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Phase composition of Early Bronze artefacts from Przeclawice (SW Poland) and its meaning for archaeological interpretations

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The study of pre-historic artefacts by methods used in mineralogy and petrology is widely applied in archaeological sciences. It can give the information on the provenance of the artefacts (e. g. stone tools), about the technology applied to produce ceramic and metal artefacts as well as on the raw materials used. We studied the Bronze Age metallic artefacts from the Przeclawice cemetery in SW Poland (30 km south of Wroclaw, SW Poland) by means of electron microprobe and LA-ICP-MS. The cemetery is located in a region of very dense early Bronze Age settlement, however the site is unique because the graves come from all stages of the *Únětice* culture, which covered large parts of Central Europe ca. 2350-1600 BC. The aim of the study was to define the phases forming the metal, and to find trace elements which potentially could serve as tracers of provenance of ores used for metal production.

All the studied metal samples are copper rich ($>$ 75 wt. % Cu). Some contain significant traces of Rh and Pd. That coming from the oldest studied grave (*Únětice* stage I, 2000 – 1900 BC) is inhomogeneous and consists of two phases (phase A: Sn $\sim$20, As $\sim$1.5, Sb $\sim$1.3 wt.%, phase B: Sn $\sim$11, As $\sim$0.6, Sb $\sim$0.3 wt. %). Both phases contain significant Mn ($\sim$30 ppm) and Bi (A – $\sim$1000 ppm, B - $\sim$100 ppm), are rich in silver (up to $\sim$1 wt. %), relatively poor in Co (2 ppm) and Au (1 ppm). The ring excavated from the *Únětice* stage II (1900 – 1800 BC) grave is pure Cu-Sn alloy (91 and 9 wt. %, respectively), containing 25 ppm Co, 2 ppm Bi, 80 ppm Ag and 1 ppm Au and no Mn.

The metal products (mostly rings) from graves dated at *Únětice* stage III/IV (1800 – 1700 BC) are homogeneous, contain $>$ 95 wt. % of Cu and only traces of Sn. The contents of As varies from $\sim$0.3 to 3.0 wt. %, and that of Sb from $\sim$0.2 to 1.4. wt. %. These alloys contain small ($<$0.8 wt. %) amounts of Al, practically no Zn, Fe and Ni. In some of the studied artefacts from the stage III/IV few tens of micrometer inclusions of Sb occur, as well as sparse grains of copper sulfide or tin oxide. These alloys contain relatively much Mn ($\sim$15 ppm), Co (850 ppm), Au (up to 7 ppm) and up to 60 ppm Bi and up to 1 wt % of Ag. Various amounts of post-gas bubbles are present in the stage III/IV artefacts, only two of them have deformed metal grains or inclusions suggesting forging.

The major element composition of studied metal artefacts fits the observations suggesting increasingly developing smelting technology, leading to production of homogeneous, tin poor alloys. The contents of trace elements (Mn, Co, Au, Bi, Pd, Rh) as well as the Ag content my vary due to smelting techniques, but potentially may be a source of information about the ores used.