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Luminescence dating of glacial deposits near the eastern Himalayan syntaxis using different grain-size fractions

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ABSTRACT

Numerical dating of glacial deposits is important for understanding Quaternary glacial evolution. Optically stimulated luminescence (OSL) dating is one of the techniques widely used on such sediments. Owing to the short distances traveled before deposition, the incomplete bleaching of luminescence signals in glacial sediments may introduce serious dating problems *vis-à-vis* glacial and any associated sediments. Here, we report a comparison of OSL ages obtained from the fine (4–11 μm) and medium (38–63 μm) grain size fractions of quartz extracted from glaciofluvial sediments and from glacial tills in the Basongcuo catchment near the eastern Himalayan syntaxis. Initially, four glacial stages were identified based on field observations of moraine distribution and geomorpho-stratigraphic relations. A total of 39 OSL samples were then collected from glaciofluvial sand layers or lenses and from till. Quartz grains in the fine (4–11 μm) and medium (38–63 μm) size fractions were extracted from each sample, and dated using the single-aliquot regeneration (SAR) protocol. The modern supraglacial sediment sample was dated to ~0.2 (fine grain) to ~0.7 (medium grain) ka, suggesting that the sediment was not completely bleached on deposition. Contrary to previous experience suggesting that coarse grains are usually better bleached than fine grains prior to deposition, our results show that estimated OSL ages for fine grains are generally younger than those for medium grains. This suggests that the two fractions may have come from different sources and thus have different bleaching histories, and that fine-grained quartz may be more suitable for OSL dating of these materials. Applying the minimum age model to data from medium-grained quartz yields ages close to those obtained from fine-grained quartz, suggesting that both can be used for dating glacial advances. The OSL dates suggest that glaciers in the studied area advanced at 0.1–1.3 ka, ~7.5 ka and 11–13 ka, and were furthest advanced between ~16 and ~30 ka. The timing of the local Last Glacial Maximum (LGM) is broadly consistent throughout the eastern and central Himalaya and frequent glacial advances after the LGM. All suggest that glaciers in the humid eastern Himalayan syntaxis are sensitive to global cooling.

1. Introduction

Numerical dating of glacial sediments is a worldwide challenge. Radiocarbon dating is limited by the lack of suitable organic material. Terrestrial cosmogenic nuclide (TCN) exposure ages usually express minimum ages of glacier advances and may be underestimates due to post-depositional shielding (Heyman et al., 2011). The OSL dating technique has been widely applied to glacial and associated sediments from the Himalaya and Tibet (*e.g.* Richards et al., 2000a, b; Tsukamoto et al., 2002; Owen et al., 2002a, 2009; Spencer and Owen, 2004; Narama et al., 2007; Xu et al., 2009; Ou et al., 2010, 2014; Zhang et al., 2012; Mehta et al., 2012; Zhao et al., 2012, 2013; Ali et al., 2013; Wang et al., 2013; Chen et al., 2014). However, incomplete bleaching of luminescence signals is sometimes a serious problem in OSL dating (Fuchs and Owen, 2008; Thrasher et al., 2009a). Previous studies in Norway (King et al., 2013, 2014) and Sweden (Alexanderson, 2007; Alexanderson and Murray, 2012a, b) have found that some modern glacial sediments are only partially bleached. Owing to short distances traveled before deposition, glacial sediments on the Tibetan Plateau (TP) are also

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occasionally only partially bleached (Richards, 2000; Fuchs and Owen, 2008; Ou et al., 2015). However, the influence of this residual dose on the OSL age estimations of glacial sediments from the TP has rarely been discussed (Ou et al., 2015).

Mean annual precipitation (MAP) in southeastern Tibet is >700 mm (Yatagai et al., 2012), resulting in the formation of many glacial rivers. Glaciofluvial deposits can easily be found in moraines, and are relatively good for OSL dating (Fuchs and Owen, 2008; Thrasher et al., 2009a). Most studies of Quaternary glacial chronology have been focused on the eastern part of this region (Schäfer et al., 2002; Tschudi et al., 2003; Owen et al., 2005; Graf et al., 2008; Kong et al., 2009; Strasky et al., 2009; Fu et al., 2013; Wang et al., 2013). Only a few have discussed Quaternary glaciations near the eastern Himalayan syntaxis (Zhou et al., 2007, 2010; Chen et al., 2014).

We dated a total of 39 samples of glaciofluvial sand and till from the Basongcuo (BSC) catchment in this area using the OSL technique. The goal of the study was to assess the degree of bleaching of the sediment samples, and to establish a chronological framework for Quaternary glaciations in the area.

2. Glacial and geomorphic setting

The southeastern TP is bounded by the Nyainqentanglha Mountains to the north, the Himalaya to the west and the Henduan Mountains to the east. The highest mountain in the region is Namche Barwa, with an altitude of 7756 m above sea level (asl). Moisture is mainly from the Indian Monsoon. According to a meteorological record from Bomi (29.52°N, 95.46°E, 2736 m asl), MAP between 1961 and 2008 was 835 mm, with 74.9% falling between April and September (Zhu et al., 2013a). There are over 4000 mountain glaciers, with a total area of 8012.7 km^2, around the "Great Bend" of the Yarlung Zangbo River (Fig. 1a) (Shi et al., 2006).

