



# Sedimentary records of a palaeo-lake in the middle Yarlung Tsangpo: Implications for terrace genesis and outburst flooding

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## ABSTRACT

The middle reaches region of the Yarlung Tsangpo in the southern Tibetan Plateau consist of broad valley reaches, alternating with gorges, which were easily dammed by glaciers and/or glacial moraines during the last glacial period. We investigated three palaeo-lake sedimentary sequences on terraces located in the broad Xigazê valley reach and the Dazhuka-Yueju gorge in the middle reaches of the Yarlung Tsangpo. We found that the altitude of the palaeo-lake was 3811 m above sea level, while its minimum area and volume were ~679 km<sup>2</sup> and ~22 km<sup>3</sup>, respectively. The palaeo-lake was formed during the period from about 30.2 to 32.3 cal. kyr BP, and it failed at about 13.2 cal. kyr BP. The dam was possibly located at the eastern end of the Dazhuka-Yueju gorge and may have been a glacier and/or a moraine during the late part of the last glacial. The failure of the dam and related flooding from the Dazhuka-Yueju gorge probably triggered a chain reaction of dam failures downstream, forming a megaflood. Terrace genesis and valley evolution in the investigated region can be divided into four phases: Phase I (>32.3 cal. kyr BP), river occupation; Phase II (<32.3–13.2 cal. kyr BP), palaeo-lake occupation; Phase III (after 13.2 cal. kyr BP), erosion and aeolian deposition; Phase IV, modern downward incision.

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## 1. Introduction

The Yarlung Tsangpo originates from the Jiemayangzhong Glacier on the northern slopes of the western Himalayas (30°15' N, 82°21' E, 5593 m above sea level (a.s.l.)). It follows the Indus-Tsangpo suture through the southern Tibetan Plateau and then becomes the Brahmaputra, following a bend into India through the Yarlung Tsangpo Gorge. The middle reach is from Lizi to Pai, with a gradient of 1.3‰ and decrease in altitude from 4552 to 2918 m a.s.l. In the middle reach, narrow gorges alternate with broad valleys (Zhang, 1998); the broad valleys are 5–10 km wide, whereas in the various gorges the width is reduced to hundreds or even tens of meters (Yang et al., 1983). In the two types of valley, four to six terraces occur. At present, more terraces occur in the broad valleys and at the entrances to gorges; however, they occur only sporadically in the gorges (Yang et al., 1983; Hu et al., 2017). The age,

genesis and spatiotemporal relationships of these scattered terraces remain poorly understood (Yang et al., 1983; Hu et al., 2002; Korup and Montgomery, 2008; Owen, 2008; Zhu et al., 2013a, 2014; Huang et al., 2014). Moreover, the implications of the terraces for the evolution of the valley and the changes in tectonic-climatic settings are unclear (Li, 1957; Yang et al., 1983; Korup and Montgomery, 2008; Owen, 2008; Wang et al., 2014). The valleys of the middle Yarlung Tsangpo catchment are characterized by active glaciers, deep incision, narrow river gorges, threshold hillslopes and intensive tectonic activity (Kirby et al., 2002; Ouimet et al., 2007; Owen, 2008; Scherler et al., 2014). In this unique region, river gorges are readily dammed by glaciers and/or moraines, landslides, rock avalanches and debris flows. The occurrence of damming and the failure of natural dams are important and extreme geological events, which would have had a strong effect on the shaping of the river valley, human activities downstream, and even on oceanic thermohaline circulation (Bretz, 1969; Costa and Schuster, 1988; Hewitt, 1998; Shang et al., 2003; Montgomery et al., 2004; Broecker, 2010).

Previous research, including our own field investigations indicates that lacustrine sediments occur in the middle Yarlung

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Tsangpo valley from Yarlung Tsangpo Gorge up to the Xigazê broad valley reach. However, because of intensive reworking by local slope erosion and river erosion, the distribution of confirmed and suspected palaeo-lake sediments on terraces along the middle valley is sporadic. In addition, there is no evidence of the former shoreline of the palaeo-lake in the valley. Thus, the origin of the dam, its location and age, the spatiotemporal relationships between the sedimentary sequences, the characteristics of the palaeo-lake, its influence on valley geomorphology, and the downstream effect of dam failure in the middle Yarlung Tsangpo valley, are controversial or unclear (Yang et al., 1983; Hu et al., 2002; Zheng et al., 2003, 2004; Montgomery et al., 2004; Korup and Montgomery, 2008; Owen, 2008; Kaiser et al., 2010; Korup et al., 2010; Lang et al., 2013; Zhu et al., 2013b, 2014; Huang et al., 2014; Wang et al., 2014; Liu et al., 2015).

