ARCHAEOMAGNETIC DATING OF COPPER SMELTING SITE F2 IN THE TIMNA VALLEY (ISRAEL) AND ITS IMPLICATIONS FOR THE MODELLING OF ANCIENT TECHNOLOGICAL DEVELOPMENTS*

E. BEN-YOSEF,[1] L. TAUXE[2] and T. E. LEVY[1]

[1]*Department of Anthropology, University of California, San Diego, La Jolla, CA 92093, USA*
[2]*Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093, USA*

Site F2 in the Timna Valley, Israel, is a small copper smelting site of 'primitive' technology, dated by its excavator to the Pottery Neolithic (sixth to fifth millennium BCE). This early date challenges the common view of the beginning of smelting technology in the Levant and has been contested by various scholars since its publication. In this study, we present results of archaeointensity experiments conducted on slag fragments from the site. The slag yielded an excellent ancient geomagnetic value ($64.1 \pm 1.1 \mu T$) that, when compared to the Levantine master curve, suggests an age not older than the second millennium and most probably between the 13th and 11th centuries BCE. In addition to demonstrating the applicability of geomagnetic archaeointensity experiments to independent dating of slag, we discuss the implications of the current results for the socio-historical picture of the Timna Valley, and in particular for the way in which technological developments were previously modelled in the archaeometallurgical research on the region.

KEYWORDS: ARCHAEOINTENSITY, ARCHAEOMETALLURGY, TIMNA, DATING TECHNIQUES, ARCHAEOMAGNETISM, COPPER PRODUCTION

INTRODUCTION

Reconstructing sequences of technological achievements in human history depends first and foremost on accurate dating of the archaeological record. This is often a difficult task, especially when no charcoal is available for radiocarbon dating or when the context of the technological remains is not clear. Persistent efforts have been made in archaeological research to find independent methods for direct dating of archaeological objects and to avoid contextual or typological problems. This paper is concerned with such an independent method and its application to the technological remains of Site F2 in the Timna Valley, Israel (Rothenberg and Merkel 1995). According to its excavator, the site represents the earliest evidence of copper smelting in the Levant and is a key to understanding the beginning of metallurgy in the Old World. This view has been contested by others on various grounds (e.g., Adams 1997; Avner 2002; Hauptmann and Wagner 2007), yet the potential importance of Site F2 called for further investigation. Here we present results from an archaeointensity study of slag material from F2, which support a much younger age of approximately the 13th to 11th centuries BCE.
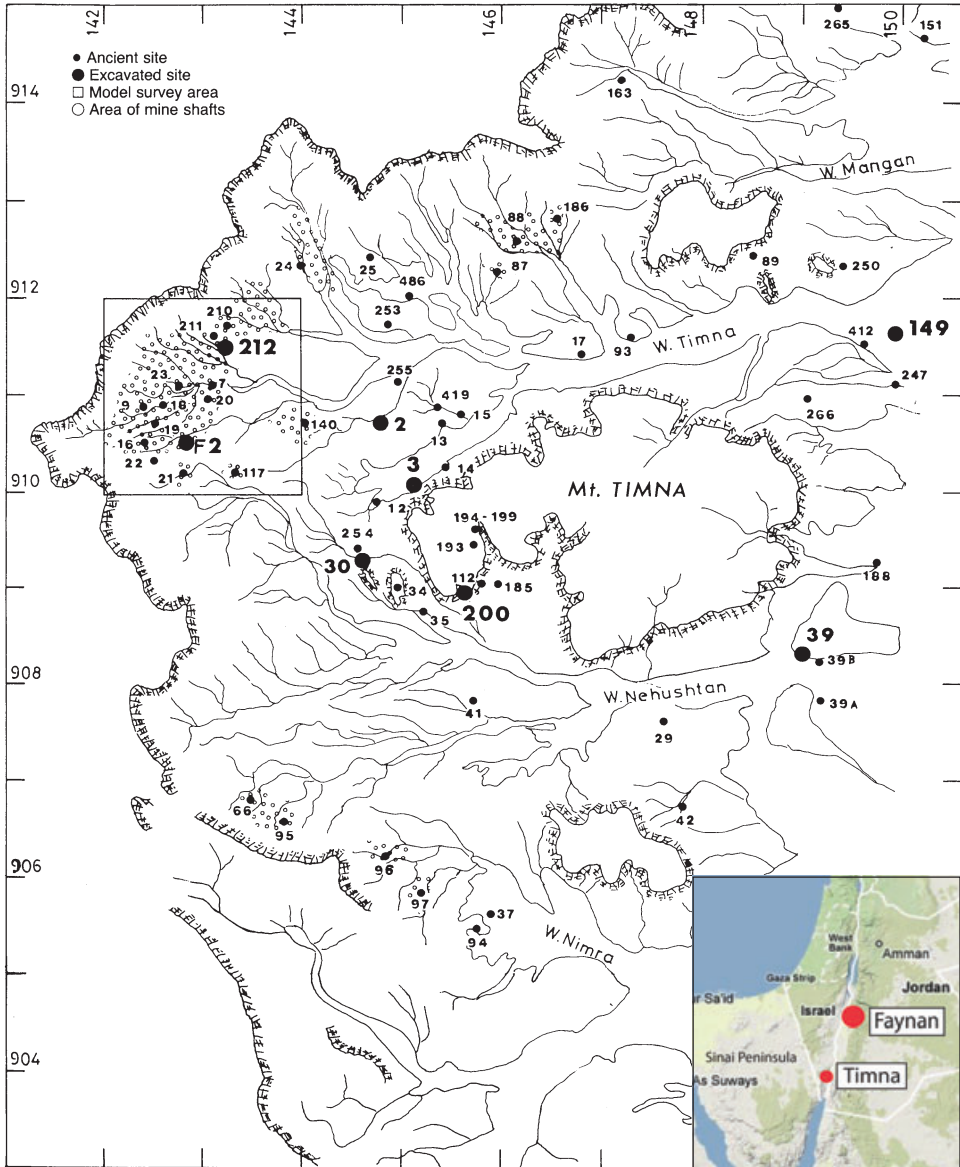
Figure 1 *A survey map of the Timna Valley (Rothenberg 1990), showing the location of Site F2 (in close vicinity to the copper mine fields; the square indicates the area of the 'Model Survey' of the Arabah Expedition, where Area G and Site F2 are located) and other archaeological sites. The inset indicates the location of Timna and Faynan, the major copper ore districts of the southern Levant.*

