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# Archaeometallurgical characterization of the earliest European metal helmets

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## ABSTRACT

Archaeometric analyses on conical and decorated cap helmets from the Bronze Age are presented. The helmets are dated to the 14–12th century BC according to associated finds in hoards. Alloy composition, material structure and manufacturing processes are determined and shed light on the earliest development of weaponry production in Central and Eastern Europe. Analyses were carried out using light and dark field microscopy, SEM-EDXS, PIXE, TOF-ND and PGAA. The results allowed reconstructing the manufacturing process, the differences between the cap of the helmets and their knobs (i.e. alloy composition) and the joining technique of the two parts.

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## 1. Introduction

Bronze Age European metal defensive armour, as opposed to weapons, is scarce. With a few exceptions such as the armour from Biecz, Dendra or Knossos, the first armour appears in Central and Eastern Europe in the beginning of the Urnfield culture (ca. 1300 BC). Today, we know of approximately 120 helmets, 95 shields, 55 greaves and 30 cuirasses from the European Bronze Age. The distribution area of each type of

armour is different; only in the Carpathian basin and a bit further to the north we find all types of armour. Indeed, we do not know any finds of shields in France or the Iberian Peninsula, though depictions are known. In the United Kingdom, finds of metal helmets or greaves are unknown, while shield finds are common [25, pl. 166–167].

European Bronze Age helmets are distinguished in two main groups: in Western Europe, the conical cap is usually made of two halves, resulting in a central crest where the halves are joined

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together. In Austria, three cap helmets with different crests are known. Their chronological classification is still a matter of discussion (most recent: LIPPERT 2011). In Central and Eastern Europe, conical helmets, cap helmets and bell helmets dominate: all three types consist of a cap made of one single metal sheet. In most cases, the cap bears a central knob or socket. In the following, we focus on the manufacture of conical helmets, the oldest European helmets, and their successor, the decorated cap helmet. Of the conical helmets and decorated cap helmets (including fragments) discussed, two thirds could be studied in detail, since some are in private collections or simply could not be found in the museums concerned (Table 1).

Two conical helmets are under analyses at other facilities. The Hungarian helmets could be studied non-invasively only, without being brought outside the country. The European CHARISMA-project enabled analyses with Prompt-gamma activation analysis (PGAA), particle induced X-ray emission spectroscopy (PIXE) and Time of Flight-Neutron Diffraction (TOF-ND) at the Budapest Neutron Centre. The effectiveness of neutron-based methods in provenance, authenticity and conservation studies has been demonstrated earlier [2,7,14]. The micro-fragments of the helmets that museums allowed to be sampled were analysed with bright and dark field light microscopy and SEM-EDXS at the metallurgical lab of the DCCI, Università degli Studi di Genova.

## 2. The Helmets

So far, ten conical helmets are known; another close related find with boar tusk decoration is noted as well [5]. They are distributed from Knossos, Crete in the southeast of Europe to Biecz, Poland, in the northwest. The distribution centre, with the highest number of finds, is the Carpathian basin (Fig. 1). The helmets are dated to the 14–13th century BC; only the helmet from Knossos derives from the middle of the 15th century BC. Chronological aspects as well as development and distribution were recently discussed in detail [16]. Four helmets are complete or missing only small parts: Biecz, Dunaföldvár, Lúčky and Oranienburg. From the two Slovakian finds from Spišská Belá and Žaškov only the sockets are preserved. The helmet from Keresztéte consists today of one fragment only; however, an older photograph still shows an almost complete helmet [27, pl. 150:9]. The knobs are missing on the unfortunately not completely preserved helmets from Dunaföldvár and Keresztéte. The caps from the helmets from Knossos, Nadap and Síg are not completely preserved either; however, typological and chronological classification as well as sampling in two cases was possible. All conical helmets (Fig. 2) have a very thin cap, which is also indicated by their light weight, ranging from 353 g (Biecz) to 638 g (Oranienburg) and almost 700 g (Knossos) for complete pieces with a total height of 17 cm (Biecz) to 21 cm (Oranienburg). On top of the conical cap, a small, spool-shaped socket with hole in the centre was applied (Fig. 3). Only the helmet from Knossos has a riveted-on knob. The closely related helmet with the boar tusk decoration instead bears a knob, which was made out of the same bronze sheet as the cap and thus is a direct part of the cap. The socket or knob served to support an organic plume. According to the rivet holes all along the edge of the

helmets, usually an inner organic padding was riveted to the helmets.

Decorated cap helmets are more numerous than conical helmets. So far, seven complete helmets and nine fragments most likely belonging to decorated cap helmets are known (Fig. 4). The helmets are dated to the 12th century BC, maybe even up to the early 11th century BC [15]. The main distribution area of complete decorated cap helmets, though poorly provenanced, is the Carpathian basin. So far, the helmet from Paks represents the only known complete helmet with a firm provenance and more detailed find circumstances. Fragments of the same type of helmets are all part of large Late Bronze Age hoards and show a much wider distribution than the complete helmets (Fig. 1). The distribution area spreads from Elsterwerda, Germany, in the north to Poljanci, Croatia, in the south and from Strassengel, Austria in the west to Gușterița, Romania in the east. The completely preserved cap helmets from Žiar nad Hronom, Paks and four other examples from Hungary with uncertain findspot are richly decorated caps with tubular sockets on top. On the side of the helmets, two or three bundles of several embossed, parallel ribs are visible. On top of the cap of some helmets, the so-called star decoration is visible [15]. The helmets from Žiar nad Hronom as well as one from the former Guttmann collection are the only ones with cheek plates being preserved. This made it possible to connect the cheek plates from Gușterița, Hočko Pohorje, Mezőnyárad, Stetten and Uiora de Sus to this type of helmet as well. The cheek plates all have a rather round, kidney-shaped form with a central ridge. Unfortunately, three of the complete decorated cap helmets could not be studied in detail at all, since their actual repository is unknown. However, the alloy composition of the two helmets from the former Guttmann collection was previously published by Born and Hansen [3, p. 270].

The helmets were not worn on the bare head. An inner organic padding or a separate organic cap beneath was used. In addition, an organic plume – possibly feathers, horsehair or something similar – was attached to the knob or socket. Both types of helmets show regularly distributed rivet holes parallel to the rim of the helmet. Only the conical helmet from Biecz has three rivet holes each only in the centre of its broader sides – most likely to attach cheek plates. For chin straps, two rivet holes would be sufficient and they would not be so far from each other, as it is known from other bronze cap helmets (Thonberg, Wonsheim Szikszó). For the helmet from Biecz, we therefore have to assume a separately worn organic cap or padding under the helmet and not directly fixed to it. The other helmets instead show regularly distributed rivet holes all around the rim to attach the organic padding.

## 3. Protocol of Investigations: Invasive Methods

### 3.1. EDXS Compositional Analysis

The EDXS composition analyses were performed on drilling samples as well as cross-sections of microfragments mechanically sampled from the helmets or the cheek plates. In order to perform the metallographical analyses, the microfragments were mounted in epoxy resin and polished with diamond paste up to 0.25 μm of diameter. The alloy composition was characterized by

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