Journal of Archaeological Science 87 (2017) 108–124

Contents lists available at ScienceDirect

Journal of Archaeological Science

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

Circulation of iron products in the North-Alpine area during the end of the first Iron Age (6^{th}-5^{th} c. BC): A combination of chemical and isotopic approaches

Philippe Dillmann [a, *], Roland Schwab [b], Sylvain Bauvais [a], Michael Brauns [b], Alexandre Disser [a], Stéphanie Leroy [a], Guntram Gassmann [c], Philippe Fluzin [a]

[a] LAPA-IRAMAT, NIMBE, CEA, CNRS, Université Paris-Saclay, CEA Saclay, bâtiment 637, 91191 Gif-sur-Yvette, France
[b] Curt-Engelhorn-Zentrum Archäometrie, D6 3, 67159 Mannheim, Germany
[c] Landesamt für Denkmalpflege Baden-Württemberg, Berliner Straße 12, 73728 Esslingen, Germany

ARTICLE INFO

Article history:
Received 14 February 2017
Received in revised form
28 September 2017
Accepted 2 October 2017

Keywords:
Iron
Os isotopes
Trace elements
Slag inclusions
Provenance
Iron age

ABSTRACT

Os isotopic ratios and trace element approaches were used to compare the signatures of ore and slag from different potential production sites located in eastern France and South-West Germany with the signature of artefacts from the end of the first Iron Age. A set of 31 artefacts was tested, consisting of bipyramidal semi-products, chariot tires, blooms and other commodities. The complementarity of the two approaches is demonstrated. Bipartite bipyramidal semi-products made by assembling two crude masses of distinct origins are evidenced suggesting the existence of intermediate producing centres assembling products from different origins. Only the provenance of blooms and wheel-tires could be established as local. Two spheres of metal circulation were evidenced: prestige and local. Bipyramidal semi-products and chariot tires belong to different long distance distribution networks.

1. Introduction

Understanding the production and supply networks of iron during the Iron Age and particularly the Hallstatt D and La Tène A1 periods (625-425 BCE – Fig. 1) is one of the means to highlight the technical and social organisation of societies. Indeed a specific increase of social hierarchy and a development of craft activities in fortified agglomerations (princely sites) occurred at that time. Iron is considered by some authors as one of the main driving forces supporting social hierarchy processes (Brun, 1987; Olivier, 1986; Olivier and Béhaque-Tahon, 2002), landscape structuration (Gassmann et al., 2006; Stöllner et al., 2014; Wieland, 2009) and geostrategic changes in post Bronze Age societies (Brun, 1993; Krausse and Steffen, 2008).

The earliest traces of iron smelting in Celtic Europe have been found in northern and north-western Europe and date from the late Hallstatt period (6th century BC). In France, for example, the most ancient smelting sites are not located in the Hallstatt Principalities area, but further west in Northern Burgundy, Sarthe and Brittany (Cabboi et al., 2007; Dunikowski et al., 2007; Leroy and Cabboi, 2014; Vivet, 2007). Only two sites, Gondreville "ZAC de la Roseraie" and Velaine-en-Haye "ZAC Herbue-Chalin" in Lorraine, are dated from the late Hallstatt period (Ha D3) to the early La Tène A (LTA1) (Deffressigne et al., 2002; Leroy and Cabboi, 2014). In Germany, iron smelting centres inside the Hallstatt zone were unearthed in the Northern Black Forest near Neuenbürg and on the Schwäbische Alb at Sankt-Johann Würtingen (Gassmann et al., 2005, Gassmann et al., 2006; Gassmann and Wieland, 2008; 2012). At the beginning of its use, iron was a prestige good, highly visible in burial deposits with wagon tires and with swords, daggers and fibulas which began to be made of iron as well. Therefore, it is of crucial importance to identify the extent of iron production and its trade during the Hallstatt period. In addition to these artefacts, numerous semi-products were also found. Given that semi-products represent an intermediary state of the metal for stock and trade, their study seems to be a good way to address the issues evoked previously. The geographic distribution of iron bipyramidal semi-products is mainly concentrated in the Hallstatt

* Corresponding author.
E-mail address: philippe.dillmann@cea.fr (P. Dillmann).

https://doi.org/10.1016/j.jas.2017.10.002

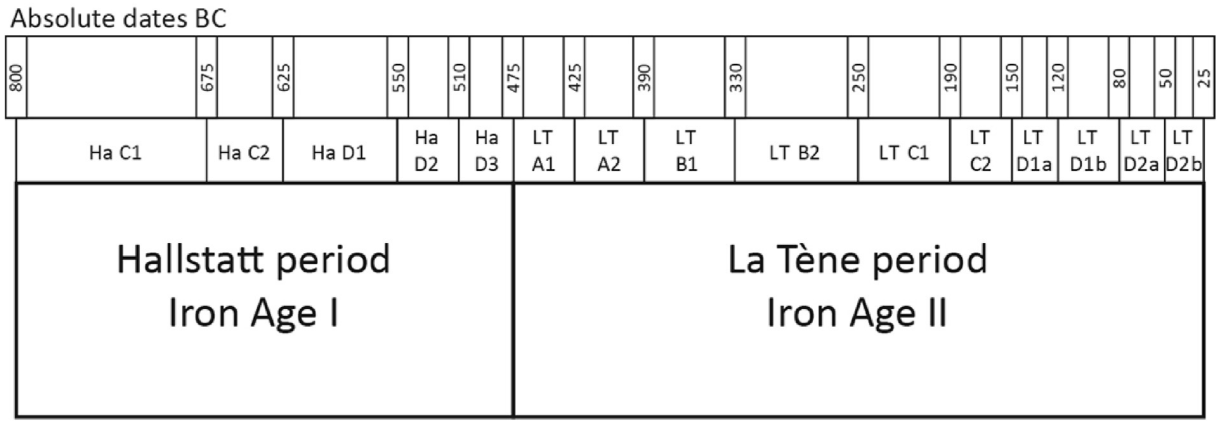

Fig. 1. Main period discussed in the present paper.

