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# Carbon and oxygen isotopic records from Lake Tuosu over the last 120 years in the Qaidam Basin, Northwestern China: The implications for paleoenvironmental reconstruction

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ABSTRACT

Isotopic compositions of total organic carbon (TOC) and authigenic carbonate in lakes have been widely used to reconstruct paleoclimatic changes and the depositional environments of lake sediments. However, since these proxies are often controlled by multiple environmental factors, detailed examinations of modern environmental processes is necessary before further applying them into paleoclimatic studies, especially in arid/semi-arid northwestern China. Here we generate High-resolution multi-proxy sedimentary records from Lake Tuosu, a hydrologically closed, saline and alkaline lake located at the north margin of the Qaidam Basin, through analysis of carbon isotope of TOC, and $\delta^{18}O$ and $\delta^{13}C$ values of ostracods over the last 120 years. Together with the meteorological data (precipitation and temperature), lake area record, and other tree-ring evidence, we examine how these sedimentary indices respond to changes in hydrologic balance and climate at interannual to decadal timescales. We found that sedimentary $\delta^{13}$Corg values resemble the variation of lake areas of Lake Tuosu over the last 40 years, suggesting that $\delta^{13}$Corg values would be an ideal indicator of lake area/level fluctuations and thus effective moisture variations (precipitation vs. evaporation). However, ostracod $\delta^{18}O$, which was previously used as proxies of effective precipitation, is not well correlated with $\delta^{13}$Corg values in Lake Tuosu. Therefore, the changes of ostracod $\delta^{18}O$ values cannot be straightforwardly explained as the effective precipitation. Instead, the isotopic composition of carbonate would be additionally controlled by other factors including isotopic compositions of input water and drainage pattern.



## 1. Introduction

The northeastern Tibetan Plateau, located at a triple junction of influences of the Asian summer monsoon, westerly jet stream and Siberian high, is of considerable significance with regard to regional responses to global climate change. Due to the lack of relatively long instrumental records, past climatic changes in this region have been reconstructed mainly by natural archives instead, including tree rings, ice core and lake sediments (e.g., Kelts et al., 1989; Zhang et al., 1989a, 1989b; Sun et al., 1991; Thompson, 1995; Yao et al., 1996; Yu and Kelts, 2002; Shao et al., 2005; Liu et al., 2006; Zhao et al., 2010, 2013; Fan et al., 2012; Liu et al., 2015a). Therefore, reasonably interpreted records of past climatic variability are vital to our understanding of the sensitivity of climatic change to different forcings and to better prediction on its future behavior.

Lakes, especially hydrologically closed lakes, are natural integrators of surficial processes and are important information sources for paleoclimatic reconstruction in the northeast Tibetan Plateau (Lister et al., 1991; Zhang et al., 2003, 2009; Ji et al., 2005; Shen et al., 2005; Liu et al., 2007; Henderson et al., 2010; He et al., 2013; Chen et al., 2015). Changes in volume, chemistry, and isotopic compositions of lake sediments and organisms commonly are influenced by variations in effective moisture and temperature (Holmes et al., 2007; Li et al., 2012a, 2012b; Liu et al., 2013; Li and Liu, 2014). As an indicator of environmental change in lakes, the isotopic compositions of carbonates and total organic matters (TOM) have been used in lake studies to decipher paleoenvironmental conditions on the north Tibetan Plateau (Henderson et al., 2003; Xu et al., 2006; Colman et al., 2007; Aichner et al., 2010a; Mischke et al., 2010; Wang et al., 2013a; Thomas et al., 2014; Liu et al., 2015b).

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In general, $\delta^{18}O$ values of lacustrine authigenic carbonates are mainly controlled by the isotopic composition of the water at the time when carbonates precipitated in lakes, with secondary modification by temperature (0.24% decrease in the $\delta^{18}O$ value of carbonate for every 1 °C increase in water temperature, O'Neil et al., 1969). Therefore, records of $\delta^{18}O$ values of carbonate in lake sediments have been widely used to indicate changes in the lake's Evaporation/Precipitation ratio (P/E), salinity (Liu et al., 2009a) and hydrological balance (Lister et al., 1991; Henderson et al., 2003; Leng and Marshall, 2004; Qiang et al., 2005; Yuan et al., 2006), although the $\delta^{18}O$ of lake carbonates has also been occasionally used as an indicator of temperature (e.g., Xu et al., 2006, 2014). In the case of northeastern Tibetan Plateau, a study from the Qaidam Basin showed that variations in carbonate $\delta^{18}O$ values could not have been the result of varying effective precipitation but were due to changes in water temperature and $\delta^{18}O$ of the source water (Holmes et al., 2007). However, another study indicated that the oxygen isotopic compositions of ostracod shells can be used to indicate changes in precipitation over a short time scale in Qaidam Basin (Li et al., 2012b). A recent study also suggested that variation in carbonate $\delta^{18}O$ values from lake sediments cannot be explained as changes in effective moisture in arid area (Liu et al., 2014a).

Thus, it is often difficult to interpret the carbonates $\delta^{18}O$ data unambiguously unless detailed observations of modern environmental processes are available because the $\delta^{18}O$ of lake carbonates are often controlled by multiple environmental factors (Leng and Marshall, 2004; Liu et al., 2007, 2009a; Holmes et al., 2007). In addition, another isotopic proxy, the $\delta^{13}C$ values from lake carbonates, has rarely been fully exploited as proxies because their interpretation is thought to be difficult to assess and only a few coupled oxygen and carbon isotope records spanning the entire postglacial evolution of the studied lake was reported (Mischke et al., 2010; Schwalb et al., 2013).

