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High-resolution climate archives from archaeological sites in Central Europe: new data from freshwater bivalve shells

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For the last seven thousand years climatic and environmental changes have played a major role in the development and migration of humans in Central Europe. Freshwater shells of the genus *Unio* are often preserved in archaeological, shell-bearing deposits and also as grave goods associated with individual burials. This study deals with shells from the Saale-Unstrut area of East Germany that date from the Neolithic (6000 BP) to Bronze Age (2500 BP). This time interval covers a number of important phases in human history, such as the Neolithic Revolution and the Roman Climate Optimum. High-resolution climate archives from archaeological, freshwater bivalve shells are rarely utilized despite their obvious potential. The major advantage of using freshwater shells is that they record terrestrial, subannual climate signals that are directly linked to the human habitat. The shells investigated here are typically very well-preserved, which strongly suggests that they were collected alive. This has been verified using cathodoluminescence microscopy.

In order to fully understand the archaeological archives, a calibration against recent shell records was required. For this purpose, high-resolution stable isotope ($\delta^{18}O$ and $\delta^{13}C$) sclerochronology was conducted on modern *Unio crassus* shells collected from the river banks of the Helme and Kleine Helme Rivers. Two cross-sections were prepared from each specimen, one for growth increment analysis (using Mutvei′s Solution) and the other for stable isotope measurements. The results from the recent shells were then compared with the archaeological *U. crassus* shells.

The recent $\delta^{18}O$ values from the Helme River *U. crassus* shells varied between –7.87‰ and –4.23‰ whilst those from the Kleine Helme River shells ranged from –7.72‰ to –5.41‰. According to monitoring experiments, the shell aragonite was precipitated in environmental equilibrium with the surrounding water. The records from both sites showed distinct seasonal variations in ambient temperature. Major growth lines coincide with the most positive values in the $\delta^{18}O$ record and were therefore formed during the coldest months of the year. The main growing season ranges from April to October. Overall, the archaeological specimens showed more negative $\delta^{18}O$ values than their modern counterparts. Neolithic shells varied from –8.56‰ to –5.83‰ and Bronze Age shells varied from –7.99‰ to –6.29‰.

Preliminary results from the microincrement investigation of the modern shells are compatible with the concept of an April–October growing season as determined by the $\delta^{18}O$ values. Approximately 200 (daily) microincrements were counted between the major (annual) growth lines. This is consistent with the approximate number of days in the year when water temperatures remain above c. 10°C. Below this temperature growth cessation is typically observed in *U. crassus* shells.

Stable carbon isotope ($\delta^{13}C$) profiles from both the recent and archaeological shells showed distinct annual cycles that correspond with those in the $\delta^{18}O$ profiles (i.e. in most instances, the $\delta^{13}C$ and $\delta^{18}O$ peaks occurred simultaneously). In addition, the average $\delta^{13}C$ values from the shells become more negative through time, for instance, –11.43‰ during the Neolithic, –11.68‰ in the Bronze Age and –12.73‰ at present day. These results demonstrate that the primary $\delta^{13}C$ signal is preserved in, and can be revealed by, these shells. As such, the use of stable carbon isotope ratios in freshwater bivalves is likely to provide a significant contribution to future palaeoenvironmental reconstructions.

The results of this study clearly show that temperatures can be reconstructed from unionid $\delta^{18}O$ values and that $\delta^{13}C$ might also be used to reconstruct additional palaeoenvironmental parameters. If the isotopic signature of the water ($\delta^{18}O_{water}$) remained largely unchanged in this area, then the Neolithic and Bronze Age shells must have experienced warmer temperatures and/or more precipitation than their modern counterparts.