The beginning of Iron Age copper production in the southern Levant: new evidence from Khirbat al-Jariya, Faynan, Jordan

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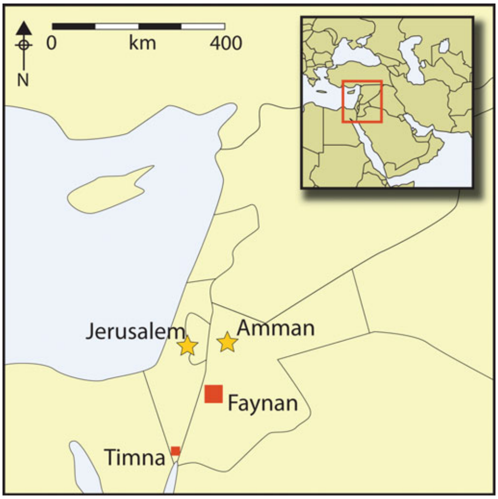

The authors have explored the workplace and house of copper workers of the early Iron Age (twelfth to tenth century BC) in Jordan's Wadi Faynan copper ore district, showing that it belongs in time between the collapse of the great Bronze Age states and the arrival of Egyptians in the area under Sheshonq I. They attribute this production to local tribes – perhaps those engaged in building the biblical kingdom of Edom.

Keywords: Iron Age, Edom, copper archaeometallurgy, radiocarbon, archaeomagnetism

Introduction

The resurgence of copper production in the southern Levant, at the end of the second or start of the first millennium BC, relates to the widespread civilisation collapse at the end of the Late Bronze Age (*c*. 1600-1200 BC) when new socio-economic opportunities became

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available to societies living on the periphery of the once vibrant cores such as Mycenae, New Kingdom Egypt, and the Hittite Empire of Anatolia and Syria. Recent excavations of copper mining and production sites in Jordan's Faynan district, the largest copper ore deposit in the southern Levant, shed new light on the nature of the reappearance of copper production following its demise in the Middle Bronze Age (early second millennium BC).

The excavations at the copper production sites of Khirbat en-Nahas and Khirbat al-Jariya in southern Jordan (Biblical Edom) provide the first detailed record concerning the timing, scale and social control of copper production at the beginning of the Iron Age when copper was still the most widespread metal produced in the eastern Mediterranean. These data relate to questions concerning the link between social and technological change and recent debates about the relationship between archaeology and history from a period when these data can first be linked to the biblical world. In the region of Faynan, these questions are specifically related to the emergence of the Iron Age polities of Edom and ancient Israel, since both had a potential interest in one of the most significant natural resources of the region.

The data presented in this paper are the result of the ongoing excavations of Iron Age copper production sites in Faynan, utilising on-site GIS recording (Levy & Smith 2007) coupled with high precision radiocarbon dating. The excavated materials and the radiocarbon dataset (from these excavations and other sites) help to establish a solid contextual and temporal foundation for assessing the impact of technology on major changes in the socio-political organisation of this region during the formative period of the early Iron Age (*c*. 1200-900 BC).

Iron Age copper production in the southern Levant

The two major copper ore deposits in the southern Levant, Timna (Rothenberg 1999a & b) and Faynan (Hauptmann 2007), are located along the margins of the Arabah Valley, separating Israel and Jordan. They were exploited from the ninth millennium BC to the medieval Islamic period, with one of the prominent peaks of exploitation occurring during the Iron Age (Levy *et al.* 2004b, 2005, 2008; Hauptmann 2007; Mattingly *et al.* 2007). At Timna, research showed that the flourishing Late Bronze Age copper production ceased in the mid twelfth century BC as a result of the decline in Egyptian economic power during the Twentieth Dynasty (Rameses V) (Rothenberg 1988: 270-78). Only Stratum I at Timna Site 30 was interpreted as a phase of revived copper production during the tenth-ninth centuries BC, again under Egyptian influence, but during the Twenty-second Dynasty (and in particular Sheshonq I, see Rothenberg 1980: 198-201). However, close examination of the radiocarbon dates for metallurgical sites in the southern Arabah Valley (Table 1) reveals a more complex situation with evidence of continuous metal production throughout the Iron Age I-IIA (*c*. 1200-900 BC), and possible ore exploitation in the late Iron Age as well.

In Faynan, *c*. 100km to the north, intensive archaeological work in recent years has resulted in a marked increase in high precision radiocarbon measurements for Iron Age copper production sites (Table 1, Figure 1). Excavations have been made at the Iron Age IIA cemetery of Wadi Fidan 40, at the Rujm Hamra Ifdan watchtower/enclosure, and copper processing sites of Khirbat Hamrat Ifdan and the *c*. 10ha central site of Khirbat en-Nahas

