

# A Bronze Button from Late Bronze Age Site of Inzersdorf ob der Traisen

Roland Haubner<sup>1,a\*</sup> and Susanne Strobl<sup>1,b</sup>

<sup>1</sup>Technische Universität Wien, Institute of Chemical Technologies and Analytics,  
Getreidemarkt 9/164-03, A-1060 Vienna, Austria

<sup>a\*</sup>roland.haubner@tuwien.ac.at, <sup>b</sup>susanne.strobl@tuwien.ac.at

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**Abstract.** In the region of Inzersdorf ob der Traisen in Lower Austria, 273 cremation graves from the late Bronze Age (ca. 1300–800 BC) were recovered. Also, various bronze artefacts were found in some graves, including a button which was analyzed by metallography. It should be determined how the button was manufactured, for example by casting or soldering, and microstructural changes can be detected due to temperature effects by cremation. The button is made of bronze whose composition was determined by XRF: 87 wt.% Cu, 9 wt.% Sn and 1 wt.% Pb. The microstructure of the bronze clearly shows a temperature influence during cremation. The bronze microstructure is recrystallized as well as parts were melted, causing oxidation at the grain boundaries. Also, some areas of the bronze show small shrink holes. Further corrosion took place during long-term storage of the button in the soil.

## Introduction

During the construction of the S33 expressway, large-scale rescue excavations were carried out in Inzersdorf ob der Traisen, Lower Austria [1, 2], because an Urnfield period cemetery was detected. In one of the graves the investigated bronze button was found.

About 273 graves were documented in the cemetery of Inzersdorf ob der Traisen. The cemetery was used from the earliest Urnfield period (about 1300 BC) to the late Urnfield period (about 800 BC). The majority of the graves date back to the early Urnfield period (1300–1000 BC), when small urn graves were used [3–5].

During a cremation the deceased persons are burnt on a pyre together with their clothing, jewellery and other grave goods. Then the cremated residuals are placed in a grave, usually in an urn [6].

Large quantities of bronze artefacts were found in some of the graves. These were primarily costume objects such as bracelets, pins and buttons, while tools such as knives were in the minority and weapons were completely absent [5].

During cremation a heat influence on the metallic objects can be expected and their microstructure will change depending on the local temperature and the duration of the heat exposure. Depending on the bronze composition, the alloy melts between 900 and 1000 °C. As a part of experimental archaeology, cremation experiments were carried out with pigs and bronze parts, which were subsequently examined [6–8].

This work is a continuation of studies on prehistoric buttons [9, 10].

## Experimental Procedure

The button was photographed and was subsequently examined using micro-computed tomography (micro-CT) [11]. It was then cold mounted in epoxy resin under vacuum. Once hardened, a cut was made parallel to the eyelet of the button. This cross-section was again cold mounted. The metallographic preparation was carried out in stages by grinding and polishing up to a diamond grain

size of 1  $\mu\text{m}$ . The sections were analyzed in the as-polished state and after etching with Klemm 2 solution.

A light optical microscope (LOM) and a scanning electron microscope (SEM) with energy dispersive X-ray analysis (EDX) were used. To determine the overall chemical composition of the samples, measurements were additionally carried out on the metallographic sections using X-ray fluorescence analyses (XRF).

