A New Chronological Framework for Iron Age Copper Production at Timna (Israel)[1]

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This paper presents the results of the 2009 excavations at Site 30 in the Timna Valley, Israel. The results, coupled with a suite of 11 new radiocarbon dates, fix the chronology of the site between the 11th and 9th centuries B.C.E. *and challenge the previous chronological framework of the copper production activities in the southern Arabah Valley. The paper also presents a striking correlation between Site 30 and the recently reported archaeological record of Iron Age Faynan, indicating technological and social unity between the two regions. In light of the new results and reexamination of previously published materials, we suggest that the peak in copper production in the southern Arabah occurred after the Egyptians had left their small outpost at Timna; this activity was an offshoot of the more elaborate enterprise at Faynan. The well-organized Iron Age copper production in the Arabah Valley was based on local initiatives and conducted by local seminomadic tribes, probably belonging to the Edomite polity.*

INTRODUCTION

The main smelting sites of the southern Arabah (Timna Valley) were considered by early scholars to be a southern counterpart to the archaeological record in the northern Arabah (Faynan), representing the same 10th-century B.C.E. (or more generally Iron Age II) time frame and technologies (e.g., Glueck 1935). It was only later that developments in archaeological research disconnected the two records: in Timna, excavations of the Egyptian sanctuary in the late 1960s implied earlier dates for the main copper production sites (namely, 14th–12th centuries B.C.E.; e.g., Rothenberg 1999, and see below), while in Faynan, British research on the Jordanian southern plateau (e.g., Bienkowski 1992) implied later dates for the main smelting sites in Faynan (namely, 7th–6th centuries B.C.E., with a strong Assyrian influence; see overview in Levy, Najjar, and Higham 2005). Recent work in Faynan completely repudiated

[1] This paper is partially based on the Ph.D. dissertation of Ben-Yosef (2010) and a talk given at the ASOR Annual Meeting in Atlanta in 2010 (Ben-Yosef, Shaar, et al. 2010). The author continued the research leading to the publication of this article while a postdoctoral fellow at the University of California, San Diego in 2010–2011.

the later date there and, based on a comprehensive set of AMS radiocarbon dates, fixed the chronology of the main copper production to the 12th–9th centuries B.C.E. (Levy et al. 2008). In this paper, we present new evidence in support of the contention that the main smelting sites in Timna should be dated to the same time frame represented in Faynan. In addition to a critical overview of the history of research and a scrutiny of previously published data, we provide results from new excavations of one of the major smelting sites in the southern Arabah Valley, Site 30 in Timna. In contrast to the previously applied relative dating method, based on ceramic typology and material culture parallels, we present for the first time absolute dates for the main archaeometallurgical sequence of copper production in the valley. The dates are based on high-precision AMS radiocarbon dating of short-lived organic samples, coupled with high-resolution archaeomagnetic dating of the archaeometallurgical artifacts themselves. We emphasize the significance of applying absolute dating methods in a region with poorly established relative typologies of material culture (see also Ben-Yosef, Tauxe, et al. 2008).

Accurate dating of the different phases of copper production in the southern Arabah is fundamental for any social, historical, or cultural reconstructions. The copper industry of the Arabah Valley was undoubtedly an important economic resource and a trigger to social and political developments. However, the industrial archaeological record stands not only as evidence of potential economic stimulus for sociopolitical processes but also as a mirror for such processes even when those had other triggers (see below). In the Iron Age, this industry was directly related to the development of local polities, such as ancient Edom and neighboring Judah (e.g., Levy et al. 2008). An accurate and high-resolution time framework of the main phase of copper production in the Arabah Valley is thus crucial for understanding the origin and development of local sociopolitical entities in this region and for critically assessing different models of sociopolitical evolution. Models that rely on the previous paradigms of Assyrian/Egyptian hegemonies over the copper enterprises in the northern/southern Arabah, respectively, such as the "core–periphery" model (e.g., Stein 1999), are now challenged by the new data from Faynan (Levy et al. 2008; Levy 2009; Levy, Najjar, and Ben-Yosef in press) and by the new data from Timna presented here.

The core of the new research is the result of a collaborative project of the University of California, San Diego (Department of Anthropology and Scripps Institution of Oceanography) and the Hebrew University of Jerusalem (the Institution of Earth Sciences). The main objective of the project was to clarify the stratigraphy of Site 30 in Timna, to establish an absolute chronology of the site, and to obtain archaeometallurgical samples for technological and magnetic studies. The unexpected results call for a reevaluation of the previously accepted chronological and historical frameworks for the copper production in the southern Arabah.

Iron Age Timna: The Chronological Debate and King Solomon's Mines

Directly relevant to the current research is the debate around the chronology of the major smelting camps in Timna, a debate that took place during the 1960s and 1970s. Nelson Glueck was the first scholar to assign a date to copper production remains, both in Faynan and Timna. Based on ceramic finds and historical considerations, Glueck claimed that the major smelting sites, as well as the remains at Tell el-Kheleifeh, should be dated to the Iron Age II, from the era of King Solomon to the end of the Judaean Monarchy (e.g., Glueck 1940). With the publication of Glueck's research, the concept of "King Solomon's Mines," born in Henry Rider Haggard's legendary book (1885), apparently gained historical and archaeological validity.[2]

Shortly after the Arabah Expedition commenced its investigations at Timna in 1959 (Rothenberg 1988: 1–18), the accepted chronological framework was contested. Y. Aharoni, the expedition's advisor on ceramic typology, claimed that none of the Arabah pottery should be dated later than the 11th century, and most likely dated to the Iron Age I (12th–11th centuries B.C.E.; Aharoni 1962). This new date was reassured after the excavation of Site 2 in 1964 (Rothenberg 1966) but was immediately rejected by Glueck (1967; 1969), who was supported by Albright, the greatest "authority" in biblical archaeology at the time (Glueck 1969: 54, and n. 16) (regarding Albright, see Levy and Freedman 2009).

The major revision in the chronology of the copper smelting sites of Timna happened only after the discovery (1964) and excavations (1969) of the Egyptian sanctuary in the central part of the valley (Rothenberg 1972a; 1972b). The same pottery types found in the

[2] The plot of Haggard's book, *King Solomon's Mines,* takes place in East Africa and has nothing to do with copper mines. It is also important to note that copper exploitation during Solomon's era is not explicitly mentioned in the Hebrew Bible.

smelting sites were reported from the sanctuary and were associated with Egyptian finds and cartouches from the 19th and 20th Dynasties (Seti I–Rameses V). As a consequence of these finds, all of the sites that had hitherto been considered as Iron Age were redated to the period of the Egyptian New Kingdom (Late Bronze–Early Iron Age, 13th century to first half of the 12th century B.C.E.), including the major smelting camps and the vast copper mine fields.[3] Glueck acknowledged the Egyptian finds in the second edition of *The Other Side of the Jordan* (1970: 93–94) but still did not accept that his ceramic dating had been refuted, and insisted that the pottery represented the tenth to sixth centuries B.C.E. (1970: 73). While this was Glueck's last word on the subject, Albright finally accepted the new chronology of the sites (Albright 1971: 4). Thus, after some years of academic debate (see, e.g., Avigad 1963; Yadin 1965; 1966; Wright 1961), the "Solomonic paradigm" for the copper mines of the southern Arabah was entirely replaced by a new "Egyptian paradigm." The major copper production remains in the southern Arabah were now interpreted as another aspect of Late Bronze Age Egyptian control over Canaan and its resources, and the option of Iron Age mining in the region (controlled by local social groups) was completely taken out of the archaeological and biblical scholarly discourse.[4] This stands in contrast even to the reports of the Arabah Expedition itself, in which Layer I at Site 30 was interpreted as an Iron Age II resurgence of copper production in the valley (also here under Egyptian control; see more details below). The debate over the dating of the Iron Age sites in Timna, the confusion and disagreement regarding the date of many other earlier sites (especially Sites 39 and F2; see, e.g., Muhly 1984; Ben-Yosef, Tauxe, et al. 2008; Ben-Yosef, Tauxe, and Levy 2010), and some inherent problems in the dating methodologies and reference typologies of the Arabah Expedition (e.g., Ben-Yosef, Tauxe, and Levy 2010; Avner 2002; Ben-Yosef 2010: chapter 4) probably contributed to the exclusion of Timna from almost any further discussion and research in regard to the Iron Age of the southern Levant. However, the currently accepted chronological scheme for the main phase of copper smelting in Timna creates contradictions and discrepancies in various aspects of the archaeological research in the region, from the chronological context of Qurayyah Painted Ware (QPW) (e.g., Bimson and Tebes 2009) to the pinpointing of the domestication of camels (e.g., Jasmin 2006). The results of the current research solve many of these issues that were the center of debate for decades (see discussion below).

Close scrutiny of the reports of the Arabah Expedition and the results of some later works (e.g., the reinvestigation of Glueck's pottery collection from the southern Arabah and reassurance of his dating: Baron 1978; 1981) already present some challenges to the "Egyptian paradigm" advocated by the expedition itself (see a good summary in Bimson and Tebes 2009). One of the more noticeable difficulties relates to radiocarbon dates published as part of the previous research in Timna.

Previously Published Radiocarbon Dates from Timna

Ben-Yosef, Levy, et al. (2010: 729–30) present a compilation of 21 Late Bronze and Iron Age radiocarbon dates from Timna and the southern Arabah that appeared in previous publications (mostly as footnotes). Even though sample contexts are not always secure, these dates clearly indicate significant Iron Age copper production activities throughout the Iron Age I–IIA sequence, *after* the end of 20th Dynasty Egyptian presence in the region.[5] In addition to the two Iron Age II dates for Site 30 that appear in the compilation (BM1598 and BM1162), another radiocarbon date from the site (probably from Layer II) was recently published by Caroline Grigson (2012: 84) and also indicates Iron Age II activities.[6] Except for the latter, which was based on a camel bone, the previously published dates were obtained from charcoal samples. As we demonstrate below, the "old wood effect" is a significant factor in analyzing charcoal from

[3] It is important to note that in the expedition's publications, from the beginning of the Arabah Project in 1959 until the excavation of the Egyptian Sanctuary in 1969, there was not a single mention of Egyptian finds or of an Egyptian presence in Timna, although a major excavation had taken place at Site 2 (1964).

[4] In Mazar's textbook *The Archaeology of the Land of the Bible 10,000–586 B.C.E.* (1990), Timna is mentioned as part of the Late Bronze Age chapter and briefly in regard to the Iron Age I; Faynan is mentioned only once in the entire book, in regard to the Iron Age I and in a speculative manner. This was the common case in publications regarding the Iron Age southern Levant until recently, when the preliminary results were published from the University of California, San Diego research in Faynan, of which this research is part.

[5] For a broader time frame covering all periods of the history of metallurgy in the southern Levant (including Faynan), see Ben-Yosef, Levy, et al. (2010: 727–30); Avner (2002); Weisgerber (2006: 27); Hunt et al. (2007); and Hauptmann (2007).

[6] The date was obtained from a burned camel phalanx (bone no. cam 1) as part of the Camel Bone Dating Project of Caroline Grigson (OxA2165, 2650 ± 90 B.P., 931–755 B.C.E. [68.2% prob.; OxCal v.4.1, Ramsey 2009; Reimer et al. 2009]).

Timna, and most of the dates are probably older than the activity they are assumed to represent by at least 100 years.

SITE 30 IN TIMNA VALLEY

Previous Research of Site 30

Located in the center of the Timna Valley, Site 30 is one of the largest "smelting camps" in the southern Arabah (Rothenberg 1980) (fig. 1). It extends over ca. 0.5 ha below a small hill, a few hundred meters from the "Egyptian sanctuary," Site 200. The site is surrounded by a semicircular wall with a north-facing gateway approximately in its middle. The southern side of the site is protected by the natural steep slopes of the hill, up which the wall climbs approximately 20 m before it abuts the cliffs. On the top of the hill, a small smelting site (Site 30A) was reported by the Arabah Expedition; it was dated to the Late Bronze Age and associated with the main period of copper production at Site 30 below. Site 34, known as "The Slaves Hill," is located on a flat-top hill about 100 m to the east. Almost all the rich archaeological remains of Site 30 are located within its perimeter wall, except for an extensive thin scatter of broken slag to its north and a series of shallow walls and two mortar-like features to its southwest.

The first to report Site 30, one of the more noticeable smelting sites in the Timna Valley, was John Petherick, who visited the southern Arabah in 1845:

> At Riguel Hadid [Site 4 of the Arabah Expedition = Tell Hara Hadid] and Wadi-il-Muhait [Site 30], on the west side of Wadi Arabah, are two very interesting spots, where copper ores were formerly smelted; the slag still remained, which contained a large proportion of copper. The latter of the two must have been the most considerable smelting locality, judging by the quantity of slag lying there, the whole of which, comprising a large area, is enclosed within a dry-stone wall; the greater number of stones, being lime-stone, were probably brought there as a flux for the reduction of the ores. But from whence those ores, or the fuel with which to smelt them, were derived, or who were the operators, are questions which the Arabs could not answer, nor myself divine. (Petherick 1861)

One of the seven smelting camps in Frank's report on the southern Arabah (1934: 234) is described as a "*brandstatte* surrounded by a semi-circular wall with a diameter of 70–80 m," undoubtedly referring to the remains at Site 30. Interestingly, he noted two distinct types of slag at the site, small and thin (1–2 cm) and large and thick (5–10 cm), an observation that was later confirmed and linked to different technologies (below). In Glueck's report (1935: 42–45), Site 30 is called "Khirbat Meneʾiyyeh II" and is described as follows:

> Inside of the walls are the ruins of houses and furnaces and great black heaps of slag, with numerous pieces of EI I–II pottery strewn about. The nature of this large enclosure, with its thick walls of tumbled masonry, suggests that it too was used as a prison camp [as the Slaves Hill, the Arabah Expedition Site 34, and as the fortress of Khirbat en-Nahas in Faynan], in which the members of the corvée were held to their arduous tasks. (Glueck 1935: 44)

Rothenberg did not accept Glueck's interpretation of the wall (or fence) and has attributed to this feature a defensive function (Rothenberg 1980). There are other ways to interpret the walls, or confining features, which appear also in other archaeometallurgical sites of the Iron Age southern Levant. For example, these could serve to delineate boundaries used to segregate the highly specialized metallurgists from common miners and passersby (see discussion in Ben-Yosef 2010: chapter 9).

Site 30 and its metallurgical remains were thoroughly investigated by the Arabah Expedition. The site was studied during the surveys of 1959 (Rothenberg 1962: 19–20) and 1969 (Rothenberg 1973: 68–71) and was excavated in 1974 and 1976 (Bachmann and Rothenberg 1980; Rothenberg 1980). The bulk of Rothenberg's (1990) discussion of Late Bronze–Iron Age technology was based on the archaeometallurgical finds from the site; and they were used also as the basis for experimental reconstructions of the smelting process (Bamberger and Wincierz 1990; Bamberger et al. 1986; 1988; Merkel 1990). Site 30 has never been published in the format of a "final report"; a general overview and a few ceramic plates from the 1970s excavations are available in Rothenberg (1980), and a description of the technology and the archaeometallurgical material culture is available in Rothenberg (1990).

