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Optical dating of young glacial sediments from the source area of the Urumqi River in Tianshan Mountians, northwestern China

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ABSTRACT

Incomplete bleaching, which will lead to overestimation of age, still remains one of the most significant problems in luminescence dating on glacial sediments. In order to test the bleachability of luminescence signals of mountain glacial sediments, nineteen young samples from different geomorphological positions and different sediment settings, in the source area of the Urumqi River in Tianshan Mountains, a key area of Quaternary glaciation study in China, were collected and dated using optically stimulated luminescence (OSL) dating methods. Equivalent dose (D_e) was determined by quartz SAR-SGC procedures. Results show that most of the samples suffer from varying degrees of overestimation. In general, glaciofluvial and lateral moraine till samples show relatively low residual doses (0–20.5 Gy); while subglacial tills, tills from terminal moraines, ground moraines and hummocky moraines, show higher residual doses (22.4–205.6 Gy). Reworked loessic sediments exhibit surprisingly high residual doses (24.1 and 46.5 Gy). Glaciofluvial and materials from lateral moraine (upper part) are recommended when sampling, whereas those from subglacial tills, terminal moraines, ground moraines and hummocky moraines should be avoided.

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1. Introduction

The abundant mountain glacial landforms and the associated sediments in the Qinghai-Tibetan Plateau and the bordering mountains (including the Tianshan Mountains) are valuable archives for reconstructing the glacial history. However, our knowledge about Quaternary glaciations in this region is still limited due to insufficient chronological data. Over the last two decades, optically stimulated luminescence (OSL) methods have been extensively tried for dating glacial sediments in this region (Sharma and Owen, 1996; Owen et al., 1997; Richards, 2000; Richards et al., 2000a, 2000b; Tsukamoto et al., 2002; Xu et al., 2009; Zhao et al., 2009, 2012; B. Zhang et al., 2012; W. Zhang et al., 2012; Wang et al., 2013; Zhao et al., 2013; Hu et al., 2014). However, relatively few studies focused on assessing the adequacy of the methodology (Rhodes and Pownall, 1994; Rhodes and Bailey, 1997; Rhodes, 2000; Richards, 2000; Tsukamoto et al., 2002; Spencer and Owen, 2004; Ou et al., 2010).

It was reported that some of the glacier-related sediments were well bleached, such as glacio-aqueous (glaciofluvial and glaciolacustrine) (Richards, 2000; Alexanderson and Murray, 2007; Boe et al., 2007; Fuchs and Owen, 2008; Alexanderson and Murray, 2012b; King et al., 2014; Ou et al., 2014) and glacio-aeolian deposits (Richards, 2000; Fuchs and Owen, 2008). It was also reported that some glacial sediments were also well bleached, such as supraglacial tills (Richards, 2000; Tsukamoto et al., 2002; Ou et al., 2014) and subglacial sediments (Swift et al., 2010; Bateman et al., 2012). However, incomplete bleaching of glacial sediment still remains one of the most significant problems in luminescence dating (Richards, 2000; Tsukamoto et al., 2002; Spencer and Owen, 2004; Klasen et al., 2007; Lukas et al., 2007; Duller, 2008; Fuchs and Owen, 2008; Thrasher et al., 2009; Alexanderson and Murray, 2012b) and leads to overestimation of age. This has hindered the

