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Hard-water dynamics and their reservoir effects on radiocarbon dating of Lake Heihai sediments (NE Tibetan Plateau, Qinghai, China)

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Age determination of lake sediments with radiocarbon dating can always entail a perturbation with hard water. Atmospheric carbon (expressing the "real" ages) can be mixed with older carbon from allochthonous input (e.g. marl or limestone), causing an overestimation of ^{14}C ages. The usual approach to eliminate this effect is to date living plants or shells to determine the modern offset in age. Subsequently, this offset is subtracted from ^{14}C ages of a sediment core to attain hard water corrected ages. However, this approach assumes a constant hard water effect over the entire period under consideration, which generally is unlikely.

Here we present a highly variable hard water effect through time determined from a combined chronology of two long sediment cores from Lake Heihai (NE Tibetan Plateau). The chronology is based on 20 ^{14}C AMS dates of *Potamogeton* spec. Based on the relation between ^{14}C ages and the input of allochthonous carbonates as well as calculated sedimentation rates, we developed an age-depth-model that estimates the actual ages of the sediments and allows the quantification of hard water effect through time. As a result this model suggests a fluctuating hard water effect varying between 10^2 to 10^3 ka.

Ages in the lower 3 meter of the core, which corresponds to late glacial times, strongly correlate with the input of dolomite ($CaMg(CO_3)_2$). The correlation suggests a strong linkage between the allochthonous input of old carbon and the variations in dating results. In this section, the estimated hard water effect shows its highest values. Results of XRD, grain size and pollen data confirm a shallow lake with high rates of detrital input.

The Late Glacial - Holocene transition to warmer and wetter conditions is marked by prominent changes in the mineralogy of lacustrine carbonates and the composition of pollen taxa. During this time the lake constantly rose and increasingly buffered the influence of allochthonous carbonates. The episode is characterized by a straight and steady rise in the ^{14}C ages, hence the hard water effect can be assumed as constant. The stability lasted for about 5 ka, while Lake Heihai probably reached its highest stand of +6 m above recent lake level.

The following period was dominated by colder and dryer conditions, causing a drop in lake level and the exposure of the formerly deposited lake sediments. Periglacial conditions caused freezing of the exposed lake sediments and the formation of segregated ice in the pores and between the strata layers. The increase in volume and permafrost heave caused further uplift of the sediments. The subsequent exposition to fluvial and littoral wave activity eroded these fossil lake sediments and thus contaminated younger sediments with older organic particles. Seasonal thawing of the frozen ground leached the sediments and mixed dissolved inorganic carbon with the lake water. Both, dissolved old and modern carbon was incorporated in plants through metabolism and led to the alteration of their ^{14}C ages.