Earth and Planetary Science Letters 433 (2016) 10–20

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Spatial and temporal pattern of erosion in the Three Rivers Region, southeastern Tibet

Rong Yang [a,*], Maria Giuditta Fellin [a], Frédéric Herman [b], Sean D. Willett [a], Wei Wang [c], Colin Maden [a]

[a] Department of Earth Sciences, ETH Zurich, Sonneggstrasse 5, 8092 Zurich, Switzerland
[b] Institute of Earth Surface Dynamics, Université de Lausanne, Geopolis – Bureau 3871, 1015 Lausanne, Switzerland
[c] School of Ocean and Earth Science, Tongji University, 200092 Shanghai, China

ARTICLE INFO

Article history:
Received 25 March 2015
Received in revised form 16 October 2015
Accepted 19 October 2015
Available online 29 October 2015
Editor: A. Yin

Keywords:
southeastern Tibet
thermochronometry
river profile
inversion
erosion rate
indentation

ABSTRACT

Convergence and collision between India and Eurasia have produced the Tibetan Plateau, which stands 5 km high over a region of 3 million km^2. Its southeastern margin lies in the restraining bend between the Sichuan basin and the Eastern Himalayan Syntaxis. In this region three parallel rivers, the Salween, the Mekong and the Yangtze, carve gorges up to 3 km deep. Along the longitudinal profiles, large-scale knickzones, defined by very high steepness, correspond to the gorges of the Salween and Mekong. The Yangtze, instead, has a nearly linear profile upstream from its first big bend. New low-temperature thermochronometric data reveal a complex pattern of erosion in the Three Rivers Region. From the Salween in the west to the Yangtze in the east the magnitude and rate of erosion decrease. From south-to-north erosion rates exhibit variable gradients in space and time. Along the Salween and the Mekong a northward increase of erosion rate is followed by a decrease with additional distance to the north. Variations of erosion rate in time are characterized by a deceleration along the Salween and a general deceleration with local acceleration along the Mekong. This pattern, together with river profile analysis, is best explained by active coupling between tectonics and river incision related to the indentation and northward migration of the corner of the Indian continent.

1. Introduction

The convergence between India and Eurasia has produced the Tibetan Plateau, which stands 5 km high over a region of 3 million km^2, but also extensive mountainous regions over a broader region, including the Three Rivers Region (TRR) of southeast Asia (Fig. 1). Although the onset of continental collision at about ∼40–50 Ma is well established (e.g. DeCelles et al., 2014 and references therein), both the mechanisms and the timing of plateau uplift are the subject of considerable debate (Clark et al., 2005; Clark and Royden, 2000; England and Houseman, 1986; Royden et al., 1997; Tapponnier et al., 1982). Several studies suggest regional incision of the plateau margins since 15 to 10 Ma following a phase of surface uplift (e.g. Clark et al., 2005; Duvall et al., 2012; Ouimet et al., 2010; Wang et al., 2012). Contradicting this model are paleo-altimetry studies indicating that both central and southeast Tibet were already close to their modern elevation at 35 Ma (DeCelles et al., 2007; Hoke et al., 2014; Rowley and Currie, 2006) and recent studies demonstrating that the geomorphology of the southeast margin of the plateau is also consistent with widespread shortening and river reorganization (Yang et al., 2015). In addition, the time of incision roughly coincides with continental scale climate change at about 8 Ma (Molnar, 2005), so it is difficult to assign a tectonic cause to changes in morphology or incision rate. As a result, there are numerous, disparate models for plateau formation and outward growth of its margins (Royden et al., 1997; Tapponnier et al., 1982; Houseman and Molnar, 2001).

A key area for many of these models is the southeastern margin of the Tibetan plateau, in particular, the TRR (Fig. 1a), where three large rivers, the Salween, Mekong, and Yangtze (Chinese names: Nujiang, Lancangjiang, and Changjiang, respectively), originate from the high Tibetan Plateau, run closely parallel to the topographic gradient on the plateau margin and create bedrock gorges up to 3 km deep (Fig. 1b–d). The region is close to the collision boundary in the high-strain zone between the Eastern Himalayan Syntaxis and the Sichuan Basin. As the transition between the plateau and the surrounding lowlands, the timing and pattern of uplift for this region can help differentiate between models.