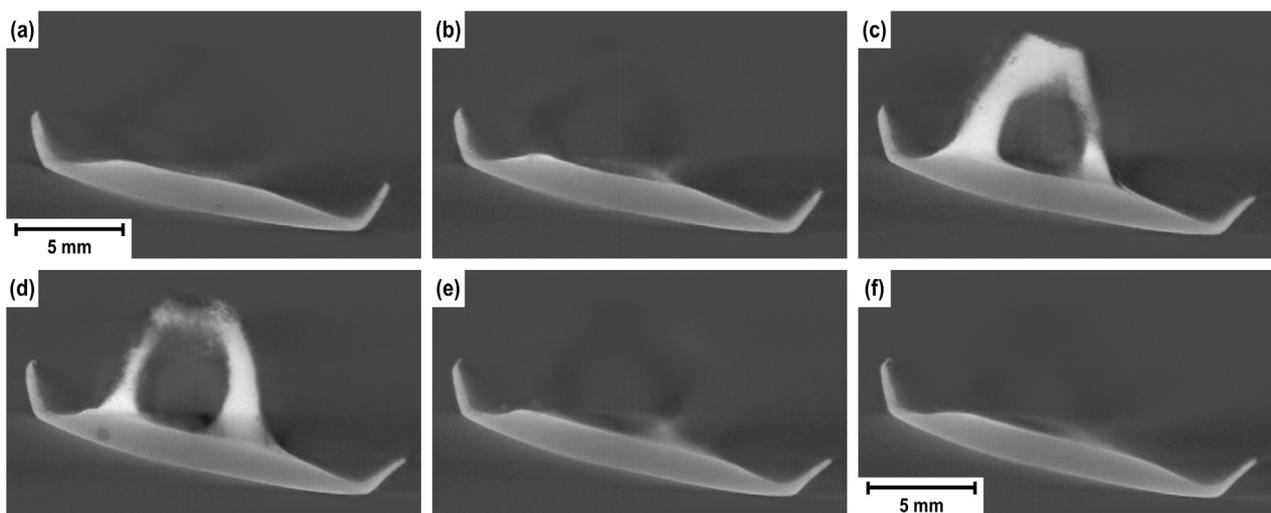
## Results and Discussion

### Non-destructive testing methods.

The button face is a flat disc whose edge is bent inwards. The eyelet is not centered. The button is entirely covered with a greenish-brown patina (Fig. 1). The button plate appears homogeneous in the CT sections. In the area of the eyelet inhomogeneities are visible, which can be attributed to defects during manufacture or corrosion (Fig. 2).



**Fig. 1.** Photos of the knob from different perspectives. (a) avers, (b) reverse, (c) side view.



**Fig. 2.** Images of CT cuts through the button.

### The bronze alloy.

The button consists of a bronze alloy with approximately 9.5 wt.% Sn and 1.2 wt.% Pb (Table 1). From the CT sections and the overview images of the metallographic sections no evidence of a joint is observable. Consequently, this button was cast (Fig. 3).

One would expect a dendritic solidification structure of a cast bronze [12–14], but this is not the case. Instead, the microstructure is coarsely crystalline and has isolated annealing twins. One explanation is that the button was heat-treated during cremation [9, 15].

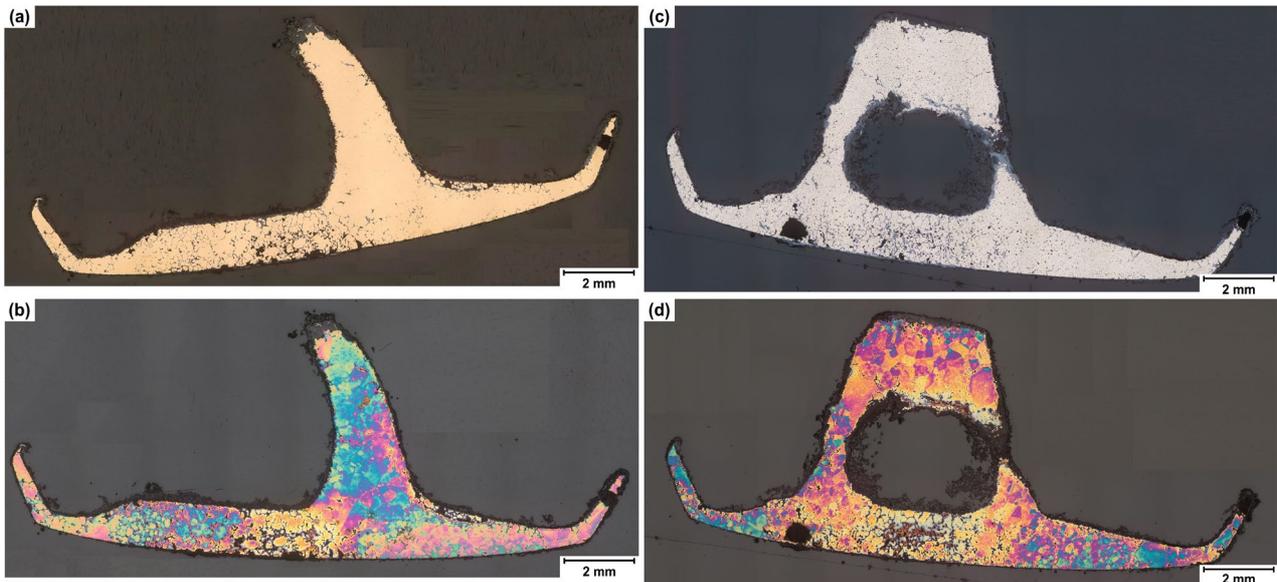
**Table 1.** XRF on the metallographic sample of the button.