In contrast to the major smelting camps in the Timna Valley described, for example, by Rothenberg (1999b), Site F2 is located in close vicinity to the copper mines themselves, on the edge of a large pit mine field (Area G, Fig. 1). It was found and excavated in 1976 by the 'Arava Expedition' (Rothenberg and Merkel 1995), as part of a systematic ~4 km² 'Model Survey' of a

representative ancient mining landscape. The site is described as a smelting workshop and consists of a few working tools, slag scatter (Segal *et al*. 1998, fig. 7), fragments of small tuyères (Rothenberg 1990, figs 14 and 15), iron-rich copper ore nodules, rough coil-made ceramic sherds and numerous flint tools and debitage. No architecture or stone-built installations were found. In one of the excavation squares, at some distance from the workshop itself, a copper needle and an ash and charcoal pocket (described as 'intrusive') were unearthed (Merkel and Rothenberg 1999, 152). Charcoal from this pocket yielded a radiocarbon date of 3030 ± 50 BP (1386–1215 cal. BCE [OxCal2009]: Burleigh and Matthews 1982, 165).

The various finds and the analytical results of the slag fragments (chemistry and mineralogy) were interpreted as representing a 'very primitive smelting technology' based on a 'trial and error' method in a period when deliberate fluxing was unknown and self-fluxing ore was in use (Segal *et al*. 1998, 233). The smelting installation was no more than a 'hole in the ground', powered by simple bellow pipes (reeds?) whose nozzles were protected by the very small clay tuyères (~2 cm in diameter). The excavated ash and charcoal pocket was interpreted as an intrusive melting furnace, used by the much later occupants of the site for re-melting the copper-rich slag (Merkel and Rothenberg 1999, 152–3).

The proposed Pottery Neolithic age of the site is based primarily on the ceramic finds, whose typology and petrography were thought to be similar (except for the matrix) to the Qatifian ware (Merkel and Rothenberg 1999), a cultural horizon defined for sites in the southern Gaza Strip and dated by radiocarbon to the (calibrated) mid-sixth and most of the fifth millennium BCE (Gilead and Alon 1988). According to the original research team who investigated the site, the early date is also supported by: (1) the 'primitive' (or 'incipient') metallurgy, indicated by the extremely inhomogeneous furnace slag ('not yet slag in the true sense of this term'—Rothenberg 1999a, 78), the lack of stone-built installations, the abundance of copper prills, a lack of the deliberate use of flux (suggesting a lack of fluxing know-how) and the 'most primitive' tuyères; (2) the 'primitive' quality of the pottery (even without the proposed identification of Qatifian ware); (3) the proximity to 'primitive pit mining'; and (4) scattered flint tools of 'prehistoric' date (not published). It appears that the basic guideline in dating the site was what Segal *et al*. (1998, 233) termed as a 'technological horizon', a concept that embodies the 'Standard View' of technology (Pfaffenberger 1992; and see below) and is based on the postulation of unilinear technological evolution, always from simple to complex.

