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Wetland evolution in the Qinghai Lake area, China, in response to hydrodynamic and eolian processes during the past 1100 years

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ABSTRACT

The Daotanghe riverine wetland in close proximity to the Qinghai Lake was investigated to demonstrate the interrelationships between Qinghai Lake hydrodynamic processes, eolian mobility and ecological conditions during the past 1100 years in response to climate change. We used ostracod assemblages from various sites east of Qinghai Lake and from the sediment core QW15 of Daotanghe Pond and combined them with grain size and geochemical data from the same core. The statistical extraction of grain size endmembers (EM) revealed three different transportation processes responsible for pond-related fluvio-lacustrine, pure fluvial and eolian deposits. Identified seasonal effects (eolian mobility phase) and timing of ice cover are possible tracers for the competing influence between the Asian summer monsoon and the Westerlies in the Daotanghe Wetland and surrounding area.

Our results show that ostracod associations and sediment properties are evidence of a fluvio-lacustrine fresh water environment without ingression of Qinghai Lake into the wetland. Hydrodynamic variations coupled with phases of eolian input indicate highly variable water budgets in response to climate-induced effective moisture supply. The Medieval Warm Period (MWP) until about 1270 CE displays generally moist and warm climate conditions with minor fluctuations, likely in response to variations in summer monsoon intensity. The three-partite period of the Little Ice Age (LIA), shows hydrologically unstable conditions between 1350 and 1530 CE with remarkably colder periods, assigned to a prolonged seasonal ice cover. Pond desiccation and replacement by fluvial deposits occurred between 1530 and 1750 CE, superimposed by eolian deposits. The phase 1730–1900 CE is recorded by the re-occurrence of a pond environment with reduced eolian input. Principal Component Analysis (PCA) on ostracod abundances shows similar trends. All three phases of the LIA developed during a weak summer monsoon influence, favoring westerly-derived climate conditions until ca. 1850 CE, in accordance with records from the adjacent regions.

Seasonal freezing periods in excess of the average time of frozen water bodies also occurred in periods of the well-known grand solar minima and indicate stronger seasonality, possibly independent from variations in summer monsoon strength but with links to global northern hemispheric climate.

1. Introduction

Wetlands, defined as ecotones in the transition zone between terrestrial and aquatic ecosystems, play an important role in ecological changes because of their specific and various biodiversity and huge water capability (Bullock and Acreman, 2003; Zhang et al., 2011). They are inherently different from pure terrestrial and aquatic systems but highly depend on both (Mitsch and

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Gosselink, 2007). Owing to differences in landscape topography, hydrology and vegetation, wetlands vary in a wide range and strongly depend on their hydrological settings in riverine, lacustrine or palustrine environments, influenced by the spatial and temporal dispersion, flow and physico-chemical characteristics of surface and groundwater (Fraser and Keddy, 2005; Keddy, 2010). It is known that hydrological conditions of wetlands influence the local water cycle and hydrologic processes (Zhang et al., 2011).

Studies on alpine wetlands on the Tibetan Plateau, such as wetlands in headwater regions of the Yangtze River, Yellow River and Zoige Basin, show a strong sensitivity to climate changes (e.g., Jorgenson et al., 2001; An, 2003; Zhang et al., 2008a,b). Their individual extent and spatial distribution pattern and the effects on hydrological and biological processes have been frequently discussed (e.g., Price et al., 2005; Cui and Yang, 2006; Wang et al., 2007a,b; Zhang et al., 2011). However, interlinked relationships between alpine wetland ecosystem developments and adjacent river and/or lake system dynamics including morpho- and hydrodynamic processes on a catchment and even regional scale are still less considered. Deciphering the links between biotic habitat changes and abiotic sedimentary processes (fluvial, lacustrine, eolian) of wetland systems on the Tibetan Plateau are therefore of crucial importance for a better and comprehensive understanding of the climate-influenced wetland evolution through time. Mischke et al. (2015) discussed the potential response of wetlands to lake level changes at Donggi Cona based on ostracods communities.

Despite a large number of investigations on wetland soils and their biochemical cycling (e.g., Tian et al., 2012; Liu et al., 2013a,b; Deng et al., 2014), clastic sediments in wetland ecosystems on the northern Tibetan Plateau remain less investigated, although they provide detailed information about various processes and environmental conditions, well reflecting the formation and alteration of wetland ecosystems through time. Comparable studies on sediment characteristics from lakes, such as grain size, geochemical and mineral composition, combined with fossil remains confirm the high potential for reconstructing hydrologic balances, limnological conditions and sources of sediments through time caused by different morphodynamic and sedimentary processes linked with climate dynamics and non-climatic factors as well (Colman et al., 2007; Mischke et al., 2008, 2010; Dietze et al., 2012; Yan and Wünnemann, 2014; Wang et al., 2015).