Element	Cu	Sn	Pb	Ni	Fe	S	Ca	Si	Al
wt.%	87.34	9.51	1.24	0.35	0.18	0.09	0.29	0.86	0.12

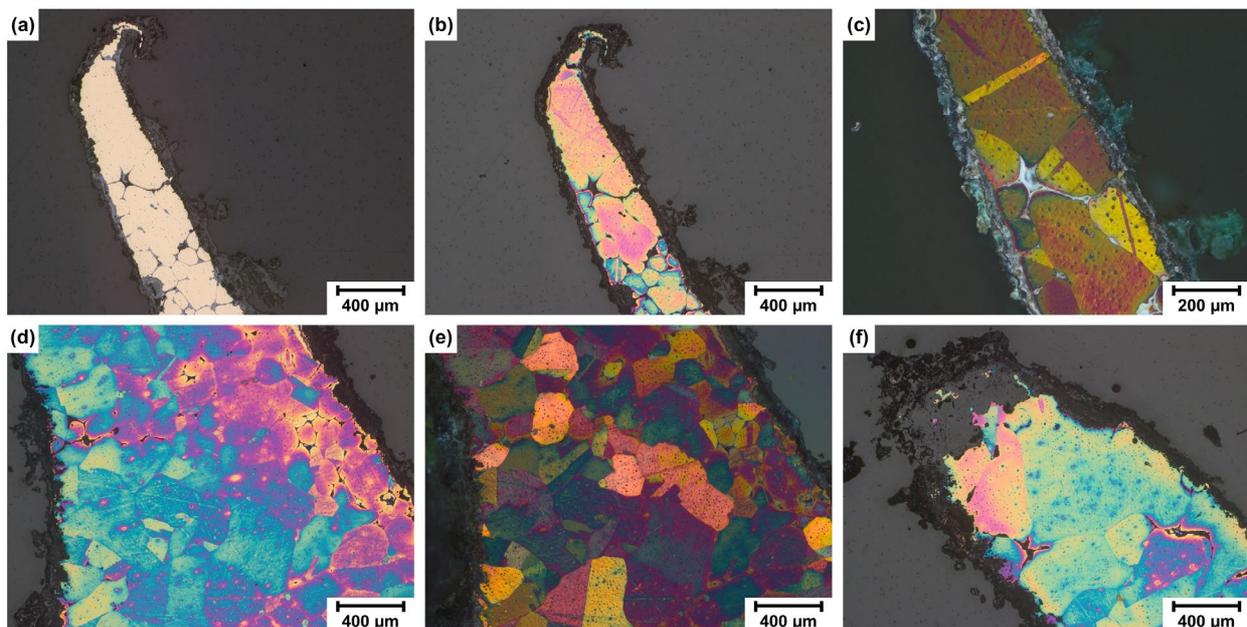
**Observed bronze microstructures.**

At the bent-up edge of the button, which has a thickness of approximately 400  $\mu\text{m}$ , the microstructure is very coarse with grain sizes of up to 400  $\mu\text{m}$  (Fig. 4a, b). Annealing twins are occasionally visible (Fig. 4c). Also, corrosion products can be seen along grain boundaries and at the surface.

