Journal of Archaeological Science 70 (2016) 1–14

Contents lists available at ScienceDirect

Journal of Archaeological Science

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

Research papers

Experimental smelting of iron ores from Elba Island (Tuscany, Italy): Results and implications for the reconstruction of ancient metallurgical processes and iron provenance

M. Benvenuti [a, b, *], A. Orlando [b], D. Borrini [a], L. Chiarantini [b], P. Costagliola [a], C. Mazzotta [a], V. Rimondi [a]

[a] *Dipartimento di Scienze della Terra, University of Firenze, Via G. La Pira 4, 50121 Florence, Italy*
[b] *CNR-Istituto di Geoscienze e Georisorse, Via G. La Pira 4, 50121 Florence, Italy*

ARTICLE INFO

Article history:
Received 18 May 2015
Received in revised form
10 March 2016
Accepted 6 April 2016

Keywords:
Iron bloomery
Elba Island
Experimental archaeometallurgy
Provenance

ABSTRACT

Iron deposits from Elba Island (Tuscan Archipelago) were extensively exploited since the 1st millennium BC: both raw iron ore and smelted blooms were extensively traded through the Mediterranean region. Within the frame of the multidisciplinary research Project "AITHALE" (from the Greek name for Elba Island), we have performed a series of archaeometallurgical experiments primarily to investigate the traceability of Elban iron ores during the various steps of the *chaîne opératoire* of bloomery iron production. Results of experiments performed both in the field (reconstruction of a bloomery furnace) and in the laboratory (smelting experiments carried out in a gas mixing furnace) are discussed in the text. Slags produced by smelting of W-Sn-rich iron (hematite) ores, like those from Elba island, show the presence of these elements in phases of their own, either relic (scheelite, ferberite, cassiterite) and/or newly formed (iron-tin alloys). Iron bloom obtained from this kind of iron ore could also bear evidence of the peculiar geochemistry of smelted ore, with tungsten preferentially associated with slag inclusions and tin eventually enriched in the metallic phase.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

One of the main targets of the research project "AITHALE" (from the ancient Greek name for Elba Island) is the characterization of the three-millennia-long mining and metallurgical processing of ore deposits from Elba Island across the whole Mediterranean area, with particular reference to the pre-Modern periods, from the 1st millennium BC up to the Middle Ages (cf. Corretti et al., 2014).

Notwithstanding many decades of archaeological research in the ancient territory of Etruria, our knowledge about technological aspects of iron smelting in Etruscan and Roman periods is still very tenuous and fragmentary (cf. Corretti and Benvenuti, 2001; Benvenuti et al., 2010; Corretti et al., 2014). The strategic location of Elba Island at the very cross-road of many trade routes through the Tyrrhenian Sea, and only a few miles distant from the Etruscan town of Populonia – one of the most important metalworking centres of the whole Mediterranean region – greatly favoured a wide circulation of Elban iron in the Western Mediterranean since at least the 6th century BC (Corretti et al., 2014). According to Diodorus Siculus in the 1st century BC (but even earlier) a complex 'metallurgical chain' involved the working of iron well outside Elba Island, supporting a long-distance trade of iron (both as raw metal – blooms or bars – and ore) from the island (Diodorus, Bibliotheca Historica, liber V, 13). Therefore, retrieving the provenance of iron ore, bloom and/or semi-finished products would be of the utmost relevance for the reconstruction of ancient trade routes in the Mediterranean region. Recently, Benvenuti et al. (2013) proposed that the peculiar W-Sn signature of the hematite-rich ores from eastern Elba Island provides us with a powerful tool to ascertain the extent of trading of Elba's iron in the Mediterranean area in antiquity. As suggested by these authors, it would be very important to ascertain whether the characteristic W–Sn-rich geochemical signature of Elba iron ores is still detectable through the various steps of the *chaîne opératoire* of iron production, as apparently suggested by analyses of the bloom recovered at Baratti as well as of many smelting and smithing slags from Baratti and several