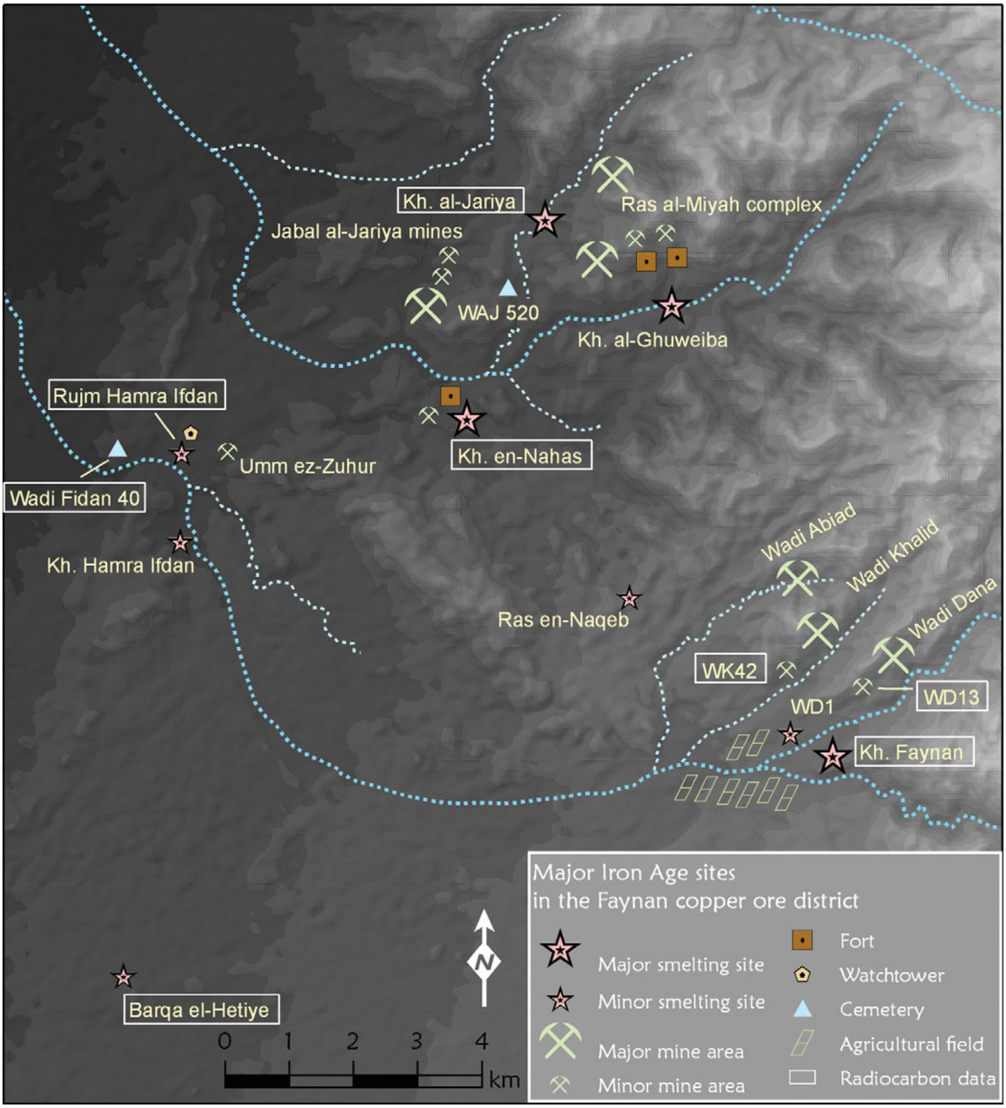

Figure 1. Major Iron Age sites in Faynan, Jordan. Kh. = 'Khirbat' ('ruins of' in Arabic). For radiocarbon dates and references see Table 1; note that several sites include Late Bronze Age radiocarbon dates (map drawn by E.B.-Y).

(Levy *et al.* 2004b, 2008). The site of Khirbat al-Jariya reported here has provided survey indications of early Iron Age date (twelfth to eleventh century BC, Hauptmann 2007: 89, 131-2 and see Table 1 in this paper), and thus was presumed to precede and complement the archaeological and archaeometallurgical assemblage obtained from the mostly tenth- to ninth-century BC site of Khirbat en-Nahas.

Khirbat al-Jariya

Khirbat al-Jariya (KAJ) is located *c.* 3km north-east of Khirbat en-Nahas (KEN) (30.707°N, 35.452°E, *c.* 150m asl, Figure 1) in an enclosed valley hidden in the rugged terrain of the

Table 1. Compilation of radiocarbon dates from Late Bronze Age and Iron Age copper production sites in the southern Levant. All dates are calibrated using OxCal v.4.1, © Ramsey 2009; dates for Timna were compiled with the help of U. Avner. l. = locus; elevation is in metres (m) below surface.

Site	Lab #	Radiocarbon age BP	Cal age – 68.2% prob. (BC)	Context	Reference
Faynan copper ore district (northern Wadi Arabah)					
Wadi Khalid, Mine 42	HD1492	3197±39	1500-1432	Backfilling, 17m inside entrance	Hauptmann 2007: 89
Wadi Dana, Mine 13	HD10578	2949±63	1262-1056	Waste dump in front of entrance, −0.6m	"
Khirbat al-Jariya (KAJ)	HD16351	2915±30	1192-1048	KJ2-4	"
	HD10990	2886±56	1191-979	Slag heap, wadi edge −0.3m	"
	HD16530	2839±22	1026-936	Base of slag heap, −0.75m	"
	See Table 2 in this paper				**This study**
Khirbat en-Nahas (KEN) Basal Strata	OxA17646	2871±26	1112-1005	Stratum M4: basal Stratum of 'slag mound', domestic and industrial mix	Levy *et al*. 2008: 16463, here indicated as an 'outlier'
	OxA19040	2942±27	1254-1117	Stratum M5a: charcoal (*Retama r.*) near installation l.676	**This study**
	OxA19041	3026±27	1373-1260	Stratum M5b: charcoal from sediment above virgin soil	**This study**
	OxA12169	2899±27	1126-1026	Stratum S4: basal Stratum below industrial structure, domestic and industrial mix	Levy *et al*. 2005: 149, including important discussion on context
KEN, fortress, excavations at Area A	GrA25334	2910±50	1193-1016	Stratum A2A, l.21	Levy *et al*. 2005: 135
	GrA25318	2920±35	1193-1051	Stratum A3, l.89	"
	GrA25354	2880±50	1151-977	Stratum A3, l.89	"

Table 1. Continued

Site	Lab #	Radiocarbon age BP	Cal age – 68.2% prob. (BC)	Context	Reference
KEN ‘slag mounds’	HD14308	2876±38	1122-1002	KN-Eisen-5, −1.15/−1.25m	Hauptmann 2007: 89
	HD14057	2905±40	1189-1016	KN-2, −0.85/−0.9m	Engel 1993: 209
	HD14302	2880±28	1114-1012	KN-Eisen-2, −0.17/−0.2m	Hauptmann 2007: 89
	HD14336	2895±35	1127-1014	KN-3, −1.15/−1.3m	Engel 1993: 209
	HD14113	2864±46	1116-976	KN-Eisen-6, −1.65/−1.8m	Hauptmann 2007: 89
KEN 10th - 9th centuries BC	See published dates in Engel 1993: 209, Higham *et al.* 2005, Levy *et al.* 2005, Hauptmann 2007: 89, Levy *et al.* 2008 and Levy *et al.* in press for new results of areas T, R and F				
Rujm Hamra Ifdan (watchtower, minor smelting)	OxA14849	2747±28	914-842	Sounding A (hill top), charred date	Levy *et al.* 2008: online supplementary material
	OxA14850	2849±28	1050-941	"	"
	OxA14851	2537±27	791-595	Sounding B (hill bottom), charcoal (*Tamarix*)	"
	OxA14852	2473±28	752-524	"	"
	OxA14853	2495±28	761-546	"	"
Khirbat Faynan (smelting activities)	HD10581	2726±102	1000-801	Slag heap 5, l.3, storage jar	(Hauptmann 2007:89)
	HD10992	2664±74	910-786	Slag heap 5, −0.3m	"
	HD10582	2647±47	889-789	Slag heap 5, l.2, furnace	"
	HD10580	2380±45	516-396	Slag heap 5, l.2, furnace	"
	Beta203407	2900±40	1188-1012	WF455, slag heap 9 or 7 (inconsistency in publications)	Hunt *et al.* 2007: 1334; Mattingly *et al.* 2007: 282
	Beta203406	2890±40	1129-1005	"	"
	Beta203409	2830±40	1039-923	"	"

