Quaternary International xxx (2016) 1–9

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Chronology for terraces of the Nalinggele River in the north Qinghai-Tibet Plateau and implications for salt lake resource formation in the Qaidam Basin

QiuFang Chang [a, d, e], ZhongPing Lai [b, d, *], FuYuan An [a], HaiLei Wang [c], YanBin Lei [d], FengQing Han [a]

[a] Key Laboratory of Salt Lake Geology and Environment, Qinghai Institute of Salt Lakes, Chinese Academy of Sciences, Xining 810008, China
[b] State Key Laboratory of Biogeology and Environmental Geology, School of Earth Sciences, China University of Geosciences, Wuhan 430074, China
[c] MLR Key Laboratory of Saline Lake Resources and Environment, Institute of Mineral Resources, CAGS, Beijing 100037, China
[d] Key Laboratory of Tibetan Environment Changes and Land Surface Processes, Chinese Academy of Sciences, Beijing 100101, China
[e] University of Chinese Academy of Sciences, Beijing 100049, China

A R T I C L E I N F O

Article history:
Available online xxx

Keywords:
Luminescence dating
Terraces of Nalinggele River
Salt lakes in the Qaidam Basin
Kunlun Mountains in Qinghai-Tibetan Plateau (QTP)

A B S T R A C T

The Nalinggele River, located in the northern Qinghai-Tibetan Plateau, is the largest river originating from the northern slope of the eastern Kunlun Mountains and flowing into the enclosed Qaidam Basin. Controversy exists whether the formation of its terraces reflects the history of the plateau uplift, or climate changes, or both. The salt lakes in the enclosed Qaidam Basin fed by this river bear an unusual world-class enrichment of lithium and boron elements, which are critical resources for regional economy. The concentration of lithium is one of the highest found in brine resource in the world, and sourced from the upstream water of the river. The chronology of the river terraces is essential to understand the plateau uplift history, the regional climate change, the evolution of the terminal salt lakes, and the process of enrichment of the valuable elements. However, the age constraint for the terraces of the rivers in the east Kunlun Mountains is still limited and debated, and no dating work has been reported yet for terraces of the Nalinggele River. Five terraces were identified in this river. In this study, the terraces were dated using quartz optically stimulated luminescence (OSL) dating. The results indicate that the OSL ages (~7.5 ka, ~9.9 ka, ~11.3 ka, and ~13.1 ka) of the four terraces (T1, T2, T3, and T4) are consistent with geomorphic relationship, and that they formed since ~13.1 ka and were probably triggered by climatic change rather than by the plateau uplift. The sediment of T5 is too coarse to collect OSL samples and not dated. Based on our dating we confirm the previous view that the lithium concentration in the terminal salt lakes should have initiated since 15–13 ka. We further propose that the formation of salt lakes and the enrichment of their resources in the Qaidam Basin should have occurred mainly in interglacial periods (e.g. the Holocene), a warm and humid period, not as previously thought to be in the glacial periods, a dry and cold period, and that during the glacial periods the basin was mainly under wind erosion.

1. Introduction

Well-developed fluvial terraces in river valleys can record complex history of tectonic movements and climate variations through changes of deposition and incision processes (Bridgland, 2000; Vandenberghe, 2003; Bridgland and Westaway, 2008). The river terraces in the north slope of the Eastern Kunlun Mountains in the Qinghai-Tibetan Plateau (QTP) have been investigated since the 1980s, and 3–5 terraces have been recognized (Wu and Qian, 1982a,b; Li et al., 1999; Wang et al., 2003; Chang et al., 2005; Owen et al., 2006; Wang et al., 2009; Chen et al., 2011) (Fig. 1). Terrace landforms of the Golmud River in the Qaidam Basin (QB) were first surveyed by Wu and Qian (1982a,b), who identified five terraces but with no dating work. Li et al. (1999) obtained a thermoluminescence (TL) age of 113.0 ± 3.8 ka from the upper part of

* Corresponding author. State Key Laboratory of Biogeology and Environmental Geology, School of Earth Sciences, China University of Geosciences, Wuhan 430074, China.
E-mail address: zhongping.lai@yahoo.com (Z.P. Lai).