The BSC catchment (N30.00°, E93.92°) is located on the southern slopes of the junction of the eastern Nyainqentanglha and Himalaya Mountains, about 110 km northwest of Namche Barwa (Fig. 1a and b). BSC, the main valley, is presently occupied by Lake Basongcuo (Fig. 1c). The valley has four U-shaped tributaries: Zaba (ZB), Zhongcuo (ZC), Bailangou (BLG) and Xincuo (XC). The total area studied is 1670 km^2. Modern glaciers occupy the heads of the valleys. According to the glacier inventory, there are 27 modern glaciers in this study area, with a combined area of 139 km^2. The mean altitude of the glacier termini is ~4100 m asl, with an equilibrium-line altitude of 4970 m asl (Shi et al., 2006). Many lakes are found in the area; the three largest are lakes Basongcuo, Zhongcuo and Xincuo. These lakes are all dammed by moraines at their outlets. Lateral moraines extend from the modern glacier termini along both valley sides to the outlet of Lake Basongcuo. The bedrock in the area is granite. Granite pebbles and boulders are common. Moraine sediments contain many fine- and coarse-grained glaciofluvial sand lenses, several centimeters to several meters in thickness.

Based on the geomorphological position of lateral and terminal moraines, the degree of lithification, and the vegetation cover, four glacial moraine successions have been identified: Stage-IV, Stage-

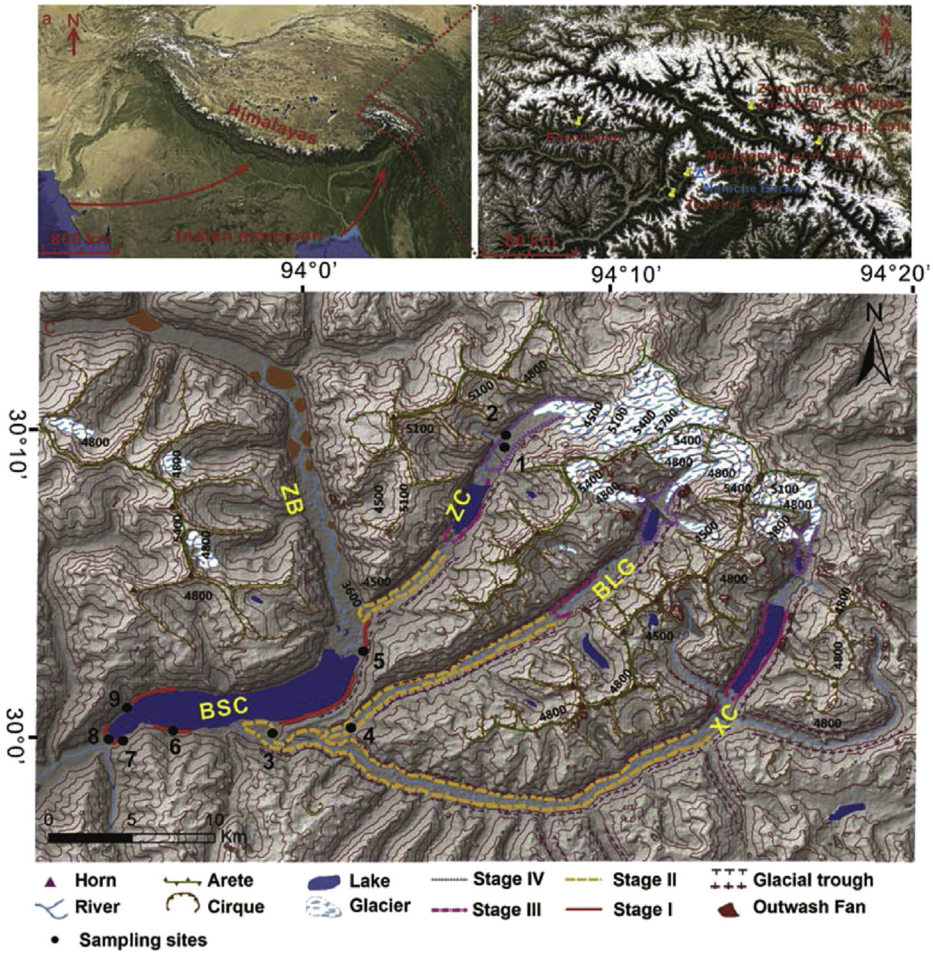

Fig. 1. (a), (b) Google Earth images showing the location of this and previous studies in southeastern Tibet; (c) DEM of the Basongcuo catchment, showing glacial cover, valley, moraines, and sampling sites. ZB, ZC, BLG, XC and BSC represent the Zaba, Zhongcuo, Bailangou, Xincuo tributary valleys and Lake Basongcuo, respectively.