In the thicker area of the eyelet, grain sizes of up to 500  $\mu\text{m}$  are observed (Fig. 4d, e). Corrosion products are present at the surface (Fig. 4f).



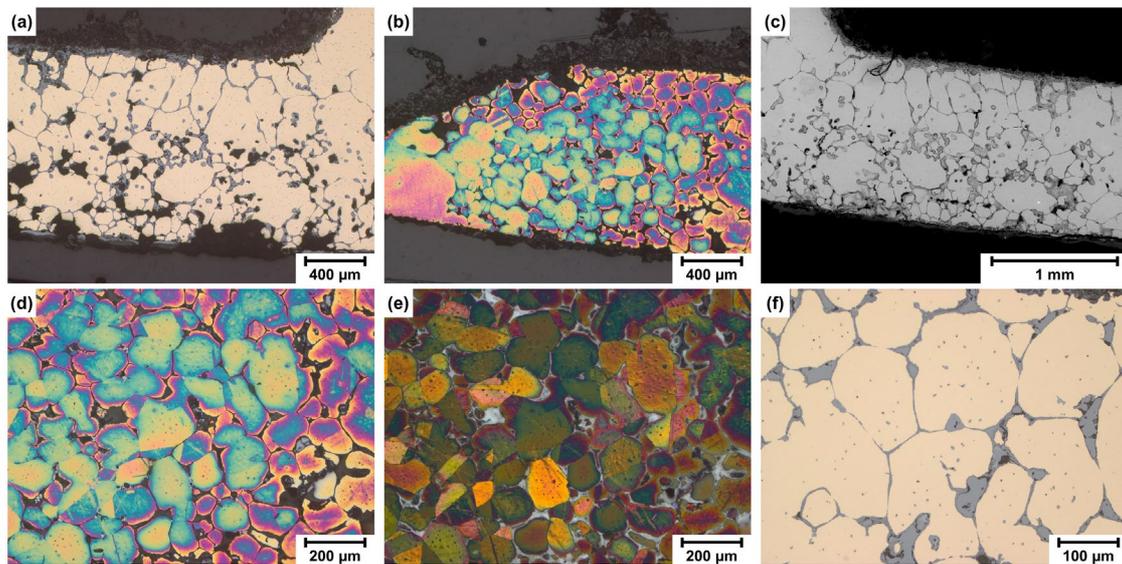
**Fig. 3.** Different metallographic grinding levels of the button. (a, b) 1<sup>st</sup> grinding level, (c, d) 2<sup>nd</sup> grinding level, (a, c) polished, (b, d) Klemm 2 etched.