Previous research indicates that relict lacustrine sediments are intercalated within the sedimentary sequences of terraces in the middle Yarlung Tsangpo valley from the Yarlung Tsangpo Gorge up to the Xigazê broad valley reach. Relict palaeo-lake sediments provide stratigraphic records enabling the reconstruction of lake-damming events and associated palaeo-lakes, and understanding of terrace genesis and long-term dynamic evolution of fluvial systems. In this study, we focus on a sedimentary sequence consisting of intercalated palaeo-lake sediments in the three terrace localities of Dazhuka-Yueju gorge and the Xigazê broad valley reach (Fig. 1).

Our main objectives were (i) to establish the sedimentological and geochronological framework of the fluvial terrace; (ii) to date the formation and failure of lake dams and/or the palaeo-lakes themselves; (iii) to determine the features of palaeo-lakes; and (iv) to elucidate the evolution processes of the valley and its terraces.

## 2. Stratigraphy of terrace sedimentary sequences, and field sampling

In the investigated region (Fig. 1), ~167 km in length, the altitude of the river bed decreases from 3796 to 3626 m a.s.l., with a mean gradient of 0.98‰. We focus on three terrace localities with the palaeo-lake sediment sequences: Xigazê, Lhainxiang and Toinda. They are located in different geomorphic units of the valley, all on the second terrace of the Yarlung Tsangpo.

The Xigazê terrace sedimentary sequence is in the middle part of the Xigazê broad valley reach, at the junction of the Yarlung Tsangpo and the Nyangqu River (29°18'20.54" N, 88°52'7.67" E; Fig. 1). Based on a high precision GPS survey (Hu et al., 2017), the elevation of the uppermost lacustrine sediments is 3811.31 m a.s.l. and ~13.8 m above present river level. The sequence is about 1.7 km from the modern channel of the Yarlung Tsangpo, and is about 12 m in thickness. The site is identical to that of Xigazê terrace sequence previously reported by Hu et al. (2017), who reconstructed its sedimentological and geochronological framework. In the present

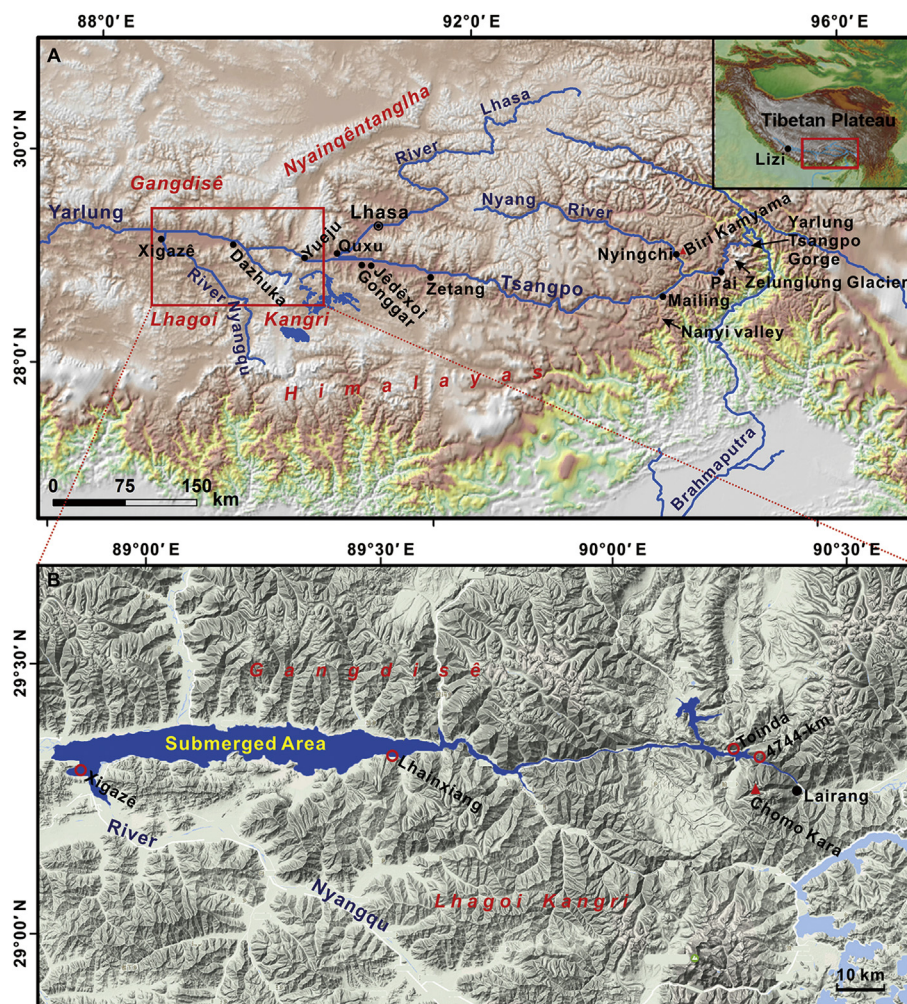


Fig. 1. A. Middle reach of the Yarlung Tsangpo from Nyingchi to Xigazê. B. Palaeo-submerged area of the palaeo-lake at the Dazhuka-Yueju gorge to the Xigazê broad valley reach.

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