobium. The second setting used the machine's blue filter (Ti filter) at 15 KeV and 29 micro-amps, with the vacuum system. These settings optimize the XRF to read low-mass elements, from magnesium to iron. All XRF trials were run for 300 seconds each.

The purpose of this experiment was to determine the utility of XRF and FTIR for lithic studies. Specifically, the project's aim was to examine whether combining XRF and FTIR methods would allow researchers to identify a specific chemical fingerprint for different chert sources. Unfortunately, the results of these tests only confirm that more experimentation is necessary before the usefulness of combining these technologies can be thoroughly assessed. The data obtained by the experiment show that the ten specimens are all extremely similar to one another. It may be possible that the specimens tested in this experiment came from the same tabular flint source and are therefore similar or identical in chemical terms. Furthermore, it may also be the case that chemical differences between the specimens cannot be seen with these technologies.

FTIR analysis was only able to show that each chert sample was more similar to other cherts than to any other chemical compound from current project libraries. FTIR analysis of the samples' cortex showed that areas in direct contact with the chert portion of each specimen were very similar to the chert itself, while areas further out contained high levels of calcite and lower levels of chert. The various peaks visible in the XRF spectra varied in width slightly from specimen to specimen, but it is unclear whether this variation is due to sample-to-KBr ratio, variations in the chemical composition of each sample or other causes, or indeed whether this variation is significant or not. These data do not allow any conclusions to be drawn regarding the similarity or dissimilarity of the flints used at each site to one another, or to other flints from the region.

XRF analysis of these specimens also yielded inconclusive data. Virtually all the XRF trials run on the chert side of the specimens showed high to moderately high levels of silicon, small to very small amounts of strontium and very small to trace levels of iron, nickel, calcium, aluminum and potassium. Some specimens also contained trace levels of manganese, copper, and / or chlorine. Unfortunately, neither these trace elements, nor the more common elements, nor the ratios of the various elements correspond in any significant way with the different sites from which the specimens were recovered. The XRF trials run on the cortex side of each scraper yielded similar data; all trials run on the cortex appear identical to the trials run on the chert side of that artifact, except with regard to higher levels of calcium, increasing in direct proportion to the thickness of the cortex in the area towards which the X-Ray beam was directed.

Although the results obtained from this experiment are inconclusive, they should be compared to spectral data from chert samples from elsewhere in the region and further afield. Such comparison will provide a greater frame of reference within which the significance of these results – or lack thereof – may be understood.

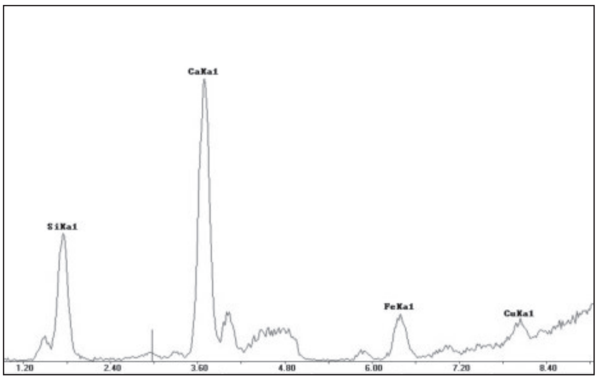
Geology Sample Reference Collection

The most significant project undertaken in 2011 by the digital chemistry lab was the creation of a spectral library from the project's geology sample reference collection. In previous seasons, 40 different samples of rocks typical of the Faynān region were collected and their provenience identified by Jordanian geologist Ibrahim Rabb'a, who published the 1:50,000 geology map of the Faynān region (**Fig. 17**) (Rabb'a 1994). During the 2009 season, each sample was tested using XRF. This season, the samples were re-tested with XRF in their whole (unground) and pulverized states. Limestones, dolomites and granites were sampled with the machine's green filter (0.006" Cu, 0.001" Ti, 0.012" Al) at 40 KeV and 15 micro-amps. Sandstones were sampled with the blue filter (0.001" Ti) at 15 KeV and 29 micro-amps. For each sample, two readings were taken from the unbroken specimen and two more from the specimen ground and homogenized. Each reading was run for 300 seconds. A small amount from each specimen was also ground and pressed into a KBr pellet and sampled using the FTIR spectroscope. These spectra now form a searchable digital reference library that can be used by researchers to compare the chemical compositions of samples collected in the field to those of the reference collection, allowing for rapid identification and sourcing of geological materials.