Table 1. Continued

Site	Lab #	Radiocarbon age BP	Cal age - 68.2% prob. (BC)	Context	Reference
	Beta203408	2790±40	1001-901	"	"
	Beta201410	2790±40	1001-901	"	"
	Beta203411	2680±40	894-803	"	"
	Beta110840	2630±50	841-771	WF5017, Barrage section, −2.4m (bulk sediment)	Hunt *et al.* 2007: 1334
	Beta110841	2630±50	841-771	WF5017, Barrage section, −2.6m (bulk sediment)	"
Barqa al-Hetiye (habitation, smelting activity)	HD13977	2743±23	908-843	House BH2, l.108 (Ceramic: Iron Age I)	Levy *et al.* 1999: 305; the date obtained by Fritz was not available in time for the original publication of the site (Fritz 1994)
Timna Valley and surroundings (southern Wadi Arabah)					
Timna 30 (smelting site)	Ham216	3340±60	1689-1531	(Charcoal?) from Layer I, slag heap	Scharpenseel *et al.* 1976: 287
	BM1598	2785±50	1003-851	Charcoal from metallurgical debris, Layer III-II	Conrad & Rothenberg, 1980: 201; Burleigh & Matthews 1982: 165
	BM1162	2480±35	756-539	Charcoal associated with 'slag cake' from Layer I	"
Timna S28	HAM212 (Bonn2361)	2780±90	1027-827	Copper mine	Scharpenseel *et al.* 1976: 287 confused in Conrad & Rothenberg 1980: 179
Timna 2 (smelting site)	BM2382	3220±50	1530-1430	Slag heap, Layer II	Rothenberg 1990: 71
	Pta4121	3090±60	1430-1294	Area Z, bottom of slag heap	"

Table 1. Continued

Site	Lab #	Radiocarbon age BP	Cal age - 68.2% prob. (BC)	Context	Reference
	GrH4493	3000±50	1370-1131	Area F, Layer II	"
	H3625-2782	2940±50	1257-1056	Furnace IV, Layer I	"
	Pta4123	2880±60	1189-943	Slag heap, Layer II	"
	BM1115	2840±51	1109-919	Area E, Layer I, Furnace I	"
	RTT5276	3125±35	1441-1322	Area C, l.100, B1	T. Erickson-Gini *pers. comm.* 2009
	RTT5277	2920±35	1193-1051	Area A, l.500, B20	"
	RTT5278	2965±35	1260-1129	Area A, l.501, B23	"
	RTT5279	2965±40	1263-1127	Area A, l.1001, B27	"
N. Amram	Pta4127	2920±60	1212-1021	Smelting camp	Rothenberg 1990: 71
Timna S27	HAM208 (Bonn2357)	2910±60	1210-1012	Copper mine	Scharpenseel *et al.* 1976: 286–7 confused in Conrad & Rothenberg 1980: 179
	HAM207 (Bonn2356)	2910±70	1252-1008		"
Timna S18	HAM210 (Bonn2359)	3050±70	1411-1215	Copper mine	Scharpenseel *et al.* 1976: 287 confused in Conrad & Rothenberg 1980: 179
Timna 200	BM1117	2779±55	999-847	Sanctuary	Burleigh & Hewson, 1979: 349
Timna F2 (smelting site)	BM1368	3030±50	1386-1215	Furnace remains, charcoal, square 3, l.3	Burleigh & Matthews, 1982: 165
Timna S19	HAM211 (Bonn2360)	2640±60	895-774	Copper mine	Scharpenseel *et al.* 1976: 287 confused in Conrad & Rothenberg 1980: 179

Figure 2. Satellite image of Khirbat al-Jariya and its vicinity; JAJ = Jabal al-Jariya; for key see Figure 1 (reproduced using Google Earth Pro).

eastern Wadi Arabah. It extends over 7ha on both banks of Wadi al-Jariya and consists of shallow 'slag mounds', numerous architectural features, installations and some large structures preserved to a height of five courses and more (Figures 2 & 3). Deepening of the wadi bed over the past three millennia has eroded the site centre (*c*. 3ha) that was situated on the western bank of the wadi (see Figures 2 & 4). With the exception of several recent Bedouin graves and some robber trenches, the site has been relatively undisturbed since its abandonment in the Iron Age.

Following fieldwork by Glueck (1935) and the German Mining Museum (Hauptmann 2007), our team surveyed and mapped the site in 2002 (see Figure 4) (Levy *et al.* 2003). The first stratigraphic probe took place at KAJ between 13-27 November 2006. Area A was selected in the southern portion of the eastern bank of the Wadi al-Jariya, where a

Figure 3. The Iron Age copper smelting site of Khirbat al-Jariya, looking toward the north (note people in Area A for scale). The site is bifurcated by Wadi al-Jariya whose deepening eroded a significant portion of the ~5ha ruins. Also visible are the relatively shallow 'slag mounds' and some substantial stone structures, probably dating to the eleventh to tenth century BC (photograph: T.E.L., UCSD Levantine Archaeology Laboratory).

rectangular structure found in survey (see below) seemed to be associated with one of the larger 'slag mounds,' resembling the situation in Area M at KEN (Levy *et al*. 2008). A grid of four 5 × 5m squares was established over the 'slag mound' and structure. The building was exposed to its floor level and the western half of the 'slag mound' to bedrock (Square F-16) where the accumulation of archaeological material appeared to be the thickest and six layers representing at least three occupation phases were recorded (Figure 5, Table 2).

The 'slag mound' sounding: copper production at Khirbat al-Jariya

Although commonly regarded in the literature as piles of slag, 'slag heaps' or 'mounds' are rarely composed of only slag material. At KEN, approximately 20-30 per cent (in volume) of the excavated material of the 'slag mound' in Area M was slag in various forms and types with the remainder of material consisting of decomposed furnaces, tuyères, charcoal, etc. At KAJ the situation is even more striking as only a very small volume of the excavated material was slag. The rest of the deposit consisted of fills with considerable amounts of domestic (*not* pyrotechnological) debris, including relatively large quantities of ceramic sherds, ash and other material (see below). This observation should be taken into consideration when calculating production intensities by estimation of slag mass from surface observations, as is

Table 2. KAJ Area A stratigraphy, radiocarbon and archaeointensity results, cf. Figures 5 & 8 for sample location, and Figure 9 for the Bayesian model of the results at 68.2 and 95.4% probability. N=number of specimens per sample; archeointensity sample JS02b is from Ben-Yosef *et al.* 2008a.