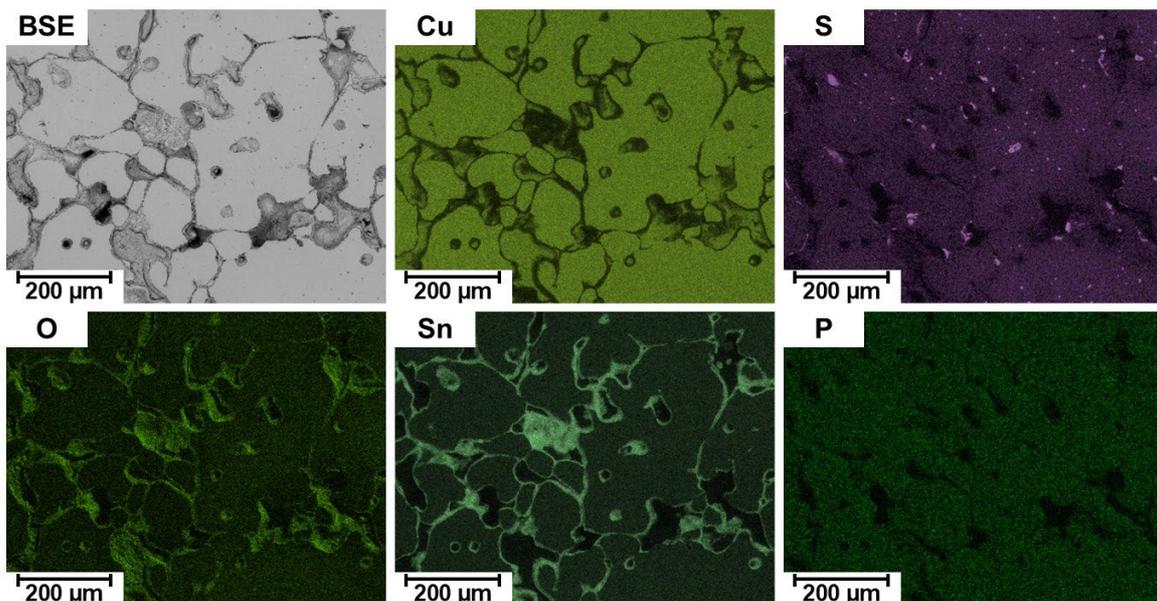
**Fig. 4.** 1<sup>st</sup> grinding level. (a–c) bent-up edge of the button, (d–f) eyelet region. (a) polished, (b–f) Klemm 2 etched, (c, e) polarized light.

In the button's center the bronze had melted partially during cremation (Fig. 5). These areas have shrinkholes and the grain boundaries are oxidized partially (Fig. 5a–d). Due to these grain boundary oxides, the grain size in these areas is low with about 200  $\mu\text{m}$  (Fig. 5d–f), because oxidation along the original grain boundaries of the bronze occurred faster than the recrystallization of the structure. A SEM-EDX element distribution shows that Sn is enriched in the oxidation products at the grain boundaries. Also, local enrichments of S were detected, but no metal can be assigned to S. Possible are PbS or  $\text{Cu}_2\text{S}$  precipitates (Fig. 6).

In the slightly thicker areas of the button, at the 2<sup>nd</sup> grinding level, spheric inclusions within the bronze grains were observed (Fig. 7). These inclusions are completely or partially filled. Additionally, some holes are visible (Fig. 7b, e, f) which could be shrinkholes. The inclusions may consist of PbS or  $\text{Cu}_2\text{S}$ . By a SEM-EDX element distribution S was detected in areas of the holes but no Pb, which could be due to the lower detection limit for Pb (Fig. 8). However, the Sn enrichment in the oxides at the grain boundaries is clearly observable.