$\delta^{13}C$ values of sedimentary TOM ($\delta^{13}C_{org}$) are also an important proxy for tracking variation in the water depth, temperature, aquatic biomass, and the relative contribution of terrestrial sources in lakes (Meyers, 1994, 1997; Shen et al., 2005; Xu et al., 2006; Mackay et al., 2012), which are all directly or indirectly linked to changes in the climate of the lake catchments (Leng and Marshall, 2004). Basically, lacustrine sedimentary TOM consists of a mixture of organic materials from sources within the lake including aquatic plants and microorganisms, and external sources like vegetation and soils and aeolian dust around the catchment. Since these sources have distinguishable isotopic signatures, information on changes in proportion of different TOM sources would be well preserved in the stable isotope composition of sedimentary TOM (Meyers, 1994; Lücke and Brauer, 2004). Studies in Lake Qinghai on the northeastern Tibetan Plateau have shown that the TOM is mainly from water-depth related aquatic plants with distinctive $\delta^{13}C$ values, thus $\delta^{13}C$ values of sedimentary TOM mainly reflect changes in water depth (Wang et al., 2013b; Liu et al., 2013, 2015b). However, whether this method can be used in other lakes with similar environmental setting, need further investigation.

In this paper, we evaluate controls on the lake-sediment carbon and oxygen isotopic compositions of carbonates and total organic matters from Lake Tuosu, located at the northeastern edge of the Qaidam Basin on the northern Tibetan Plateau. On this base, the environmental implications of these proxies would help us understand paleoclimatic and paleoenvironmental changes using the materials from lakes.

## 2. Study site

Lake Tuosu (37°04′ N, 96°50′ E) is located at the northeastern edge of the Qaidam Basin on the NE Tibetan Plateau (Fig. 1). The Qaidam Basin, with an area of 120,000 $km^2$, is surrounded by the Kunlun Mountains to the south, the Altun Mountains to the west and the Qilian Mountains to the north and east. The surrounding mountains rise to an elevation of >5000 m above sea level, while the average elevation of the basin is 2800 m. The surface area of Lake Tuosu is approximately 145 $km^2$ with a maximum water depth of 25 m. The water of Lake Tuosu was mainly obtained from Lake Hurleg through a ~3 km long river northwest of the lake besides, some ground water and intermittent river water from around mountains. Lake Hurleg (37°17′ N, 96°54′ E) is a freshwater lake, which is mainly fed by the Bayin River, the Balegen River and groundwater from the mountains north of the basin (Fig. 1).

The region is in an extremely arid desert climate. The annual precipitation is about 180 mm and annual mean temperature is 4 °C, based on recent 50 years climate data from the nearby Delingha meteorological station. Most precipitation falls as rain during the summer months. The potential evapotranspiration is about 2000 mm. Modern vegetation of this region is dominated by desert plant communities, mainly consisting of Chenopodiaceae (including *Salsola abrotanoides*, *Kalidium gracile*, *Ceratoides aritim*, *Haloxylon ammodendron* and *Sympegma regelii*), Ephedra, Nitraria and Asteraceae (Zhao et al., 2008).

## 3. Materials and methods

A 33-cm sediment core (TSLC14-1) was taken from Lake Tuosu in April 2014 at approximately 12 m water depth (37°10′36″ N, 96°57′12″ E) using the UWITEC corer 60. The sediment core was sub-sampled at

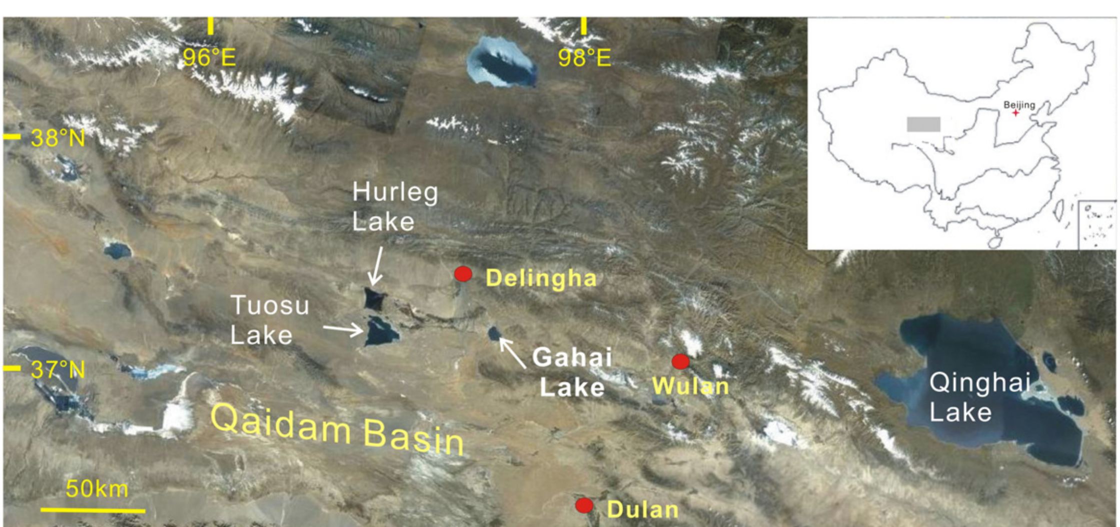


**Fig. 1.** Map of Lake Gahai, Lake Tuosu, Lake Hurleg and their surrounding environment.