		^{14}C results (calibrated with OxCal4.1 © Bronk Ramsey 2009)					Archaeointensity results				
Layer	Description	Lab #	Material	δ^{13}C ‰	Radiocarbon age BP	Cal age - 68.2% prob. (BC)	Lab #	Material	N	B_{anc} (μT)	vadm (zam^2)
A1a	Top sediments of the 'slag mound': copper production debris, aeolian dust and a few stone installations	OxA-19033	Charcoal Tamarix sp.	−24.54	2864±28	1113-997	JS02b	Tapping slag and clay (slag attached to furnace fragment)	5	76.8±8.7	149±17
A1b	Fill inside structure 276, large boulders and stones	OxA-19034	Charcoal Retama ra.	−11.18	2898±28	1125-1026					
A2	Occupation phase of structure 276 and probably copper production debris at the top of the 'slag mound'	OxA-19087	Charcoal Indet.	−26.98	2797±26	995-912					
A3	'Fill': accumulation of copper production debris, part of the 'slag mound'	OxA-19035	Charred seed Phoenix dac.	−22.92	2799±26	994-915					
		OxA-19130	Charred seed Phoenix dac.	−23.5	2851±36	1108-934	W03268a	Ceramic	3	68±3.1	131±6
A4	Occupation phase: stone installations, living/activity floors, tent dwelling?	OxA-19036	Charcoal Tamarix sp.	−22.54	2803±26	995-919					

Table 2. Continued

		^{14}C results (calibrated with OxCal4.1 © Bronk Ramsey 2009)					Archaeointensity results				
Layer	**Description**	**Lab #**	**Material**	$\delta^{13}C$ ‰	**Radiocarbon age BP**	**Cal age - 68.2% prob. (BC)**	**Lab #**	**Material**	**N**	B_{anc} (μT)	**vadm** (zam^2)
A5	‘Fill’: accumulation of domestic debris mixed with industrial remains	OxA-19037	Charred seed Phoenix dac.	−24.75	2902±27	1128-1026	W03269a	Slag	3	63.3±8.9	122±17
A6	Occupation phase above bedrock: fine crushed slag, ore, ash pockets and pits dug into bedrock	OxA-19038	Charcoal Phoenix dac.	−26.7	2880±26	1113-1012					
		OxA-19039	Charcoal Indet.	−21.53	2884±27	1114-1016					

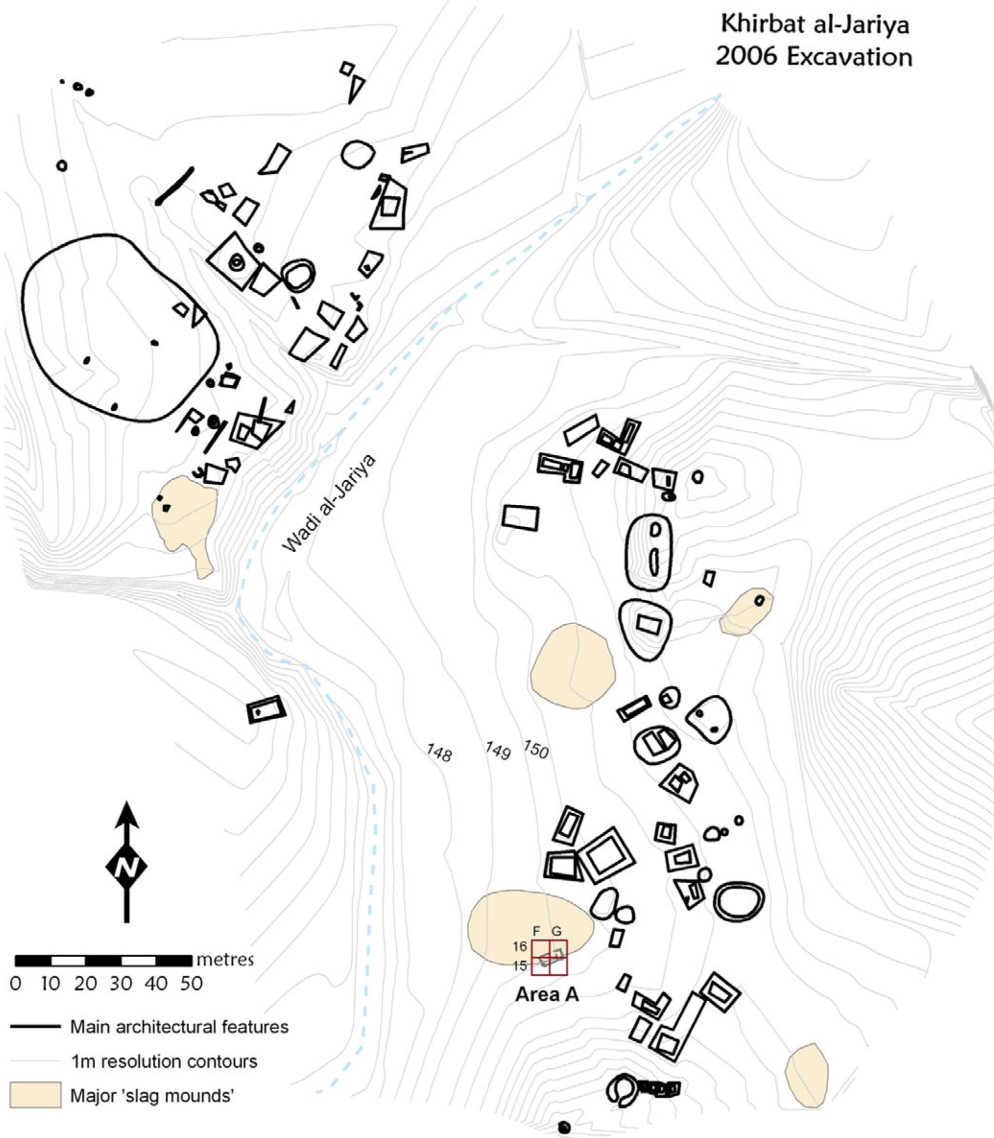

Figure 4. Architecture and 'slag mounds' in Khirbat al-Jariya (after Levy et al. *2003: 274). The 2006 excavation Area A, including its grid and building 276, is indicated in the south-east part of the map. The 'empty' area in the centre is a result of erosional processes (see text).*

commonly done in archaeometallurgical research around the world (see e.g. Ottaway 2002; Craddock & Lange 2003; Hauptmann 2007). The Area A 'slag mound' is 2.4m deep, and includes three distinctive activity horizons (layers A6, A4 and A1a/A2; Figure 5, Table 2), and two thick fill layers that accumulated as a result of deliberate disposal of waste in the direction of the wadi channel, which originally was a few metres to the west.

Above the red sandstone bedrock (Salib Formation), is a layer that probably represents the initial occupation phase of the site (A6). Evidence for copper production-related