The wall (Rothenberg calls it a "defense wall") of the site was mapped and measured by the Arabah Expedition; it is about 1 m wide and 1.5–2 m high, with a gateway flanked by two "watchtowers" (the wall was reconstructed as part of the Timna Park development in the 1990s, without carefully marking the original remains) (fig. 2). Between the area of the main archaeological accumulation and the slopes of the hill, a small wadi passes through the site; this is where the

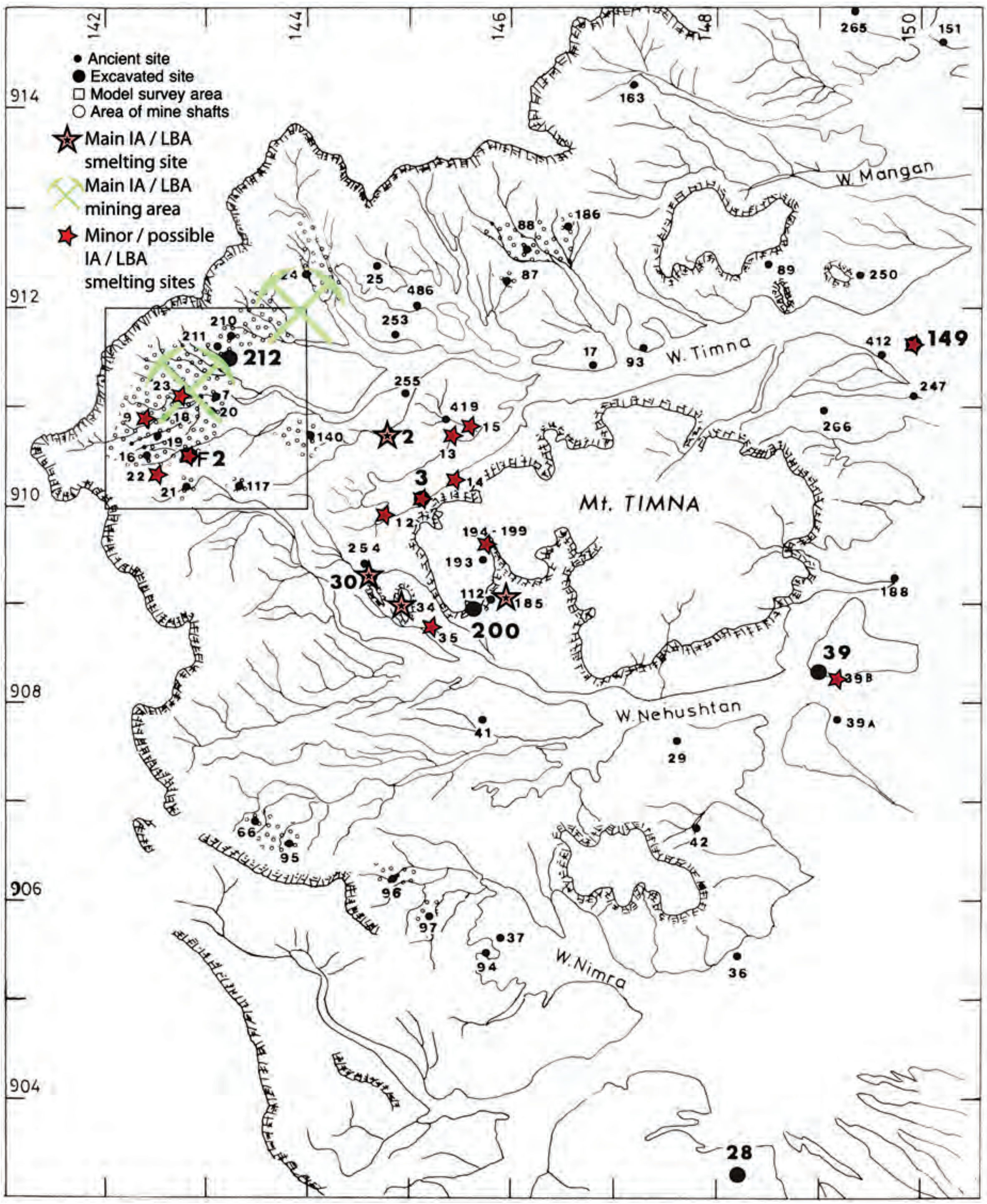


Fig. 1. Sites recorded by the Arabah Expedition in the Timna Valley; Late Bronze Age and Iron Age copper production sites are emphasized (base map from Rothenberg, ed. 1990: 2). For dating provided by the Arabah Expedition, see Rothenberg and Glass (1992); for the late date of Site 39B and Site 149, see Ben-Yosef, Tauxe, et al. (2008); for the late date of Site F2, see Ben-Yosef, Tauxe, and Levy (2010); for a comprehensive list of Late Bronze Age and Iron Age radiocarbon dates from Timna, see Ben-Yosef, Levy, et al. (2010).

Fig. 2. Site 30 in the center of the Timna Valley during the new excavations (April 2009), looking northwest. A prominent "slag mound" is clearly visible close to the center of the site; the stone built fence was partially restored as part of developments of the Timna Park during the 1990s.

excavated earth was disposed of in 1974 and 1976 (and in the recent excavations of 2009) (fig. 3).

The work of the Arabah Expedition at Site 30 included the most extensive excavations conducted so far in any of the archaeometallurgical sites of the southern Arabah. The stated goals of the project at Timna 30 were to clarify the stratigraphy, to establish correlation with the Egyptian sanctuary, and to achieve a large exposure of remains for reconstructing the organization of production at the site. The entire area was divided into a 10 × 10 m grid and excavated mostly along straight transects (fig. 4). Rothenberg (1980: 189–92) describes the challenges in establishing stratigraphy and chronology for Site 30:

> The technological and chronological sequence of a metallurgical site has a very different nature [from ancient settlement sites]: every metallurgical process generates slag, which often accumulates to notable mounds around the smelting area. Each smelting procedure, even as short as a few hours, produces enough material around the smelting area and creates a new working level, on which the varied raw materials and waste products accumulate. This working procedure leads to the fast formation of many thin layers that have very limited chronological meaning. The challenge then is to understand the smelting procedure that appears in the excavation as a colorful, irregular and often very disturbed strip of lines [. . .]. [T]he stratigraphic location of the remains of buildings [in Site 30] was of great importance to the chronology of the metallurgical site [. . .]. By exposing extensive and mutually-dependent plots in which ceramic sherds and other small findings were found adjacent to ruins of buildings, and by their meticulous correlation to the stratigraphically important remains . . . chronological criteria for Site 30 could be formulated. *The correlation of these criteria to the findings of the Mine-*

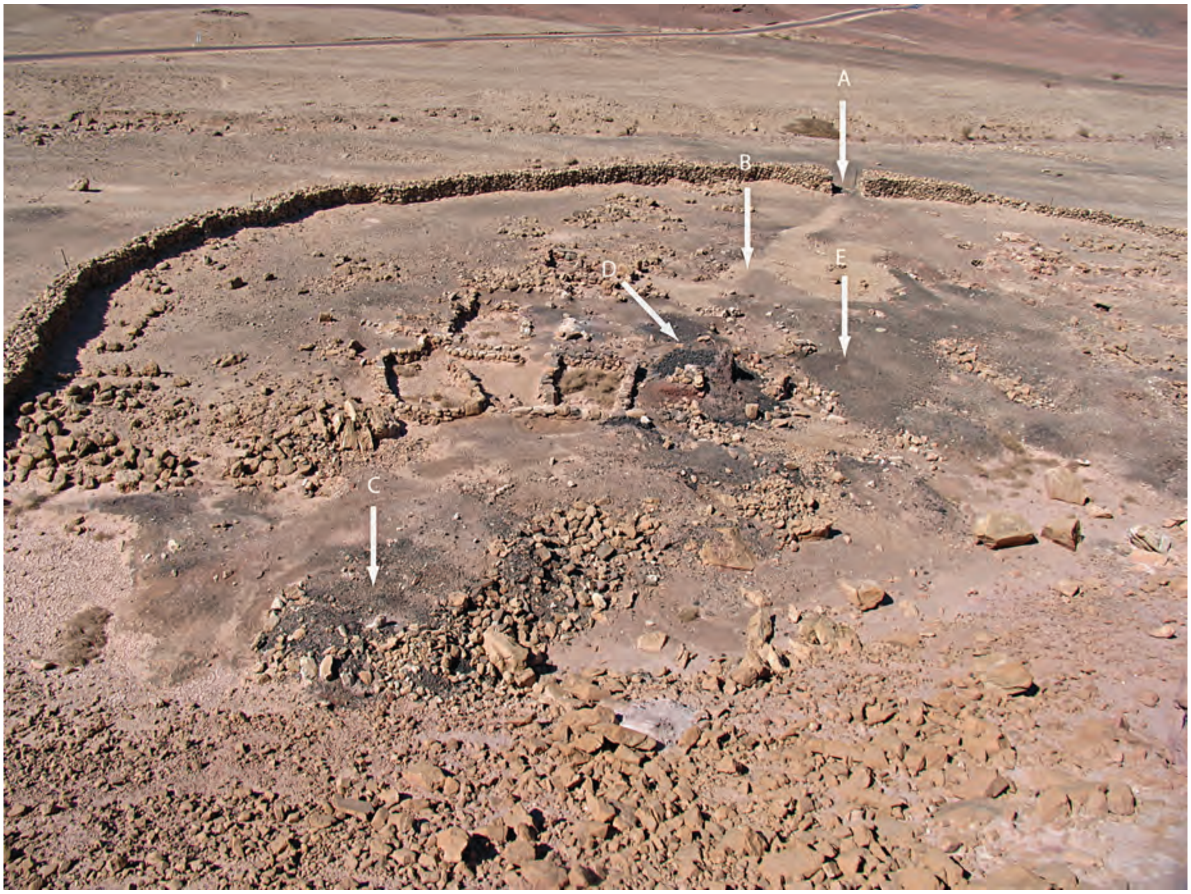


Fig. 3. An overview of the western part of Timna Site 30 before the 2009 excavations (looking north). The site is poorly preserved and is heavily disturbed by unsupervised restoration works. (A) The gateway in the restored fence flanked by two "watchtowers"; (B) a modern path leading from the gateway to the "slag mound" (shown by the bright earth) and backfills of some excavation pits; (C) the location of earth disposal from the excavations of 1974 and 1976; the small wadi is filled with the excavation waste; (D) the central "slag mound" studied in the current research. The eastern face of the mound was exposed in the 1970s and had retreated about 1 m since; the western side (where the edge of the arrow is located) was damaged by unsupervised restoration works; the mass of large black tapping slag seen in the photo were returned to this spot after part of the upper portion of the mound was dug to be used as backfill in the 1990s. The new excavations avoided the disturbed contexts.

> *Temple leads to absolute dating.* (translated from the German by Maayan Shalev; emphasis E.B.-Y.)

The Arabah Expedition distinguished three major layers at the site (table 1; fig. 5), from the 14th century, the mid-12th century, and the 10th–9th centuries B.C.E. The absolute chronology of Site 30 was based almost exclusively on correlation to the findings of Site 200 (the Egyptian sanctuary). This is a crucial point, as later research took the results of this dating methodology at face value, without critical evaluation, despite the evidently poor assemblage of material culture. This methodology was applied to fix the chronology of all other major copper production sites in the region, even when artifactual evidence was meager or almost nonexistent (in the case of the mine fields).

The 2009 Excavations at Site 30

Two major developments in the research of the Wadi Arabah slag deposits triggered the new excavations at Timna Site 30: (1) the recently firmly established Iron Age date of the major copper production sites in Faynan, Jordan (Ben-Yosef, Levy, et al. 2010; Levy et al. 2008), and (2) the discovery of a unique geomagnetic intensity spike recorded in the Iron Age slag deposits of Khirbat en-Nahas (Ben-Yosef et al.

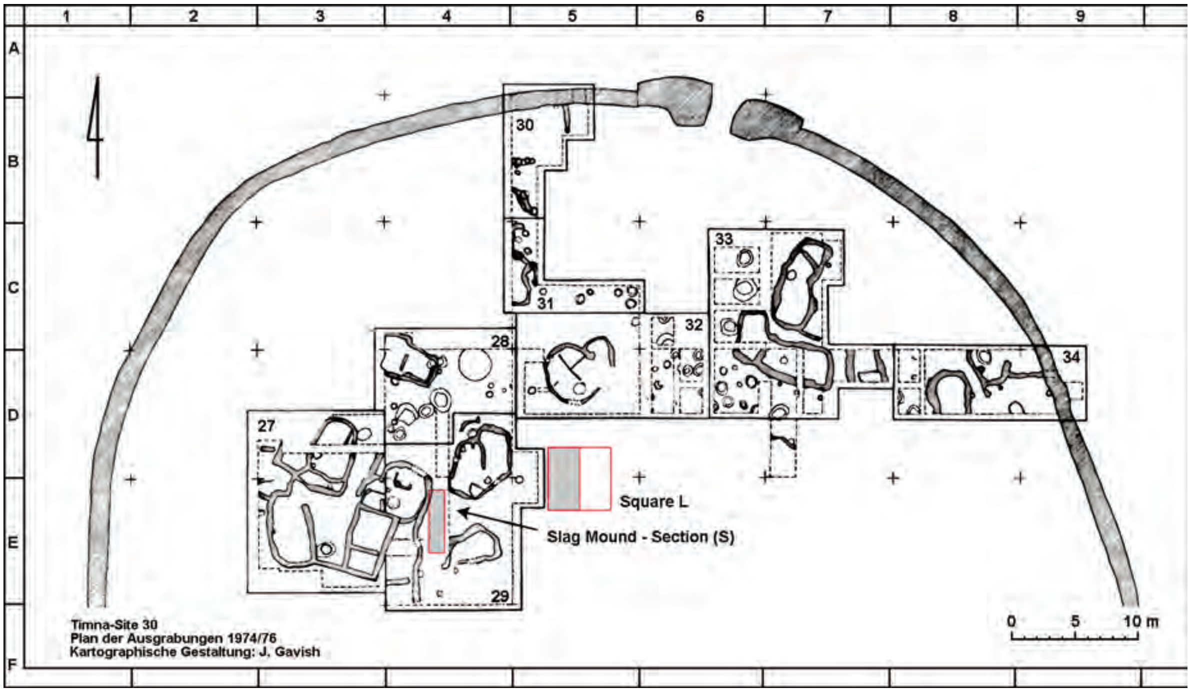


Fig. 4. Plan of Site 30 in Timna showing the original grid of the Arabah Expedition and the plots excavated in 1974 and 1976 (adapted from Conrad and Rothenberg 1980, with the kind permission of J. Gavish). The 2009 project focused on two areas, the sections in the "slag mound" (S) and a metallurgical area (Square L).

TABLE 1. The Stratigraphy of Site 30 in Timna According to the Arabah Expedition

Layer	*Description*	*Date*
I	Represented by a distinct type of tap slag (different in composition and texture from slag of Layers II–III) associated with large tuyères. The slag is concentrated in two mounds (areas E4-West and C5-Southwest). The limited volume of this layer was interpreted as representing little activity, possibly lasting only a few weeks. Most of the structures of Layer II remained intact and some were reused (e.g., Locus 171, where a small chamber was used for storage of manganese ore pieces and smashed pieces of raw copper). No substantial newly built architectural features were attributed to this layer. No complete furnaces or furnace bases were found in situ, but an interesting dome-shaped installation was recorded (L.10) and interpreted as being related to the smelting process. Ceramic finds: Negebite Ware; "22nd Dynasty Egyptian pottery"; no QPW.	22nd Dynasty (Egypt); 10th–8th centuries B.C.E. Represents "a short and rather limited revival of Pharaonic Egyptian activities in Timna" (Rothenberg 1990: 45).
II	The site is surrounded by a semicircular stone wall and is divided into a metallurgical area located around the central "slag mound," and an architectural complex, located mostly in the eastern side of the site, which contained storage pits and small workshops. The metallurgical area includes a sequence of thin layers of metal production debris, a series of relatively broad (1–1.5 m wide) working surfaces, a "typical smelting workshop" (L.50), and a smelting installation (L.219). The latter was reused as a potter workshop (still in Layer II), with two large stone basins (L.194, 163) for clay preparation and a small kiln (L.177). The slag appears in small pieces of thin (2–3 cm) tap slag and chunks of furnace slag with embedded charcoal fragments. The slag represents the typical type of Late Bronze Age smelting site in Timna and is associated with small tuyères and relatively small smelting furnaces. Ceramic finds: Negebite Ware, QPW, Egyptian pottery, and "normal" ware (local Late Bronze Age) were identified.	13th to mid-12th century B.C.E., the main phase of copper production in Timna Valley.
III	A thin layer (a few centimeters thick) with small slag fragments, charcoal, and pieces of burned clay, representing an open metal production area without any architecture (possibly a few storage pits), and extending beyond the wall (Layer II) mostly to the north. Ceramic finds: Negebite Ware, QPW, "normal" ware (local Late Bronze Age), and Egyptian red-polished based on Nile clay. The latter was found only in this context and not in the Egyptian sanctuary, and is the basis for dating (Rothenberg 1980: pl. 211.3, 12, 13).	14th century B.C.E., Egyptian New Kingdom, *before* the construction of the Egyptian sanctuary (Seti I).

Source: Rothenberg 1980; 1990; Bachmann and Rothenberg 1980; cf. fig. 5.

Fig. 5. The section in the main "slag mound" at the end of the 1976 excavations at Site 30. The three main layers are indicated on the original photograph (from Rothenberg 1980: 197, fig. 214; photograph reproduced with kind permission of the author).

2009). In order to investigate the regional system of copper production in the Iron Age and to obtain further documentation of the geomagnetic spike, we looked at the evidence from Timna, the other main copper ore district in the Arabah. The only context that has been previously reported as having Iron Age II metallurgical remains in the entire southern Arabah region is Layer I at Site 30 (see above). For this reason, we planned a short field season at the site designed to answer specific questions, mostly regarding chronology and metallurgical technology. As the site had already been thoroughly investigated by the Arabah Expedition, our main goal was to contextualize the previous research in light of a better established chronological framework, based on high-precision radiocarbon dates. In addition to the archaeological/anthropological questions, we investigated the magnetic properties of slag from the site (Shaar et al. 2010) and conducted a comparative archaeointensity study on slag from the main section. The latter study, in addition to producing another independent record of the unique geomagnetic spikes (Shaar et al. 2011), facilitated the correlation of archaeometallurgical deposits at Site 30 to those recently excavated at Khirbat en-Nahas in Faynan (below).

Fig. 6. The new excavations at Timna 30 (2009), looking north: Area S (central shade), Area L (right shade), and the location of sieving and dumping of excavated earth.

The excavations took place April 9–17, 2009,[7] and focused on two areas, a section in the main "slag mound" of the site (Area S) and a probe in metallurgical deposits (Area L) (fig. 4). We found the site in badly disturbed condition, the result of both unprofessional restoration attempts and the intensive work of the Arabah Expedition. The previous excavations at the site left behind open trenches as well as unmarked dumps of excavated earth that needed to be sorted out before we could determine where to situate our new probes. These dumps are located mostly in the small wadi at the southern portion of the site, and this is also where the 2009 excavated materials were discarded (fig. 6). We restored the old grid of the Arabah Expedition as a reference for our measurements, including the relative elevation used in the previously published reports. In Area L, the exact positions of loci boundaries and findspots of most of the artifacts were recorded with a Total Station (slag, ore, and charcoal for species identification were sometimes collected as part of general baskets). The bulk of the excavated sediments was sieved in a 2 × 2 cm screen, and sediment samples were collected for further analysis in the laboratory. The section (Area S) and all of the artifacts collected directly from it were recorded by a vertical grid (50 × 30 cm) and precise drawing on a millimetric graph paper (fig. 7). The artifacts are currently stored at the Institute of Earth Sciences and the Conservation Laboratory of the Institute of Archaeology, both in the Hebrew University of Jerusalem.