http://dx.doi.org/10.1016/j.quaint.2016.02.022

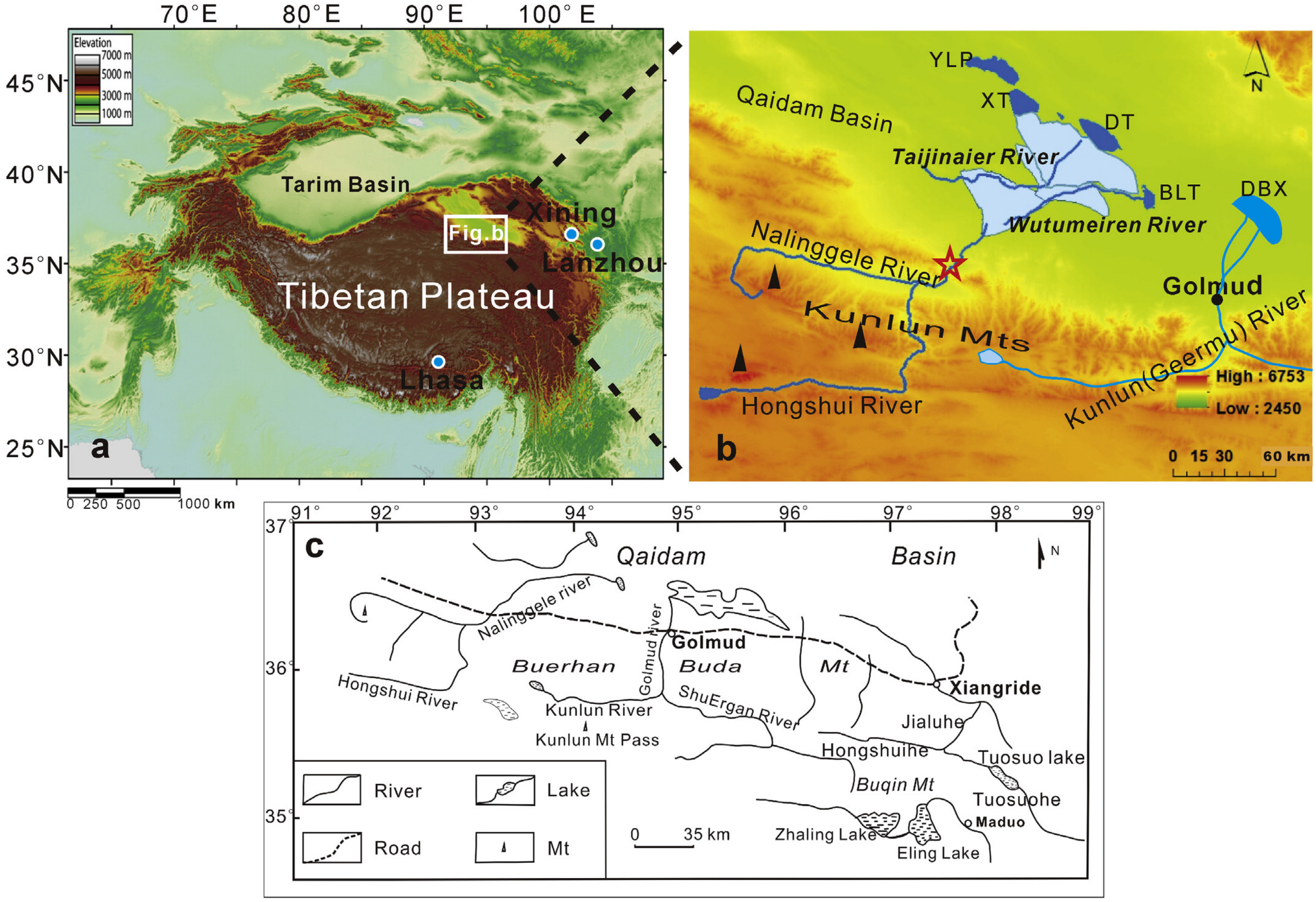

Fig. 1. (a) The DEM map of the eastern of the Tibetan Plateau. The white square denotes the location of the study area. (b) The Nalinggele River system and sample section (red star), abbreviations YLP, XT, DT, BLT and DBX are Yiliping, Xitaijinaier, Dongtaijinaier, Bieletan and Dabuxun lakes, respectively. (c) Sketch of the river systems in the northern slope of the Eastern Kunlun Mountains. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the fourth terrace (T4) of the Jialuhe to the south of the Qaidam Basin and pointed out that the terrace formation is due to the plateau uplift. Wang et al. (2003) argued that the tectonic events in the area have been frequent but with limited intensity, and that five terraces have been developed since 18.4 ka. They obtained two OSL ages (12.9 ± 1.3 and 13.3 ± 0.7 ka) for T3 from Kunlun River and one OSL age (10.9 ± 1.3 ka) for T3 of Halaguole River on the north slope of the Eastern Kunlun Mountains. Using optically stimulated luminescence (OSL) and radiocarbon ^{14}C dating, Chang et al. (2005) obtained ages (~57.5, ~12.8, and ~5.7 ka) for the three terraces of Yazi Spring Stream with headwater originating from the Tagh, flowing into the Toklesayi River which eventually disappears in the Gobi, and calculated the average tectonic uplift rate of 1.18 mm/a during the Holocene. OSL ages of ~8.6 ka (Owen et al., 2006) was obtained for the lowest terrace of the Golmud River. Using OSL dating, Wang et al. (2009) dated three samples of Golmud River (Kunlun River) (8.8 ± 1.0, 16.6 ± 2.2, 90.1 ± 10.0 ka), two samples for Hongshui River (9.9 ± 1.1, 19.7 ± 2.2 ka), and identified four terrace formation periods: 13.4–11.8 ka, 11.0–9.6 ka, 7.7–6.1 ka, and 5.8–4.6 ka. They attributed terrace formation to increased precipitation. Chen et al. (2011) constrained the Golmud River terraces using OSL and radiocarbon dating. They showed that the Sanchahe deposition, which could be classified as the exposure/rework of the Teriary bedrock near Kunlun Bridge, was in 82–16 ka, and that the Golmud River incision stage was at 0–16 ka, during which four terraces were formed, with ages 16–13, 13–11, 11–5, and 5–0 ka, respectively. Table 1 summarized previous age data of river terraces in the north slope of the Eastern Kunlun Mountains.