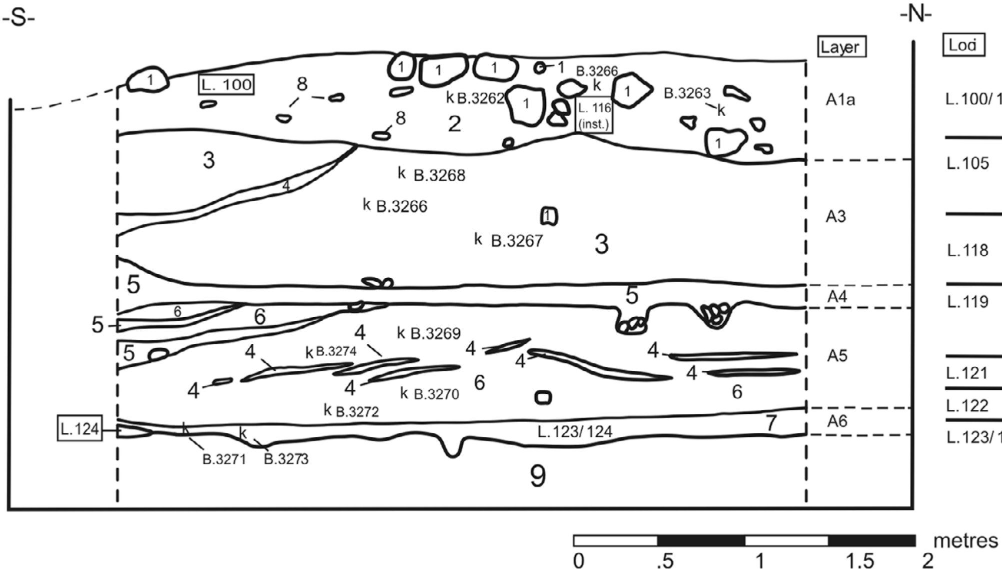

Figure 5. Khirbat al-Jariya: Area A, schematic drawing of the west section in the 'slag mound' probe, representing the stratigraphic sequence of the site, from surface to bedrock (located in Figure 7): 1) stones; 2) broken slag with ashy sediments; 3) broken slag with clay and silt; 4) light coloured ash pockets; 5) hardened ashy sediments; 6) light brown soil, domestic debris, ashy pockets; 7) fine crushed slag; 8) large slag fragment; 9) bedrock; B) archaeointensity sample (slag/ceramic). For description of layers and associated ^{14}C dates see Table 2. Note that only the location of samples for archaeointensity research is indicated here, as they were collected directly from the western wall of the excavation pit.

activities was found here, including thin, cemented patches of fine crushed slag (L.123 on Figure 5), small pits dug into the bedrock (related to crushing activity?), ash pockets and some copper ore fragments (Figure 6c) in a thin and noncontiguous layer of light brown sediment (L.124). This supports the supposition that the *raison d'être* of KAJ, like most Iron Age archaeological sites in the extreme arid environment of Faynan, was the exploitation of the copper ore deposits. There are no water sources in the close vicinity of the site (the closest is 'Ain al-Ghuweiba, located across a steep ridge *c*. 2.7km to the south-east, Figure 2), but numerous Iron Age copper mines are located a few hundred metres up the wadi and its tributaries (Levy *et al.* 2003: 270) as well as *c*. 2km to the south-west, on the other side of Jabal al-Jariya (Jabal al-Jariya mines, Ben-Yosef *et al.* 2009a) (Figure 1).

Above the horizontal basal layer was *c*. 70cm of 'fill' - mostly domestic debris, composed of light brown sediment rich in ceramic sherds, bone and ash pockets (A5). The scant copper production refuse included small fragments of furnace linings, slag and tuyères (cf. Figure 6g–h), copper prills (Figure 6i) and some chunks of copper metal (Figure 6j); nevertheless, the general characteristic of the fill is of domestic activities, mostly cooking, eating and storage of water and food represented also by the ceramic assemblage. The sequence of inclined fine layers was cut abruptly by levelling of the surface in preparation of a flat area for habitation and other activities represented in layer A4. The latter is made of thin horizons of hardened light-brown earth with some charcoal and pottery sherds, stone installations, patches of stone pavement, and several pits dug into the fill of A5. Two of the pits were distinctive, narrow (3-5cm in diameter) 'holes' in the ground; one was 23cm deep

Figure 6. From ore to metal — finds from Area A excavation: A) 23cm hole in the ground level of layer A4 with a red clay plug in its bottom (L.120); B) large sandstone basin unearthed by robbers near the 'slag mound'; C) copper ore from the manganese-rich dolomite-shale Burj formation; D) hammerstone made of a chert nodule; E) dimples hammerstone; F) grinding slab; G) tuyère (front) with cloth imprints on the clay; H) tuyère (back) with a 'niche' for fixing the inner part of the nozzle; I) copper prill; J) a chunk of copper metal; K) copper pin; L) decorated pottery fragment; M) worked fossil of a sea urchin used as an ornament (L.118) (photographs: UCSD Levantine Archaeology Laboratory).

with hardened blackish walls and a red clay plug in its bottom (Figure 6a) and the other, 0.5m to the north-northwest, was 10cm deep. Coupled with the stone installations and other finds from layer A4, these may reflect tent habitation activities. Other finds from layer A4 include a copper pin (Figure 6k), several grinding stones (see similar examples in Figure 6d-f) and a mollusc fossil probably used as an ornament and similar to a worked fossil of a sea urchin found in L.118 above (Figure 6m). It is interesting to note the abundance of such fossils in the eighth- to sixth-century BC site of Busayra, approximately 15km to the north-east on the Edomite plateau (Reese 2002, including comparative discussion of this phenomenon).

After the layer A4 occupation ceased, the area became a disposal zone again, but rich with archaeometallurgical remains (A3), including pieces of tap and furnace slag (2-10cm in diameter), ample charcoal remains, tuyère and furnace fragments and chunks of copper metal and ore in a matrix of ashy sediment and clay indicating decomposed furnace materials. Evidence of some domestic trash was present as well, including ceramic sherds and date pits. Layer A3 is truncated by a horizontal accumulation of copper production debris, representing the last phase of activity in this part of the site (A1a-A2). A few metres to the north of the 'slag mound' a huge sandstone basin (*c*. 1.5 × 1.2m; see Figure 6b) was found on the surface, exposed by recent robbery. The basin also relates to the last phase of copper production, and was probably used to crush ore, flux, charcoal or slag as part of the copper smelting process. The large size of this ground stone mortar is similar to ones found in Area F at KEN that date to the tenth century BC and indicate considerable investment in metallurgical activities at this time (Levy *et al.* in press).

The evidence from the 'slag mound' in Area A indicates small-scale copper production, considerably different from the massive enterprise at nearby KEN. The mound is relatively shallow (cf. 6.5m of industrial layers at KEN Area M) and only partially represents copper production activities. All contexts show a mixture of industrial and domestic debris and, even in layers directly related to smelting procedures, the archaeometallurgical artefacts indicate work in small installations and quantities indicative of limited production. The most notable technological difference between the sites relates to the size of the metallurgical installations. Furnace fragments and tapping slag at KAJ are smaller than in most excavated contexts at KEN, and the tuyère are shorter and less sophisticated (Levy *et al.* in press). The latter was first recognised by Hauptmann (2007: 131-2) who points out the similarity between the small tuyères of KAJ and the Late Bronze Age tuyères of Timna, suggesting to date the beginning of the smelting activities at KAJ to the Late Bronze Age.

