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Eneolithic copper smelting slags in the Eastern Alps: Local patterns of metallurgical exploitation in the Copper Age

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ABSTRACT

A number of slags of all known sites in the Italian Eastern Alps showing occurrences of copper smelting activities in the Copper Age have been characterized by lead isotope analysis. All the investigated smelting slags from Trentino (Romagnano Loc, La Vela, Gaban, Acquaviva di Besenello, Montesei di Serso) and Alto Adige/Sud Tyrol (Millan, Gudon, Bressanone Circonvallazione Ovest) have been recently characterized by thorough mineralogical, petrographical and chemical analysis and demonstrated to be the product of copper smelting activities of chalcopyrite-based mineral charges, with an immature technological extraction process referred as the "Chalcolithic" smelting process. Revision of the available radiocarbon dates show that the metallurgical activities pertaining to the analysed slags can be attributed to the third millennium BC. The lead isotope analysis indicates clearly that the mineral charge use for the smelting process was extracted from nearby mineral deposits. The detailed analysis of the spatial distribution of ores and slags allows for the first time to define the local organization of the metallurgical operations.

1. Introduction

The Italian Eastern Alps are a well-known source of copper metal that was exploited since prehistory, possibly since Late Neolithic times. Due to the large amount of archeological evidence, especially the widespread and abundant occurrence of copper smelting slags (e.g. Cierny et al., 2004; Cierny, 2008), the climax of the mining activities and copper production is currently attributed to the Recent and Final Bronze Age (Marzatico, 1997; Weisgerber and Goldenberg, 2004), and subsequently to Roman and Middle Age times, when large groups of German miners moved to some of the Alpine valleys to organize and carry out the mining operations (Šebesta, 2000; Zammatteo, 2009). However the copper metal was circulating well before the Bronze Age, as the archeological evidence clearly shows (Pedrotti, 2002: p. 213): metal objects were circulating at least from the late neolithic (Angelini et al., 2013) and a number of Copper Age sites in the Trentino and Alto Adige areas yield evidence of smelting activities in the form of metallurgical slags, tuyeres, a multitude of copper objects including the Iceman's axe, and a few occurrences of pyrotechnological installations (Perini, 1989; Pedrotti, 2002; Pearce, 2007).

The focus of the present investigation is to characterize the isotopic signal of the known Eneolithic smelting slags and to compare the measured lead isotope ratios with the signal of the copper deposits in the Eastern Alps (Nimis et al., 2012; Artioli et al., 2013), in order to pinpoint which deposits were actually exploited in the Copper Age, and possibly outline the local organization of the metallurgical activities.

2. Slag samples: selection and characterization

The slag samples to be investigated were selected based on (1) their secure occurrence in archaeological sites dated to the 3rd millennium BC, and (2) previous results of mineralogical, petrographic, and chemical studies on the slags confirming that they are indeed the product of copper smelting activities.

Table 1 lists the sites where the investigated copper smelting slags were located together with the related archeological literature. Fig. 1 shows the geographical distribution of the sites, all located in the Trentino and Alto-Adige areas.

The sites are clustered in three main areas:

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Table 1
List of sites yielding the investigated copper smelting slags, with the related references of previous archaeological and archaeometric work.

Locality	Area	References
Millan	Isarco Valley, Alto Adige	Tecchiati 2009, Colpani et al., 2009, Angelini et al., 2013
Gudon	Isarco Valley, Alto Adige	Colpani et al., 2009, Angelini et al., 2013
Bressanone Circonvallazione Ovest	Isarco Valley, Alto Adige	Angelini et al., 2013
Gaban	Adige Valley, Trentino	Cattoi et al., 1995, Cattoi et al. 1997, D'Amico et al., 1998, Artioli et al., 2009
La Vela	Adige Valley, Trentino	Fasani 1988, Perini 1989, Metten 2003, Artioli et al., 2009
Acquaviva di Besenello	Adige Valley, Trentino	Cattoi et al., 1995, Cattoi et al. 1997, D'Amico et al., 1998, Pedrotti 2002, Metten 2003, Artioli et al., 2009
Romagnano	Adige Valley, Trentino	Perini 1971, Perini 1989, Cattoi et al., 1995, Cattoi et al. 1997, Metten 2003, Artioli et al., 2009
Montesei di Serso	Valsugana, Trentino	Perini 1989, Metten 2003, Artioli et al., 2009