Ostracods are considered to be ideal biotic indicators of changing hydrological and hydrochemical conditions of water bodies (Mischke, 2012) including habitat preferences of some species to a specific sediment type as their hosting medium. These small bi-valved micro crustaceans widely occur in different aquatic environments, comprising permanent to temporary, still to flowing and fresh to salty water bodies (Meisch, 2000; Griffiths and Holmes, 2000; Delorme, 2001; Griffiths et al., 2002). They are well preserved in various depositional environments and were frequently used as indicators of aquatic ecosystem dynamics (Ruiz et al., 2013), water quality (Boomer and Attwood, 2007; Pieri et al., 2012), water temperature (Horne, 2007), water depth (Wrozyna et al., 2009a,b; Frenzel et al., 2010; Mischke, 2012; Yan and Wünnemann, 2014) and palaeo-salinity/conductivity reconstruction achieved by transfer functions and chemical analysis on ostracod shells (Mischke et al., 2007; Frenzel et al., 2010; Li et al., 2012).

The largest inland lake in China, the Qinghai Lake, is located in the marginal zone between Westerlies and Asian monsoon atmospheric influence and thus has been in the focus of paleoclimate studies for decades with quite different and even conflicting results (e.g., Lister et al., 1991; Shen et al., 2005; Liu et al., 2007; Colman et al., 2007; Henderson et al., 2003, 2010; Liu et al., 2009a,b, 2013a,b; Li et al., 2010, 2012; Rhode et al., 2010; Lu et al., 2011; An et al., 2012; Li and Liu, 2014; Liu et al., 2011, 2015). Studies on the relationship between catchment processes and lake hydrology in this area are hardly investigated and wetland studies in relationship to the evolution of Qinghai Lake were not undertaken so far. Here we combine ecological information with sediment properties from the riverine Daotanghe Wetland in close proximity to Qinghai Lake in order to validate the process-response-based relationship between wetland formation and river-/lake hydrodynamics, controlled by climate variability throughout the past 1100 years.

2. Study site

Daotanghe is a small meandering river at the south-eastern side of Qinghai Lake that originates from the Riyue Mountain (ca. 3300 m a.s.l.) and flows through a wide-spread valley over a total distance of about 40 km toward Erhai Lake. The latter is considered a former bay of Qinghai Lake which was separated from the lake by the formation of an elongated and dune-covered sand bar during the early 20th century (Kozloff, 1909; cited in Wang and Shi, 1992) and thus formed a shallow lagoon attached to Qinghai Lake but currently morphologically separated from the lake. It was suggested that the former Qinghai Lake drained along Daotanghe valley towards the Paleo-Yellow River before tectonic uplift of the Riyue Mts. promoted the closure of Qinghai Lake during the Middle to Late Pleistocene (Yuan et al., 1990; Pan, 1994; Li and Fang, 1999). Rhode et al. (2010) however, suggested an overflow farther north at Kelu Pass once Qinghai lake level exceeded 3299 m a.s.l.

Numerous paleoshorelines surround the south-eastern shore of Lakes Qinghai and Erhai, of which the highest traceable one is about 16 m above the present lakeshore (Fig. 1C). Liu et al. (2011) dated several shorelines in the Haiyanwan Bay (north-east) and at Erlangjian (south-east) of Qinghai Lake at elevations of up to 3203 m a.s.l. The OSL ages indicate the time of shoreline formation during the past 3700 years and a possible transgression of Qinghai lake water into the Daotanghe Wetland during the Roman Warm Period at around 1.77 ka BP as a result of lake level increase by about 8–9 m.

The Daotanghe watershed wetland (100°45′5″E, 36°34′33″N, 3199 m a.s.l., Figs. 1C and 2) close to the Erhai Lake is one of two larger water-covered and vegetated flat areas of about 4 km^2 in area, including temporary ponds with water depths of 50–70 cm. Water in the western pond area is slightly flowing by few cm/sec, whereas higher flow velocities are restricted to the main river located at the southern border of the wetland. The wetland has no further perennial inflow from the surrounding sub-catchments. According to Hou et al. (2009) the total dissolved solids (TDS) and pH of Daotanghe account for 661 mg/L and 8.98, respectively. The up to 1.35 cm long cores QW14 and QW15 were taken in the western part of the pond (Figs. 1 and 2), comprising organic-rich sandy silt, partly layered, and coarser material at the bottom of the cores.

The area around the wetlands is vegetated by a high mountainous alpine meadow, alpine steppe and desert vegetation, currently strongly impacted by grazing (Chang et al., 2014). Vegetation in the shallow pond is dominated by charophytes and other aquatic plants (not identified so far). Molluscs (*Gyraulus* sp., *Radix* sp. and *Pisidium* sp.) were frequently found in nearshore areas and in the river itself.

Climate information is based on the observation data from the nearest weather station (Qinghai Lake-151, station code: 52854) with 30 years (1981–2010) records, located near National Road 151, west to Daotanghe Wetland (100°17′24″E, 36°21′N, 3200.8 m a.s.l., National Metrological Information Center: http://data.cma.gov.cn/data/detail/dataCode/A.0029.0004.html). The mean annual