Structure 276

The top layer A1a provides the context for Structure 276, although some of it may be related to a post-structure abandonment phase, including some ephemeral stone installations close to the surface (L.116 and 117). The layer includes similar materials to layer A3 only with larger pieces of slag (3-15cm in diameter) and a yellowish horizon of aeolian sediment that accumulated below the slag fragments covering the surface. Structure 276 is a rectangular building with outer dimensions of 6.5 × 3.2m and one doorway in its north-northwest broad wall (Figures 7 & 8). Its walls have only one course of massive local boulders and

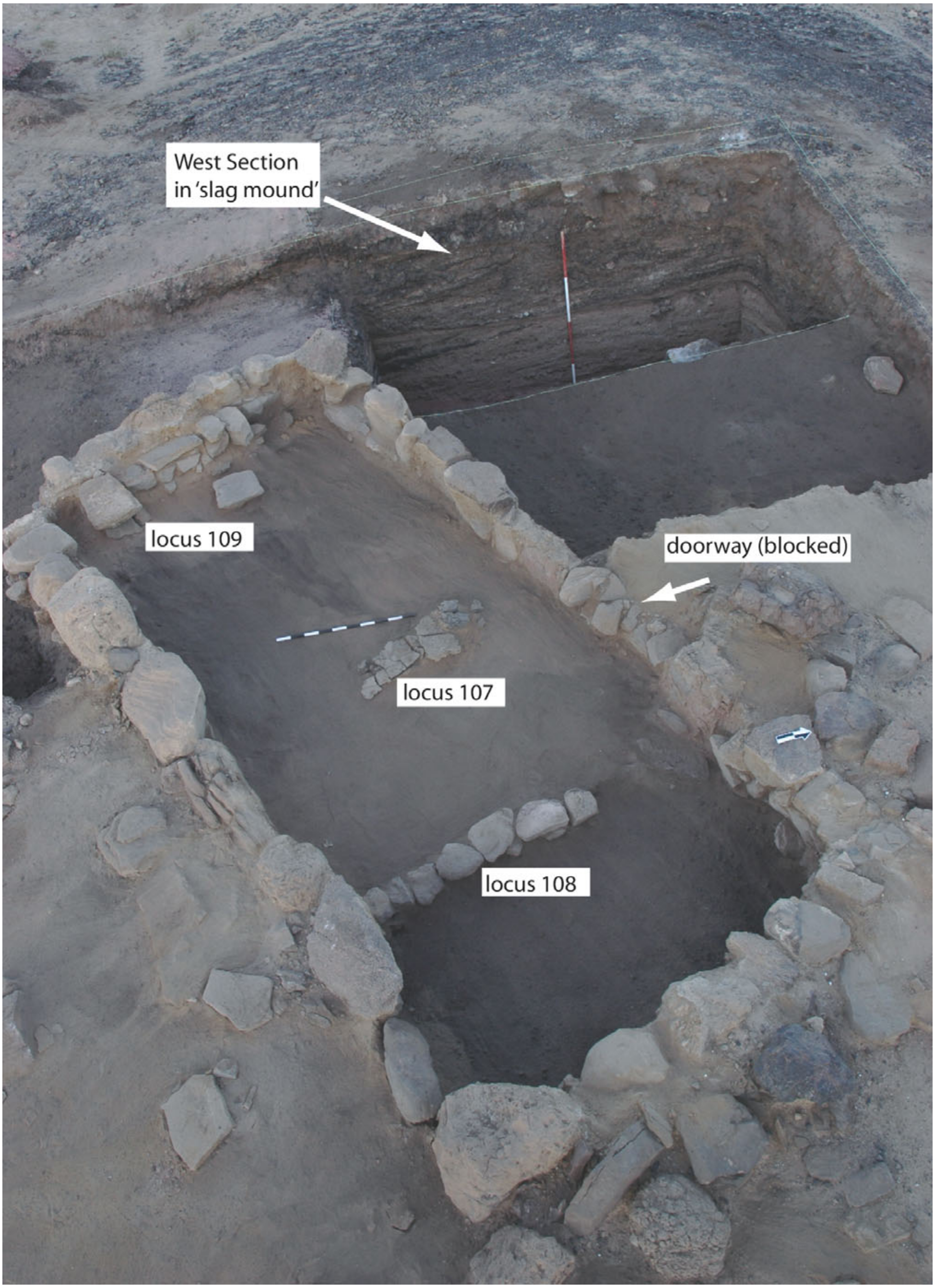

Figure 7. Khirbat al-Jariya: Area A, general view at the end of the 2006 season. The excavation exposed structure 276 to its floor level (hardened earth), revealing a stone-and-plaster 'bench' with a flat worked stone in front of it (locus 109), a patch of large tapping slag close to the doorway (locus 107) and a partitioning stone line abutting one of the structure walls (locus 108). In half of square F-16 the excavation penetrated a 'slag mound' to bedrock, exposing stratigraphic sequence of waste and occupation layers (compare with Figure 5, a drawing of the west section visible here) (photograph: T.E.L., UCSD Levantine Archaeology Laboratory).

roughly cut stones of *c*. 0.5m in width, built on the truncated pile of copper production debris (A3). Limited finds from the occupation phase of the building (A2) came from an elusive floor level and included small quantities of pottery sherds, some grinding stones and charcoal, in addition to three interesting features: a line of stones perpendicular to the south-east wall, partitioning the inner space of the building; a pavement of large tapping slag (in sizes not found in the 'slag mound') in the middle of the structure; and a bench-like installation abutting the interior of the south-west wall made of flat stones, stuck together with plaster. Some 10-15cm in front of the bench-like installation, on the floor level of the building, a flat, square, hewn stone with marks of intensive use was found. The building had a massive fill of heavy irregular stones (A1b) not indicative of wall collapse, but rather of an intentional blocking of the structure's inner space. Approximately 15 grinding stones of various types and a few pieces of charcoal were found in the fill.

Structure 276 presents difficulties regarding its interpretation. It was abandoned (or evacuated) prior to the deliberate filling of its inner space, resulting in scarcity of finds. It has substantial stone foundations that did not hold any substantial walls, as well as a few intriguing installations. Whatever the interpretation of these may be, it does not seem that the building was an important industrial feature.

Radiocarbon measurements

Nine new carbon samples from well-defined contexts at KAJ are presented here (Figure 9, Table 2). Modelling of the results using stratigraphic constraints and Bayesian statistics (Bronk Ramsey 1995; Buck *et al.* 1996) indicates that occupation of Area A started between 1092-1017 BC (68.2% probability; 1147-1007 BC, 95.4%) (start of A6) and ended between 1002-933 (68.2% probability; 1016-904 BC, 95.4%) (end of A1-2) with an overall occupation span of 20.5-133.5 years (68.2% probability; 0-206 years 95.4%).

Geomagnetic archaeointensity investigation: correlating Khirbat al-Jariya and Khirbat en-Nahas

Absolute determinations of the rapidly changing geomagnetic field intensity may refine correlation between archaeological horizons by complementing datasets of material culture and radiocarbon dates from different locations (e.g. Ben-Yosef *et al.* 2008b). Following the procedure of Ben-Yosef *et al.* (2009b) we obtained two new determinations from KAJ layers A5 and A3 in addition to the one published by Ben-Yosef *et al.* (2008a) for a sample collected from the upper portion of the same 'slag mound' (Table 2).

