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Western Tibet relief evolution since the Oligo-Miocene

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ABSTRACT

Western Tibet, between the Karakorum fault and the Gozha–Longmu Co fault system, is mostly internally drained and has a 1.5–2 km amplitude relief with km-large valleys. We investigate the origin of this peculiar morphology by combining a topography analysis and a study of the Cenozoic sedimentation in this area. Cenozoic continental strata correspond to a proximal, detrital fan deposition, and uncomformably rest on a palaeorelief similar to the modern one. Zircon U–Pb dating from trachytic flows interbedded within the Cenozoic continental sediments indicates that detrital sedimentation occurred at least between ca 24 and 20 Ma in the Shiquanhe basin, while K/Ar ages suggest it may have started since ~37 Ma in the Zapug basin. The distribution of continental deposits shows that present-day morphology features, including km-large, 1500 m-deep valleys, were already formed by Early Miocene times. We suggest that today's internally drained western Tibet was externally drained, at least during late Miocene, contemporaneously with early motion along the Karakorum Fault. Detailed study of the present day river network is compatible with a dextral offset on the Karakorum Fault of 250 km at a rate of ~10 ± 1 mm/yr. Displacement along the Karakorum fault possibly induced the shift from external to an internal drainage system, by damming of the Bangong Co ~4 Ma ago, leading to the isolation and preservation of the western Tibet relief.

1. Introduction

The India-Asia convergence zone is characterized by the juxtaposition of the Earth highest mountain range, the Himalayas, and the largest high plateau: the Tibetan Plateau. The Himalayas, with 10 peaks above 8000 m, show steep topographic slopes in comparison with the Tibetan plateau where the relief is smoother (Fig. 1) (e.g., Fielding et al., 1994). The Tibetan Plateau corresponds to an area of more than 2,000,000 km^2 of high elevation (mean elevation of about 5000 m) that straddles several continental blocks accreted from the Paleozoic to the lower Eocene (Fig. 1a). Quantifying the morphology in northern, central, and southeastern Tibet, Liu-Zeng et al. (2008) emphasize strong morphological contrasts within the Tibetan plateau. The plateau is separated from the surrounding basins by high relief ranges often associated with large active, either thrust or strike-slip, fault systems. The flattest part of the plateau is internally drained (endorheic). It is surrounded to the east and south by the headwaters of the major Asian rivers, all flowing out of Tibet, and to the north by the endorheic Tarim basin. Within the endorheic zone the high-relief areas are often related to active normal faults (e.g., Armijo et al., 1986).

The origin and timing of high elevations and low relief of the Tibetan plateau are the subjects of a lively debate, and many questions were raised. In particular, were the low relief and high altitudes acquired early or late in the India-Asia collision history? In central Tibet, Shackleton and Chang (1988) suggested that the plateau surface formation, i.e., the peneplanation, occurred in mid to late Miocene times, more than 40 Ma after the onset of the India-Asia collision. This hypothesis was based on the interpretation of summits as an ancient planar surface. However, recent studies rather suggest an earlier peneplanation (Hetzel et al., 2011; Rohrmann et al., 2012; Haider et al., 2013). These later studies are based on low-temperature thermochronology data that allow estimating exhumation rates, which would have shifted from fast to slow as early as 50–40 Ma ago, with less than 2 km of exhumation since then. Other studies tried to constrain Tibet paleoelevation evolution, from oxygen stable isotopes (Garzione et al., 2004; Currie et al., 2005; Cyr et al., 2005; Rowley and Currie, 2006; DeCelles et al., 2007a, b; Quade et al., 2011; Xu et al., 2013) or palaeobotanic (Dupont-Nivet et al., 2008; Song et al., 2010; Hoorn et al., 2012; Sun et al., 2014) studies. Most studies proposed that, within uncertainties (~ +/− 1000 m), southern and central Tibet reached their modern elevation (about 4500–5000 m) at least 35 Ma ago (Currie et al., 2005; Rowley and Currie, 2006; Quade et al., 2011). However, based on fossil pollen record, Sun et al.(2014) estimate a late Oligocene elevation of only ~3200 +/− 100 m in central Tibet, suggesting that central Tibet may

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have gained an additional ~1.5 km since the Oligocene. From thermochronolgy data, van der Beek et al. (2009) inferred that the Deosai plateau in Pakistan (D on Fig. 1a) is the remnant of a wider Eocene Tibetan plateau, while Tapponnier et al. (2001) and Liu-Zeng et al. (2008) proposed that basin filling due to internal drainage played a major role in smoothing out the tectonically generated structural reliefs, with such reliefs dating back to Eocene in southern Tibet, Oligo-Miocene in central Tibet and Plio-Quaternary in the northeastern Tibet.

In this debate the study of western Tibet could bring key answers because that zone presents the highest mean elevation (nearly 5100 m) and straddles the internal and external drainage zones (Fig. 1). Moreover, despite the presence of few local active normal faults, and the absence of external drainage on most of its surface, western Tibet relief is strong and reaches 1.5 to 2 km (Figs. 1a and 2b).

