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Research paper

Late pleistocene evolution of Lake Manas in western China with constraints of OSL ages of lacustrine sediments

Anchuan Fan [a,b], Sheng-Hua Li [a,*], Yue-Gau Chen [b]

[a] Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong
[b] Department of Geosciences, National Taiwan University, Taiwan, ROC

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ABSTRACT

Lake Manas, located in northwestern China, has been formed in a structure depression since early Quaternary. Optically stimulated luminescence (OSL) dating is applied to the lacustrine and aeolian deposits collected from the lake to construct a chronological frame for lake level fluctuations since the last inter-glacial period. The results yielded two stages of high lake stands (~20 m above the present lake bed) occurred before 66 ka and 38–27 ka ago. No evidence for Holocene high lake level was found in the studying area.

1. Introduction

Lake Manas is a closed-basin lake located on the western edge of Junggar Basin, northwestern China (Fig. 1). Its east is adjacent to the Gurbantunggut Desert, which is the second largest desert in China. At present, the regional climate is controlled by the Westerly wind system (Wang et al., 2005). Mean annual precipitation in the area is 64 mm, and the annual evaporation is 3110 mm (Yao et al., 2007). Lake Manas was once a large saline lake with a surface area of 550 km^2, 55 km long and 15–20 km wide, and an average depth of 6 m in 1957 (Guo and Tang, 1966). During the 1950s and 1960s, dams and water channels on the upstream rivers of Lake Manas were built for agricultural irrigating. The lake dried up around 1972 ~ 1976 as a result of significant reduction in water supply (Cheng et al., 2001). At present, the dried lake region is a salt depression exploited for halite. Lake Ailike is a saline lake to the northwest of Lake Manas, separated by a NE–SW ridge (Fig. 1). The ridge is around 45 km long and 3–10 km wide. The elevation and the width of the ridge decrease from the northeast to southwest and eventually become part of the alluvial fans of Manas River.

Previous geomorphic and satellite imagery studies suggested Lake Manas is a relict lake of the palaeo Lake Manas cluster, which was a large wandering lake during Quaternary (XCET, 1978). The lake was formed in a structural depression region in the west part of Junggar Basin during Pleistocene (Wang, 1991). The depression was formed due to the tectonic activities of west Tianshan Mountains and west Junggar Mountains (Mu et al., 2001). The south of the depression was fluvial fans formed by rivers from the Tianshan Mountains. The palaeolake was the confluence centre of rivers in this depression region. Quaternary sediments can reach a thickness of up to 200 m in the depression area (Zhu et al., 1980). In the early Pleistocene, It was supplied by Wulungu River and Elqis River from the North and Manas River from the South (Fig. 1). The palaeolake level has reached an elevation of 282 m, based on the distribution of lacustrine sediments and present satellite data. The elevation of current lake is 188.9 m above sea level. In late Pleistocene, the large Manas lake cluster separated into several lakes, including modern Lake Manas and Lake Ailike (Shi et al., 2008). However, there is no age control of these stages concerning lake evolution in that area.

Lacustrine sediments from Lake Manas contain abundant information about regional environmental history at various time scales. Climate records in the lake region can also provide information about the interaction between the lake and the adjacent Gurbantunggut Desert. However, previous attempts using radiocarbon dating to obtain a detailed chronology for palaeolake level changes were hindered by the lack of organic material (Rhodes et al., 1996) as well as the problem of 'old carbon' in lacustrine sediments (Wang et al., 2002).

* Corresponding author.
E-mail address: shli@hku.hk (S.-H. Li).

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Here, we report the dating results of sediments associated with evolution of Lake Manas.

2. Sampling sites

Fieldwork was performed in the lake region, mainly along the profile across Lake Manas and Lake Ailike (Profile p–p′). Based on investigations of the geomorphology features of the lake region, 3 sites-Site A, G and H (Fig. 2) were selected for sampling. The corresponding altitude, latitude and longitude of each sample site were measured using a differential global positioning system (DGPS). Site G is at the geometrical centre of the dried lake bed. The ground surface is covered with a layer of salt crystals. DGPS measurement performed on the salt layer yielded an altitude of 188.9 m above sea level. The value was taken as the altitude of present lake bed. Site H locates at Aeolian sand dunes identified along the palaeo shorelines. Sampling site A is along a gradual descent from the ridge to the lake centre. The altitude decreases from 209.5 m (Site A) to 188.9 m (Site G) in a horizontal distance of around 2 km.

2.1. Site A

The ground of Site A is at an elevation of 209.5 m, which is ~20 m above present lake bed. Rounded and semi-rounded cobbles are widely distributed on the ground. A vertical section was excavated for stratigraphic investigation and OSL sampling. The sampled section is comprised of layers of lacustrine sand, clay and beach gravel (Fig. 3).