The archaeointensity data published here support the correlation of KAJ layers A3-A1a and KEN Stratum M3, probably to its early phase (cf. Ben-Yosef *et al.* 2009b: fig. 4), and also for correlating between layers A5-A6 with KEN Stratum M4. As more absolute archaeointensity determinations become available, Table 2 will provide a useful reference for correlating KAJ and other sites in future research. The extremely rapid changes in field intensity values, or 'spikes', during the Iron Age suggest that two statistically identical determinations from different sites indicate contemporaneity (up to a resolution of a few decades in certain time intervals).

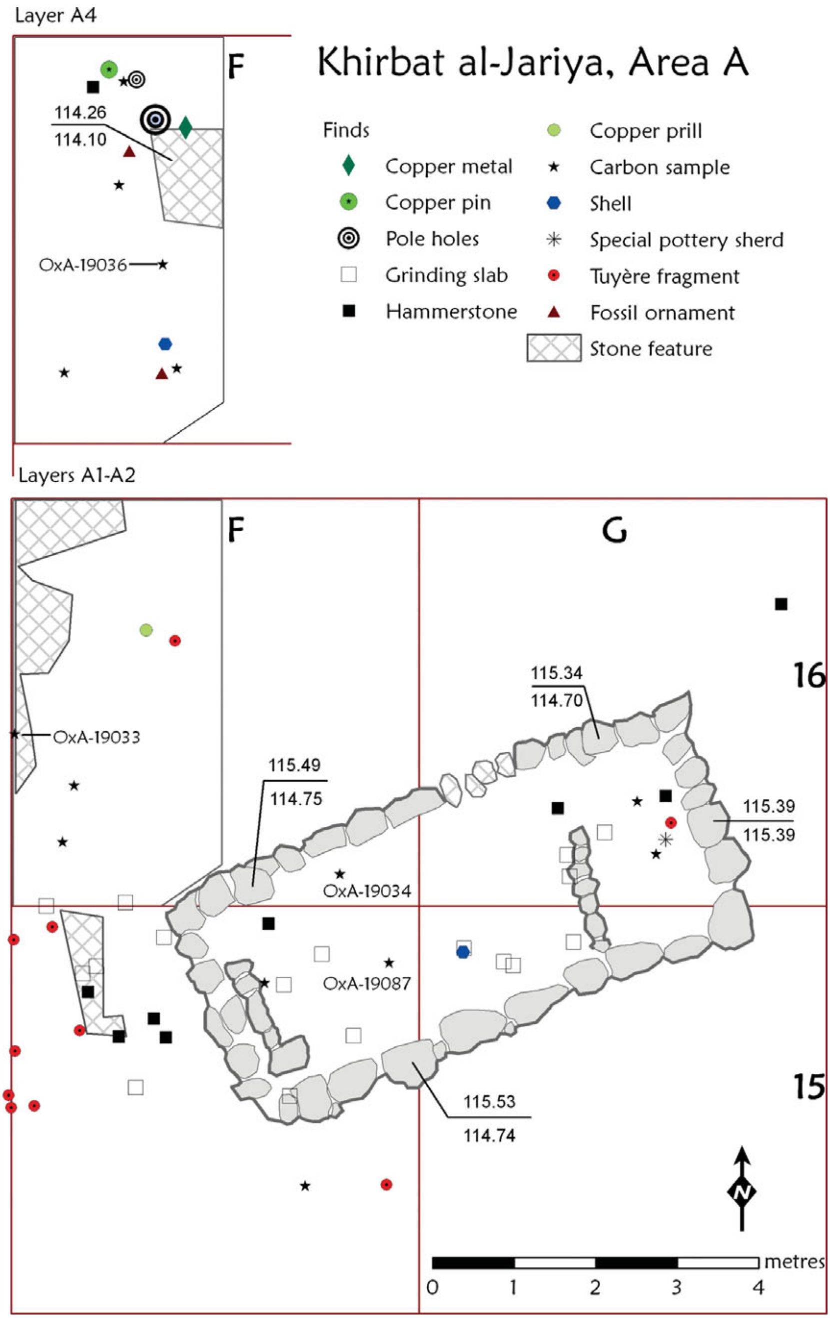

Figure 8. Map of Khirbat al-Jariya: Area A, layer A4 at the top and layers A1-A2 (including structure 276) at the bottom (see Table 2 and text for a description of the layers). The GIS-generated map displays the spatial distribution of artefacts and helps in interpreting the occupation layers. For example, note the concentration of tuyère fragments in square F-15 layers A1-A2 that may represent a broken furnace in this location, the high density of hammerstones and grinding slabs inside the structure that may hint to its usage, the relative size and location of the 'pole holes' in layer A4 suggest a smaller construction than a tent (maybe a wooden frame for a churn?). Note the location of carbon samples; the ones used for radiocarbon dating are indicated with their laboratory numbers (cf. Table 2) (GIS map drawn by E.B.-Y).

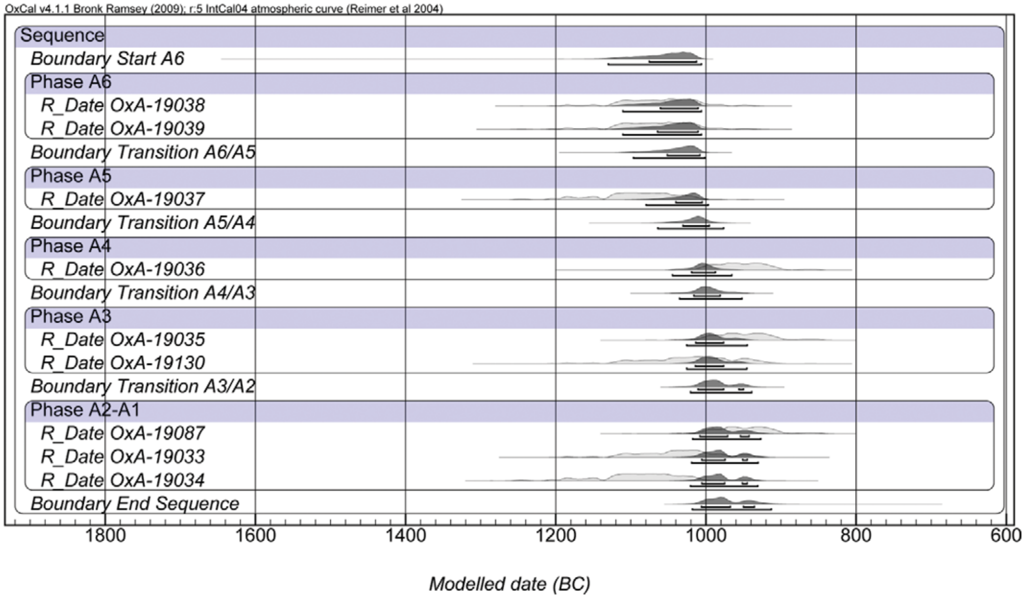

Figure 9. Bayesian age model of radicarbon data distribution for Khirbat al-Jariya (see Table 2 for the uncalibrated and calibrated laboratory dates). The site spans the eleventh and tenth centuries BC (see text for details).

