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Original Paper

Experimental and microscopic studies of some copper alloy objects from the *Biregan* Archeological site of *Kouhrang*, Second millennium BC

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Abstract

Exploring the Biregan is part of the rescue stage of the ancient sites behind the dam and Kouhrang third tunnel. Several exploration stages have been conducted in this area, that excavated in 2012 by Ahmed Azadi, an archaeologist at the Archeological Institute, and one of the ancient sites in the region is named KR385, attributed to the late Bronze Age and Early Iron Age. Archaeological investigations in this region were began in 2007 and during which Tens of ancient sites and numerous historical objects were discovered. The enclosure KR385 in the region of Biregan in the Kouhrang city of Chaharmahal and Bakhtiari province was identified in the third season of the archaeological survey of Kouhrang city in 2010, and a number of metallic and clay works were obtained from graves no 1 and 2. The metalwork obtained from this ancient site from ancient archaeological and metallurgical point of view is an interesting example. In this paper, five metallic objects of copper - alloy included pendants in the form of bird, pendants and stamped stamps in the form of headdresses, decorative pendants, arrowhead and pins are investigated. In this study, experimental tests and instrumental analyzes including radiography, metallography, SEM-EDS, Micro-PIXE were used to determine the type of alloy, chemical composition and manufacturing technique of objects. The alloy composition of the objects obtained according to the elemental analysis showed that the main elements in the KR-1, KR-2, KR-4 and KR-5 samples include copper and tin (tin with different percentages), and the main elements of the KR-3 sample contains copper and arsenic, which represents the construction of these objects from bronze and arsenic copper. According to the results of the analysis of inclusions and phases, the main elements of dark gray phases, i.e., points A, include copper and sulfur, and significant amounts of lead, especially in KR-1, KR-2, and KR-5 samples, followed by oxygen has it. Other elements with a low percentage (between 1 and 3%) are identified at these points. The result is that these points A are sulfide inclusions. the main elements black dots (points B), are copper, oxygen, sulfur and tin. Due to the high oxygen content, these points are copper oxide. Regarding to the micrograph in as polished samples, in some places the pseudo-structure of the dendrites was seen in black, this type of structure is known as a trace-structure or ghost-structure that in patina layer many of ancient bronzes are in the form of dendrites or corrosion grains has been seen. The dendritic structure and $\alpha + \delta$ eutectic in KR-1 and KR-2 samples, and the presence of strain lines, grains crystallized and

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the twin lines in KR-3 and KR-4 samples showed that the formation of the objects of this ancient site of operations Metalworking including casting and hammering are used. Radiographic results show that these objects lack decorative and attach, and the absence of the connection represents an integrated construction. The X-ray radiography of the studied objects shows no evidence of joining or welding of different parts on them.

Keywords: Biregan of Kouhrang, Tin bronze, Arsenical copper, Metallography, Hammering, Casting