Journal of Archaeological Science 40 (2013) 4319–4330

Contents lists available at SciVerse ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Iron smelting and smithing in major urban centers in Israel during the Iron Age

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ARTICLE INFO

Article history:
Received 8 November 2012
Received in revised form
28 May 2013
Accepted 10 June 2013

Keywords:
Iron production
Slag cakes
Bloom fragments
Iron Age
Israel

ABSTRACT

By-products of iron production, mainly slag and bloom fragments, unearthed at three Iron Age urban centres in Israel (Hazor, Tel Beer sheba and Rehov), were analysed in order to better understand the organization of iron production during the Iron Age. The production remains studied are all dated not earlier than the Iron Age IIA, and thus shed light on a period of transition from bronze to iron production. Chemical composition and microstructural analyses enable us to determine that both the smelting of iron ores and the refining of the bloom took place within the urban centres of Hazor and Beer-Sheba. We show that slag cakes are the products of smelting, possibly carried out in pit-furnaces. Hammerscales, products of primary and secondary smithing, were attached to slags. From these observations we infer that all stages of iron production were practiced in these urban centres.

1. Introduction

Studying the advent of iron technology in the Southern Levant is significant for understanding both the history of technology, and the economic and political changes that took place during the Iron Age. The transition from bronze to iron is widely accepted to be a gradual process, in which bronze remains the predominant metal throughout the Iron Age I (Gottlieb, 2010; McNutt, 1990; Waldbaum, 1978). Although the use of iron for utilitarian purposes began during the Iron Age IB, it is only during the Iron Age IIA that the number of iron artefacts surpassed those of bronze. (Throughout this article we use relative chronology for the Iron Age phases. For absolute chronology according to the Modified Conventional Chronology see (Ben Tor et al., 2012; Mazar, 2011), and the absolute dates according to the Low Chronology see (Finkelstein and Piasetzky, 2010, 2011))

To date, direct evidence of iron production in the Iron Age I was identified in Tell Tayinat in south-eastern Turkey (Roames, 2010) but is lacking in the southern Levant. In the southern Levant, evidence of iron production has been documented in only a few sites all dated to not before the Iron Age IIA. These include the iron smelting site at Tell Hammeh, Jordan and the Beth-Shemesh iron smithy in Israel (Veldhuijzen and Rehren, 2007). Recently, at Tell es-Safi/Gath, in Israel, a small but unique iron and bronze workshop was uncovered where both iron smelting and smithing were identified (Eliyahu-Behar et al., 2012). We have also studied the spatial and temporal distribution of metallurgical production remains of both bronze and iron at Hazor, (northern Israel) where iron first appeared in stratum Xa, dated to the Iron Age IIA (Yahalom-Mack et al., 2013). It thus appears that there is a time gap between the first use of iron for utilitarian purposes (in the Iron Age I) and the earliest evidence for iron production activity (in the Iron Age IIA).

In the current study, we analysed by-products of iron production from Hazor, and from two other major urban centres in Israel, Tel Beer-Sheba and Tel Rehov, dated to Iron Iron Age IIA (Fig. 1). The production of iron from its ores by the direct, bloomery process is a long procedure that can be roughly divided into three main stages; the smelting (reduction) of the ores to produce a bloom, the refining of the bloom (primary smithing) to produce a more compacted metal (a bar ingot) and the forging of the end product (secondary smithing). Fig. 2 is a schematic representation of this process, showing the products and by-products formed at each stage. All these stages can be performed continuously at the smelting site. Alternatively, iron in the form of a bar could have reached iron smithies through trade, where subsequently secondary smithing would be carried out until the final product is formed. It is assumed, that the bloom itself with its rough form was not fit for transportation. Our main goal is to determine, based on the

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http://dx.doi.org/10.1016/j.jas.2013.06.009

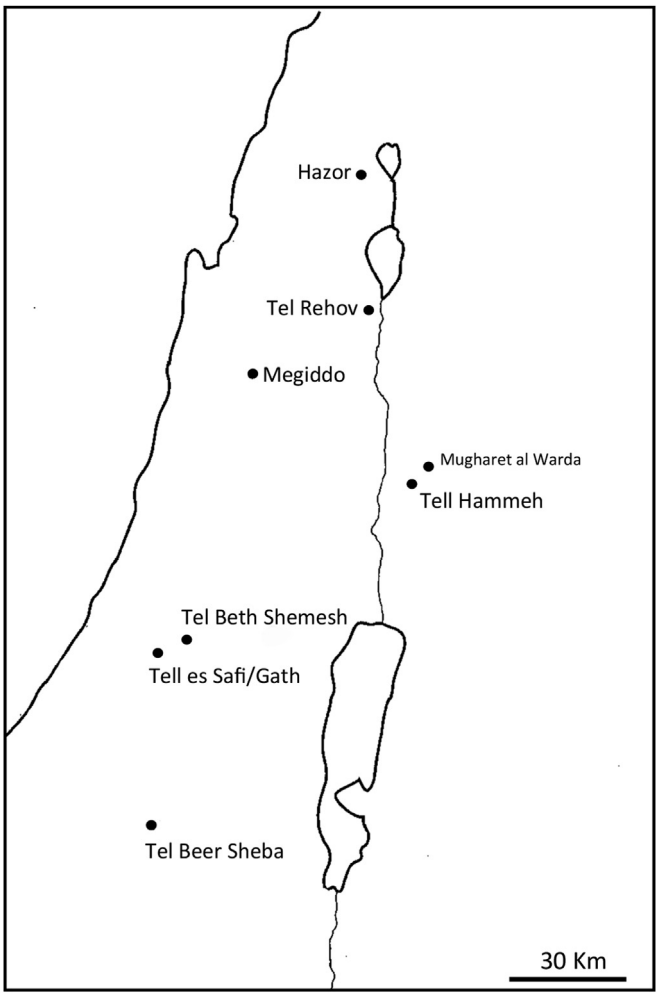

Fig. 1. Map of Israel, showing sites of iron production.