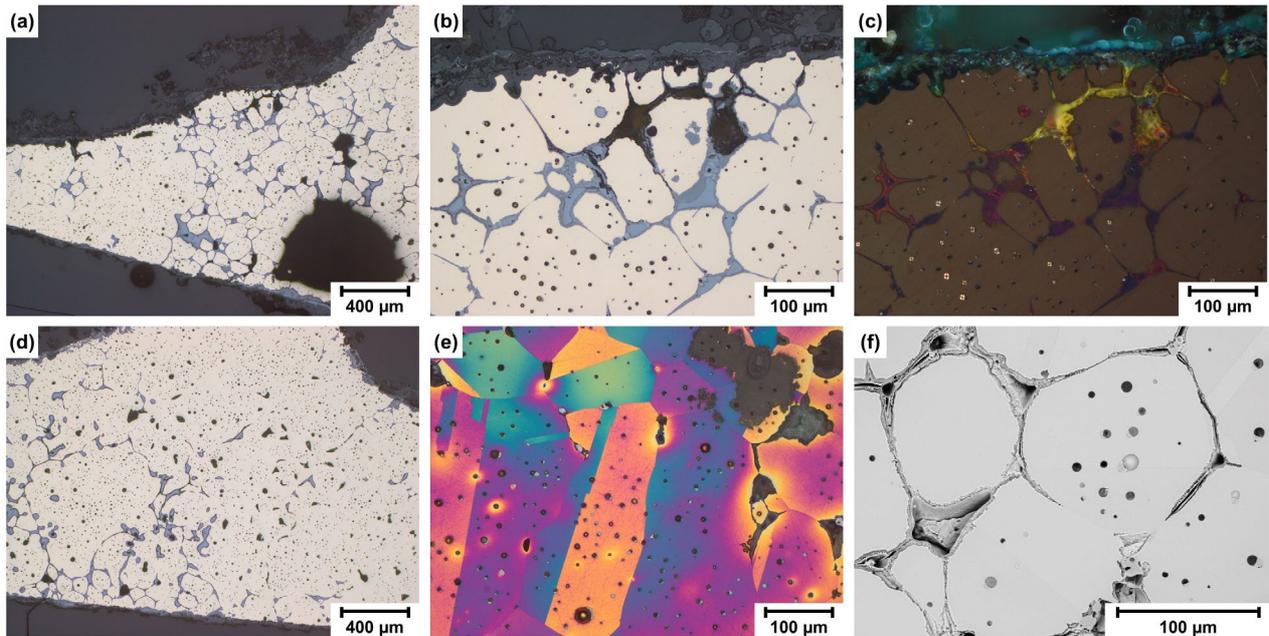
**Fig. 5.** Partially molten area of the button. (a, f) as-polished. (b, d) Klemm 2 etched, (c) SEM, (f) polarized light.



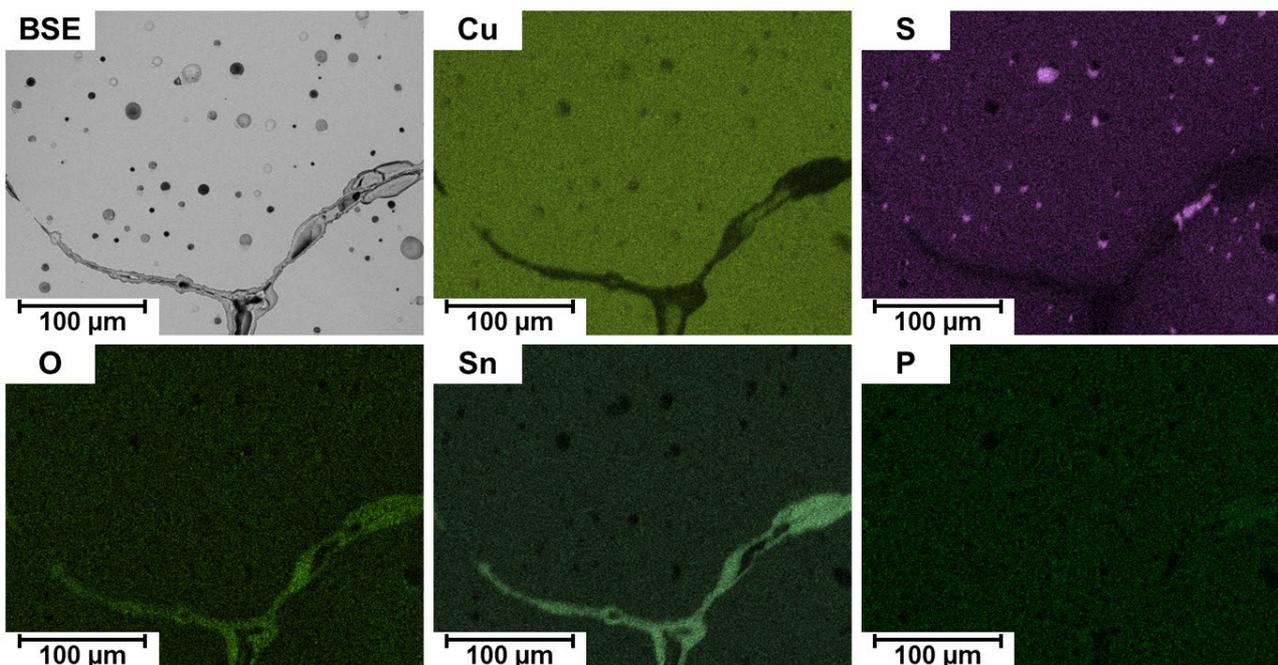
**Fig. 6.** SEM-EDX element distribution.