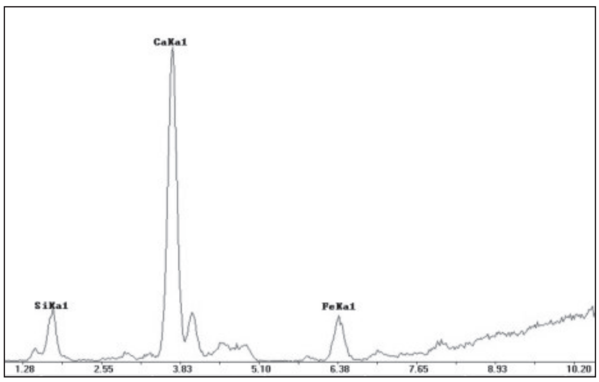
The usefulness of the digital reference library was tested in the field by comparing geological samples collected from the Khirbat Faynān *tall* site to the reference spectra (**Fig. 18**). The Khirbat Faynān samples were originally collected and tested with XRF and FTIR in order to establish a baseline for magnetrometry and ground-penetrating radar tests that were performed at the site. By establishing a basic understanding of the elemental and mineral composition of the major geological components of the site - and therefore their general resistivity, conductivity and metal content - the geophysics team were able to more accurately understand and interpret their data. Comparison of the five Khirbat Faynān geological samples to the Southern Levant Digital Geological Reference Library yielded one 89 % match, three matches above 95 % confidence and one sample that did not match any of the reference samples above 52 %. This test shows that although the geology reference samples provide an excellent baseline for the identification of many samples, the digital reference library could be improved in future seasons by the collection, identification and spectral sampling of additional geological specimens from the Faynān region and further afield. In particular, local rock formations should be sampled, along with any known sources of clay, flint, materials used for ceramic temper and local flora.

Sampling of Copper Objects and Special Finds

14 copper objects and one ceramic special find, a figurine head (45/90035; **Fig. 14** above), were recovered from the site of Khirbat Faynān. The single copper axe (522/60122; **Fig. 8** above) recovered from Khirbat Ḥamrat Ifdān in 2011 was also sampled. These 16 objects were tested with XRF in order to study their elemental composi-



17. XRF spectrum of 'Calcareous Sandstone - High Calcite' geology reference sample.



18. XRF spectrum of 'Ferruginous Sandstone' geology sample from Khirbat Faynān (surface grab sample).

tion. The ceramic figurine head was tested with the instrument's green filter (0.006" Cu, 0.001" Ti, 0.012" Al) at 40 KeV and 15 micro-amps. Two tests were run at 180 seconds each. These settings optimize the instrument to read higher-mass elements from rubidium to niobium, enabling researchers to view and analyze ratios of the elements rubidium, strontium, yttrium, zirconium and niobium, which are often present in trace amounts in ceramic artifacts and therefore can be of use in sourcing pottery. The tests showed that the figurine head contained a small amount of iron, along with trace amounts of copper, strontium and zirconium. Future comparison with spectra obtained from local clay sources may allow researchers to ascertain the original provenience of this artifact.

The copper items were tested using the XRF's yellow filter (0.001" Ti, 0.012" Al) at 40 KeV and 4.5 micro-amps. These settings optimize the instrument to identify metals. All tests were run for either 180 or 300 seconds. The copper axe from Khirbat Ḥamrat Ifdān proved to contain extremely high amounts of copper, with only a trace amount of iron present. No tin or other hardening material was present in the spectra, indicating that this object was most likely not intended as a utilitarian object.