* Corresponding author. Dipartimento di Scienze della Terra, University of Firenze, Via G. La Pira 4, 50121 Florence, Italy.
E-mail address: m.benvenuti@unifi.it (M. Benvenuti).

http://dx.doi.org/10.1016/j.jas.2016.04.008
0305-4403/© 2016 Elsevier Ltd. All rights reserved.

archaeological sites of Elba Island (Benvenuti et al., 2013). It becomes important, therefore, to evaluate how the mineralogical and chemical composition of iron ore, furnace materials (other than fluxes and charcoal) employed for the metallurgical process influence the trace element distribution (namely, W and Sn concentration) in the metallurgical products (slags and bloom). After the pioneering work by Hedges and Salter (1979), in the last fifteen yeas a large wealth of scientific papers have been devoted to iron provenancing in central and northern Europe (Buchwald and Wivel, 1998; Schwab et al., 2006; Dillmann and L'Héritier, 2007; Blakelock et al., 2009; Desaulty et al., 2008, 2009; Brauns et al., 2013; Charlton, 2015). To our knowledge, Sn was never investigated as a potential provenance tracer while tungsten was considered by Desaulty et al. (2009) only. This is apparently due, at least in part, to the different type of iron ores exploited in antiquity in the Tyrrhenian area (Elba island) with respect to central-northern continental Europe.

In this paper we report the first results of archaeometallurgical experiments performed both outdoor and in the laboratory primarily to investigate the extent of Sn and W partitioning during the various steps of the *chaîne opératoire* of bloomery iron production. As described in detail here below, the main target of our experiments was not to reproduce early processes of iron production carried out in ancient Etruria since the half of the 1st millennium BC but, rather, to compare the mineralogical, textural and chemical features of the bloomery products (namely, bloom and slag) with those found at archaeological sites. In particular, we wanted to test whether the peculiar geochemical features of hematite-rich iron ores from NE Elba, i.e., their co-enrichment in both W and Sn (Benvenuti et al., 2013) were still detectable in tapped slag and in the iron bloom. In parallel, in our lab investigations, we carried out several smelting experiments of a Sn/W-rich hematite ore from Elba (Terranera mine) under variable operating conditions (namely, temperature and oxygen fugacity) in order to evaluate the influence of these parameters on the final products (slag and metallic iron).

2. Etruscan iron smelting process: what we know

The furnace we built for our experiment was not modelled after any archaeological example, since at this preliminary stage of our research we were mainly interested in the smelting of a peculiar type of iron ore (W-Sn-rich hematite ore from eastern Elba mines: cf. Benvenuti et al., 2013) and the analysis of final products (bloom and slag) to ascertain the potential of geochemical markers (i.e., W and Sn contents) as tools for tracking provenance of ancient iron-made objects. On the other hand, notwithstanding metallurgical wastes related to ancient iron working are widespread both in Elba Island (cf. Corretti, 1988, 1991, with references) and southern Tuscany (Corretti and Benvenuti, 2001), archaeological evidence regarding bloomery furnaces of Etruscan to Roman age (8th–7th century BC up to 1st–2nd century AD) is scarce and partly unclear, thus actually hindering the reconstruction of a precise kind of smelting furnace.