The early date of Site F2 challenges the common view of the beginning of copper smelting technology. As Hauptmann and Wagner (2007, 69) state, 'the proposed dating . . . not only would predate the beginning of extractive metallurgy in the Levant by a few millennia, it also would raise the know-how of earliest metallurgical techniques in the entire Old World to a hitherto unknown level of sophistication, unparalleled by any other findings'. Moreover, such a date calls into question a widely accepted model of the organization of production for the early stages of copper smelting technology in the southern Levant (and possibly worldwide), according to which the smelting activities were conducted by communities of experts inside settlements and *far* from the ore source (Levy and Shalev 1989; Hauptmann and Wagner 2007—although misunderstood by the latter, both references present the same model).

Avner (2002) and Hauptmann and Wagner (2007) among others used the evidence of relatively advanced technology as an argument against the early dating of the site, while Adams (1997) emphasizes the lack of any parallel Neolithic smelting from the Faynan copper ore district (in Jordan, ~100 km to the north of Timna), which has settlements from the same period (Adams 1997). The identification of the ceramic ware as Qatifian has also been disputed (Avner 2002, fn. 24). However, the site still may present a unique case in the very early 'trial and error' attempts

to produce metal, and more decisive evidence is needed. Hauptmann and Wagner (2007, 70–1) conducted a 'simplified variant' (due to the small amount of material) of thermoluminescence (TL) measurements on one piece of slagged tuyère that produced a date of 1585 to 115 BCE (1σ), which suggests a younger age for the site. Following this attempt to independently date technological artefacts, and encouraged by the results of Ben-Yosef *et al.* (2008a), we conducted archaeointensity experiments on slag fragments from Site F2. Dating the slag material itself complements the study on the tuyère fragment, and stands against a possible claim that the tuyère may belong to the intrusive phase of occupation.

METHOD

In recent years, published ancient geomagnetic intensity values for archaeological periods of the Levant (in short, 'archaeointensity' values) have accumulated to a robust data set that can be used, in some cases, as a dating reference (Genevey *et al.* 2003; Gallet and Le Goff 2006; Gallet *et al.* 2006; Ben-Yosef *et al.* 2008b; for a dating application, see Ben-Yosef *et al.* 2008a). In addition, slag material was found to be highly suitable for archaeointensity experiments, demonstrating a high yield of reliable results (Ben-Yosef *et al.* 2008b; Shaar *et al.* 2010). Slag (and many other types of materials, of which most commonly in use for archaeological periods is ceramic and other baked clay) records the properties of the ambient geomagnetic field at the moment of its cooling below the corresponding blocking temperature of its dominant ferromagnetic minerals (e.g., below 580°C for magnetite). As most slag (and ceramic) fragments are not found in their original orientation of the time of cooling, we are able only to retrieve the ancient intensity component and not the directional one (declination/inclination).

The most common experiments for retrieving intensity values from a sample that recorded geomagnetic properties while cooling are based on some variant of the Thellier–Thellier method (Thellier and Thellier 1959). The basic physical theory behind this method is that the magnetic intensity of the sample (Natural Remanent Magnetization, NRM) is, in low fields such as the Earth's, approximately linearly proportional to the ambient field at the time of cooling. Thus, by applying a known field on a re-heated sample in the laboratory and measuring the artificially acquired intensity (Thermal Remanent Magnetization, TRM), the constant of proportionality can be estimated and calculation of the ancient field is feasible. However, the original magnetic component of a sample may be complex (e.g., if the sample was later partially re-heated) and/or the mineralogy and texture of a sample may alter during the heating process, resulting in an unreliable proportionality constant. In order to assess the quality of the results, the experiment is divided into separate steps of gradually heating the sample in an oven with a controlled magnetic field, usually alternating between 'in-field' and 'zero-field' steps and with repetition of selected temperature steps for checking constancy in the quality of magnetic recording. The experiments usually require several weeks, although many samples can be processed together (depending on the capacity of the oven). The data accumulated during the experiments are usually represented graphically as 'Arai plots' and 'vector end-point diagrams' (see Figs 2 and 3), as well as quantitatively by a suite of variables that characterize different aspects of the sample behaviour (for a more complete description, see Ben-Yosef *et al.* 2008b). Both kinds of data representation are used for quality control, and are the basis for accepting or rejecting results. A complete survey of the Thellier–Thellier derived experimental protocols can be found in Tauxe (2010, ch. 10).