Of the 14 metal objects from Khirbat Faynān, four were copper-colored coins (383/90388). These four coins contained high levels of copper, but also contained significant amounts of lead and very small to trace amounts of both tin and iron. The lead, tin and iron most likely served to harden the metal of the coins, contributing to their preservation. This alloy is also similar to the one used in debased Roman brass coinage of the late 1st and 2nd centuries AD, which replaced zinc with lead and tin (see Kallithrakas-Kontos *et al*. 1993: 267). However, without further analysis and in the absence of a reading from a numismatics expert this can only be regarded as an intriguing speculation.

One of the copper objects recovered from Khirbat Faynān was a bell (298/90288). This object contained extremely high levels of copper, with small amounts of iron and lead, and a trace amount of calcium, suggesting that is local. Five copper objects were in the shape of bracelets. These bracelets all contained extremely high levels of copper, small to very small amounts of iron and very small to trace amounts of manganese and lead. One specimen (127/90117) contained a moderately high level of zinc. This piece was the only bracelet made of a flattened piece of metal; the others were rounded like thick wires. The added zinc may have allowed the metal to be more pliable or stronger in thinner shapes.

Two of the metal objects recovered from Khirbat Faynān were in the shape of pins (539/90529; 398/90388); a third appeared to be either a very large pin or a nail (128/90118). These three objects all contained high levels of copper. The large pin or nail also contained very small amounts of iron and lead. In addition to extremely high copper levels, the two smaller pins contained small amounts of silver and very small to trace levels of iron, lead and bromine. With regard to these objects, areas with higher amounts of silver also contained higher levels of bromine. It is likely that the bromine was either present in the silver ores used by the metalworkers, or it was used somehow in the creation of these metal objects.

The final metal object from the site of Khirbat Faynān was a copper pendant. The pendant contains a female figure in relief (540/90530; see **Fig. 16** above) and was found in association with several small crimped metal clasp-like fragments. Like the small metal pins described above, the pendant and its associated metal fragments contained high levels of copper and moderately high amounts of silver. They also contained very small to trace amounts of iron, lead and bromine. Also like the pins, the bromine levels in the pendant and fragments increased in areas of higher silver content. It is possible that the silver could have been plated over the copper core of the pendant; the silver may have been imported to Faynān.

The testing of these objects with XRF provided a great deal of useful information for identifying the metal and chemical composition of these artifacts. In the future, it may also be useful to compare the spectra obtained through these tests with samples of other ancient metal objects or more modern objects in order to gain a more detailed understanding of their manufacture.

Summary and Future Directions for Chemistry Research

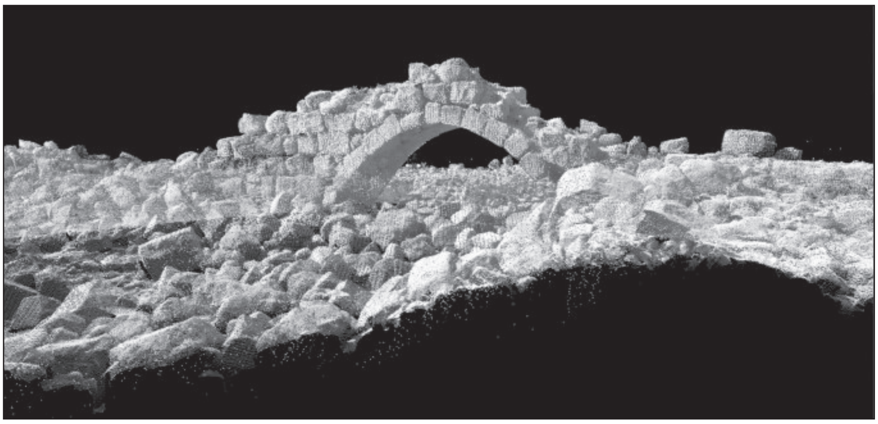
The 2011 addition of the FTIR spectroscope to the ELRAP Digital Chemistry Lab was a major improvement to the lab this season. In conjunction with the XRF spectroscope, the FTIR instrument allowed the research team to collect more detailed data regarding the chemical composition of many different kinds of artifacts, archaeological materials and cultural sediments. The establishment of a searchable spectral library of local and regional geological samples will allow the ELRAP team to develop a more accurate understanding of the local landscape and the ways in which ancient populations interacted with this landscape. In particular, one important undertaking for future seasons should be the expansion of the spectral library; categories such as ceramics, lithics, clays and other materials should be strategically sampled for future comparison. Overall, the combination of X-Ray Florescence and Fourier-Transform Infrared Spectroscopy allowed the ELRAP team to gain a more complete understanding of the chemical properties of many different objects and sediments. These two techniques complement one another very well, because in many areas where one is insufficient, the other is quite useful. There are also many areas in which the use of both techniques is helpful. Nevertheless, there are certain problems - such as the analysis of lithic objects - that will require much more experimentation before serious progress can be made.

