The two Late Roman slag heaps located near Polis Chrysochous, western Cyprus, are studied to reconstruct the technological processes of copper production. The Pelathousa slag heap (4th-6th century C.E.) is located on the foothills of the Troodos Mountain close to the Limni mine, while the Argaka slag heap (6th-8th century C.E.) is near the coastline approximately five kilometers from the mine. Macroscopic examination, HgXRF analysis, optical microscopy and Scanning Electron Microscopy (SEM-EDS) showed that the slag from both slag heaps has the same variability in manganese content, which varies from less than 1 wt% to almost 40 wt%. The slag assemblage derives exclusively from copper-smelting melting. The second part of the research focuses on the spatial analysis of the metallurgical remains. Using GIS spatial tools, the locations of the slag heaps are investigated in their topographic context and distance from the nearby mines, i.e., the Limni and Krounous mines. The results will be used to understand the organization of copper production within the landscape.

Introduction

The two slag heaps span the peaceful period from the 4th century, during which Cyprus (Fig. 1) is part of the Eastern Roman Empire or Byzantium, to the Arab invasions in the 7th century and may well continue to the turbulent end of the 8th century, according to radiocarbon dating (Socratous et al. 2013). During this period there is a significant increase in copper production on the island with large slag heaps found all over the periphery of the Troodos Mountains. Previous studies have shown that there is a uniformity in the metallurgical remains, something that could indicate one main organizational center (Kassianidou 2003, Georgakopoulou and Kassianidou 2013). The Argaka slag heap (Fig. 3, 4) is characterized as large’ (Stos-Gale et al. 1998) while the Pelathousa slag heap (Fig. 2) was much smaller. Unfortunately, recent building in the village has obscured the slag heap completely. This study aims to explore this possibility for the region.

Methodology

• 50 samples from both slag heaps were analyzed by HgXRF.
• 49 samples were further studied through optical microscopy and 15 were also analyzed with SEM-EDS.
• Least Cost Path analysis, as a GIS spatial tool, was employed to investigate the routes between the mines and the slag heaps to estimate the time needed to walk each route.

Results

• All are copper-matte smelting slags, indicating that copper sulfide ores were smelted (Table 1). The copper inclusions have a chemical composition that ranges from that of chalcopyrite to copper metal (Fig. 6, 8).
• There are two distinctive groups of slags based on the manganese content, according to the HgXRF and SEM-EDS data. Group 1 has a low-manganese content between 0.1 wt% and 6.5 wt% (27 samples in total) and Group 2 has a high-manganese content between 14.2 wt% and 38.2 wt% (19 samples in total).
• The manganese content does not change the microstructure of the slags, as almost all slags are typical olivine crystals of free iron oxides and some spinel is observed. Most of them retain the optimum smelting temperature (Graph 1).
• There is no correlation between the type of metal inclusions (matte or metallic copper metal) and the groups of slag according to their manganese content.
• Only a few small prills of metallic copper are evident. Very glassy slags are the ones that are rich in copper metal prills, perhaps indicating that they are products of secondary smelting (Fig. 9).
• All walking routes from the ore deposits to the slag heaps take within 0.5 and 1.5 hours, based on Tobler’s hiking function (Table 2).

Discussion

The chemical analysis of the slag samples agrees with past studies on late antique metalurgy across the island. The manganese does not come from the ore which is in the form of a massive sulfide, but rather from an added flux. Terra Umbra (also called an earthy brown), an earthy brown mixture of iron and manganese oxides, and pyrolusite (pure manganese oxide) have been suggested as manganese sources, both suitable to be used as flux and both available in the Troodos mining regions (Bachmann 1982, Kassianidou 2003, Georgakopoulou and Kassianidou 2013). The low copper content verifies the high degree of copper smelting expertise of the area in this period.

Conclusion

Copper smelting technology is interestingly homogeneous across the island in Late Antiquity, a period during which the exploitation of the ore deposits had reached an industrial level. This raises the question concerning the organization behind it. It has been suggested that the production of copper stopped by the end of the 7th century AD, due to a combination of factors including Arab invasions. Nevertheless, the mining exploitation in this area seems to be intense and continuous even during, and perhaps for a short time after the Arab invasions. Cyprus either in war or peace, is almost continuously one of the important copper metal exporters throughout the ages.

References


Fig. 1. The Argaka slag heap.