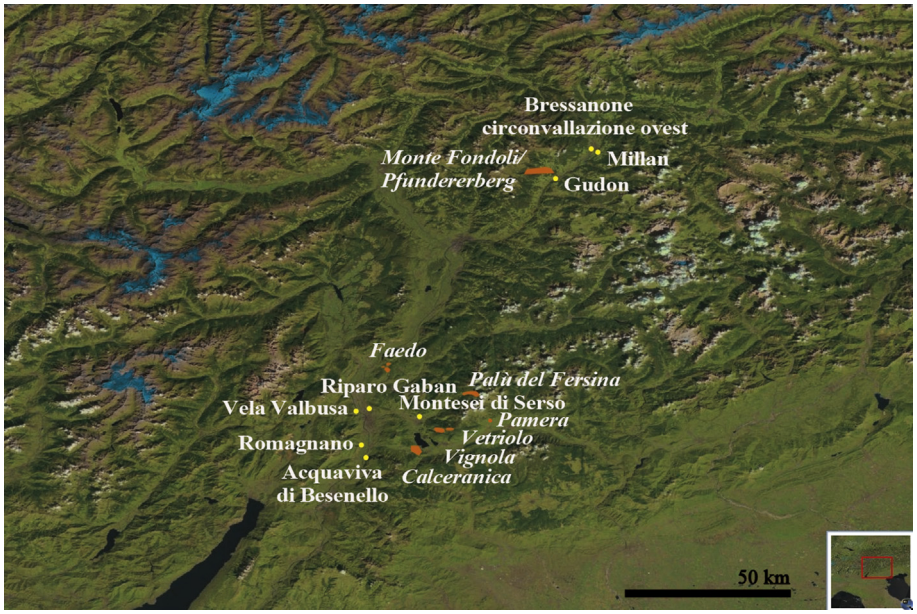

Fig. 1. Map of the location of the Eneolithic sites in the Eastern Alps showing the investigated copper smelting slags (yellow dots). Some of the nearby copper mining areas are also marked in the map (red fields, names in italics). Image courtesy of laboratoriobagolini.it/ais/. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

a) Millan, Gudon, and the site of Circonvallazione ovest are all located in the Isarco river valley near the city of Bressanone/Brixen
b) Romagnano Loc and La Vela are located in proximity of the Western bank of the Adige River, whereas Gaban, and Acquaviva di Besenello are located in proximity of the Eastern banks of the river in the outskirts of the city of Trento
c) Montesei di Serso is located in the upper Valsugana Valley near the city of Pergine, again located in the Eastern area the Adige River.

The common feature of all these sites is the location at low altitude, near the bottom of the valley, in close proximity to the river and, presumably, to the coeval settlements. The archaeological occurrences of the Trentino slags and their dates have been extensively discussed by Pearce (2007): the critical revision of the available dates indicate that the start of the metallurgical activities at Gaban and Acquaviva can be attributed to the early 3rd millennium BC, whereas the analysed slags from the other sites cluster around the second half of the 3rd millennium BC. The recent dates obtained on the Alto Adige sites (Millan, Gudon) confirm this chronology (Angelini et al., 2013).

All samples were previously thoroughly characterized by minero-petrographical and chemical analysis by X-ray powder diffraction, optical microscopy, and electron microscopy with energy dispersive spectroscopy (Artioli et al., 2009; Colpani et al., 2009). The common features of all slags are here summarized:

- Very heterogeneous and coarse texture (Fig. 2)
- Presence of primary sulphide relics (chalcopyrite) with only incipient reactions (Fig. 3)
- Abundant unreacted quartz
- Presence of typical slag minerals formed during smelting, especially fayalitic olivine, but also pyroxenes (see Colpani et al., 2009)
- Presence of abundant wuestite, frequently dendritic (Fig. 4) or agglomerated
- Presence of copper or matte droplets, frequently intermixed with magnetite

The overall features, such as the coarse texture, the presence of wuestite and magnetite even in the same slag and the occurrence of poorly reacted sulphides indicate an incomplete process of copper extraction and poorly controlled temperature and oxygen fugacity conditions. The slags never underwent a complete melting stage and the process of copper extraction was rather inefficient. These features altogether have been taken as evidence of a technologically non-standardized process of copper extraction, referred to as the "Chalcolithic" process (Pearce, 2007; Bourgarit, 2007). The observed mineralogical ad textural features are compatible with