production debris, which type of iron production activity took place in the urban centres, that is whether smelting, primary and/or secondary smithing were performed.

Each processing stage produces by-products and residual materials (Fig. 2). Some by-products are typical of a specific production stage, such as tap slags, which are formed during smelting. Other by-products can be formed during more than one production stage. Hammerscales and slag prills, which are microscopic magnetic particles, for example, are formed during both primary and secondary smithing. Primary and secondary smithing slags formed at the base of a smithing hearth have a very typical appearance; they are semi-spherical with a concave-convex shape, and are denoted variously as slag cakes, smithing heart bottoms or in a more descriptive manner, as plano-convex bottoms (PCBs) (Bachmann, 1982; Morton and Wingrove, 1969, 1972; Serneels and Perret, 2003). However, similar slag cakes with a similar appearance can also be formed at the base of a smelting pit furnace. Moreover, It had also been shown that slags of different morphologies can be formed during one specific smelting operation (Allen, 1988; Paynter, 2006; Veldhuijzen, 2005; Veldhuijzen and Rehren, 2007). Slag cakes are the most common iron production debris unearthed in archaeological excavations. However, since slag cakes are only seldom found *in-situ* it is often difficult to associate them to the specific production stage at which they were formed. Examination of their microstructure and chemical composition can help in clarifying this issue.

The materials analysed for this study, mainly slag cakes and some 'unidentified' artefacts, were unearthed in past excavations, therefore their immediate context and association to various installations reported by the excavators remains unknown. Furthermore, much of the microscopic evidence for production activity is usually preserved in the associated archaeological sediments in the form of metal contamination, hammerscales and slag prills (see e.g. Eliyahu-Behar et al., 2012). Unfortunately, these sediments were not collected at the time of excavation and therefore the information that could have been obtained through chemical and mineralogical analysis is lacking. Here we show that the microstructural information embedded within the production remains is the key to reconstructing the production stages.

2. Materials

2.1. Hazor

Excavation in Area A at Hazor (1989–2006)[1] produced 45 complete and many more fragmented slag cakes and other iron production by-products in Iron Age II contexts (Strata XA-V). The slags and other production remains originated mainly from a series of buildings along the Strata X-IX city-wall, and not far from the six-chambered gate (Ben-Ami, 2012). A detailed description of the spatial and temporal distribution of the production remains is given by Yahalom-Mack et al. (2013).

The earliest production remains consist of two slag cakes found on a Stratum Xa (Iron Age IIA) floor (Locus 8147) and twelve others that were found in the fill below the earliest floor of a Stratum IX building (e.g. Locus 8010). In Stratum IX (also dating to the Iron Age IIA) three clusters of iron slag cakes were identified. The largest concentration ($n = 12$, Loci 8934 and 8948) was found within a sequence of ash layers and *tabun*[2] fragments. Another concentration consisted of two slag cakes and a tuyère fragment found inside a *tabun*-like installation (Locus 8623). It is unknown whether the *tabun* was related to the metallurgical activity or merely reused for refuse deposition. A third concentration of iron slag cakes ($n = 8$) was found in a room with light clay floor on which several hearths/fire patches as well as two *tabun*-like installations were unearthed. Interestingly, *tabun*s were found in proximity to many of the slag clusters, however their association to the metallurgical activity could not have been tested.

In Stratum VIII (transitional Iron Age IIA-B), with the expansion of the city and change in its layout, iron production expanded. Production remains were found in an open Area (e.g. Locus 9060) as well as in a large building in the centre of the acropolis. In one of its rooms (Locus 3754) nine slag cakes and four square tuyère fragments were scattered on the floor and inside a round installation (Locus 3776). Both the installation and the floor were covered with a thick ash layer. In Strata VII-V (Iron Age IIB) the number of production remains decreased, indicating a general reduction in metallurgical activities at least in Area A.

The Hazor slag cakes possess the characteristic plano-concave/convex shape of smithing-hearth-bottom slags. Typical tap slags with their unique visual appearance – the best indicators for iron smelting – were not identified in the Hazor assemblage.

2.2. Tel Beer Sheba

Excavations at Tel Beer Sheba conducted in the early 1970's[3] unearthed in addition to numerous iron objects four artefacts

[1] The Selz Foundation Hazor Excavations in Memory of Yigael Yadin, under the direction of Amnon Ben-Tor.

[2] An hemispherical mud constructed installation, usually attributed to cooking.

[3] Excavation of Tel Aviv University under the direction of Y. Aharoni (1969–1975) and Z. Herzog (1976, 1994–1995).