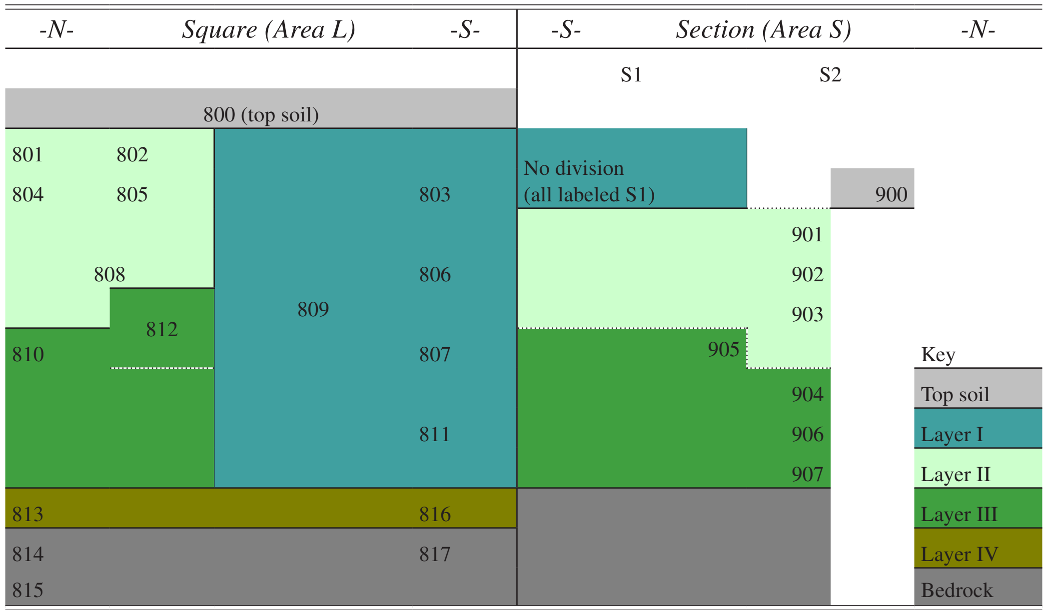
Results of Excavations at Area L. The half (5 × 5 m) excavation square is located ca. 5 m east of the "slag mound" (Area S). The surface of the square was covered with small broken fragments of slag with a few large rocks (fig. 8); most were found to be "floating"

[7] The new project at Timna Site 30 was initiated by a multidisciplinary team and had a twofold goal, archaeological/anthropological and geophysical. It was directed by Erez Ben-Yosef (license # G-38/2009), with the help of Ron Shaar from the Institute of Earth Sciences at the Hebrew University of Jerusalem.

Fig. 7. Working on the section of the main "slag mound" in Site 30 (Area S).

Fig. 8. Before the 2009 excavations, Area L was one of the few undisturbed contexts left at Site 30. The surface is made of small fragments of broken tap slag (of the "Type B" discussed in the text) and a few large stones, representing artifacts of Layer II redeposited on top of aeolian dust and fine soil as a "desert pavement." This is the typical appearance of slag in sites considered to be Late Bronze Age in the southern Arabah.

TABLE 2. HARRIS MATRIX OF THE 2009 EXCAVATIONS AT TIMNA AREAS L AND S



Notes: For the concept of the Harris matrix, see Harris (1977). The correlation between Areas L and S is tentative and based on field observations and ^{14}C dates (see text). Note that in Area L, Locus 809 and the loci to the south of it are intrusive; Loci 810 and 812 are relatively thin activity surfaces in Area L, but metallurgical debris in the area of the section resulted in a considerably thicker accumulation.

on a layer of ashy dust and silt. The metallurgical deposits were excavated from surface to bedrock. Seventeen loci were defined, and four major layers were recognized (tables 2, 3). The entire accumulation of metallurgical debris in this area is no more than 1.25 m, representing a complex stratigraphic deposition. The archaeological layers are described in the following, from the oldest to the youngest.

The lowermost archaeological deposit, Layer IV, was exposed in very limited areas and is represented by Locus 813 in the north of the square (fig. 9) and Locus 816 in the south of it. This archaeological layer is located below the hard activity surface of Layer III, which was first thought to represent the top of the bedrock. Only limited probing conducted to check the characteristics of the presumed "bedrock" revealed a distinct deposit of artifacts in a mix of gravel and sand. The finds from Layer IV are scarce but include firm evidence of copper smelting activities, probably in the close vicinity of this location: tiny fragments of slag and charcoal (up to 1–2 cm in diameter) were found, in addition to a few fragments of ore. The layer is about 35 cm thick, more or less evenly distributed across the excavation unit; it is situated on top of virgin gravel/wadi-terrace (the small fragments of ore in L.814 and L.815 are part of the natural sediments in this area). Layer IV represents redeposition of limited smelting/slag processing debris from the earliest phase of occupation of Site 30 (or its immediate surroundings); it is not likely that artifacts infiltrated from the upper layers, as the contact is firmly sealed and the slag fragments are considerably different in appearance. Layer IV of the 2009 excavations is not reported in the publications of the Arabah Expedition.[8]

Layer III is represented in Area L by a distinct activity surface (L.810) of very compact earth, with clear

[8] Based on its stratigraphic location and the appearance of slag, we first assumed that Layer IV represented a much older phase of copper production, possibly corresponding to one of the two early radiocarbon dates previously published for the site: a Middle/early Late Bronze Age date (HAM216: 3340 ± 60 B.P., 1689–1531 B.C.E.; 69.2% prob.; OxCal v.4.1, Ramsey 2009; Reimer et al. 2009, Layer I, charcoal) and an Early Bronze Age (HAM 215: 4020 ± 100 B.P., 2856–2409 B.C.E.; OxCal v.4.1, Ramsey 2009; Reimer et al. 2009); both dates appear in Scharpenseel, Pietig, and Schiffmann (1976: 287). The context of the Early Bronze Age date is not clear; in Scharpenseel, Pietig, and Schiffmann (1976: 287), it is reported as "charcoal, mining site, slag pile, Cut 25, Layer 2," with no direct reference to Site 30 (but cf. radiocarbon table in Avner 2002). In any case, the results of our new radiocarbon measurements preclude a pre-Iron Age date of this layer (see below).

TABLE 3. LOCUS LIST OF AREAS L AND S OF THE 2009 EXCAVATIONS AT TIMNA 30

Locus	*Top (m)**	*Bottom (m)**	*Description*
Area L – Excavations in metallurgical deposits			
800	0.85	0.64	Top soil of square L; locus bottom quite arbitrary, by elevation and because of sloping surface (sloping toward the southeastern corner of excavation square); ingot mold came from this context
801	0.65	0.52	Northern locus of Square L; darker soil, blackish sediments; part of the "slag mound" debris
802	0.66	0.51	Middle of the square; contains thin layers of fine bright dirt (the other two adjacent loci contain slag and charcoal)
803	0.65	0.49	Southern part of the excavation square; metallurgical debris
804	0.48	0.33	Northern locus in Square L; dark earth with many slag fragments, homogeneous material in the "slag mound"
805	0.50	0.33	Part of the "slag mound," metallurgical debris; dark layer with charcoals and slag material; similar to Locus 804
806	0.45	0.30	Top material from the inside of the installation defined by Locus 809; contains burned stones (collapse of 809?)
807	0.42	-0.20	Yellowish sediments (loess, fine dust), not clean; fragments of slag and other materials (part of installation defined by wall 809?)
808	0.34	0.10	"Slag mound" material, debris of copper production (blackish, plenty of loose slag fragments); in the middle part, there is a cemented patch of red clay (this patch is a substantial feature that probably correlates with Locus 818 in the southeastern part of the excavation square; thus, the red clay is older than the structure/wall 809 and younger than most of Loci 808 and 800 (and the ones in-between). See photos of eastern section of excavation square for some problems—namely, the red soil is much more cemented than the slaggish layer above it, and contains dark red clay, slag, and charcoals
809	0.55	?	Wall collapse; line of stones marking clear separation of loci; made of irregular stones and "slag cakes"; part of small structure / pit; mostly sandstones, some of which went through heating trauma
810	0.135	0.00	Was first defined as "bedrock" and Locus 812 as "charcoal and fire remains on bedrock" (hearth); later on, Locus 813 proved to contain remains of smelting activity (small chunks of slag); see relevant description
811	-0.20	-0.19	Bottom of the deposits inside the intrusive installation defined by stone feature Locus 809
812	0.18	0.13	Shallow rounded pit, burned layer of a hearth / firing place (50–70 cm in diameter) that is located on the top of Locus 810; this surface is a well-defined occupation / activity area; the pit contained charcoals (collected separately)
813	0.00	-0.34	Gravel, course sand, mixed with brown soil, small fragments of charcoals, and tiny pieces of slag
814	-0.34	-0.13	Bedrock (wadi terrace, gravel)
815	-0.13	-0.40	Bedrock (wadi terrace, gravel)
816	-0.01	-0.35	Similar to Locus 813 (coarse sand, brown soil and charcoals, but in the southern part of excavation square)
817	-0.27	-0.54	Lowermost part in the "installation" area
Area S – Section in the "slag mound"			
900	0.72	0.03	Top of fill on east side of Area S (section collapse)
902	1.04	0.94	Loci within section and corresponding materials in the collapse
903	0.94	0.80	
904	0.65	0.40	
905	0.68	0.64	Installation: storage pit of crushed ore
906	?	?	
907	?	?	
other	2.10		Top of slag mound (highest point in site)

* Elevation is in relative measurements and in accordance with the system used by the Arabah Expedition (cf. table 2).

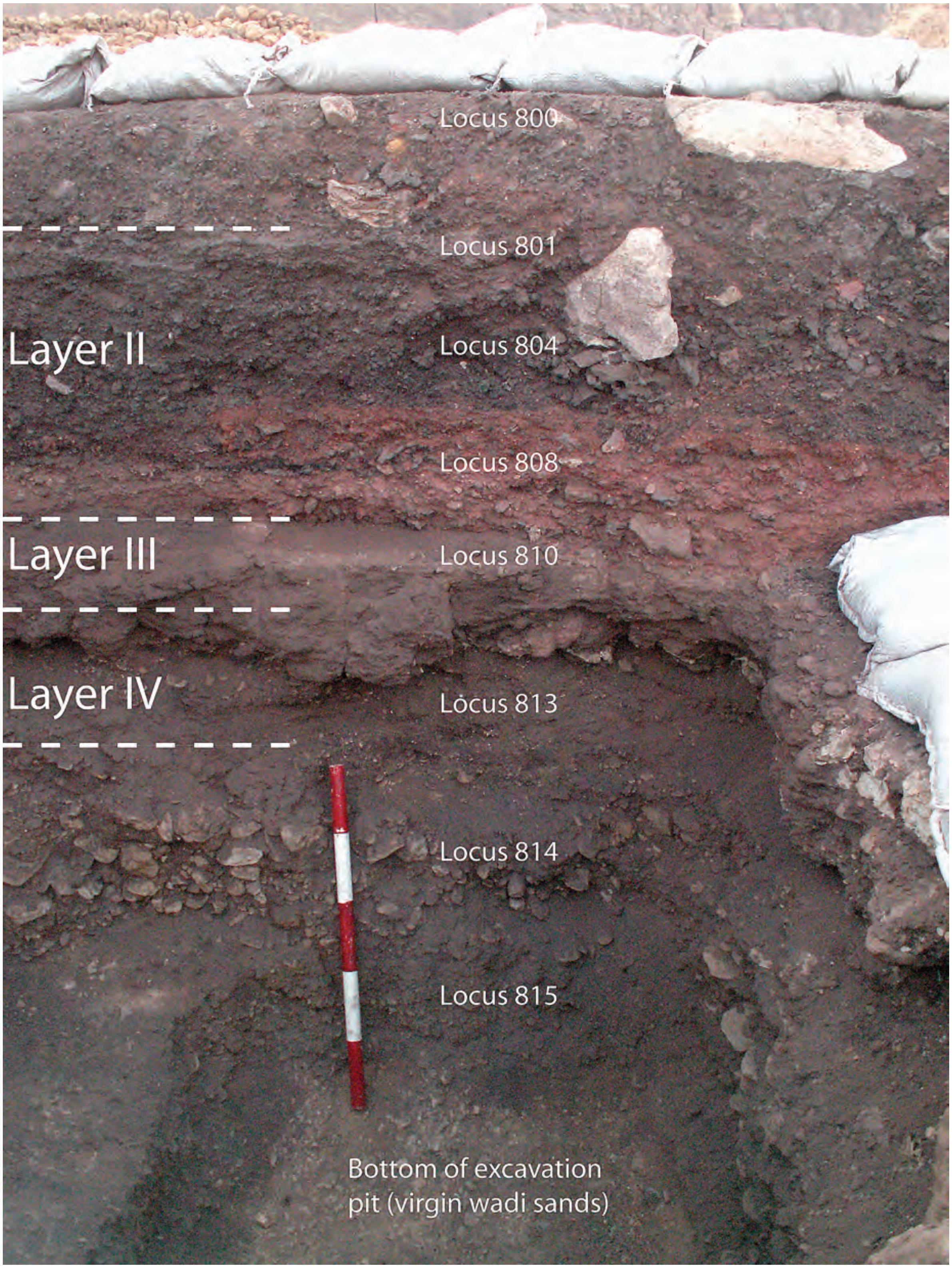


Fig. 9. Photograph of the north side of the eastern wall of the excavation square in Area L, Site 30, indicating excavated loci and layers. Layer I is presented only in the intrusive installation in the southern side of the square.

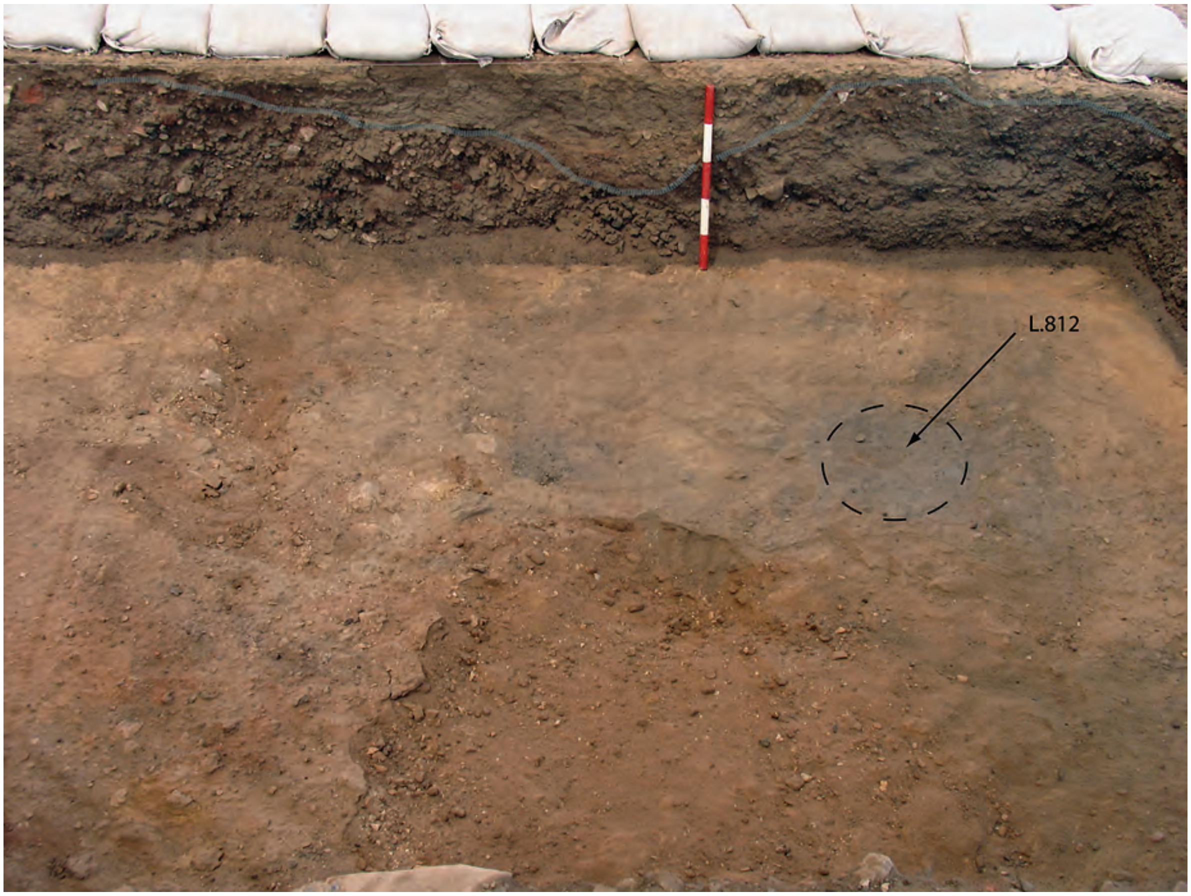


Fig. 10. The activity horizon of Layer III in Area L, and the location of the dated hearth (L.812, sample EDM 261; see table 4). The compact earth surface was assumed to be the top of the bedrock, but probing below it revealed additional archaeological deposits (Layer IV). The original heaps of copper production debris of Layer II are visible in the western wall of the excavation square (marked with a gray line).

marks of a hearth located in the northern side of the square (L.812; fig. 10). The finds from this layer were scarce; some were probably confused with the metallurgical debris of Layer II loci above. Layer III of the 2009 excavations should be correlated with Layer III of the Arabah Expedition by its stratigraphic location (right below the characteristic thick accumulation of Layer II) and by its distinct appearance as a thin horizon of limited activity (see table 1).