Terrestrial Laser Scanning in the Field

The unique ancient landscape of Jordan's Faynān district is a prime candidate for the application of a LiDAR (Light Detection and Ranging) survey as a High Definition Documentation (HDD) tool. The potential threat of modern mining and development puts some of the sites in the region at risk of destruction. However, the main goal of using LiDAR in Faynān is to create a 'digital scaffold' on which many different datasets can be embedded, analyzed and visualized (Petrovic *et al*. 2011). During the 2011 ELRAP field season, nine sites and their surrounding environs were laser scanned with terrestrial LiDAR using a Leica Scanstation 2 (Model HDS 4050). These nine sites include: Khirbat Faynān, Khirbat Nuqayb al-Asaymir, Khirbat Ḥamrat Ifdān, Tallit Ifdān, Umm al-'Amad, Khirbat al-'Irāq, survey site JS001 on Jabal Ṣuffāḥah and survey site JS002 on Jabal Suffāḥah, as well as a digital model of the Calit2 Digital Archaeology Lab in Shawbak. Khirbat Faynān, Khirbat Nuqayb al-Asaymir, Khirbat Ḥamrat Ifdān and Tallit Ifdān are located within the *wadi* systems of the lowlands between Wādī 'Arabah and the Sharāh mountains, while the latter four sites and the digital lab are located in the Edom highlands of the Sharāh mountains. Here we describe the LiDAR work carried out at Khirbat Faynān and the unique ancient Roman mining complex at Umm al-'Amad overlooking the Faynān valley.

Khirbat Faynān

Khirbat Faynān was the primary focus of the 2011 LiDAR survey and the majority of time on the scanning calendar was allotted to this *ca.* 15 hectare site (**Fig. 19**). The site's heavy concentration of architecture and considerable size were significant stumbling blocks in carrying out its successful scanning. In particular, the geomorphological shape of the *tall* and its several plateaus precluded the use of central targets that would have been visible from all areas of the site (hence the pre-season decision to utilize free-station scanning without targets). Unregistered traverse targets were, however, used during daily set-ups to speed up the field



19. Screenshot of 2011 LiDAR scan of the so-called monastery complex at Khirbat Faynān. The date currently rests on a single late 6th century AD inscription found in the building (Sartre 1993).

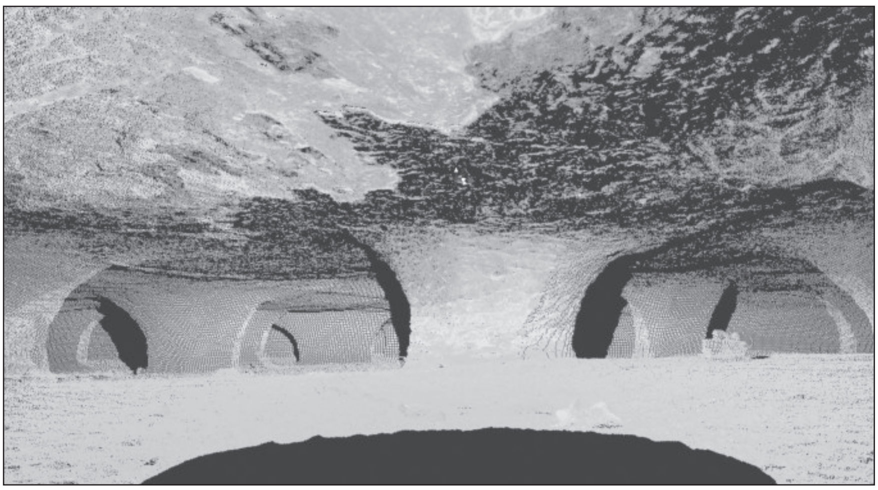
registration of daily point clouds from the data collected. A large-scale, stitched point cloud of approximately four and a half billion points was ultimately created of the 130 scans taken from Khirbat Faynān. Such a large point cloud can only be manipulated in Visicore, the point manipulation software developed as part of an associated ELRAP project with UC San Diego (Petrovic *et al*. 2011). This point cloud dataset will provide the 'data scaffold' needed for future excavation and survey work at KF.