The recorded properties of the geomagnetic field are directly dependent on the geographical latitude. Thus, for comparison of data from different locations, the laboratory result of magnetic intensity (in units of microtesla) is represented as a virtual axial dipole moment (VADM) that

simulates the same dipolar source of the field (Tauxe 2010, ch. 10). The small-scale variations of the geomagnetic field (called 'secular variations') are commonly taken to be more or less consistent over an area of up to 1000 km in extent, as they mostly represent non-dipole components (Valet 2003). However, global models based on data collected worldwide are still in use (see, e.g., Korte and Constable 2005), although they should be treated with caution, both for the robustness of the input data and for probable regional variations.

For the current study, we obtained slag fragments from the collection of the 'Arava Expedition', with the kind permission of Beno Rothenberg. Out of one fragment of shiny black colour and with visible green spots, ~3 cm in diameter (sample IS27), we chipped five slivers, each a few millimetres in diameter (specimens IS27a1–5) and placed them in small glass tubes for further processing in the oven. It is worth noting that the specimens needed for archaeointensity experiments are usually very small in size for most burnt archaeological materials. We followed the 'IZZI' experimental protocol described by Tauxe and Staudigel (2004) (for a graphic illustration of the experiment, see also Ben-Yosef *et al.* 2008b, fig. 11), in which the first pair of heating steps are carried out with the zero-field step first and the second with the in-field step first. In addition, all successful specimens were subjected to an anisotropy of anhysteretic remanence (AARM) correction procedure (compensation for inherent possible bias derived from constraints of crystalline structure: see Tauxe 2010, ch. 10), as well as to non-linearity correction measurements (Selkin *et al.* 2007). Due to the fast cooling rate of slag material, there was no need for cooling rate corrections (see Ben-Yosef *et al.* 2008b). The experiments were conducted in the Paleomagnetic Laboratory at Scripps Institution of Oceanography (University of California, San Diego).

<center>RESULTS</center>

We show the experimental data from all acceptable specimens in Figure 2 and those that were rejected in Figure 3. Arai plots are shown in Figures 2 (a), 2 (e) and 2 (i), and in Figures 3 (a) and 3 (b). These are generally linear from 200°C to the maximum unblocking temperature of about 520–540°C, although the plots in Figure 3 are less linear than those in Figure 2. The slope of the line between the two selected end-points (diamonds) multiplied by the laboratory field gives an estimate of the ancient magnetic field (B_{raw}). These range from 58.4 to 68.7 µT.

The behaviour of the remanence vector during cooling is depicted in the vector end-point diagrams (Figs 2 (c), 2 (g) and 2 (k), and insets to Figs 3 (a) and 3 (b)). Our acceptance criteria rule out multi-component behaviour as displayed in Figure 3; the diagrams in Figure 2 generally show simple decay to the origin (although the data in Fig. 2 (g) are modestly curved).

The directions of magnetic remanence during the heating experiments are also shown in the equal area projections in Figures 2 (b), 2 (f) and 2 (j). The remanence directions measured in the zero-field first steps are circles, while the in-field first steps are squares. The triangles are the directions of the remanence acquired during the in-field cooling. Nominally, these should be parallel to the laboratory field directions (at the centre of the diagram) and deviation from this direction (as in Fig. 2 (b)) indicates that the specimen's remanence acquisition is anisotropic.

In addition to the demagnetization and remagnetization experiments described above, we have also performed two additional experiments. The first is to check the primary assumption of the Thellier–Thellier technique, of a linear relationship between the applied field and the remanence acquired. For this, we heat the samples to above their Curie temperatures and cool them in laboratory fields ranging from 20 to 70 µT. The resulting curves are shown in Figures 2 (d), 2 (h) and 2 (l), and demonstrate that the linearity assumption is excellent. The intensity estimates after

Figure 2 (following page)   *Experimental results from accepted specimens. (a, e, i) Arai plots are shown, together with the calculated ancient field calculated in three ways. B_{raw}: the slope of the heavy/green line times the laboratory field. B_{nlc}: corrected for non-linear TRM acquisition (see (d), (h) and (l)). B_{anc}: B_{nlc} further corrected for remanence anisotropy. The open (closed) circles are the in-field first (zero-field first) steps. The triangles (squares) are the pTRM (tail) check steps. The NRM intensities are in Am^2. (b, f, j) Directional results plotted as equal area projections, with vector end-point diagrams shown in (c), (g) and (k). The solid line from the centre to the edge of the equal area projections is the direction of the NRM, which serves as the x-axis direction in the vector end-point diagrams. The triangles in the equal area projections are upper hemisphere projections of the directions of the pTRM gained at the in-field temperature step. The applied field was at the centre of the diagram (in the up direction). The offset from the applied field direction implies significant anisotropy of remanence; it requires anisotropy correction. The circles (squares) are zero-field first (in-field first) steps and the closed (open) symbols are lower (upper) hemisphere projections. (d, h, l) TRM acquisition experiments. Specimens are given a total TRM by heating to 600°C and cooling in varying applied fields (dots). The data are fitted with the best-fit hyperbolic tangent (solid line). B_{raw} (diamond) is found using the linear acquisition assumption. The actual field required to produce the same TRM (square) is B_{nlt}.*