Layer II is a rich accumulation of copper production debris (fig. 9), probably deliberately dumped in this location. The layout of the deposit as heaps, or small "mounds" of production waste, is visible on the walls of the excavation square (fig. 10). We did not find any in situ installations, but many fragments of tuyères, charcoals, slag, and ore were collected. No large fragments of furnaces were found, and the identifiable fragments of furnace clay were surprisingly scarce. A patch of red clay mixed with stones, slag pieces, and small artifacts (fig. 9, part of L.808) is located right on top of the surface of Layer III in the eastern part of the excavated square. The clay might represent decomposed furnace fragments dumped in this location, although it is also possible that such clay piles had been gathered near the smelting areas and were prepared for use (or reuse) in the construction of smelting installations. Similar to the "slag mound" of Area S, the preservation of organic material in Layer II was extraordinary. Long uncharred branches of acacia, as well as several twigs, were uncovered, reinforcing the possibility that wood, and not only charcoals, were used in the smelting process. Ground stones of several types mostly related to crushing activities were also present, along with several large pieces of bones. Camel bones were reported from this context by the Arabah Expedition (Caroline Grigson, personal communication

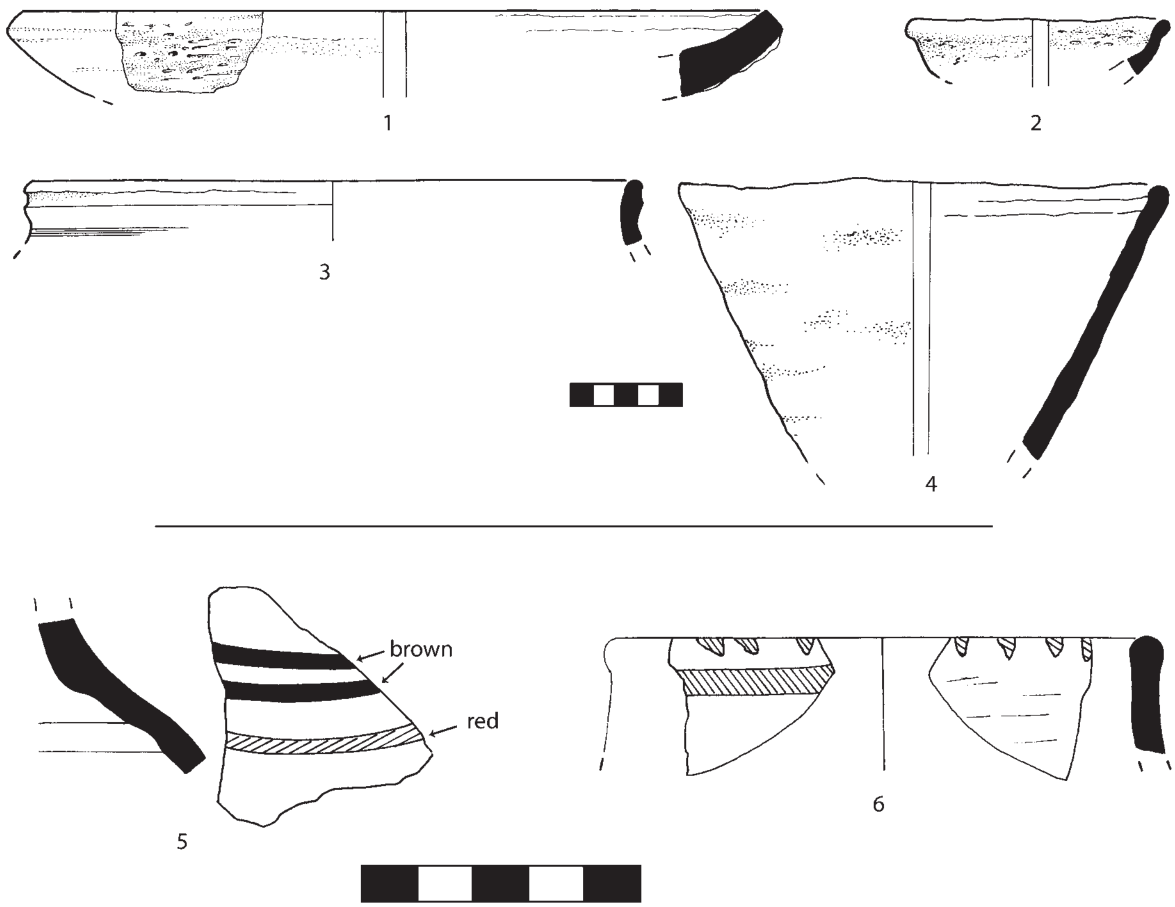


Fig. 11. Ceramic plate showing *all* of the identifiable sherds found in the 2009 excavations at Timna Site 30: (1) L.802, B.1107, bowl, Negebite Ware; (2) L.808, B.156, bowl, Negebite Ware (?); (3) L.803, B.155 (cooking pot?); (4) L.804, B.1107, bowl; (5) EDM 188b, L.808 (cf. Rothenberg 1988: pl. 8.2), QPW; see also fig. 12:B; (6) EDM s-1-pF10, uppermost horizon of Layer II, QPW; see also fig. 12:A.

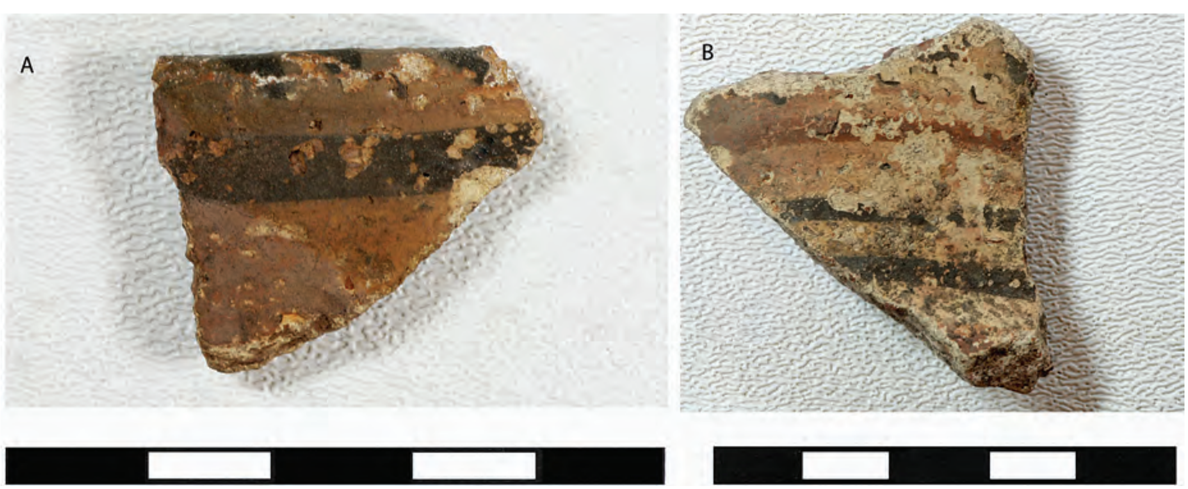


Fig. 12. Two sherds of QPW ("Midianite pottery") found during the new excavations of Site 30 in Timna. Both came from well-dated contexts (cf. fig. 11). (A) EDM s-1-pF10, uppermost horizon of Layer II (for location, see fig. 18); (B) EDM 188b, L.808 (cf. Rothenberg 1988: pl. 8.2).

Fig. 13. Large fragments of copper ore from Layer II (top) and a shell from the Red Sea (bottom) (EDM 129, L.801, B.173).

2009; see also Jasmin 2006)[9] and were considered to represent one of the earliest records of domesticated camels in the ancient Near East. However, the new dates presented here put these samples a few centuries later than their previously assigned 13th-century B.C.E. date (see discussion below).

Layer II is the context of most of the scarce ceramic finds of the new excavations. A total of three rims and a few body sherds were recorded (fig. 11), a very limited amount even considering the relatively small size of the excavation. In the middle of the metallurgical dump of Layer II, we found a sherd of Qurayyah Painted Ware (EDM 188b, Locus 808; figs. 11:5, 12:B). Other small finds include a fragment of a Red Sea shell and ore chunks (fig. 13). Layer II of the 2009 excavations correlates with Layer II of the Arabah Expedition, with similar iron-rich slag and the same characteristics of the various metallurgical finds. The excavated area is related to smelting workshops and does not include any storage pits or stone structures recorded for this layer elsewhere in the site by the Arabah Expedition (table 1).

Layer I in Area L is represented by an intrusive installation dug into the metallurgical waste of Layer II and the activity horizon of Layer III (fig. 14). The installation is defined by a semicircular wall (L.809), made out of local stones (mostly sandstones) and large plates of tap slag, of the type that appears only in the latest phase of copper production at Site 30. The bulk of the excavated material from inside the installation was ashy bright sediments with a thin layer of fine crushed ore in the middle. Although there were fragments of smelting-related artifacts in the sediments (slag, tuyère, charcoal), the installation is not a furnace but a defined multipurpose working area dug into the ground. Layer I of the 2009 excavations presents the most advanced copper production technology at the site and correlates with Layer I of the Arabah Expedition.

Results of Excavations at Area S. The excavations in Area S, located in the central "slag mound" excavated by the Arabah Expedition (figs. 3–5), aimed at cleaning the previously exposed section that supposedly included the entire sequence of metal production at the site. After cleaning the collapsed and weathered materials, we found that in the 31 years that had elapsed since the slag mound was excavated, the face of the exposed section had retreated almost a meter (fig. 15). The collapsed materials included a relatively large fragment of a unique clay mold, used for casting a small copper ingot (fig. 16). The fragile clay fragment probably originated from Layer II and is one of the few clay molds recognized in the copper smelting sites of the Arabah. The technological, cultural, and other aspects of this artifact are discussed in detail in Ben-Yosef (2012) (cf. Rothenberg 1990 for other clay molds from Site 30).

After the section was cleaned (figs. 7, 17), 10 different horizons (or thin layers) of metallurgical debris were distinguished (numbered 0–9 from top to bottom; fig. 18). The total height of the exposed section, from the top of the mound to bedrock, was ca. 1.5 m. For convenience of recording and because of the disturbance caused by installation L.905, the section was divided into two parts, S-2 in the south, which includes only Horizon 0 and represents the topmost part of the entire "slag mound," and S-1 in the north, which includes Horizons 1–9. The metallurgical debris contained mostly slag fragments, usually small broken

[9] The camel bones from Site 30 were first identified by Hannan Lernau and further investigated by M. Jasmin (2006) and Caroline Grigson (personal communication 2009, 2011).

Fig. 14. Area L at the end of the 2009 excavations, looking north. Note the probe into the hard surface of Layer II in the north end and the intrusive installation of Layer I at the southeastern end of the square. The wall of this installation (L.809) is made of local stones and slabs of tap slag.

pieces of tap and furnace slag, with the exception of larger slabs in the highest horizon only (0, Section S-2). The slag pieces are mixed with tuyère and furnace fragments, abundant charcoals (many of which are embedded in the furnace slag), ashy and clayey sediments, and some ore pieces.

The "slag mound" of Area S provides the best evidence for the stratigraphic and chronological context of the two distinct types of slag from Site 30. The visual differences between the slag types were noticed early on by Frank (see above), and the chemical and mineralogical differences were studied by Bachmann and Rothenberg (Bachmann 1980; Bachmann and Rothenberg 1980; Rothenberg 1990), and recently by Ben-Yosef and Levy (in press). The differences in magnetic properties between the two types of slag were studied by Ben-Yosef, Ron, et al. (2008) and in more detail by Shaar et al. (2010). The basic differences between the two types are their appearance and their chemical composition. One type ("Type A") consists of relatively large fragments (or slab) of Mn-rich slag, sometimes more than 20 cm in diameter; the other ("Type B") consists of small fragments of Fe-rich slag (cf. fig. 8); both are the result of tapping technology, and each corresponds to a distinct stratigraphic context. Type A, the Mn-rich slag, is present only in Layer I (in Area S only in Section S-2, Horizon 0) and represents the latest phase of copper production at the site, while the small Fe-rich fragments of Type B slag are found in Layers II and III. The two types of slag represent substantially different technologies. A major and sharp technological change occurred in the transition between Layers II and III, as the smelting process became more advanced and efficient. This change is also evident in corresponding furnace types and related metallurgical artifacts, in particular the design and manufacturing procedure of tuyères (cf. Rothenberg 1990).

The metallurgical horizons in Area S are separated by thin layers of extremely rich and well-preserved

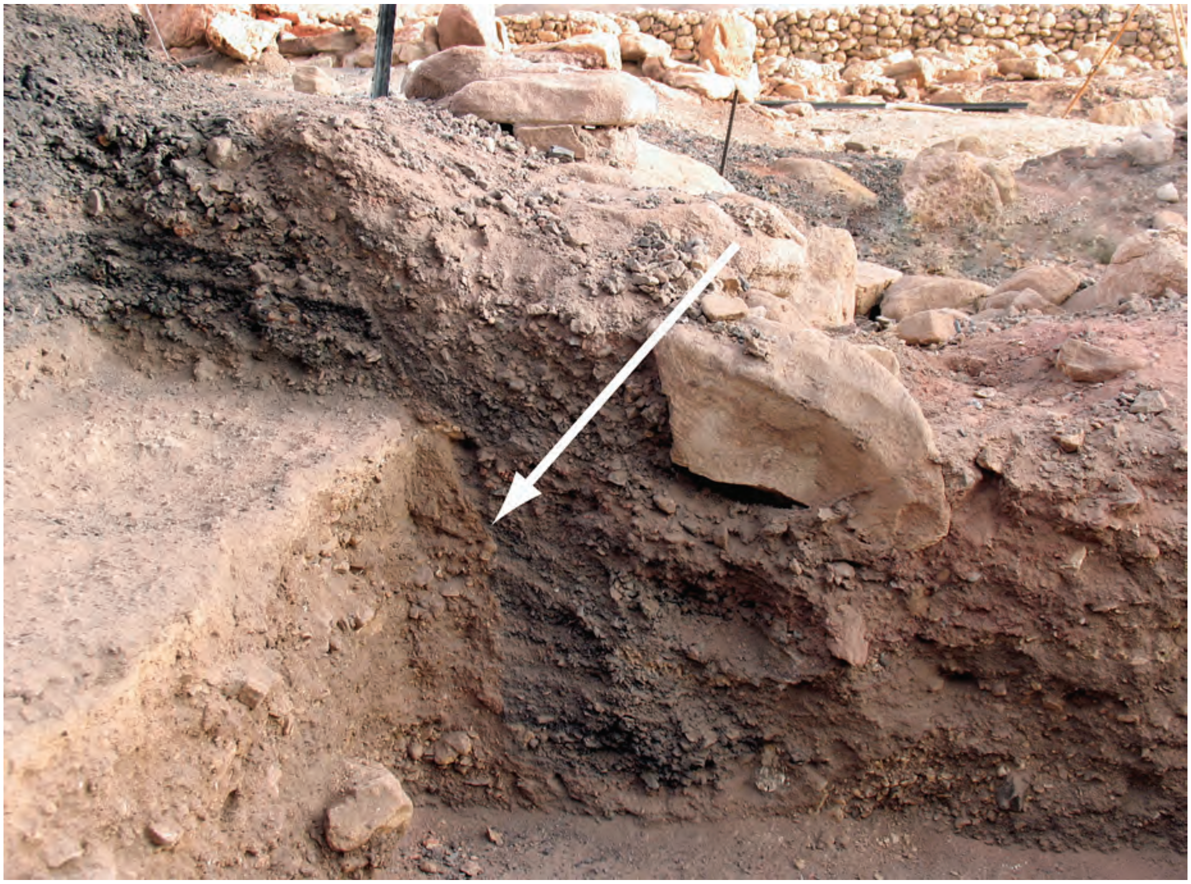


Fig. 15. A perpendicular view to the main section in the "slag mound" of Timna 30, Area S (looking north). The sharp vertical contact (indicated by an arrow) represents the location of the original (1970s) face of the section.

organic materials (figs. 18, 19), including small pieces of cloth, ropes, and other textiles, as well as hide, various types of uncharred seeds (olive pits, grape and date seeds, barley [?], pistachio, and more), and wood, including small twigs of acacia trees. A similar inventory of organic materials, including the same variety of seeds, was reported from Site 200, the "Egyptian sanctuary" (Rothenberg 1988, in particular pls. 131–33). The short-lived seed samples were used for the new AMS radiocarbon dating of the "slag mound" (below). Some of the textile and/or hide pieces probably came from activities related to copper production, including the preparation and use of tuyères that still bear textile imprints (Ben-Yosef and Levy in press).

The general stratigraphic division of the "slag mound" into three distinct layers published by the Arabah Expedition (fig. 5; table 1) includes the somewhat arbitrary boundary between Layers III and II. In the section, which indeed represents Layers III–I (but not Layer IV, which was defined only in Area L of the new excavations), the lowermost metallurgical horizons and associated installations show no significant differences from the horizons above them (fig. 18), presenting similar ceramic and metallurgical finds. Thus, we defined Layer III in this location as the lowest archaeological horizon. We suggest regarding this layer as the first episode of sequential, possibly seasonal, activity at the site, mostly represented by the interchanging metallurgical and organic-rich horizons comprising Layer II. It is important to note that the Arabah Expedition likewise found no significant differences between Layers III and II at Site 30.