The Kunlun Mountains in the north of the QTP is influenced by both the Asian monsoon and prevailing westerly winds, and experienced dramatic climatic changes (Thompson et al., 1997; Yao et al., 1997; Shi et al., 2001) and significant late Cenozoic surface uplift (Wu et al., 2001). It was proposed that from Early Pleistocene to the Middle and Late Pleistocene the Kunlun Mountains uplifted during the Gonghe Movement which occurred between the Middle and Late Pleistocene causing further uplift (Cui et al., 1998; Wu et al., 2001). Severe climate change and tectonic uplift would lead to incision and form fluvial terraces (Vandenberghe, 1995; Burbank et al., 1996; Pan et al., 2003). Thus, controversy exits on issues of chronology and trigger mechanism for river terraces in the Eastern Kunlun Mountains. A series of terraces have developed in the Nalinggele River, the largest interior river on northern slope of the eastern Kunlun Mountains, but no dating work has been reported so far.

The salt lakes in the Qaidam Basin fed by the Nalinggele River bear a world-class enrichment of lithium and boron elements, which are critical resources for regional economy (Zhang, 1987; Zhu et al., 1989; Yu et al., 2013). It has been argued that these valuable elements were sourced from the upstream water of the river since about 15 ka (Zhu et al., 1989). The early pioneering work (e.g. Chen and Bowler, 1986; Zhang, 1987) triggered the research of understanding salt lake formation and its relationships to climate change

Please cite this article in press as: Chang, Q.F., et al., Chronology for terraces of the Nalinggele River in the north Qinghai-Tibet Plateau and implications for salt lake resource formation in the Qaidam Basin, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2016.02.022