Umm al-'Amad Roman Mining Complex

Umm al-'Amad (Ar. "the mother of pillars") was first recorded by Nelson Glueck in the 1930s (Glueck 1935) and, aside from an occasional wanderer, has had little documentation since. While our team was in the field in 2011, this Roman period site fell under threat from on-going road construction for the possible renewal of mining work in the Faynān district. Thus, Umm al-'Amad was added to the scanning itinerary at the last moment and preparations were made for scanning it with very little consideration of what the site would be like on its scanning day (16 November 2011). The low cavern entrance and interior galleries precluded use of the standard tripod. Likewise, the complex galleries of columns ruled out the use of targets without significant, time-wasting backtracking (**Fig. 20**). Therefore, a specially designed 'quadropod' was utilized for the day and the free-station method of scanning continued to be employed for expediency and efficiency's sake in the field, leading to considerable time spent post-processing the data in the lab. Power for the interior scans of the cave system and one of the exterior scans was provided by portable car batteries. The final scan was completed using a generator positioned two terraces above the caves on the face of the mountain, connected to the scanner via a very long extension cord. Although the mines go into the mountain for approximately 150 meters, given the time constraints of the single day allowed for scanning, only five interior scans were made of the primary galleries and two scans of the exterior. This provided both landscape context and was an attempt to fill in parts of the front of the mine where the roof was too low for the scanner (even on the 'quadropod'). This resulted in approximately 5/8 of the cave being scanned. Scans at Umm al-'Amad were done at 2 x 2 cm resolution on a 10 to 15 meter range, thereby collecting approximately eight million points. This LiDAR scan provides an important record of this unique ancient mining complex - perhaps the largest in the eastern Roman empire (Mattingly 2011: 181).

Conclusion

This preliminary report summarizes a new archaeological research project that focuses on excavations at Khirbat Faynān - the largest settlement site in Jordan's Faynān copper ore resource zone. While our previous (2002 - 2010) research focused on studying the network of Iron Age copper extraction and processing sites (Levy *et al*. 2012), Khirbat Faynān provides a unique opportunity to investigate the social and political center of copper exploitation from the Early Bronze Age to late historic times. The 2011 expedition to KF discovered an important



20. Screenshot of LiDAR scan inside Umm al-'Amad Roman mining complex. Note the crate on the right side of the image for scale. The ceiling in this area is c. 1.8 meters in height.

Early Bronze Age settlement (*ca.* 2,500-2,000 BC), Iron Age remains including a unique anthropomorphic statuette head (*ca.* 1,200-500 BC) and a Roman / Byzantine mortuary complex. New 'cyber-archaeology' methods were employed, including digital acquisition tools such as LiDAR, GPS, geophysical surveys and a special helium balloon automated platform for geo-referenced digital photography. On-site chemical characterization tools including XRF and FTIR were employed for real-time micro-archaeology studies. A survey was conducted in the Buwayridah springs area to the south of Wādī Faynān and ten agricultural terrace systems were sampled for dating and geochemical data. As a prelude to the month-long excavation at KF, small soundings were carried out at the Early Bronze Age copper production site of Khirbat Ḥamrat Ifdān and the mediaeval Islamic period settlement at Khirbat Nuqayb al-Asaymir in order to obtain stratigraphic and dating samples. All of these research activities contribute to the underlying goal of the ELRAP expedition: to study the changing role of ancient mining and metallurgy on the evolution of societies in southern Jordan from Neolithic to Islamic times.

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