correction for non-linear TRM acquisition B_{nlt} are identical to the original estimates B_{raw}. The second experiment relates to the anisotropy of remanence acquisition. Specimens are given an anhysteretic remanence (ARM) in nine different directions. From these data, the remanence anisotropy tensor can be calculated and applied to the laboratory TRM, correcting for the anisotropy. The intensity estimates after this final correction, B_{anis}, range from 62.9 to 65.2 µT, in much better agreement with one another.

Three out of five specimens yielded excellent archaeointensity results and agree well with each other, giving an average value of 64.1 ± 1.1 µT (a VADM of 126 ± 2.2 ZAm^2) (Fig. 2). Although there is no consensus regarding cut-off values of control variables, the successful specimens pass the strictest standards of the commonly used criteria, among them a straight slope of the Arai plot, and a single component in the vector end-point diagram. The criteria applied here are the same as those used in our previous study (Ben-Yosef *et al*. 2009). The other two specimens (Fig. 3) failed because the curved vector end-point diagrams suggested multi-component remanences.

When comparing the archaeointensity data from Site F2 with the Levantine curve of Ben-Yosef *et al*. (2009) and with the global model of Korte and Constable (2005) (Fig. 4), it is evident that the only time period with VADM values as high as 126 ZAm^2 is around the second to first millennium BCE. The relatively high archaeointensity value recorded in the slag sample agrees well with the peak in intensity spanning the Late Bronze and Iron Ages (1400 to 700 BCE). Although the result from Site F2 matches more than one point on the Levantine curve (the heavy line in Fig. 4), it most probably indicates 13th to 11th century BCE smelting activity, given the published ^{14}C date from the site, the values that are similar to those of other sites from periods comparable to that of Timna (compare with values from sites Timna 2, Timna 3 and Timna 30, published in Ben-Yosef 2008a,b) and the history of metal production in the southern Arabah, which shows proliferation of metallurgical activities in this period.

<div align="center">DISCUSSION</div>

Archaeointensity dating

As demonstrated above, archaeointensity research is applicable as a dating tool for archaeological samples from the Levant, independent of their context or typological considerations. The stratigraphic situation of Site F2 is far from being clear; the total sedimentation is merely ~18 cm
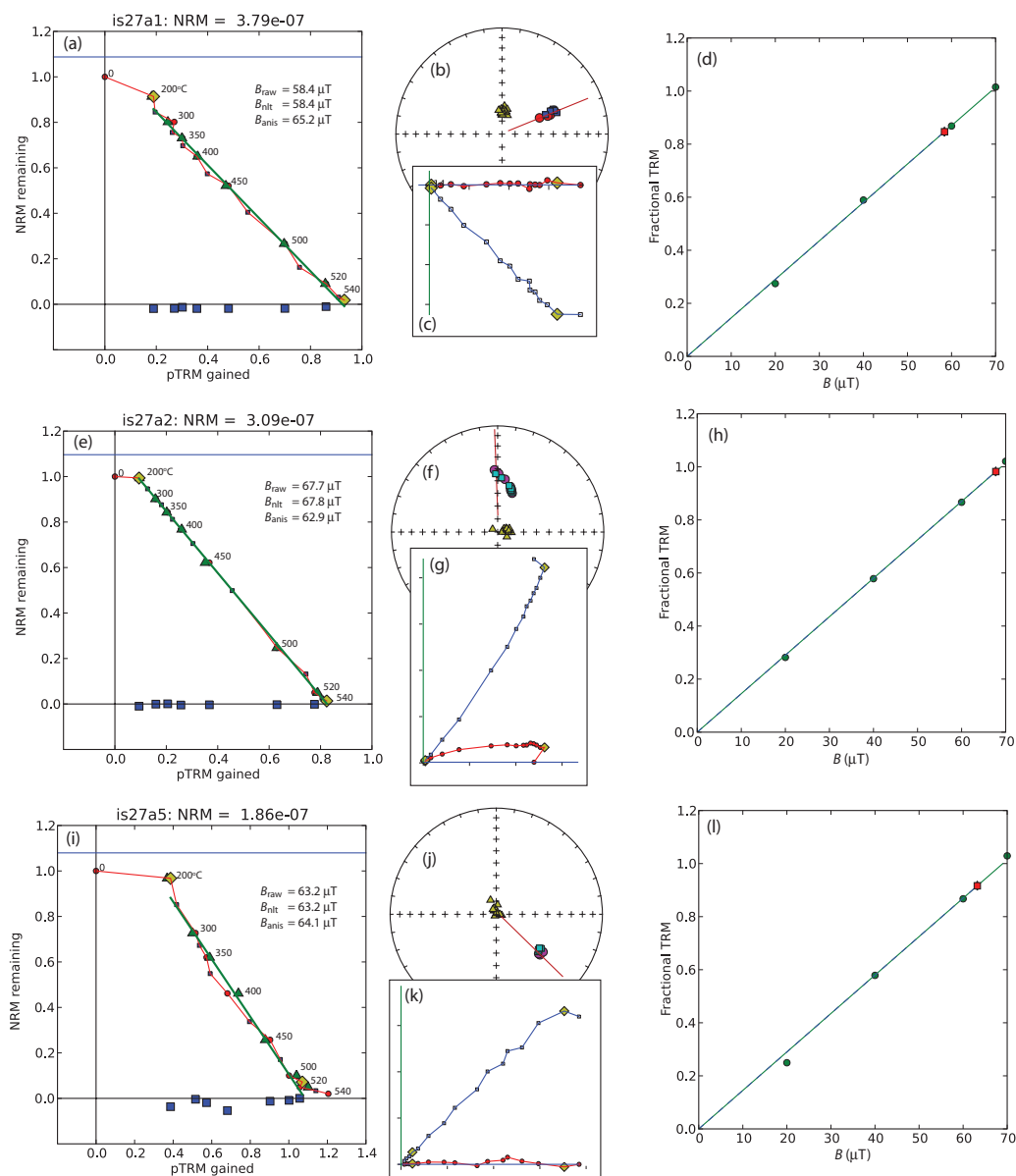
deep (Merkel and Rothenberg 1999, fig. 7) and consists of four different layers, two of which were defined as 'intrusive'. The typology, both of the smelting remains (namely ground stones, slag and tuyère fragments) and of the crude ceramic, is problematic and contested. The role of the site as supplying significant evidence for early metallurgical development is dependent on the date of the technological remains represented mostly by the slag fragments. Thus, the ability to independently confirm the age of the slag fragments themselves is of great benefit.