The top of the section is covered with loose sand and cobbles (~0.1 m), followed by a 0.4 m layer of medium to coarse sand. Beneath is a grey sand layer with a thickness of 0.3 m. The ripple-bedded sand layer is mixed with a small portion of well-rounded gravels (1–2 mm in diameter), which indicates a near-shore environment. Below is a greenish grey clay layer of around 0.35 m in thickness. This laminated clay layer suggests an offshore deep lake environment during deposition. The clay layer is followed by a lacustrine laminated layer of yellow medium sand (0.35 m), and then a 1.5 m thick layer of well-rounded gravels inter-bedded with coarse sand layers. According to the size of the gravels, it can be subdivided into three layers composed of gravels in diameters of 1–3 mm, 3–5 mm and gt; 5 mm at the depth of 1.15 m-1.6 m, 1.6 m–2.5 m and 2.5 m–3.0 m, respectively. The layer of sand-supported gravels was underlain by 0.15 m of coarse sand mixed with a small portion of gravels (1–2 mm). Beneath the sand layer is a clay layer of around 1 m in thickness (Inset in Fig. 3). The clay layer was interrupted by a 0.15 m think layer of fine sand at the depth of 3.4 m. This laminated clay layer suggests a deep lake environment during deposition, whose bottom was not reached at the depth of 4 m.

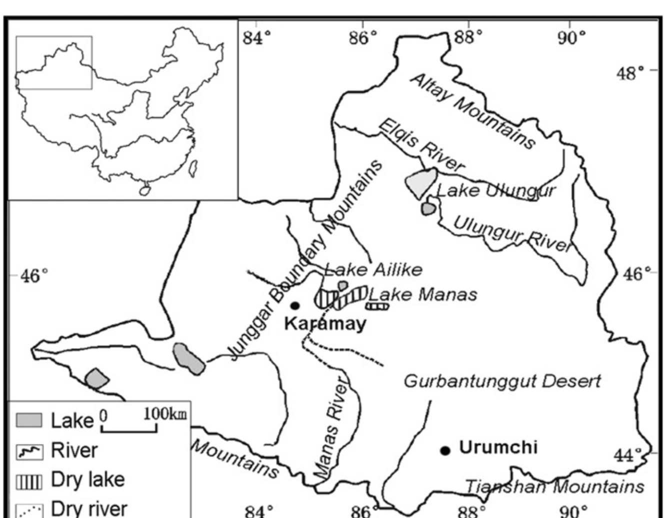

Fig. 1. Map showing the study area and the location of lake Manas and other main lakes and rivers (after Cheng et al., 2001).

2.2. Site G

Two OSL samples were taken from the centre of present salt lake bed as an analogy to modern lacustrine deposits. An outcrop was excavated (Fig. 4). The top of the section is a 0.05 m thick salt layer, followed by a grey fine sand layer of 0.05 m. Beneath the grey sand layer is a dark laminated mud layer with a thickness of 0.1 m, and then a dark coarse sand layer whose bottom was not reached at the depth of 0.4 m. Sampling at deeper depth was precluded by underground water.

2.3. Site H

The ground at Site H is beach sand gravel covered with Aeolian sands. It is at an elevation of 202.0 m, 12 m above present salty lake bed. Site H is relatively lower than adjacent Site A (209.5 m) (Fig. 2). An outcrop was excavated at Site H (Fig. 5). The section is comprised of three units. The top 0.4 m is yellow coarse sand, followed by a 0.6 m thick white/grey sand mixed with gravels (~1 mm). Beneath the white sand layer (from 1 m to 1.5 m) is yellow fine-grain sand mixed with a small portion of gravels. The bottom of the fine-grain sand layer was not reached at the depth of 1.5 m. One OSL sample was taken from each unit of the Aeolian sands.

3. Luminescence dating and instruments

The tubes of OSL samples were opened under subdued red light in the laboratory. The surface sample at both ends of the pipe was scraped away for measurements of moisture contents, radionuclide concentrations and other proxies. Only the central part of the sediment was used for OSL dating to avoid any incidental exposure to light during sampling and transportation. Chemical treatments were first adopted to remove carbonates and organic materials in raw samples, using 10% hydrochloric acid (HCl) and 10% hydrogen peroxide (H_2O_2) solution, respectively. The fraction of grain size within the 180–212 μm range was separated by sieving, unless specified. Density separations using sodium polytungstate solution (density: 2.58, 2.62 and 2.75 g/cm^3) were then applied to isolate the quartz grains from other remaining minerals in the sample. The separated grains were etched with 40% HF for at least 40 min. The purity of the etched quartz grains was checked with infrared (IR) exposure. The quartz grains were then mounted on aluminium discs using silicone oil. Small aliquots (less than 200 grains) were prepared for determination of equivalent doses (D_e).

The single aliquot regeneration (SAR) protocol formalized by Murray and Wintle (2000) was performed in Luminescence Dating Laboratory, the University of Hong Kong (Li et al., 2007). A Risø automated TL/OSL system (TL-DA-15) is used. It is equipped with stimulation units containing blue light-emitting diodes (LEDs, 470 ± 30 nm) and IR LEDs (880Δ80). The total power delivered by the blue LEDs to the sample position was about 35 mw/cm^2 (Bøtter-Jensen et al., 2000). Beta irradiation was performed using a $^{90}Sr/^{90}Y$ beta source delivering 0.08 Gy/s to grains loaded on aluminium discs (Fan et al., 2009). The OSL signals were measured through three 2.5 mm-thick U-340 filters with a bialkali EMI 9635Q