The oxidation along the grain boundaries during cremation is due to high-temperature corrosion as well as scaling and  $\text{Cu}_2\text{O}$  (cuprite) is formed. Cuprite appears red in polarized light (Fig. 7c, Fig. 9c) [9]. However, aqueous corrosion also occurred during long-term storage of the bronze in the soil, resulting in the formation of malachite at the surface (Fig. 9a–c). Malachite appears green in polarized light (Fig. 7c, Fig. 9c).

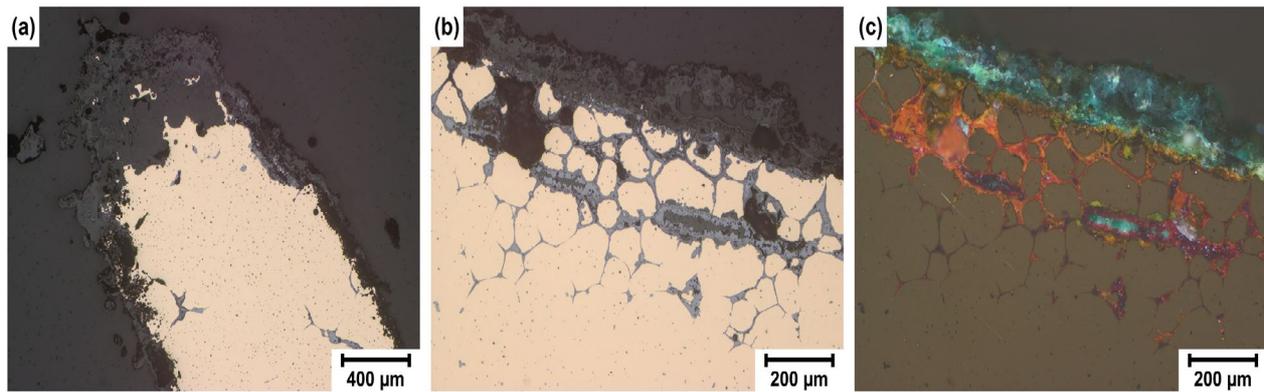
The formation of the surface layer shown in Fig. 9b and Fig. 9c can be explained as follows: during cremation oxidation occurred along the grain boundaries resulting in the formation of  $\text{Cu}_2\text{O}$  (red in polarized light) (Fig. 9c). Later the malachite layer was formed at the surface (green in polarized light) [16].



**Fig. 7.** 2<sup>nd</sup> grinding level. Small holes in the bronze grains. (a, b, d) as-polished, (c) polarized light, (e) Klemm 2 etched, (f) SEM.



**Fig. 8.** SEM-EDX element distribution.



**Fig. 9.** Corroded surfaces of the bronze. (a) edge of the button, (b) surface, (c) polarized light.

### Summary

A bronze button from the late Bronze Age (ca. 1300–800 BC) was investigated.

The button was made by casting, which is consistent with the buttons from Schandorf [9] and Mitterkirchen [10] examined so far.

During cremation the button partially melted resulting in the formation of  $\text{Cu}_2\text{O}$  at the grain boundaries. In other areas the structure recrystallized resulting in grain growth of the bronze and sizes up to 1 mm were formed.

Also, small spherical shrink holes, partially filled with  $\text{Cu}_2\text{S}$ , were observed in the bronze grains of the melted regions.

Sn is enriched in  $\text{Cu}_2\text{O}$ , which had developed by scaling, and at the bronze surface malachite had formed.

### Acknowledgement

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