Other methods for independent dating exist, such as rehydroxylation of fired clay (Wilson *et al*. 2009) and thermoluminescence (e.g., Aitken 1985), each with its own limitations and
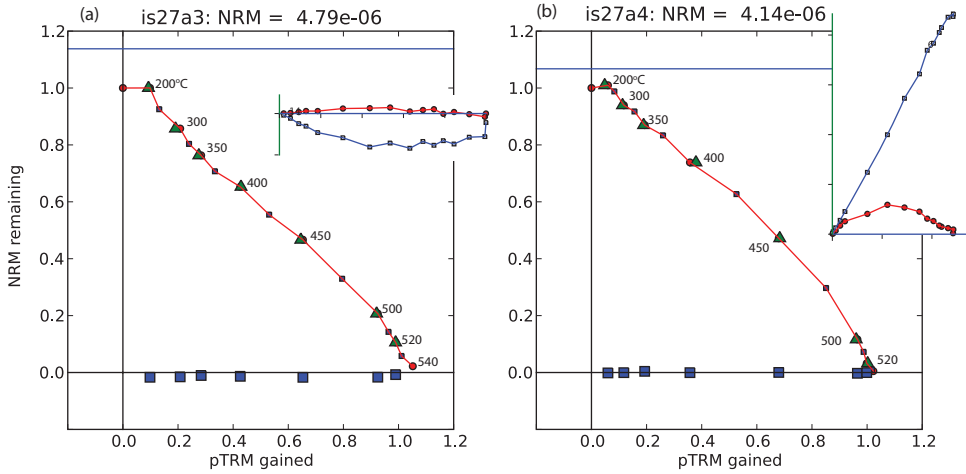
Figure 3 *Results from rejected specimens. See the caption to Figure 2. The end-point diagrams show more than one component of high temperature remanence acquisition (above 200°C) that may be the result of multiple heating/cooling episodes.*
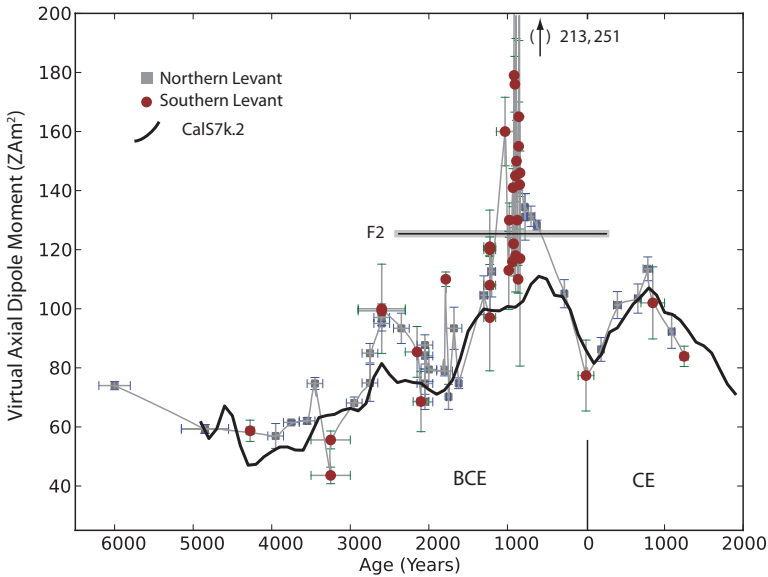