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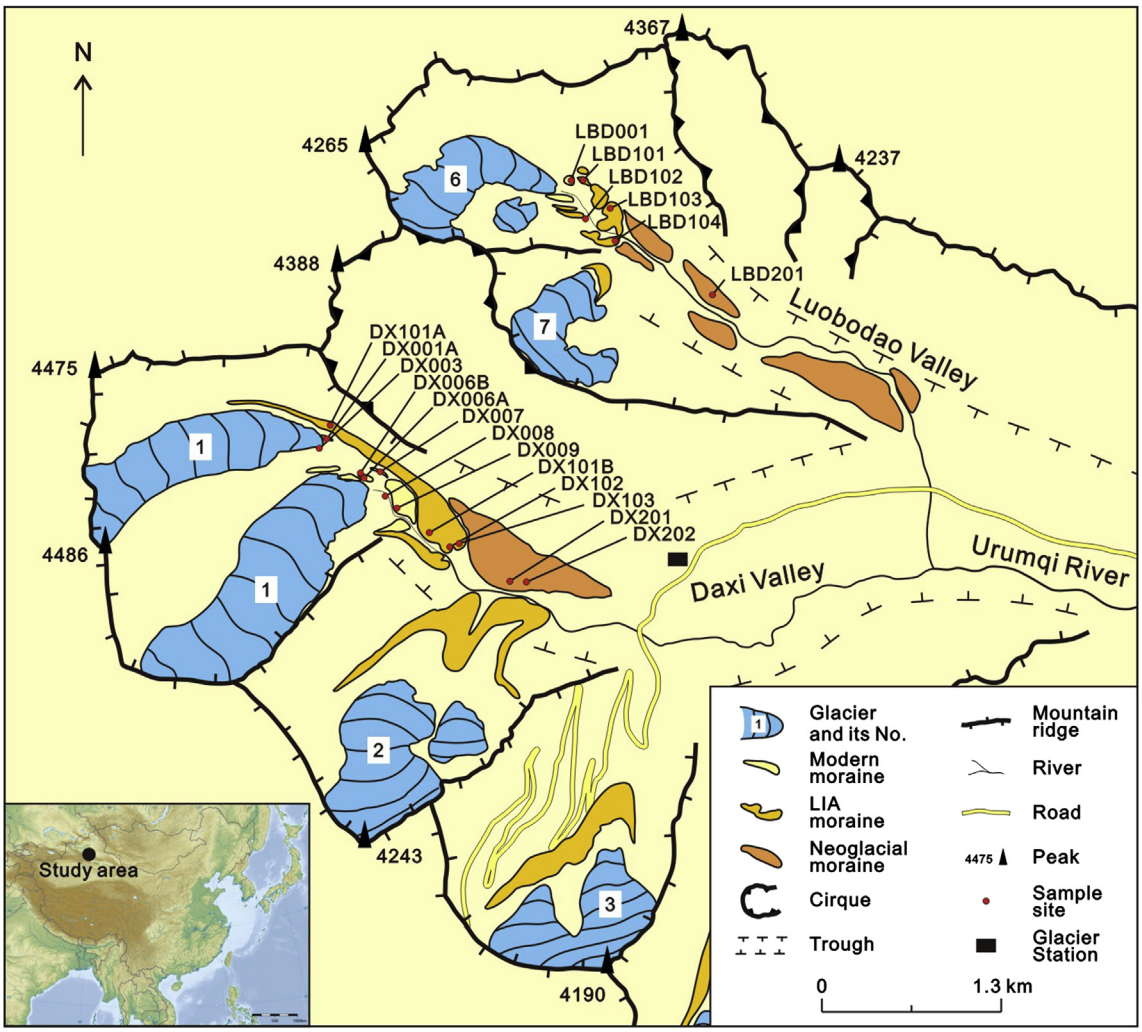

Fig. 1. Young glacial landforms in the source area of the Urumqi River and sampling sites. Samples were collected in the Daxi Valley (DX, thirteen samples) and the Luobodao Valley (LBD, six samples).

application of OSL dating on glacial sediments. Therefore, it is important to assess the incomplete bleaching effect in different glacial depositional environments. Dating young, especially modern analogue sediments, is a good way to test the signal resetting prior to deposition (Duller, 2008; Alexanderson and Murray, 2012a).

The source area of the Urumqi River is a critical place for Quaternary glaciation research in China because the glacial landforms in this area are well preserved and have been dated by multiple techniques including ^{14}C (Zheng and Zhang, 1983; Yi et al., 1998, 2004), lichenometry (Chen, 1989; Wang, 1991), electron spin resonance (ESR) (Yi et al., 2002; Zhou et al., 2002, 2006; Zhao et al., 2006), and terrestrial cosmogenic nuclides (TCN) (Kong et al., 2009; Y. Li et al., 2011). More importantly, young glacial sediments in this area have been dated by conventional ^{14}C (Zheng and Zhang, 1983), AMS ^{14}C (Yi et al., 1998, 2004), and lichenometry (Chen, 1989; Wang, 1991). Therefore, it is an ideal place to test the zero assumption of OSL dating. In this study, nineteen young glacial sediments were sampled as analogues of Pleistocene deposits. Due to dim signal, samples had to be dated using large aliquot quartz OSL methods. The aim of this study is to investigate the bleachability of OSL signal of glacial sediments from different depositional settings and different geomorphological positions. The implications for Quaternary glacial sediment dating are also discussed.

2. Regional setting and samples

The source area of the Urumqi River is located on the northern slope of Kalawucheng Mountain, a part of central Tianshan Mountains, in the Xinjiang Uygur Autonomous Region of China (Fig. 1). This part of the Tianshan Mountains is surrounded by vast deserts: the Taklimakan Desert in the Tarim Basin to the south, the Gurbantunggut Desert in the Junggar Basin to the north, and the Gobi Desert to the east. The westerly jet stream prevails across these high mountains throughout a year (Li et al., 2006).

The highest peak in this area, Tiangeer Peak II, is 4486 m asl. The modern glaciers are mostly cirque glaciers and hanging glaciers and small valley glaciers are also common. Five sets of glacial moraines are distributed along the valley downstream from the modern glaciers (Xu et al., 2010a, 2010b). The samples examined in this paper were young (since the Neoglacial) glacial sediments collected in the frontal of the Glacier No. 1 (43°07′N, 86°49′E) and Glacier No. 6 (43°08′N, 86°50′E).

Glacier No. 1 is a northeast-facing valley glacier, located in the head of the Daxi Valley (Fig. 1; Fig. 2). It has been monitored for more than 40 years (longest in China, since 1958 with interruptions during 1967–1979) and is among those glaciers listed as actively receding by the World Glacier Monitoring Service (Takeuchi and Li, 2008). It is now composed of east and west branches covering

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