Layer III in Area S includes a stone-built round installation, situated immediately on bedrock (L.905; fig. 20). On the inner side of the one-course wall that defines the installation, there was a thick accumulation of fine crushed copper ore, probably stored as preparation for smelting. If so, it might represent the typical size of ore grains (a few millimeters or less) used in

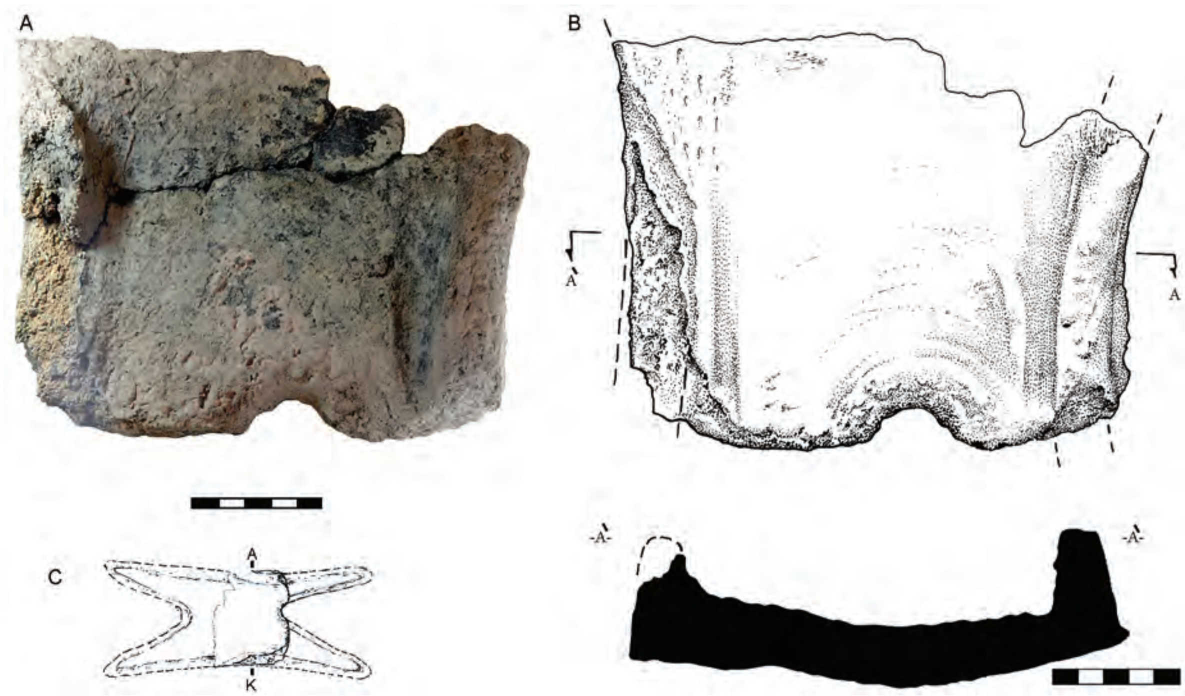


Fig. 16. A photograph (A), drawing (B), and suggested reconstruction (C) of a clay ingot mold from Site 30, Area S (see detailed discussion in Ben-Yosef 2012).

the Iron Age smelting process in the Arabah.[10] The ore of Locus 905 is associated with quartz and originated from the sandstone deposits (Amir/Evrona geological formations).

The ceramic finds from Area S are few, mostly unidentifiable small body sherds. A fragment of Qurayyah Painted Ware (figs. 11:6, 12:A; and see fig. 18 for location) and a base of a Negebite Ware vessel with textile imprints (fig. 21) were found in well-dated contexts in the section.

New Radiocarbon Dates from Site 30

The radiocarbon dates obtained previous to the current research (Ben-Yosef, Levy, et al. 2010: 729–30, and the additional date discussed above) indicated substantial Iron Age occupation of Site 30, with not a single date corresponding to the 19th or 20th Egyptian Dynasty. Eleven new radiocarbon samples from well-controlled contexts were processed as part of the current research, and the results provide an absolute chronology for the entire archaeological sequence of the site (table 4). Eight samples were obtained directly from the section of Area S ("slag mound") and three from the excavation at Area L. All of the samples were analyzed in the NSF AMS laboratory at the University of Arizona and calibrated by OxCal. 4.1.6 (Ramsey 2009; Reimer et al. 2009).

Area S represents the entire stratigraphic sequence of Site 30 as defined by the Arabah Expedition.[11] For Bayesian modeling (Ramsey 2009) of dates from this area (fig. 22; table 4), we used only the short-lived samples to avoid the possible "old wood effect," while the additional three charcoal samples provided further constraints and evaluation of this effect on charcoal

[10] The typical grain size of smelting mixtures was reconstructed mostly by experimental archaeology and is usually not based on direct archaeological evidence. The fine crushed ore in installation Locus 905 might represent a typical size of ore prepared for smelting; it is not likely to represent post-depositional processes because of its location in a distinct storage-related context; other finds of intact large ore fragments supposedly exposed to the same post-depositional environment support this interpretation.

[11] Although stratigraphic observations in metallurgical deposits have been criticized (and even dismissed) recently (e.g., Finkelstein and Piasetzky 2008; Finkelstein and Singer-Avitz 2009), the radiocarbon dates, archaeomagnetic data, and material culture (technological) typologies all correlate well with field observations and strongly confirm (fine) superposition in "slag mounds" (e.g., Higham et al. 2005; Ben-Yosef, Levy, et al. 2010; Ben-Yosef et al. 2009; Ben-Yosef, Ron, et al. 2008; Levy et al. 2005; Levy, Najjar, and Higham 2005). Thus, when careful attention is paid to the three-dimensional complexity of "slag mounds," layers exposed in excavations of such deposits can be interpreted as representing consecutive time intervals.

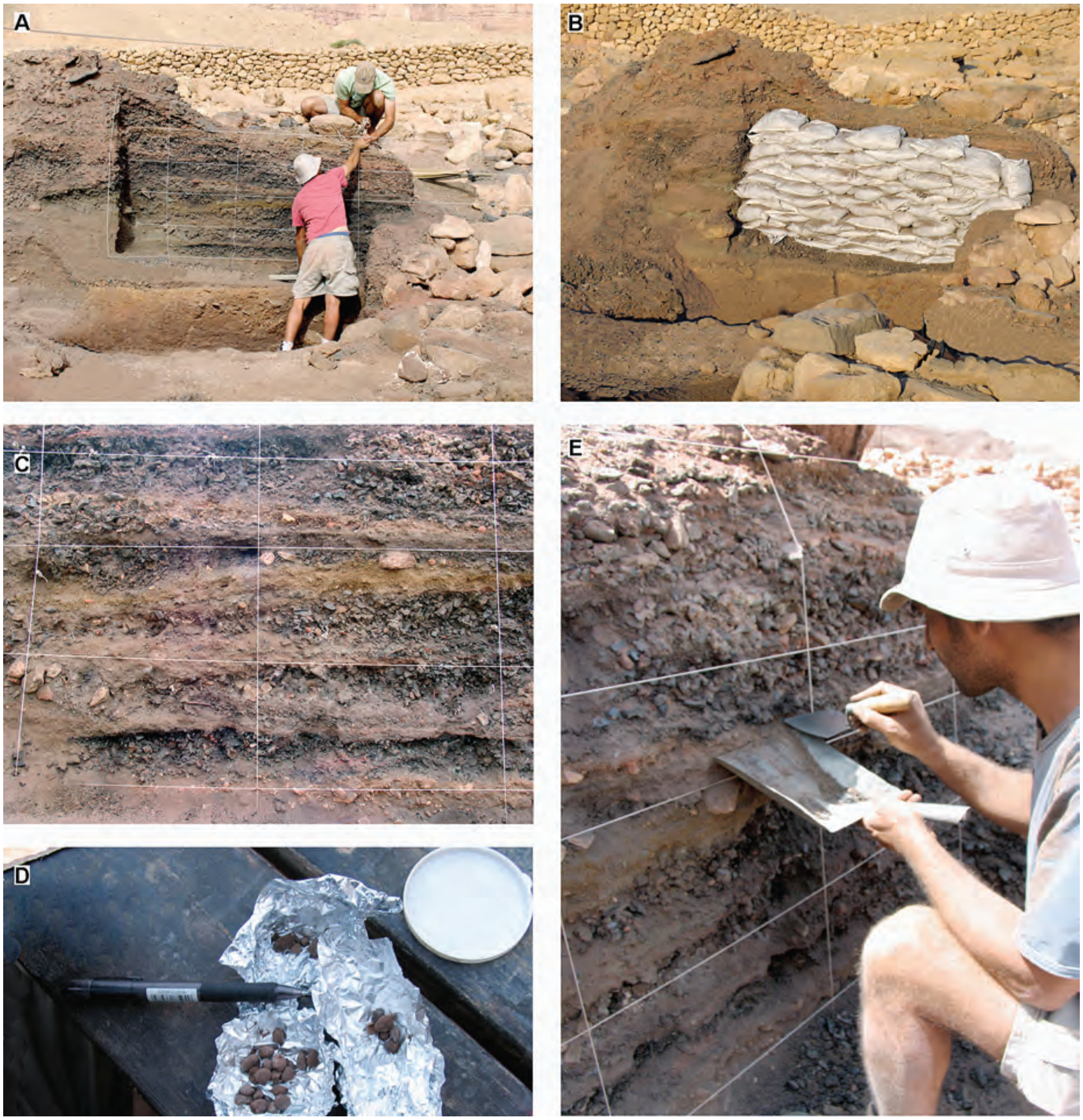


Fig. 17. Working on the section at Site 30 Area S. (A) setting up the vertical grid; (B) the section at the end of the excavation, partially covered by sand bags for protection; (C) sampling: each nail represents the exact location of a slag or other type of sample (over 100 slag and 50 short-lived organic samples were collected); (D) example of the extremely rich (usually uncharred) organic materials sampled from the greenish horizons between the metallurgical layers (this photograph shows mostly olive pits); (E) sampling organic materials from the section.

samples from Timna (below). The three charcoal samples from Area L were also modeled (fig. 23; table 4). The samples represent Layers II, III, and the deepest Layer IV defined only in the new excavations. The entire archaeological accumulation at Site 30 spans the late 12th to 9th century B.C.E., with no dates from the Late Bronze Age period, including the lowermost Layer IV.

The occupation of Site 30 started in the last decades of the 12th century B.C.E. or possibly only in the 11th century, as demonstrated by the date from Layer IV obtained from charcoal (table 4). The beginning of human occupation at the area of Site 30 is represented by ephemeral copper-production-related activities (Layer IV). This phase was succeeded by a more substantial occupation of the site, represented by the

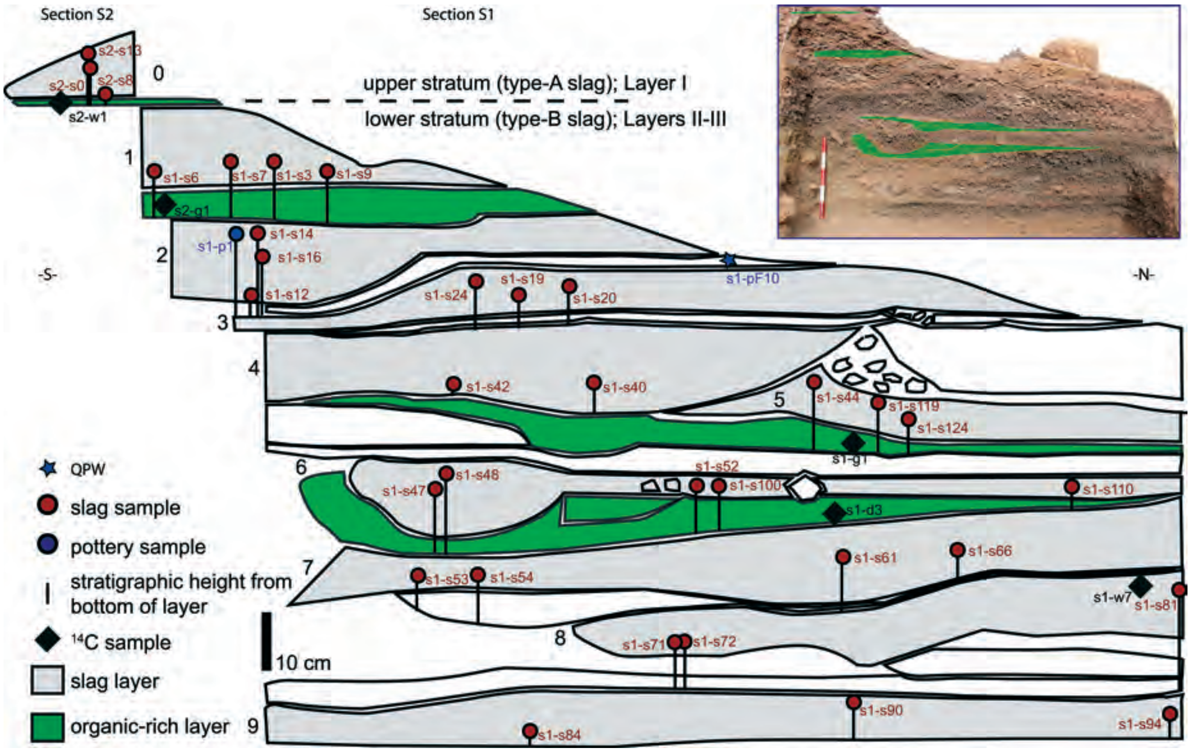


Fig. 18. Area S, section drawing of the profile in the "slag mound" (S-1, main section; S-2 is located to the south); except for s1-pF10 (QPW = Qurayyah Painted Ware) and the ^{14}C samples, all samples shown on this drawing are those that yielded successful archaeomagnetic intensity results (see text). More than 100 individual slag fragments were sampled from this section, together with dozens of well-preserved organic samples.

hard-worked surfaces of Layer III and dated from the second half of the 11th century to the first half of the 10th century B.C.E. The main copper production phase in Site 30, represented by a sequence of metallurgical debris both in Area L and Area S (Layer II), is dated from the end of the 11th century to the second half of the 10th century B.C.E. (and, in fact, Layer III is the lowest level of the same metallurgical sequence, with no distinct difference in material culture as discussed above). The end of this phase, in the second half of the tenth century, correlates well with the date of the Egyptian military campaign to the southern Levant, conducted by Pharaoh Shoshenq I (reign ca. 945–910 B.C.E.). The last phase of copper production at the site, represented by Layer I with a more advanced smelting technology, is dated to the late tenth to ninth century B.C.E. The occupation at the site ended in the end of the ninth century and was not revived.

The stratigraphy of Site 30 and the new dates show a striking similarity to the developments of the copper production enterprise in Faynan (Levy et al. 2008; Ben-Yosef, Shaar, et al. 2010). The small-scale beginning in the Iron Age I, the peak in production during the tenth century B.C.E., a major technological change at the end of this century or first part of the ninth, and a wide-scale abandonment of Iron Age II copper production sites around 800 B.C.E. were all observed in the smelting and mining sites of Faynan. The new chronological framework is supported by comparative archaeomagnetic research (Shaar et al. 2011) and a correlation of technological material culture between Timna and Faynan (Ben-Yosef 2010: 955–59).

Implications of Assessing Old Wood Effect in ^{14}C Dates from Timna. The type and context of the radiocarbon samples from Area S provide some insights regarding a possible bias in charcoal dates published for Timna sites. Three charcoals embedded in slag were obtained from the exposed face of the section prior to the new excavations (fig. 24) and were analyzed for a radiocarbon date (table 4). Comparing those results with the dates from the short-lived samples obtained from the same section after the excavations (fig. 18; table 4) reveals a difference of up to 160 years between the two types of materials. Sample IS26F (average 2σ = 1071) came from in-between samples S1-g1 and S2-g1 (arithmetic average 2σ = 981), demonstrating a difference of ca. 90 years; Sample IS26C (average

Fig. 19. Examples of well-preserved organic materials from the non-metallurgical horizons in section Area S (cf. fig. 18). (A) rope; (B) date seed; (C) textile/cloth; (D) hide. Photographs by M. Lavi, Hebrew University Archaeological Conservation Laboratory.

2σ = 1023) came from just above sample S2-w1 (average 2σ = 860), demonstrating a difference of 160 years; and sample IS26I (average 2σ = 1052) came from around the horizon of S1-g1 (average 2σ = 1005), demonstrating a difference of about 50 years.

The charcoal from Timna, including the Late Bronze and Iron Age sites, was identified as acacia (e.g., Rothenberg 1980), although the number of identified samples is limited. The bias evident in dates obtained from charcoal of this slow-growing tree is

Fig. 20. Installation L.905 in Section S-1, Area S. Only a quarter of a rounded crushed-ore storage facility was exposed. The installation is part of Layer III.

Fig. 21. Negebite Ware, Area S (Sample S1-P2). This is the bottom side of a base bearing imprints of a textile (mat?) used in the making of the vessel (cf., e.g., Cohen and Bernick-Greenberg 2007).