Figure 4 *The Levantine curve compiled by Ben-Yosef* et al. *(2009). Data from the northern Levant (Syrian data of Genevey* et al. *2003 and Gallet* et al. *2006) and from the southern Levant (Israeli and Jordanian data of Ben-Yosef* et al. *2008b and 2009) are shown as squares and circles, respectively. The reference curve (thin black line) is from the CalS7k.2 model of Korte and Constable (2005). The data from F2 are shown as the solid black bar (grey margins represent σ of the average) and are consistent with a 13th to 11th century BCE age for this site.*

capabilities. Archaeointensity dating requires a relatively small sample size and in some cases, such as the one of Site F2, it is plausible to pinpoint a very narrow age (cf., TL results for the slagged tuyère from the same site, mentioned above). The archaeointensity dating method also has the advantage of identifying post-deposition re-heating (e.g., by a later campfire on the same

spot), a potential complication in dating techniques that are based on exposure to heat (for details, see Tauxe 2010, ch. 10 and Fig. 3). As mentioned above, retrieving reliable ancient geomagnetic values is plausible for various types of archaeological materials, including ceramic, fired-clay bricks, slag of metal and glass production, and kiln walls and linings, although with different success rates. Ben-Yosef *et al.* (2008b) demonstrated the advantages of slag and other pyrotechnological ceramics (crucibles, furnace walls, tuyères etc.) in archaeointensity research, including relatively high success rates and fewer contextual problems (such as heirlooms or a long usage span for ceramics). Recently, this was further corroborated by a thorough study of the magnetic properties of slag and the mechanism of TRM acquisition in such material (Shaar *et al.* 2010).

The accuracy and resolution of archaeointensity dating depends directly on the resolution and accuracy of the reference curve. When using only data obtained by rigorous experimental methods and strict selection criteria, the time resolution of the Levantine curve is still low. Nevertheless, more high-quality archaeointensity data from well-dated sites in the Levant are published frequently and improve the quality of the curve as a dating reference. The highly fluctuating intensity of the geomagnetic field presents difficulty even when a high-resolution curve is available, as in cases the extracted value can match more than one point of the reference. In the current state of the Levantine data set, it is easier to exclude dates than to assign an exclusive age to a sample (as in the case of Site F2, in which Neolithic to Early Bronze ages were excluded—the suggested 13th to 11th century BCE date is based on supporting evidence). However, archaeomagnetic dating for the Holocene bears further potential for precision when combining the directional components (declination/inclination) with the intensity (see, e.g., Jordanova *et al.* 2004). This is plausible only with oriented samples, in regions where directional variation curves are established.

The characteristics of the geomagnetic field dictate that the secular variation curves show consistency over an area of approximately 1000 km in extent; thus the applicability of the Levantine curve is spatially limited. High-resolution archaeointensity data are available for Europe, North America and Central Asia (see, e.g., Korhonen *et al.* 2008), but are scarce in other parts of the world, most notably India and Australia, from which there are virtually none. Establishing high-resolution archaeointensity curves using samples from well-dated sites will not only benefit archaeological research in the future; it is of great interest for geophysical research aiming at understanding the Earth's magnetic field and related phenomena, one of the more enigmatic topics in geosciences.

Technological typologies

Segal *et al.* (1998, 233) use the concept of the 'technological horizon' as substantial support for the Neolithic date of Site F2 and as the only means of dating Site N3 in Timna. They state: 'Inferences can be made about the relative level of sophistication of the processes used. Comparing two prehistoric sites in Timna – Site F2 and Site N3 – it is obvious that the smelting technology at Site N3 was more developed in the appropriate use of flux than at Site F2. [. . .] The metallurgy of Site N3 had reached the "technological horizon" of Chalcolithic copper smelting in the Timna Valley, dated by the archaeological evidence found in the excavations of Site 39' (ibid.). The same approach of dating archaeometallurgical sites according to the level of sophistication and advancement in technology as represented by the archaeological finds prevails throughout the pioneering research of the 'Arava Expedition' in the southern Negev (see in particular Rothenberg 1990, 68; Rothenberg and Glass 1992; Merkel and Rothenberg 1999; Rothenberg *et al.* 2006). The central paradigm underlying such an approach assumes a strict

unilinear technological evolution throughout human history, in which a less developed technology always predates a more advanced one. The adherence to this paradigm, even when ^{14}C dates became available and suggest a different story, has created confusion in the archaeological research of this key area for the study of ancient metallurgy.