Regarding the elevation evolution, no palaeoaltimetry data are yet available in western Tibet, but study of Cenozoic sediments is another way to bring constraints on the topography evolution of the plateau. In order to understand the origins of the strong relief and the high topography of western Tibet, which is related neither to a modern fluvial incision, nor to active tectonics, the present regional study first focuses on mapping the Cenozoic sediments and constraining their ages. In the second part, we discuss how the geometry and location of these sediments help to decipher the topographic history of that part of Tibet and its implications on the understanding of the Himalaya–Tibet system evolution.

2. Geological setting

2.1. Morphology

Western Tibet has a relatively high relief, with several peaks higher than 6000 m and valley floors at 4200–4400 m. The mean elevation is

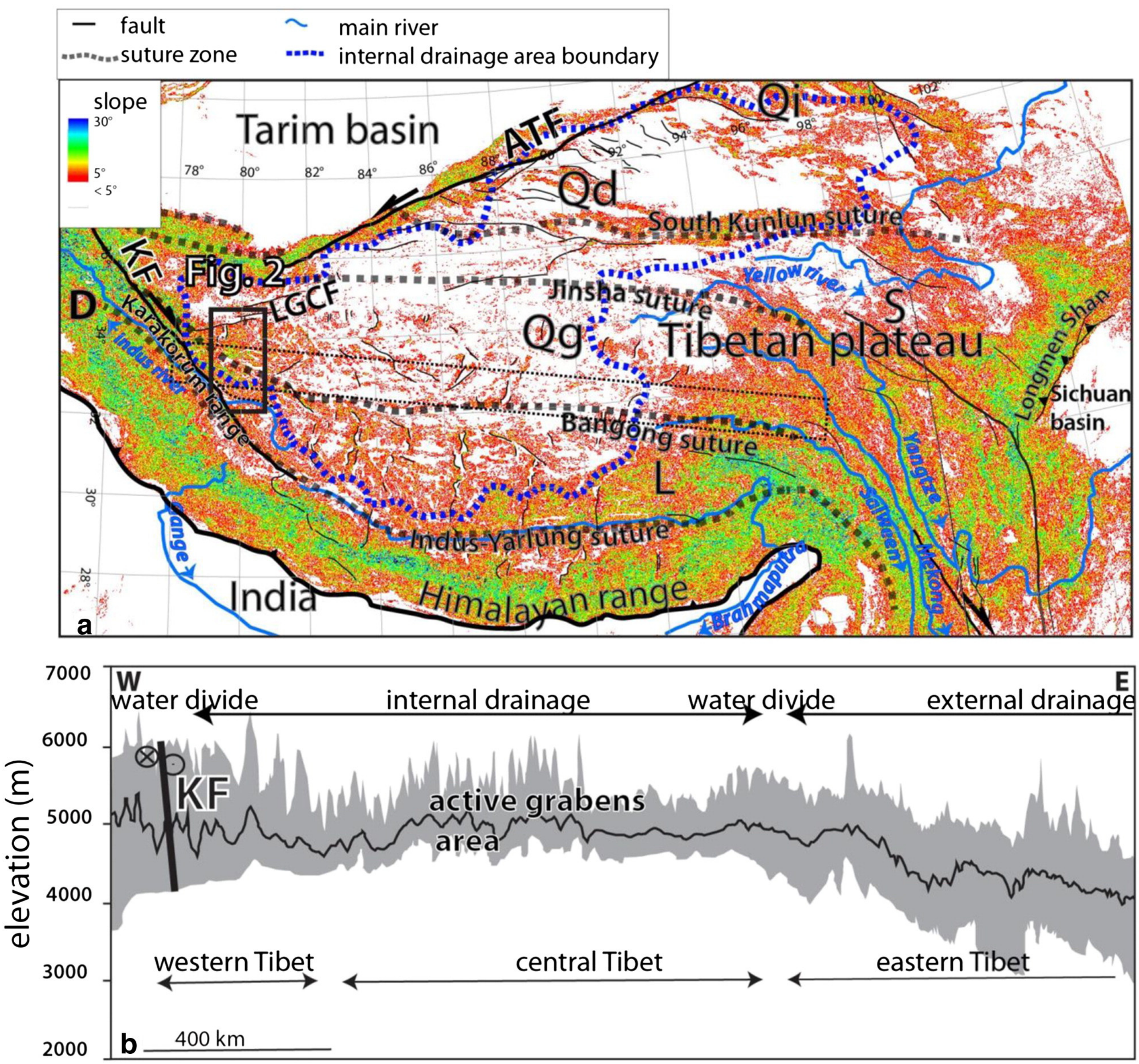

Fig. 1. India-Asia collision zone topography and tectonics. (a) Map of topographic slopes and main active faults of Tibet. The background colors refer to the local topographic slope calculated from SRTM images (765 m (EW) × 924 m (NS) pixel size). The dotted blue line contours the internal drainage area after Strobl et al. (2012). Main tectonic features are after Pan et al. (2004) and Molnar and Tapponnier (1978). KF: Karakorum fault; ATF: Altyn Tagh fault; LGCF: Longmu Co–Gozha Co fault. D: Deosai plateau. L: Lhasa block; Qg: Qiangtang block; S: Songpan block; Qd: Qaidam block; Qi: Qilian block. (b) West–East topographic profile across Tibet. The profile is based on 77 by 92 m horizontal resolution SRTM images. The gray envelope shows the minimum and maximum and the black line corresponds to the mean elevation along the profile path. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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