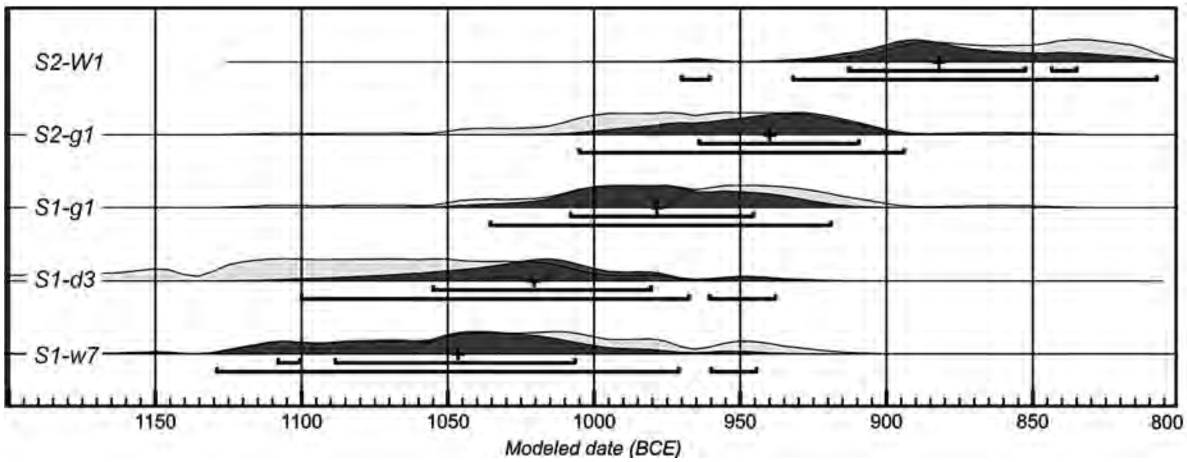


Fig. 22. Distribution functions of the ^{14}C ages of Timna 30 (Area S), calculated using Oxcal 4.1.6 (Ramsey 2009; Reimer et al. 2009) (after Shaar et al. 2011). Pale gray indicates the unmodeled age. Dark gray denotes the Bayesian modeled age assuming a stratigraphic order of the samples. Horizontal lines show 2σ and 1σ confidence intervals. Crosses mark the mean (cf. table 4; for location and context of the samples, see fig. 18).

TABLE 4. NEW RADIOCARBON DATES FOR TIMNA SITE 30

Sample Name Top–Bottom	*Material*	*Age B.P.*	*1σ cal. B.C.E.*	*2σ cal. B.C.E.*	*1σ Modeled*	*2σ Modeled*	*Stratigraphic Height*	*Layer / Context*
Area S, post-excavation (see fig. 18)								
IS26-S2-W1 AA86520	Wood twig	2705 ± 35	895–816	915–804	912–836	970–808	152	Layer I (bottom)
IS26-S2-g1-h AA86519	Olive pit	2814 ± 34	1006–921	1070–847	971–910	1006–894	135	
IS26-S1-g1-b AA86518	Grape seed (?)	2819 ± 35	1011–921	1113–896	1009–946	1037–920	71	
IS26-S1-d3a AA86517	Date seed	2893 ± 39	1129–1008	1252–941	1057–981	1101–938	57	
IS26-S1-w7 AA86516	Wood bark	2859 ± 34	1111–946	1129–919	1108–1009	1130–943	28	
Area S, pre-excavation (see text; fig. 24)								
IS26C AA84739	Charcoal	2852 ± 50	1112–934	1208–899	NA	NA		AA86520 was just below this sample
IS26F AA84740	Charcoal	2882 ± 38	1124–1006	1209–933	NA	NA		
IS26I AA84741	Charcoal	2855 ± 39	1111–939	1188–911	NA	NA		Installation L.905?
Area L (see fig. 9; table 2)								
IS26-EDM 188 AA86521	Charcoal	2872 ± 34	1116–1003	1192–928	1021–931	1051–917		Layer II, near QPW sherd (EDM 188)
IS26-EDM 261 AA86522	Charcoal	2858 ± 34	1111–943	1128–920	1033–946	1072–930		Layer III, bottom of fire pit, L.812
L813-B1604 AA86523	Charcoal	2803 ± 34	1000–916	1047–847	1050–976	1112–940		Layer IV, oldest context

Note: Dates calibrated and modeled using OxCal 4.1.6 (Ramsey 2009; Reimer et al. 2009); for explanation of stratigraphic height, see the text.

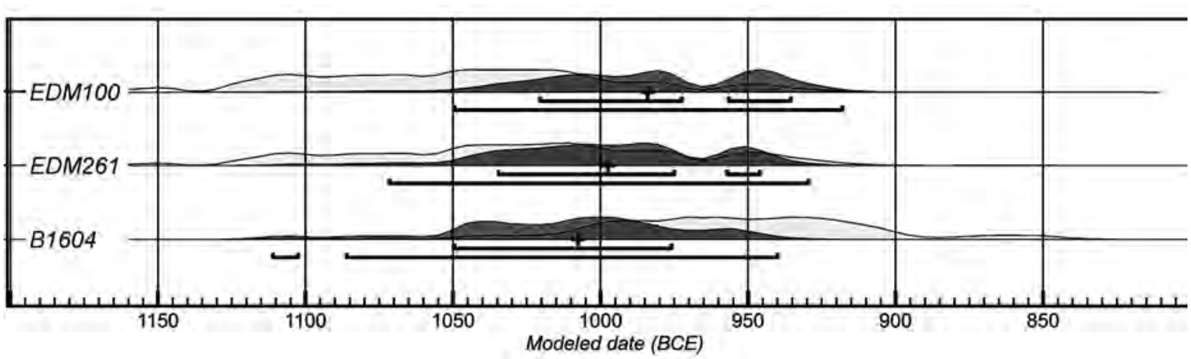


Fig. 23. Distribution functions of the ^{14}C ages of Timna 30 (Area L), calculated using Oxcal 4.1.6 (Ramsey 2009; Reimer et al. 2009). Pale gray indicates the unmodeled age. Dark gray denotes the Bayesian modeled age assuming a stratigraphic order of the samples. Horizontal lines show 2σ and 1σ confidence intervals. Crosses mark the mean (cf. table 4).

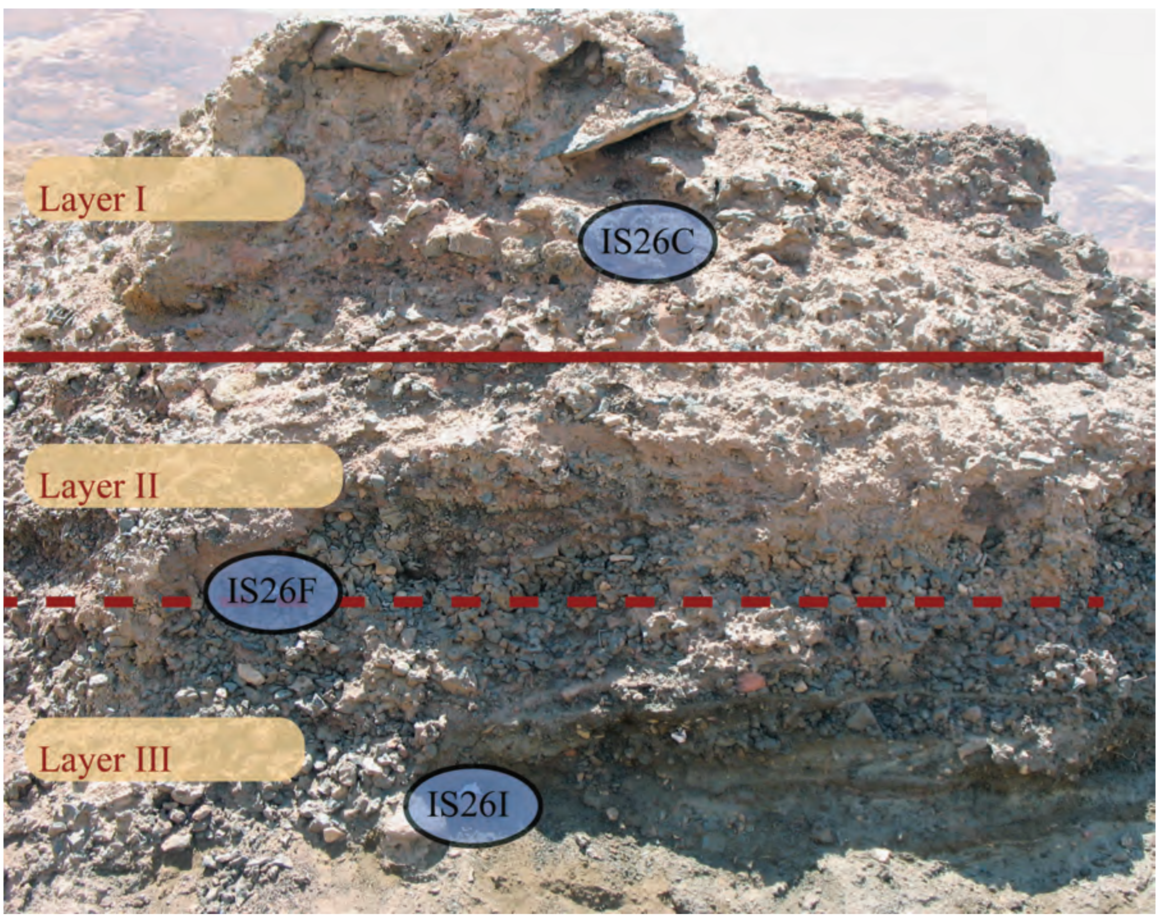


Fig. 24. The section in the "slag mound" at Area S before the 2009 excavations. The indicated layers follow the division of the Arabah Expedition (based on Rothenberg 1980, but note that the section has severely eroded since) (cf. fig. 5). The Layer III–II boundary is *not* a significant stratigraphic contact (see text for details). Slag samples IS26C, IS26F, and IS26I had embedded charcoals that were sent for radiocarbon measurements (table 4); comparing the results with the dates from short-lived organic samples from the same context (cf. fig. 18) helps us assess the "old wood effect" in smelting sites of the southern Arabah.

not surprising and should be taken into account when discussing the chronology of copper production at Timna.[12]

Archaeomagnetic Correlation with Iron Age Slag Deposits in Faynan

A Short Overview of Geomagnetic Archaeointensity Research. Different materials in the archaeological record preserve the properties of the constantly changing geomagnetic field. The most common material used to retrieve directional and intensity (strength) information in archaeomagnetic research is burned clay (pottery, kilns, etc.), which records the field properties at the time of its last heating episode. While retrieving directional information from (in situ) archaeological materials is a relatively easy experimental procedure with high success rates, obtaining reliable intensity data is a much longer and more complicated process with relatively low success rates. Recent research on copper slag from the Arabah has demonstrated the advantage of this material in archaeointensity experiments (Ben-Yosef, Ron, et al. 2008; Shaar et al. 2010), and resulted in a preliminary record of the changes in geomagnetic intensity in the southern Levant throughout the last seven millennia. The rapid changes and unique features in the archaeointensity curve, such as the spike recorded recently for the Iron Age (Ben-Yosef et al. 2009), can be cautiously used for dating and correlating archaeological deposits.

Archaeointensity of Site 30 and Correlated Age Model. Further support for the new chronology of Site 30 comes from archaeointensity data that enable correlating each metallurgical horizon of Area S to the well-dated metallurgical sequence at Khirbat en-Nahas (KEN) in Faynan. Fifty-four samples (52 slag pieces, 1 pottery sherd, and 1 tuyère piece) from Area S were subjected to archaeointensity experiments conducted in the palaeomagnetic laboratories at the Institute of Earth Sciences at the Hebrew University in Jerusalem and Scripps Institution of Oceanography, University of California, San Diego. The experimental procedure and data interpretation are presented in Shaar et al. (2011). The context of the successful samples (3 pieces of Type A slag, 31 of Type B slag, and 1 pottery sherd) is presented in fig. 18, and the results are presented in fig. 25. The relative stratigraphy is expressed by assigning each sample a *stratigraphic height*. This value (see fig. 25) facilitates interpretation of complex deposits in which the absolute elevation of a sample does not necessarily represent its relative age; e.g., Sample s1-s12 (Horizon 2) is lower in absolute elevation than Sample s1-s24 (Horizon 3) although it must be younger, as it belongs to a younger horizon (fig. 18). The stratigraphic height was calculated by measuring the height of each sample above the closest horizon contact (vertical short lines in fig. 18) and adding the cumulative *maximum* thickness of all horizons beneath it.

The striking agreement between the archaeointensity records of Site 30 and Khirbat en-Nahas in Faynan (Ben-Yosef et al. 2009) (fig. 25), including two extremely rare geomagnetic field intensity spikes, allows for a refined correlation of the two sequences and the calculation of a combined age model. The excavations of the Iron Age "slag mound" at KEN Area M have exposed about 6 m of archaeometallurgical deposits associated with more than 20 AMS radiocarbon samples (Levy et al. 2008). Seventeen slag and clay samples spanning the 11th–9th centuries B.C.E. yielded successful archaeointensity results with the two intensity spikes (Ben-Yosef et al. 2009). These spikes are correlated with the high intensity values recorded in the Timna samples from Horizons 0 and 6 at Site 30 (fig. 25). Based on this correlation and the assumptions depicted in fig. 26, we normalized the stratigraphic height of the two records (fig. 27) and calculated a combined Bayesian model for the two sites (fig. 27; table 5). In order to enhance the robustness of the model and obtain a better resolution, we split the KEN Area M data set into its original two sections of the eastern and western walls (see Ben-Yosef et al. 2009: fig. 4) and used only radiocarbon samples obtained directly from the sections (and not from associated excavation contexts). Two samples were rejected because of their anomalous old age: Sample #17637, which resulted in a low value of parameter A in the OxCal program, probably owing to bias by an old wood effect (Levy et al. 2008); and Sample #17647, which reduced drastically the overall value of parameter A. The relative context and normalized stratigraphic height of the 13 radiocarbon samples used in the combined age model is shown in fig. 27, together with boundaries of layers/horizons (4 layers in KEN Area M and 10 horizons in Timna 30 Area S). Fig. 27 presents the distribution functions of the modeled ages, with their medians marked as open circles. Assuming that depositional rates are not constant, we connected the medians of both spikes in a straight line in order to obtain the best approximation of a linear

[12] In contrast to Timna, the fuel source in Iron Age Faynan was hydrophilic, fast-growing shrubs (mostly tamarisk). Thus, the dates published for charcoal from Faynan are less affected by the "old wood effect."

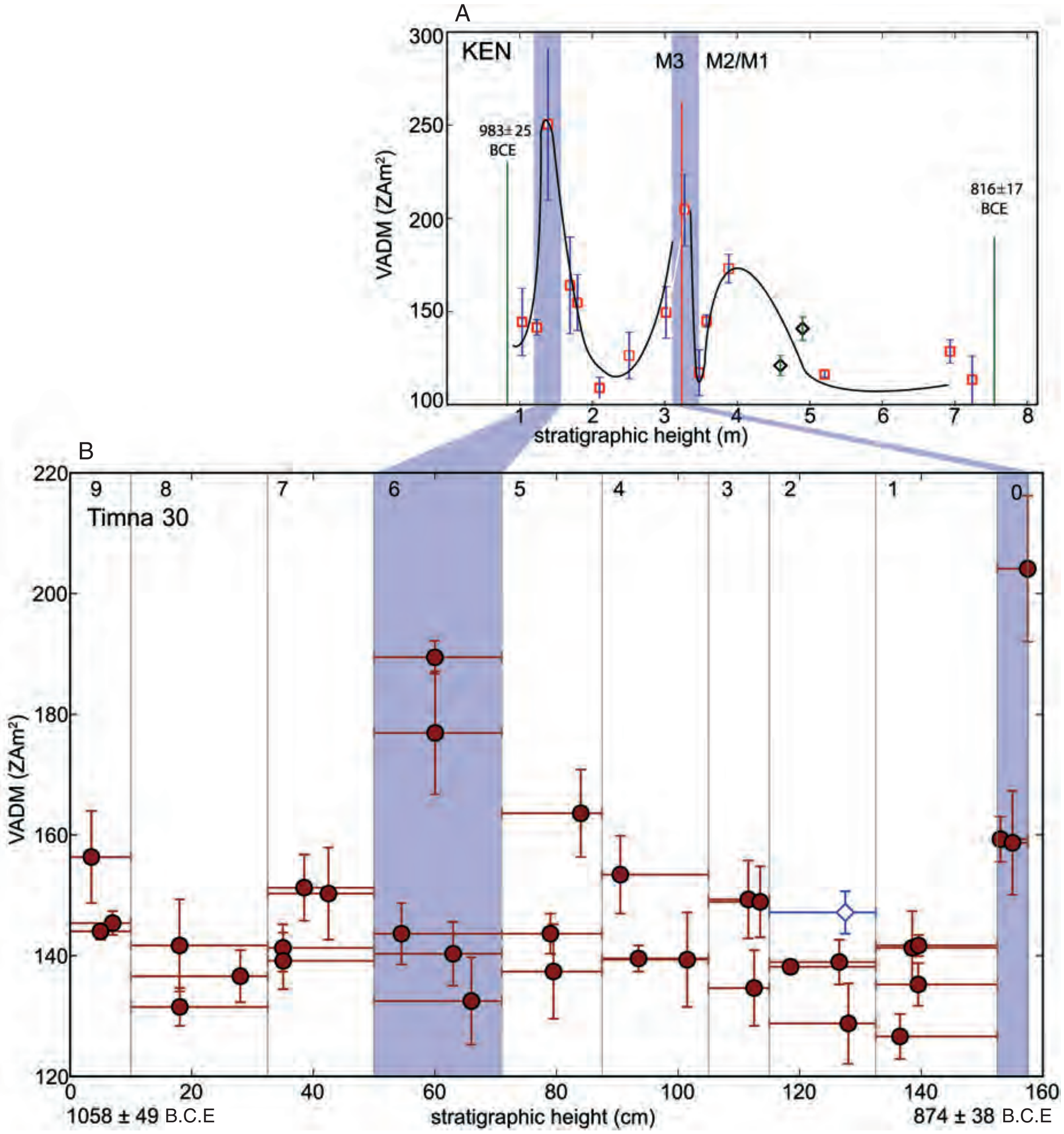


Fig. 25. (A) Geomagnetic intensity values (in Virtual Axial Dipole Moment values) vs. stratigraphic height of Area M at Khirbat en-Nahas, Faynan (Ben-Yosef et al. 2009); (B) geomagnetic intensity values vs. stratigraphic height of Area S at Timna 30 (Shaar et al. 2011). Vertical lines show stratigraphic heights of the boundaries of each stratigraphic horizon (numbered at the top); red circles = slag samples; blue diamond = a pottery sample; vertical error-bars = the standard deviation around the sample's mean; horizontal error-bars = the boundary of the layer. The geomagnetic spikes in both records are highlighted in pale blue. Ages at the boundaries represent the 1σ confidence-boundaries of the entire section, inferred from Bayesian models of each site.

