Towards reconstructing Paleo-water activity using lake level and gastropod TE/Ca ratios

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Water activity is the partial pressure of water in a solution, which is a crucial driver of chemical (e.g. dissociation constants) and physical (e.g. evaporation and stable isotope enrichment) properties of water. As such, reconstructing past climate and environmental conditions using lacustrine proxies requires a quantification of past water activity. However, very little research has been conducted on ways to reconstruct this crucial water property. In this research, we present a novel method that potentially can enable reconstructing paleo water activity in closed basin lakes. Closed-basin lakes are lakes with no outlet; thus, the size of the lakes varies as function of precipitation and evaporation (P-E), and in turn, can be used to quantitatively reconstruct these conditions. Past climate change altered P-E throughout the geological history causing lakes all around the world to expand (contract), which in turn diluted (concentrated) and reduced (enhanced) lake water activity. To fully understand past hydrological and chemical processes in the lake, it is crucial to quantify the water activity in the lake.

radix sp. is a gastropod that lives at the margins of closed basin lakes. It forms a hard CaCO$_3$ shell, which at death is deposited in the sediments, remains in the geological record, and informs on past lake levels. We sampled radix sp. shells in elevated shorelines of a closed basin lake in North China and from the modern lake shoreline. Radiocarbon ages of the shells span the past 16 ka and are used to construct the lake level curve for the Late Glacial to Holocene (Goldsmith et al., 2017). During this time period the lake level and volume changed substantially; the Early – Mid Holocene lake area high-stand was x7 larger than the modern lake. On these gastropod shells we measured high resolution profiles (sample/length) of TE/Ca ratios (e.g. Mg/Ca, Sr/Ca) using Laser Ablation ICP-MS. We calculated the dissociation constants of the different TE/Ca ratios using modern shells and modern lake water chemistry.

Our preliminary results show that of all elements analysed, Mg/Ca ratios best track lake volume and therefore can be used to reconstruct lake level. The next step will be using gastropod derived lake water chemistry to reconstruct past water activity. This method entails comparing the TE/Ca ratios of Late Glacial and Holocene gastropods with a hydro-chemical model of the lake, derived from a volume history reconstruction of the lake. The hydro-chemical model assumes a simple addition of river water to the modern lake, until the lake reaches the elevation that each gastropod was sampled at. In tandem, these two data sets constrain water chemistry, and the difference between these two estimates should represent the effect changes in water activity have on the
disassociation constant between lake water and shell TE/Ca ratios.