The occurrence of brochantite on archaeological bronzes: a case study from Lofkënd, Albania

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ABSTRACT
A technical study was conducted on a group of copper alloy artifacts excavated from the burial tumulus of Lofkënd (fourteenth–ninth century BCE) to identify the alloy compositions and methods of manufacture. The surface corrosion was also examined in order to understand the diagenetic processes affecting the preservation of the finds and their condition. Portable X-ray fluorescence spectroscopy, metallographic examination, and X-ray powder diffraction (XRD) analysis were used to characterize the alloy composition and identify the corrosion products present. XRD analysis showed the presence of brochantite (Cu₄SO₄(OH)₆) on five of the metallic artifacts. Brochantite is not commonly reported on archaeological bronzes from terrestrial sites, but is more readily found on copper alloy objects exposed to sulfur pollutants in the air or soil. The possible conditions that could have led to the formation of this corrosion on the bronzes from Lofkënd are discussed in the context of the particular burial environment found at the tumulus.

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Introduction
The study of corrosion products on excavated archaeological copper alloy artifacts can provide a wealth of information on the condition of the object and the burial environment. With increased accessibility to, and portability of, analytical techniques, these types of studies are becoming more prevalent. This latest research focus is identifying new, or uncommon, corrosion products, increasing our understanding of the conditions under which these alteration products can form.

This paper presents the results of the study of a group of bronze artifacts excavated from the prehistoric tumulus of Lofkënd where corrosion products not commonly found on archaeological bronzes were identified. Once such corrosion product was brochantite (Cu₄SO₄(OH)₆), a result that was unexpected as it is more commonly reported on outdoor bronzes in a polluted environment (Graedel 1987; Graedel, Nassau, and Franey 1987; Scott 2002). A few examples have been published where brochantite was found on ancient artifacts retrieved from terrestrial sites (Balasubramaniam et al. 2002; Robbiola et al. 2004; Nord, Mattsson, and Tronner 2005; Ghoniem 2014). When the causes for its formation have been discussed, its presence has been attributed to a high sulfur content either in the burial environment due to atmospheric pollutants or anthropogenic activities (Nord, Mattsson, and Tronner 2005) or within storage (Eggert et al. 2004; Eggert 2006; De Ryck, Pantos, and Adriaens 2007). The present study of the corrosion on the Lofkënd bronzes, however, offers another possible cause for its formation based on the specific burial conditions at the site.