age-height model for Timna 30 Area S and KEN Area M. As shown in the combined archaeointensity curve of Faynan and Timna (fig. 28), the two data sets agree with each other, with the exception of two samples: (1) the early spike recorded in KEN Area M shows a higher value than the spike recorded in Timna, possibly a result of the difference in material used (a slower-cooled furnace fragment vs. the quenched slag) or due to the fact that the fast change was not captured by slag analyzed from the thinner deposits of Site 30; and (2)

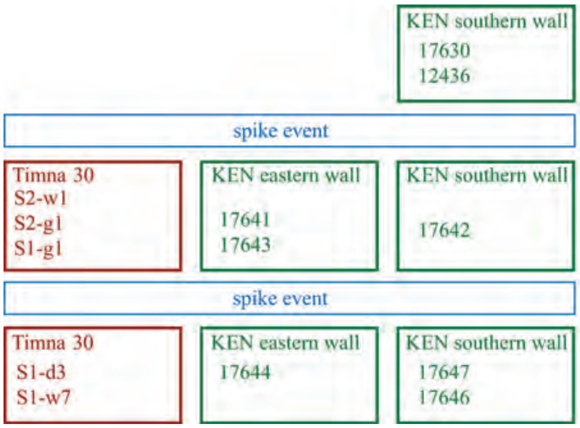


Fig. 26. The basic assumptions used for the combined Bayesian model of radiocarbon ages for KEN Area M and Timna 30 Area S. The relative stratigraphic order of the samples is taken from Ben-Yosef et al. (2009: fig. 4) and fig. 18 (normalized to represent the different accumulation rate; cf. fig. 27). The basic assumptions are (1) the early geomagnetic spike at KEN Area M is of the same age as the spike in horizon 6 at Timna 30 Area S; (2) the late geomagnetic spike at KEN Area M (M3–M2/M1 boundary) is of the same age as the spike in Horizon 0 at Timna 30 Area S; and (3) the stratigraphic order of ^{14}C samples of KEN Area M is as listed in Levy et al. (2008) and Ben-Yosef et al. (2009), and the stratigraphic order of ^{14}C samples of Timna 30 Area S is as listed in fig. 18.

Sample e10462a in KEN Area M, which yielded a low value with respect to the curve, yet with no satisfactory explanation.

The combined age model (table 5) and the high-resolution archaeointensity reference curve (fig. 28) provide a refined chronology for the Iron Age metallurgical records with a resolution of decades or less. The drastic technological change observed both in Faynan (Ben-Yosef and Levy in press) and Timna Site 30 (Layers II–I boundary) should be dated according to the combined model to 900 ± 15 B.C.E. (1σ).[13]

Comments on Copper Production Technologies at Site 30 and Their Chronological Context

The well-studied technological sequence of Site 30 and other sites in the southern Arabah was recently compared with the Iron Age technological record in Iron Age Faynan (Ben-Yosef 2010: chapters 7–10). The archaeometallurgical material culture of the two records is in fact indistinguishable, representing the same social and chronological context. In addition to the major technological change around 900 B.C.E. discussed above, other more subtle trends in technological development occurred simultaneously in both regions, with gradual improvement in production efficiency throughout the 11th–10th centuries B.C.E. (Ben-Yosef 2010: 829–33 and chapter 9). This technological similarity strengthens the reliability of the new radiocarbon dates from Site 30 and supports the application of the new chronological framework to other sites in the southern Arabah.

In light of the results of the current research, the claim of Avner and Magness (1998: 52–53 n. 7) that the slag from Timna 30 Layer I is Nabataean or later is not supported. Type A slag (see above), with its distinct appearance as solid slabs, represents the ninth-century B.C.E. technology at Site 30, although it might be easily confused with slag from later technologies that look similar (Roman or Islamic).[14]

A NEW CHRONOLOGICAL FRAMEWORK

In light of the Arabah Expedition's research at Site 30, Rothenberg (1980: 210) concluded that:

> the excavations of Site 30 delivered extensive proof that the sites in Timna are not "King Solomon's Mines" but a mining and smelting establishment of the Pharaohs of the New Kingdom of Egypt. From a historical and geographical point of view, Timna was a part of the vast Egyptian mining area of the Sinai Peninsula—in a time when the Pharaohs ruled Palestine as well.

This conclusion is based on the ceramic finds from the site. The ceramic assemblages have been used not only as a chronological reference but also as a means to identify ethnic identities. All of the three main ceramic types reported from the New Kingdom smelting sites in Timna have been found in Site 30:

1. "Negebite" (or "Negevite"): coarse handmade vessels (Glueck's "Amalekite ware"), "Negeb-type," or "Negev/Negebite ware" (Haiman and Goren 1992; Bernick-Greenberg 2007; Tebes 2006).
2. Qurayyah Painted Ware (QPW) (or "Medianite Ware") (Tebes 2007; Rothenberg and Glass

[13] The three uppermost slag samples from Timna 30 Area S (fig. 27) are from Layer I and represent the new and advanced technology. Radiocarbon Sample S2-w1 (table 5) came from the bottom of the same layer.

[14] We agree with Avner and Magness (1998: 52–53 n. 7) that all the *ring slag* (large slabs of tap slag with a distinct hole in the middle) indeed appeared no earlier than the Nabataean period. Such slag is present in Timna 2, where they are associated with metallurgical installations not found in any of the Iron Age sites and have early Islamic radiocarbon dates (Ben-Yosef 2010: 519, 728).

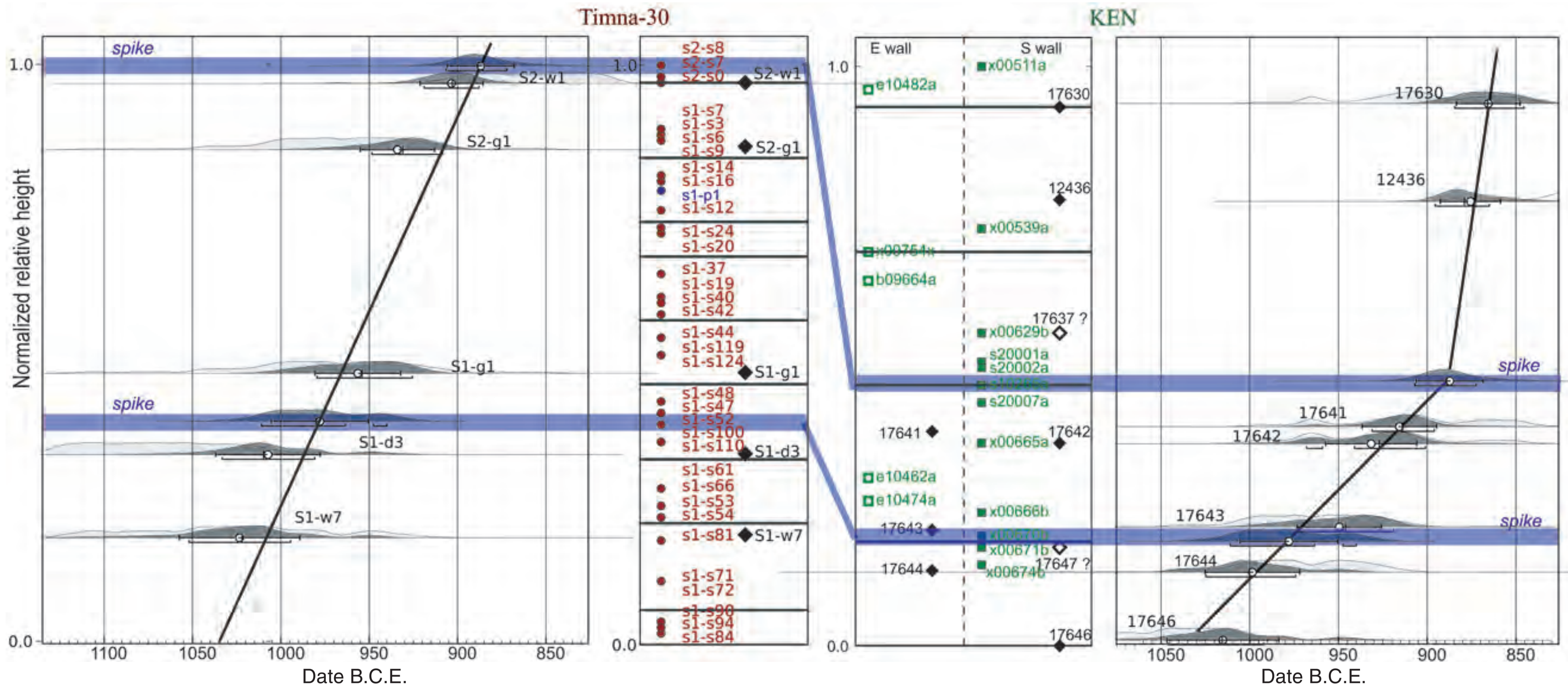


Fig. 27. Combined age-height model of KEN and Timna 30 (Shaar et al. 2011). Horizontal lines represent the relative stratigraphic height of stratum boundaries. Red circles = stratigraphic location of slag samples in Timna 30 Area S; green-filled squares = location of archaeointensity samples in KEN Area M southern section; and open green squares = samples in KEN Area M eastern section. Distribution functions of the calibrated radiocarbon dates are colored in gray, and Bayesian modeled dates are shown in black. The linear age-height model of each section is represented as a straight black line connecting the medians of the distribution function of the spike events (and in KEN Area M, also the median of the distribution function of the uppermost sample).

TABLE 5. RADIOCARBON DATES AND COMBINED BAYESIAN MODELED AGES OF TIMNA 30 AREA S AND KEN AREA M[a]

Sample ID	*Site*	*^{14}C Age B.P.*	*Unmodeled Date B.C.E. (1σ)*	*Modeled Date B.C.E. (1σ)*	*Modeled Date B.C.E. (2σ)*	*Mean (Median) Modeled Date B.C.E.*
17630[b]	KEN	2764 ± 25 [b]	969–846	886–846	902–832	866 (867)
12436 [b]	KEN	2659 ± 32 [b]	834–799	896–866	906–836	876 (880)
Spike event				908–874	923–846	888 (890)
S2-w1	Timna 30	2705 ± 35	895–816	917–886	937–862	902 (901)
S2-g1	Timna 30	2814 ± 34	1006–921	949–909	981–899	935 (932)
S1-g1	Timna 30	2819 ± 35	1011–921	980–926	1004–915	957 (955)
17641[b]	KEN	2767 ± 25 [b]	971–848	932–897	972–877	916 (915)
17643[b]	KEN	2813 ± 26 [b]	1001–927	973–920	998–911	950 (947)
17642[b]	KEN	2781 ± 25 [b]	976–898	969–902	992–891	932 (928)
Spike event				1012–941	1026–925	978 (980)
S1-d3	Timna 30	2893 ± 39	1129–1008	1033–981	1066–936	1007 (1009)
S1-w7	Timna 30	2859 ± 34	1111–946	1053–995	1105–941	1025 (1023)
17644[b]	KEN	2824 ± 25 [b]	1008–932	1026–976	1048–942	999 (1001)
17646[b]	KEN	2871 ± 26 [b]	1112–1005	1047–993	1086–938	1016 (1016)

[a] Calibrated and modeled using OxCal 4.1.6 (Ramsey 2009; Reimer et al. 2009). The stratigraphic model is illustrated in figs. 26 and 27.
[b] ^{14}C date is from Levy et al. (2008)

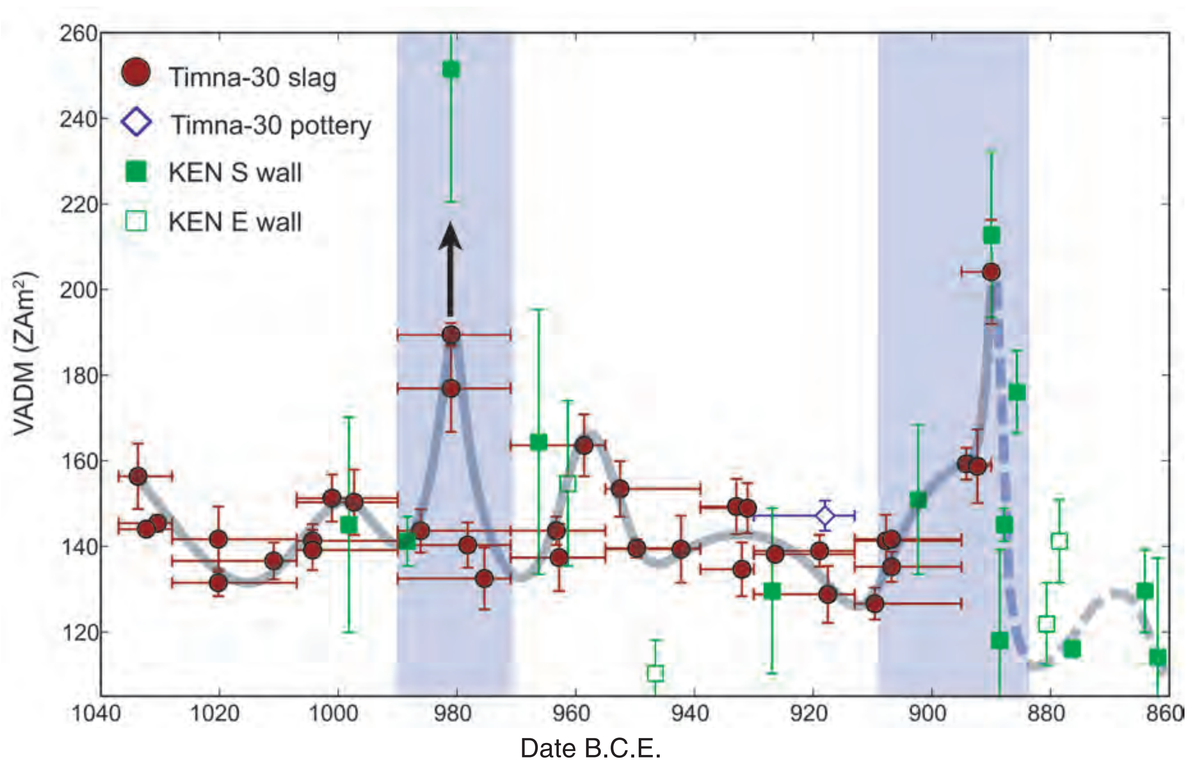


Fig. 28. Geomagnetic Intensity curve of the late Iron I and Iron Age IIA southern Levant (intensity values represented as Virtual Axial Dipole Moment [VADM; note that z = 10^{21}]. Timna 30 slag (pottery) is marked as red circles (vs. open diamond); KEN (Ben-Yosef et al. 2009) southern (eastern) walls are marked as filled (vs. open) green squares (Shaar et al. 2011). Vertical error-bars = standard deviation of samples' means. Horizontal error-bars in Timna 30 = the layer boundaries. The solid curve is constructed by a weighted cubic-spline interpolation of the Timna 30 data points. The dashed curve is an interpretation of field behavior after the ninth-century spike. Pale blue areas show the two events of geomagnetic spikes. Arrow marks a high spike value in KEN not captured in Timna.

1983; Rothenberg 1998): polychrome ware decorated with geometric designs, stylized birds, animals and human figures; majority is wheel-made, pink-buff ware with a heavy cream-colored slip, decorated in brown, reddish brown, and black.[15]
3. Wheel-made pottery, "normal types" (Egyptian or locally made). The main dating tool in early investigations of the Arabah Expedition (especially the shallow carinated cooking pots with small folded rims and no handles).

While Negebite pottery is not a good chronological marker, as it represents a long time span (Meshel 2002, and references within), and QPW was dated according to its context in the smelting sites of the southern Arabah (below), the Arabah Expedition used the "normal types" and mostly the "Egyptian pottery" as key chronological markers for dating the main smelting sites. Detailed analysis and reevaluation of the published "Egyptian pottery" from Site 30 (Rothenberg 1980: pl. 211) are beyond the scope of the current paper; however, the limited published "20th Dynasty Egyptian" vessels are *not* typical vessel types of this period, and we could not identify any direct parallels for them. Moreover, dating archaeometallurgical deposits in the southern Arabah based on ceramic assemblages is problematic, as the ceramic finds are usually slim, as demonstrated by the new excavations at Site 30 and previous excavations at this site and elsewhere in the region.