New evidence from earliest Khirbat en-Nahas

As part of re-examining the earliest phase of Iron Age copper production in Faynan, we investigated the bottom (*c*. 1.2m) strata of the Area M 'slag mound' at KEN and obtained two new radiocarbon dates (Table 1). These new dates show that a previously published date referred to as an 'outlier' in Stratum M3 (the large-scale tenth-century BC production phase, see Levy *et al*. 2008: 16462) belongs with the new dates from the deepest stratigraphic levels of the site, represented by the production debris of Stratum M4 and the occupation remains of Stratum M5a-b (starting at the fourteenth century BC). Stratum M5a-b includes two installations — an 'altar-shaped' shallow structure situated directly above virgin wadi sands (M5b) and a rectangular stone-built oven *c*. 25cm higher (M5a). Although the installations themselves are probably not related to copper production, patches of fine crushed slag and charcoals in the sediments that accumulated at the same level and adjacent to their foundations may indicate small-scale copper production activities at the very early stage of occupation at KEN (similar to KAJ A6).

The new results from KEN Stratum M4 strengthen previous evidence for Iron Age I occupation of the site, which comes from radiocarbon measurements of Stratum S4, three radiocarbon measurements from KEN Area A, and two 'slag mounds' sampled by the GMM team (Table 1). In general, the evidence of the early industrial phase of copper production at KEN has similar characteristics to the bulk of excavated material from KAJ: a sequence of fine layers of copper production and domestic debris.

Discussion

After the collapse of Late Bronze Age state-level societies in the eastern Mediterranean (e.g. Bachhuber & Roberts 2009), new socio-economic opportunities arose in lands on their periphery. A window on this process is provided at KAJ in the marginal Faynan copper ore district of southern Jordan. The stratified excavations there show that the site was first occupied around the mid eleventh century BC and abandoned sometime during the mid to late tenth century BC — earlier than previously assumed. The sounding suggests that the substantial architecture visible on the site surface dates to the first half of the tenth century, and that earlier settlement was probably based on a more ephemeral use of the site. KAJ was established to exploit the copper sources in the nearby mines, and metal production developed gradually and opportunistically from the use of simple technologies for small-scale production to mass production with sophisticated large-scale installations. The peak in Iron Age copper production in Faynan, however, is evident at nearby KEN (e.g. Strata M3-M1, tenth to ninth centuries BC) without parallel record at KAJ, and demonstrates a different and more complex social organisation of production extending into the ninth century BC — but no later.

Radiocarbon dates from three Faynan sites, including KEN, suggest small-scale copper production activities starting already in the Late Bronze Age (with dates as early as the fifteenth century BC, Table 1). At Timna, although there are fewer high precision radiocarbon dates and sample contexts are not always secure, there is evidence for small-scale copper production throughout the Iron Age I-IIA sequence, *after* the end of Twentieth Dynasty Egyptian hegemony in the region (Table 1). The resumption of copper production along the length of the Arabah Valley during the early Iron Age should be seen in light of 'global' economic and political changes, especially the disruption of commercial connections between Cyprus and the Levant at the end of the thirteenth century BC (Knauf 1995; Fantalkin & Finkelstein 2006; Finkelstein & Piasetzky 2008) and the vacuum in political power in the region after the decline of Egyptian influence (Levy *et al.* 2008) that occurred in the Late Bronze Age-Iron Age transition. Still, the questions of who or what triggered and organised this enterprise, what was the destination of its products and what social and political processes brought about the recorded technological changes within the Iron Age remain open.

There is no evidence in the early stages of Iron Age copper exploitation (before the end of the tenth century BC) for Egyptian or any other external control. The ceramic assemblages demonstrate local vessel types (see Smith & Levy 2008). In our view, the evidence from Faynan indicates that the resumption of copper production at the very end of the Late Bronze-Early Iron Age, was opportunistically initiated by local semi-nomadic tribal societies. These may be the 'Shasu' tribes mentioned in ancient Egyptian documents and suggested as having been responsible for the tenth-century BC cemetery at Wadi Fidan 40 in the Faynan district (Levy *et al.* 2004a; Levy 2009). Moreover, although the resumption of copper production may be related to the wider phenomenon of settlement intensification in the Negev highlands, and in particular to interaction with the so-called 'Tel Masos chiefdom' (Fantalkin & Finkelstein 2006), we do not consider both regions to represent the same political or social entity. Rather, these Negev sites may have played a role in the copper exchange network emanating from Faynan. Thus, during the Iron Age I, Faynan was part of the lowlands of biblical 'Edom' and provided the natural resources that enabled the beginning of processes that led to a local complex society such as a kingdom (Avishur 2007) or chiefly confederacy (Levy 2009) described in the biblical accounts.

The geographical extent of Edom is poorly delineated in historical accounts. Most scholars agree that during the late Iron Age (seventh to sixth century BC) Edom's borders extended to the west of the Arabah Valley, and according to Edelman (1995) and Zucconi (2007) the earliest references to 'Edom' may already encompass this larger area. Our Iron Age research indicates that its borders oscillated through time with Faynan as its core during the eleventh to ninth century BC and the highland plateau site of Busayra, most likely in the eighth to sixth centuries BC.

KAJ was abandoned in the second half of the tenth century BC, possibly coinciding with the date of the military campaign of Pharaoh Sheshonq I (biblical Shishak) in the region (Kitchen 1986: 292-302). Levy *et al.* (2008: 16465) ascribe the disruption marked by the M3-M2 boundary at KEN (Area M) to the impact of this campaign on the organisation of copper production at the site, while Fantalkin and Finkelstein (2006) attribute the prosperity evident in Tel Masos II and other changes in the archaeological record of the Beersheva Valley to this event (contra e.g. Fritz 2002). These researchers view the Egyptian endeavour as a positive intervention, fostering the copper industry and trade (and definitely not related to the end of Iron Age IIA in the region). Although no definitive evidence of deliberate destruction was found at KAJ or KEN, the abandonment of the first and the reorganisation of the second (that may have occurred decades after the year of Sheshonq's campaign itself) may suggest that Egypt attempted to strangle the incipient industry, which eventually was revived in greater intensity by the local political powers independent of Egypt (Kitchen 1986) by the early ninth century BC. Nevertheless, we do not think that a decisive answer regarding the Egyptian role in the copper industry is currently at hand. Other explanations for the cumulative archaeological data are possible; for example, the abandonment of KAJ may relate to exhausting the local mines and focusing on the large copper ore-filled colluvial fields of Jabal al-Jariya (Ben-Yosef *et al.* 2009a), closer to KEN.

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