Nevertheless, we have a rather defined idea of the general operation mode and the structure of an Etruscan smelting furnace. This awareness was obtained studying several iron working sites on the mainland such as Populonia (Benvenuti et al., 2000; with references), Follonica, Fonteblanda/Talamone and the Giglio Island to the south, Pisa and its harbours to the north, where iron exploited from Elban mines was worked between the 7th and the 5th century BC (Corretti et al., 2014; with references; see Fig. 1). As said above, however, the reported occurrences of "true" bloomery furnaces are only few and mostly from salvage excavations, which did not permit accurate description and analysis of the structures (Corretti and Benvenuti, 2001; Corretti et al., 2014). The earliest examples so far known of bloomery furnace in southern Tuscany were discovered in 1997 at Rondelli, near Follonica (Fig. 1), and were dated to 550–450 BCE according to Aranguren et al. (2004). They mostly appear to be open hollows in the ground lined with refractory clay, although it is not clear whether some kind of superstructure (shaft) was originally present and did not survive in the archaeological record (Aranguren and Paribeni Rovai, 1999). Salvage excavations in 1999 at the site of San Bennato, Cavo (northern Elba Island: Fig. 1) put to light archaeometallurgical remains which look very similar to the Rondelli site types and were dubiously interpreted as bloomery or forge furnaces of uncertain age (5th to 2nd century BC, Firmati et al., 2006). Recent studies of materials excavated at the archaeological site of San Giovanni (Portoferraio, Elba Island) led Manca et al. (2014) to advance the hypothesis that iron smelting in Roman times (3rd–1st century BC) was performed in furnaces made of refractory ceramics, and not armoured with stones.

Populonia, the Etruscan town built high on a promontory above the sea just in front of Elba Island (Fig. 1), after an earlier stage of copper production (Chiarantini et al., 2009b) became the major ironworking centre of Etruria probably since the 6th century BC and up to the 1st century AD (Corretti and Benvenuti, 2001). In the underlying Gulf of Baratti there is plenty of evidence of stone-made iron furnaces (although mostly as broken fragments). Here, a hypothetical iron smelting furnace was identified in 1977–1978 by M. Martelli and M. Cristofani during archaeological excavations in the metalworking area of Poggio della Porcareccia. The structure, archeologically dated to the 3rd century BC, was composed of blocks of a local beach sandstone ("Panchina"): it was cylindrical in shape and divided into chambers by a pierced slab supported by a clay pillar. However, according to Sperl (1985), given the inherent low thermal insulation, this structure was not suitable for smelting operations, but more likely it could have been used for the production of bricks or pottery. A second "furnace" identified by Voss (1988) inside a slag beach deposit (extending along the shoreline of the Baratti Gulf underneath the acropolis of Populonia) was cylindrical, with an inner diameter of 30 cm and about 45 cm high; the furnace wall was 15 cm thick and made of sandstone and clay that appeared intensively slagged. Voss suggested it was a non-tapping, smelting furnace and it was radiocarbon dated to 170 ± 70 BCE, i.e, to the Roman Republic period. A possible reconstruction of a "Baratti-type smelting furnace" has been proposed by Benvenuti et al. (2003) on the basis of furnace fragments from different places through the Baratti plain; in its general outline it consists of a low-shaft furnace of the slag-tapping type, with a shaft diameter not exceeding 40 cm. The common occurrence of tap holes/runners suggests that slags were tapped outside the furnace. Air was forced into the furnace by means of clay tuyères, probably equipped with bag bellows. Typical conical tuyères had a maximum internal diameter of about 8 cm and had circular or roughly square cross-sections. It is obviously difficult to establish the height aboveground of the furnace, but as deduced by the findings of furnace walls fragments, it possibly was not greater than about 1 m. Furnace walls were made of blocks of sandstone, commonly parallelepiped-shaped. This sandstone armour, several centimetres thick, was internally lined with clay. Benvenuti et al. (2003) suggest that the bottom of the furnace was made of a thin (3 cm thick on average) sandstone slate, also internally lined with clay. Subsequent findings after excavations on the Baratti slag beach deposit uncovered several smithing/reheating hearths employed for iron working and dated to the 5th–2nd century BC (Chiarantini et al., 2009a). These authors suggest that even Voss' furnace could be re-interpreted as a smithing hearth rather than a bloomery furnace.

From the brief review above outlined it comes out clearly that there is not a unique nor a specific type of Etruscan (or Roman) bloomery furnace in the area. Thus, since at this preliminary stage

Download English Version:

https://daneshyari.com/en/article/7441357

Download Persian Version:

https://daneshyari.com/article/7441357

Daneshyari.com