During the first 10 years of intensive research in the southern Arabah, including extensive excavations at Site 2, the Arabah Expedition did not report the discovery of *any* Egyptian-related artifacts from this region. The only chronological concerns raised during this period came from the Iron Age pottery assemblage, and specifically the shapes of some cooking pots that suggested an earlier date *within* the Iron Age (earlier than the accepted chronology at the time); the main claim was that the sites should be dated to the 12th–11th centuries B.C.E. (and not the 10th and later) (e.g., Aharoni 1962). It was only with the excavations of Site 200 (the "Egyptian sanctuary") in 1969 that a new chronological framework was imposed on the entire Iron Age smelting sites in Timna and the southern Arabah. The stratigraphy and chronology of Site 200 became an anchor for correlations and dating, even though they present many complications and discrepancies.

The Stratigraphy of Site 200 and the Date of QPW

As mentioned above, the stratigraphy of Site 200 became the main reference for dating the smelting and mining sites of the southern Arabah and a leading argument for Egyptian control over the copper production enterprise in the region (Rothenberg 1988). The site has five strata: V is Chalcolithic, and I is Roman–Nabataean (Rothenberg 1972b: 17–19). Strata II–IV yielded mixed materials, including Egyptian New Kingdom and local elements. Stratum IV represents the foundation of a sanctuary devoted to the Egyptian goddess Hathor. Rothenberg dated this phase to the time of Seti I (1294–1279 B.C.E., or in the higher chronology, 1318–1204, both used in different places by Rothenberg), based on a bracelet with a cartouche of this pharaoh. Different arguments by G. Pinch (1993: 67), K. Kitchen (1976), and A. R. Schulman (1988: 115–16) demonstrate the complexity of this date, as the reading is not secure and the bracelet might be a hereditary object or might represent a time during occupation (rather than foundation). Stratum III represents a major reconstruction of the sanctuary, suggested by Rothenberg to be the work of Ramesses II (1279–1213 B.C.E.), although others attribute it to Ramesses III (1184–1153 B.C.E.). The latest cartouche found in Layer III, which was destroyed by a rockfall (possibly an earthquake), was of Ramesses V (1147–1143 B.C.E.) (Schulman 1988: 144–45). Stratum II represents a renewed worship activity at the sanctuary, starting with little or no break after the destruction of the previous layer. The stone-built temple was not restored but instead, "[a] Semitic tented desert shrine" was built (Rothenberg 1988: 277) with no signs of Egyptian presence or connection to Hathor. Stratum II was also terminated by a rockfall. It is not clear how long the tent-shrine had been in use; however, Rothenberg considered it to have been "only a short-lived, makeshift establishment" (Rothenberg 1988: 278). QPW was found in Strata IV–II of the sanctuary, and the lack of it in Layer I of Site 30 indicates, according to Rothenberg (1988: 54), that the sanctuary was abandoned before the Egyptians returned to Timna and rekindled the copper production (at Site 30).

Based on the finds from Site 200, Rothenberg dated the QPW from the late 14th century to the middle of

[15] Glueck did not distinguish QPW from "Edomite Pottery" (QPW has more sophisticated motifs and grits in section, and far fewer vessel types). QPW was found in 1968 in Qurayyah, Hijaz, 70 km northwest of Tabuk (Parr, Harding, and Dayton 1970), where six ceramic kilns indicate that the production of this ware took place at the site. INAA and petrographic analyses in many publications have also confirmed that the Hijaz is the region where this ware was produced. Rothenberg first followed Glueck's "Edomite" identification until Parr's discovery; however, Rothenberg termed the pottery "Midianite" after the biblical people described living in the Hijaz, while Parr preferred the more neutral term "Qurayyah Painted Ware" (Parr 1988: 74).

the12th century B.C.E. (Rothenberg 1988: 201, 276, using the high chronology for Seti). The lack of QPW in Layer I at Timna 30 was the principal argument for the claim that the use of this type of ceramic ended in the 12th century B.C.E. and does not appear in Iron Age II contexts. This created considerable confusion in the research of the southern Levant, as sherds of QPW have been found in later contexts, including 10th-century Khirbat en-Nahas, Rujm Hamra Ifdan (Smith and Levy in press), and Barqa el-Hetiye (Fritz 1994) in Faynan, Tell el-Kheleifeh (Rothenberg and Glass 1983: 75–76), Tawilan (Bienkowski 2001: 261–62), and Edom in general (e.g., Finkelstein 1992), Tel Masos (Yannai 1996: 144–45; Herzog and Singer-Avitz 2004: 222–23), and ʿAin el-Qudeirat (Fantalkin and Finkelstein 2006: 20; Singer-Avitz 2008). Already Singer-Avitz raised concerns about mixed stratigraphy in Site 200 and suggested that QPW is not earlier than the 12th century B.C.E. (Singer-Avitz 2004).

In the new excavations at Timna 30, we uncovered two fragments of QPW (figs. 11, 12), one from Area L (EDM 188b, L.808, Layer II) and the other from Area S (Sample s-1pF10, upper part of Layer II; fig. 18). Both samples are from well-dated stratigraphic contexts. EDM 188b is associated with radiocarbon measurement AA86521 (1021–931, 1σ modeled age; table 4) and s-1pF10 is in between radiocarbon measurement AA86518 (1009–946, 1σ modeled age) and AA86519 (971–910, 1σ modeled age) and closer to the latter (fig. 18; table 4). This suggests a 10th-century date for the QPW of Timna Site 30, and calls for revision of the stratigraphy and chronology of Site 200. It will not be surprising if Singer-Avitz (2004) was correct and the stratigraphy of the "Egyptian sanctuary" is mixed (cf. Avner 1999 for additional critique), and the QPW finds there are *not* associated with the Egyptian phase.

The New Chronology, Historical Events, and Social Models

Using the complex stratigraphy of Site 200 as a reference for dating the copper mining and smelting sites of the southern Arabah created confusion and anomalies in related archaeological studies. The consensus about the New Kingdom date of the smelting sites, together with the previously published radiocarbon dates from Site 30, the late date assigned to other sites with QPW, and other arguments, led Bimson and Tebes (2009: 106) to conclude that:

> The dates currently given to mining and smelting operations in the southern Arabah produce a number of chronological anomalies and tensions. Taken together these suggest the need for lower dates for New Kingdom Egypt, which would in turn allow a lower date for the Late Bronze/Iron Age transition.

In support of very low Egyptian chronologies (e.g., James et al. 1991), Bimson and Tebes (2009) provide evidence from smelting sites of the southern Arabah that appears to be even more robust in light of the new dates published here. However, regarding the complicated deposition of archaeometallurgical materials and the complex stratigraphy of Site 200, it is much more likely that the pottery identification and stratigraphic discernment of the Arabah Expedition were confused. Without dismissing the significance of typological research of material culture, archaeometric dating, where possible, should be the basis of any chronological assessment of cultures and societies (contra, e.g., Singer-Avitz 2009).

The similarities between the archaeometallurgical and archaeological assemblages of Site 30 and other smelting sites in the southern Arabah previously dated to the New Kingdom (e.g., Timna 2, 3, 9, 12–15, and 34; see Rothenberg 1990, and above) suggest that they all represent the same new chronological framework, together with other related sites (e.g., Timna 35) and the thousands of associated mine shafts in the Timna Valley. The latter yielded very few artifacts and were tentatively dated to the Late Bronze Age, mostly based on their assumed correspondence to the smelting sites. Site 2 ("The Mushroom Site") might be an exception, yielding a few Late Bronze Age radiocarbon dates (in addition to Iron Age dates; Ben-Yosef, Levy, et al. 2010: 729–30). However, these dates were obtained from charcoal samples and were probably biased by the "old wood effect," which, as demonstrated above, can render the age up to 160 years older than the actual smelting operation. Incorporating the bulk of copper production sites in the southern Arabah in the new chronological framework awaits further support of future research; however, the strong archaeometric chronological anchors provided here should replace the previous chronological assumptions until new data are available.

Comparing the new chronology and the material culture from the smelting sites of the southern Arabah with the parallel record in Faynan indicates social unity between the two regions during the Iron Age; i.e., the same social groups inhabited both regions and operated the copper extraction systems simultaneously and under the same general production system and organization management (Ben-Yosef 2010: chapter 10). Thus, Iron Age copper production in the entire

Arabah should be considered as a whole, and insights from analyses of technological remains and other material culture in the northern Arabah (e.g., Mattingly et al. 2007; Smith and Levy 2008; Levy et al. 2008; Hauptmann 2007; Beherec 2011; Smith 2009; Ben-Yosef 2010) are pertinent to the understanding of the archaeological record in the southern Arabah, and vice versa (e.g., Rothenberg, ed. 1990; Conrad and Rothenberg 1980; Rothenberg 1999, and references within). It is beyond the scope of this paper to present the well-studied material culture of Iron Age copper production in the Arabah and discuss in detail its implications for our understanding of the society or societies responsible for this vast enterprise. In the following, we present briefly the main insights directly related to the new chronological framework of the Iron Age copper production sites in the southern Arabah.

Limited copper production in the southern Arabah was controlled by the Egyptian New Kingdom, probably operated with seasonal expeditions to Timna (possibly Atika mentioned in Egyptian texts; e.g., Levene 1998). A possible offshoot of this Late Bronze Age–Early Iron Age activity is indicated by early radiocarbon dates from Faynan, but without any corresponding Egyptian finds (Ben-Yosef, Levy, et al. 2010). The main phase of copper production in the Arabah Valley started only after the Egyptians left the region, during the second half of the 12th century B.C.E. Shortly after the time of Ramesses V, the last pharaoh indicated in finds at Site 200, the copper production in the Arabah Valley was rekindled, with many smelting sites founded for the first time in this period, including Khirbat al-Ghuweiba (Ben-Yosef et al. in press), Khirbat al-Jaryia (Ben-Yosef, Levy, et al. 2010), and Timna 30 (above). This industry developed gradually, with incremental improvement in smelting efficiency during the 11th century, and peaked during the 10th century B.C.E. (Ben-Yosef 2010: 829–33 and chapter 9). The archaeological evidence indicates that this sophisticated enterprise was initiated by a local, seminomadic tribal society with possible foreign components (indicated mostly by the Qurayyah Painted Ware). Even based on tent-dwellers, this society could demonstrate substantial political power and might represent the early development of biblical Edom.[16] This possible identification with Edom is based mostly on detailed ceramic studies from Iron Age Faynan (Smith 2009; Smith and Levy in press) showing typological similarities between the assemblages from the copper production sites and those of the later sedentary Edomite sites on the Jordanian plateau.[17] Some technological observations support this ethnic identification, with finds that demonstrate affinity between the copper production sites and the highlands of southern Jordan, the core of the Edomite polity in the late Iron Age (Ben-Yosef 2010: 947, 959, 968).

The abrupt disruption of the metal industry evident in Timna 30 Layer II and Khirbat en-Nahas Stratum III and the abandonment of several smelting sites both in Faynan and Timna are attributed to the military campaign of Shoshenq I (cf. Levy et al. 2008 for KEN). For Timna 30, we presented here a refined correlation of the archaeological record and the assumed time of this campaign (the second half of the 10th century B.C.E.; see, e.g., Kitchen 1986). Although neither Faynan nor Timna is explicitly mentioned in Shoshenq's inscription at Karnak, the connection of Shoshenq I to the copper industry of the Arabah is strengthened by a recently discovered scarab from Faynan bearing the name of this pharaoh (Münger in press). Shortly after the disruption of the metal industry it was revived again, although with a substantially different organization of production and technologies (above). The new industry is evident in fewer sites both in Faynan (KEN, Faynan 5, and possibly Khirbat Faynan) and Timna (Timna 30), although the production technology was now more advanced and efficient. Elements of continuity in the material culture, together with adoption of new and seemingly foreign technologies, suggest local initiatives and control, probably triggered and/or influenced by Egypt (see discussion in Ben-Yosef 2010: 971–78). The abrupt end of this industry in the

[16] A fundamental question remains: did copper production in the Arabah stimulate social processes and the development of local polity(ies), or does the evidence of these production systems only reflect a complex society that resided (in tents) in the area of the copper ore? The solution probably lies between these two options—the ancient technological record attests to the complexity of the society, and the engagement in these production systems, including the derived economic incentive, stimulated the development of a more complex social organization. It should be noted, however, that the first evidence of copper smelting during the second half of the 12th century B.C.E. already reflects a high degree of social complexity, with the absence of evidence for small-scale "trial and error" smelting practices, suggesting that a complex society existed even earlier in the region but did not leave any substantial archaeological remains (as it was not yet fully engaged in the archaeologically visible copper production).

[17] Finkelstein's (2010: 15) succinct and unsupported statement that "Khirbat en-Nahas is not located in Edom" represents a fundamental issue in the current debate regarding the new evidence from the Iron Age copper production sites of southern Jordan. The boundaries of early Edom are poorly delineated in the biblical accounts and could have definitely included the area of Faynan and Timna, if not the entire southern Negev (see, in particular, Bartlett 1989; Edelman 1995; Zucconi 2007).

last phase of the ninth century B.C.E. reflects the results of a conflict rather than a gradual abandonment or overexploitation of the natural resources. This might be attributed to the military campaigns of Hazael king of Aram (possibly to the same campaign over Gath during the late ninth century B.C.E.; Maeir and Gur-Arie 2011), or possibly to more local conflicts, such as Judah's military campaign to Edom during the early eighth century (2 Kgs 14:7). Another possible explanation is that Cyprus regained a monopoly over the copper trade in the eastern Mediterranean during the ninth/eighth centuries B.C.E. (e.g., Knauf 1995: 111–12); however, as the latter is almost by definition a gradual process, the former explanations seem more in accordance with the archaeological record, which shows a sharp and simultaneous event.

Domesticated Camels from Timna. Although yet to be properly published, the camel bones from the smelting sites of the southern Arabah excavated by the Arabah Expedition were considered as early evidence for the domestication of camels in the ancient Near East and in particular in the southern Levant (e.g., Grigson 1995; Jasmin 2006), including a camel bone from Site 2 supposedly dated to the 14th century B.C.E. (Hakker-Orion 1984), and camel bones from Site 30 (Layers II–III only) supposedly dated to the 13th century B.C.E. (for the latter, see Grigson 2012, including discussion in light of the new dates). However, as demonstrated here, the dates of the camel bones from Site 30 are no earlier than the end of the 12th or the 11th century B.C.E., and likely originate from a 10th-century context. Bones from the other main smelting sites of the southern Arabah should also be dated according to the new chronological framework and considered as Iron Age remains until further evidence is available.

While camel bones were reported from a few Late Bronze Age contexts in the southern Levant, including Tell Jemmeh (Wapnish 1981), Tel Yinʾam (Lundelius 2003), and Shiloh (Hellwing, Sadeh, and Kishon 1993), the early date of domestication is not yet secure. The context of the sample is not always clear, and analytic data supporting domestication (cf. Jasmin 2006) is still lacking. New evidence from the Arabian Peninsula indicate an Iron Age date for the domestication of camels (Uerpmann and Uerpmann 2002 and see further discussion in Grigson 2012).

CONCLUSIONS

The first systematic archaeometric dating of Site 30, one of the main smelting sites of the southern Arabah Valley, resulted in a new chronological framework for Iron Age copper production in this region. The main period of copper smelting in the southern Arabah was during the 10th century B.C.E., and the extent of New Kingdom Egyptian control over copper production in Timna was more limited than previously believed. Clear evidence shows that the intensity of production increased drastically right after the last Ramesses left the area (Ramesses V) during the second half of the 12th century B.C.E. and that a major change in production technologies and organization occurred during the second half of the 10th century B.C.E., most probably related to the military campaign of Shoshenq I. The copper production in the entire Arabah Valley ceased at the end of the ninth century B.C.E.

The new framework is in striking agreement with the recently published data from Faynan. Taken together with comparative archaeometallurgical and other evidence, it is now apparent that the two regions were socially united and that the copper production enterprise was a local initiative controlled by seminomadic tribes. The sophisticated organization of production demonstrates centralized authority and political power which might represent the early tribal state of Edom.

More than 70 years after Nelson Glueck published his observations on the smelting sites of the southern Arabah, the Iron Age should be once again part of the archaeological discourse regarding one of the most important industries of the southern Levant, the mining of ore and the production of copper.

A Note Regarding Preservation Conditions of Site 30. Even though it is located outside the common tourist track in the Timna Valley, Site 30 has suffered severe disturbances by ill-executed restoration efforts and other hazards. The little that has remained intact is unprotected and under constant threat of natural weathering and human-inflicted damage. The archaeological remains include the main slag mound discussed above, which contains an unparalleled record of Iron Age Timna. Although rains are rare in this region, when storms do occur they are relatively strong; we have found that the original face of the section of the slag mound has retreated about a meter (!) in the 31 years since it was exposed (and left unsheltered) by the Arabah Expedition. This situation is quite regrettable, as at this rate of weathering, the small "slag mound" will soon disappear and with it an invaluable record of the history of metallurgy. The preservation of different types of slag (and technologies) in one sequence, furnace fragments, tuyères, molds, and other archaeometallurgical artifacts, together with rich organic materials (textiles, hide, ropes, and grape, date, and other seeds) is unique on a worldwide scale. The new project at Timna 30 demonstrates how research methods and analytical technologies change and progress as generations replace one another; as things stand now at Timna 30, nothing will be left for the next one.

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