Perceiving technological developments as a unilinear evolution is part of what Brian Pfaffenberger (1992) has termed the 'Standard View' of technology, and is usually accompanied by the two other paradigms of 'necessity is the mother of invention' and 'form follows function and style, and meaning is a surface matter'. To exemplify the unilinear evolution paradigm, Pfaffenberger argues (1992, 494):

> This record shows a unilinear progression over time, because technology is cumulative. Each new level of penetration into Nature's secrets builds on the previous one, producing ever more powerful inventions. The digging stick had to precede the plough. Those inventions that significantly increase Man's reach bring about revolutionary changes in social organization and subsistence. Accordingly, the ages of Man can be expressed in terms of technological stages, such as the Stone Age, the Iron Age, the Bronze Age, and so on.

(Pfaffenberger uses 'Man' for 'humankind' quite deliberately to emphasize the gender ideology accompanying the Standard View.)

The socio-historical reality is much more complex, as the anthropological and archaeological records show constantly (e.g., Pfaffenberger 1992, 1998; Dobres and Hoffman 1999). Less developed technologies can reappear in the archaeological record (thus, the 'technological horizon' can be used only as a *terminus post quem*, with caution), and technological knowledge can be lost and regained. The results from Site F2 are in accordance with this view, and demonstrate the complexity of technological practices and developments in the Timna copper ore district.

The archaeointensity age range for Site F2, together with the published ^{14}C and TL dates, confirms a young age for the smelting activities, most probably around the same period when intense copper production activities took place in the region, during the Late Bronze and Early Iron Ages. The so-called 'primitive' characteristics of the technology are also well established by various studies of the slag, tuyères and ore fragments, especially in comparison to the advanced smelting technology documented for the Late Bronze and Iron Ages in the region (as mentioned above, the presence of tuyères makes it difficult to make a claim for 'most primitive' technology). A very similar case is the site of Yotvata (Site 44, Rothenberg *et al*. 2006), in which 'primitive' technological remains, considered by the excavator to represent Chalcolithic or even Neolithic smelting activities, were dated by archaeointensity to the Late Bronze Age – Iron Age I (Ben-Yosef *et al*. 2008a, 2876).

The apparent mismatch of 'primitive' technology practised in a late period can be explained in at least two ways, given that production models are not confined to the 'Standard View' of technology; both provide important insights into the society responsible for copper smelting in the research area. One interpretation suggests simultaneous occupation of Site F2 (and other sites of 'primitive' technology such as Yotvata—see details in Ben-Yosef *et al*. 2008a) with the major Late Bronze to Iron Age I smelting camps in the Timna Valley. In this case, Site F2 stands as evidence for segregation within a given society or between different social groups. The know-how concerning advanced smelting and/or the required organization of production were limited to the social group that maintained the large-scale smelting operation (this may explain the walls surrounding the large smelting camps of Timna 30 and 34), while others (the mining workers or different social groups, for instance), being aware of the potential of copper production from the

abundant ore, practised the simplest technology to hand. Another interpretation suggests that during hiatuses in the major smelting operations (even for a few years), marginal groups of nomads invaded the copper-rich area and practised small-scale, 'primitive' copper production. This may be a wider phenomenon than has been documented so far, as Site F2 was found in a 'Model Survey' of only 4 km^2 (Fig. 1), and additional similar sites are being documented constantly, some with comparable dating problems (Ben-Yosef *et al.* 2008a). In the Faynan copper ore district situated in the northern Arava valley, similar 'primitive' Iron Age smelting installations have been found in association with ephemeral camp sites that may be linked to this oscillating process of technological intensification and reduction (WFD Site 58—Levy *et al.* 2001).

In the above, we have demonstrated the applicability of archaeointensity research as a dating tool for slag samples and emphasized its advantages and further potential. In addition, the case study of Site F2 in the Timna copper ore district highlights the problems in dating technological remains by 'technological horizons' or typologies, and illustrates the complexity of technological practices in the history of the Timna Valley. In the current state of research, Neolithic smelting in the southern Levant should be excluded from archaeological discourse, as well as simplified approaches to technological evolution.

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