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Recent Archaeometric Research Using Ion-Beam Methods at the Jožef Stefan Institute

At the Tandetron accelerator of the Jožef Stefan Institute, proton-induced X-ray emission (PIXE) and proton-induced gamma-ray emission (PIGE) have recently been used for the analysis of archaeological glass and metals. For glass, we carried out three series of measurements on prehistoric material-glass beads from Novo Mesto, Ig near Ljubljana, and Ljubljana (SAZU courtyard), together with several other sites – with the aim of identifying glass types and exploring relationships between sites.

Beads from Ig near Ljubljana comprise glass manufactured using natron-based alkalis, in line with the dominant types circulating in the Late Iron Age and, later, the Roman period. Beads from Novo Mesto – mostly dated to the Early Iron Age – are also mainly natron-based, although a few are made using wood-ash alkalis with a prominent potassium fraction, characteristic of Late Bronze Age glass from northern Italy following the introduction of wood-ash fluxes. Among beads from the SAZU courtyard and other Late Bronze Age sites we identified alkalis derived from wood ash and halophytic plants, as well as natron. Several beads exhibited elevated boron and lithium concentrations, consistent with raw-material associations to thermal springs in Asia Minor.

A second assemblage – Late Antique and medieval glass – includes finds from the Capuchin Garden in Koper (Capodistria), whose results have been published (Šmit & Milavec, 2025). Part of this glass is natron-based and exhibits a high degree of recycling, a typical feature of Late Antique glass of Egyptian and Levantine origin. Other samples are unrecycled, indicating their increasing role in later glass markets. The medieval glass, made using halophyte ash, corresponds compositionally to glasses circulating across the eastern Mediterranean from the eleventh century onwards. We also analysed Byzantine glass from Morava and Braničevo (Serbia), which comprises natron-based material, glass made with halophytic-plant ash, and glass using mineral-alkali sources in Asia Minor (Balvanović et al., 2025).

Among metal objects, we analysed a series of the earliest Hungarian silver coins held at the National Museum of Slovenia (Šmit & Šemrov, 2025). We distinguished lower-quality silver issues in the twelfth century, whereas the Mongol invasion in



Figure 1 Analysis of Tinning on Armour from Hrušica

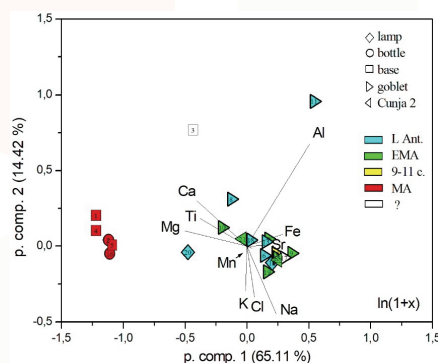
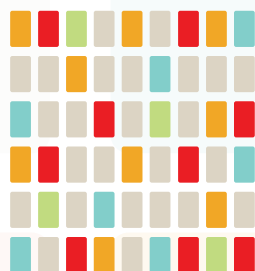


Figure 2 Distribution of Glass from Koper into Groups Using Principal Component Analysis (PCA) (after Šmit & Milavec, 2025)

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the mid-thirteenth century did not affect metal quality. We also analysed Bronze Age bronze samples collected during field surveys in Hungary (detailed study ongoing). A preliminary analysis of Late Roman armour from Hrušica showed that its silver-like appearance was achieved by tinning.

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