cultural area and around 500 of them are known today. The majority were found in hoards without context. Many researchers believe that most of them belong to the Late La Tène period. Nevertheless, in the case of dated archaeological contexts, many of the semi-products are dated from the Hallstatt D to early La Tène A periods (6th to 5th century BC) (Kurz, 1995; Senn et al., 2014). Only a few were found in Late La Tène contexts (e.g. Manching, Gründberg hoards 4 and Bibracte) (Jacobi, 1974; Mölders, 2010; Urban, 2006) and even less in Roman contexts (e.g. Kaiseraugst-Schmidmatt – Switzerland) (Müller, 1985). For the Roman contexts, the morphology of the semi-products is different enough to be clearly distinguished by their size (miniatures). The discoveries in Manching, Gründberg and Bibracte are described as "split bipyramidal semi-products" and are much more closely linked to "hooked-billet" semi-products – characteristic of the late La Tène period – than to bipyramidals. Indeed, recent research in France provided well-documented discoveries of bipyramidal semi-products belonging to the 6th - 5th centuries BC (Hallstatt D/La Tène A1) (Berranger and Fluzin, 2012), and some semi-products from isolated deposits have been dated by radiocarbon to the same time frame (Bauvais et al., 2017). Therefore, analysis of bipyramidal semi-products has been the first priority of this study, conducted within the framework of the joint French-German research project CIPIA. This project aims to investigate the iron trade during the Hallstatt period and to document the iron trade in wider areas (Bauvais et al., 2011). In a first stage, the areas corresponding to the current territories of eastern France (Lorraine) and South-West Germany were studied.

One way to decipher supply networks is to link artefacts to production areas, using the chemical composition of ores and slag from these areas. Different approaches have been proposed over the past decades with various success, including the study of siderophile trace elements in the metal (Devos et al., 2000) of Pb and Sr-isotopes (Degryse et al., 2007; Schwab et al., 2006) and, more recently, Fe isotopes (Milot et al., 2016); for reviews, see (Charlton, 2015; Leroy et al., 2012; Schwab et al., 2006). To date, only two different, but complementary methods have demonstrated their potential. The first is the comparison of major and trace elements in ore, slag and slag inclusions in iron objects and is based on the lithophile behaviour of some trace elements entering the slag during the smelting process (Coustures et al., 2003; Desaulty et al., 2009; Disser, 2014; Disser et al., 2016; Leroy et al., 2012). Different approaches, supervised (Leroy et al., 2012) or not (Disser et al., 2016), can be implemented depending on the nature of the available artefacts to define the production areas. The other approach uses osmium isotope ratios. Osmium was found to be ideal, as it requires a heavy element with a significant variable isotope composition, which resists isotope fractionation during the smelting process and which is highly siderophile, entering the metallic phase (Brauns et al., 2013). As the genesis of many iron ores is quite similar, deposits tend to overlap isotopically and chemically. Therefore, it is expected that a combination of both sets of data will provide better discrimination, as both approaches are diverse and independent of each other.

The present study will thus rely on this complementarity to examine the provenance of a set of artefacts dating from the first Iron Age and found in the core part of the West Hallstatt zone, corresponding to present-day Lorraine and Alsace in France, and Baden-Württemberg and Bavaria in Germany. This study constitutes a first step for a more general study dealing with larger areas and time periods.

2. Samples and methods

Both methods are based on the different genesis and age of iron ore deposits and require a statistically relevant number of samples to characterize a deposit or a production area. This number is sometimes difficult to determine. A possible indication is when new sampling does not extend the range of variability for selected elements. This number increases with isotopic and trace-element variations in the deposits. The Os isotopic composition in geological samples (e.g. iron ores) is generally controlled by the Re/Os ratio and age of – in this case - the host rock. In this particular application, the sample selection also has to take into account the archaeological findings about how iron ores were selected. So if isotopic Os-ratios of an object are different from that of the ore, then it can be concluded that this artefact does not derive from that specific ore source, which is clear and fundamental evidence. Conversely, if an object shares the isotopic signature of an ore deposit, it is of course possible that it can derive from another deposit, which has the same isotope ratios.

It has been demonstrated, for the provenance approach using elemental ratios, that the simultaneous use of major and trace elements can be more efficient in some cases than using solely the trace elements. This can be explained by the fact that some major elements can signify certain specific types of ore deposits (Disser et al., 2016). Nevertheless, it must be verified by an adapted inference that, despite the potential blurring of the signature due to major elements being polluted in slag by lining, charcoal and fluxes, the observations of ores and slag of a given production area form coherent clusters. This will be presented in the results. Major elements (Mg, Al, Si, K, Ca, Mn) and trace elements are separately