

Non-invasive chemical comparison of the Palaeolithic Lion man sculpture, ivory fragments and a left mammoth tusk found at the Hohlenstein-Stadel Cave, Swabian Alb, Germany

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In the Upper Palaeolithic, mammoth ivory was an important raw material for the production of tools and jewellery as well as figurative objects, which are among the oldest preserved works of art of mankind. In the caves of the Ach and Lone valleys in the Swabian Alb, which have been a UNESCO World Heritage Site since 2017, numerous objects made of mammoth ivory have been discovered in Aurignacian and Gravettian layers (e.g. Conard 2003). One of these caves is Hohlenstein-Stadel in the Lone Valley, where fragments of the largest Ice Age figurine (> 30 cm), representing a cross between a cave lion and a human, were excavated in 1939, 1969 and 2009. The Lion man is about 40000 years old and was assembled from about three hundred fragments (Ebinger-Rist et al. 2018). In the same cave, a left tusk of a young mammoth, possibly the unworked counterpart of the right tusk from which the sculpture was formed, and other fragments that could not be assigned so far were found during excavations.

The aim of the present study was to characterise the chemical composition of the Lion Man, the left tusk and the ivory fragments from Hohlenstein-Stadel as precisely as possible. On the basis of the data obtained, possible relationships between the figure and the other objects should be recognised on the one hand and characteristic site-specific or diagenesis-related markers identified on the other. Due to the value of the finds, the investigations had to be carried out non-invasively and without taking samples. Therefore, the analyses were carried out by means of proton-induced X-ray and gamma-ray emission (PIXE/PIGE) at the 2-MV tandem particle accelerator New AGLAE, C2RMF (Reiche et al. 2018) and by means of micro-X-ray fluorescence at the PUMA beamline at the synchrotron SOLEIL (Tranchant et al. 2023).

In previous studies, the trace elements Sr, Zn and Br were defined as site-specific markers for mammoth ivory from the Aurignacian (Heckel et al. 2014, Reiche et al. 2018). The comparison of the trace element patterns of the objects from the Hohlenstein-Stadel with other mammoth ivory artefacts from different European Palaeolithic sites (Reiche et al. 2018) shows, as expected, a similarity of these objects with those from the Hohle Fels cave, which is located in the same region (Swabian Alb), but at the same time a good differentiation from ivory artefacts from other regions (Tranchant et al. 2023).

However, the PIXE measurements showed a slightly higher Sr content of the Hohlenstein-Stadel ivory objects (Lone valley) compared to the Hohle Fels samples (Ach valley). As a result, a finer intraregional site discrimination should be possible based on synchrotron micro-2D XRF measurements allowing a better detection sensitivity for trace elements.

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