* Corresponding author.
E-mail address: royang1985@zju.edu.cn (R. Yang).

http://dx.doi.org/10.1016/j.epsl.2015.10.032

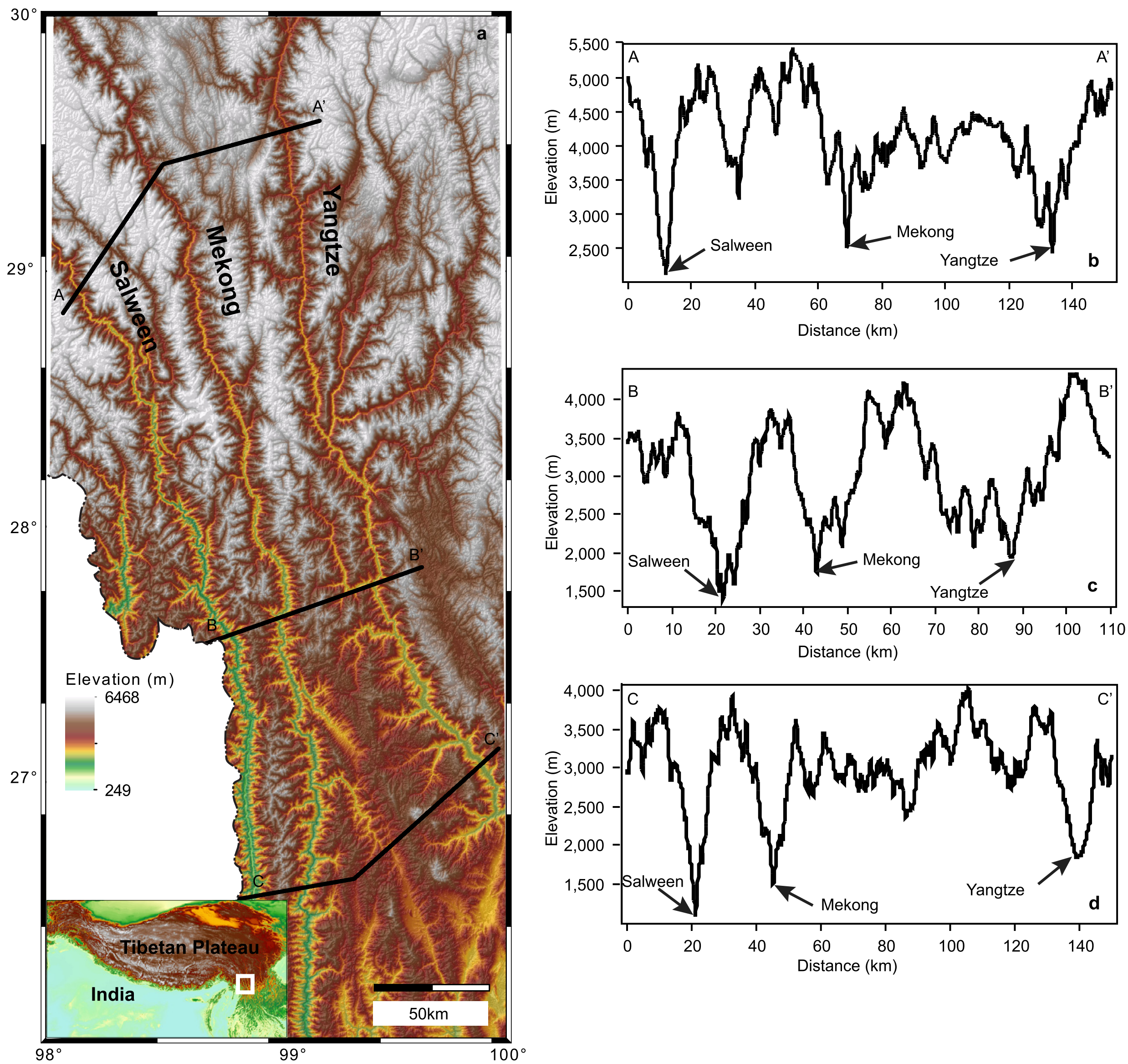

Fig. 1. Regional topography and cross sections. (a) Overview map of the regional topography in the Three Rivers Region (TRR) and locations of the Salween, Mekong, and Yangtze rivers. Locations of topographic cross transects A–A′, B–B′, and C–C′ are indicated by solid black lines. Inset shows location of the study area within the Himalaya–Tibet system. (b–d) Topographic cross sections of transects A–A′, B–B′, and C–C′, showing the plateau morphology deeply-incised by major rivers.

For example, a gradual outward expansion of the plateau by lower crustal flow would exhibit an outward propagation of topography and thus the focus of erosion. In contrast, uniform uplift would lead to progressive headward incision from the orogen margin to its interior, as transient knickpoints propagate upstream. A number of thermochronometric and geomorphologic studies have concentrated on this issue (Clark et al., 2006, 2005; Duvall et al., 2012; Ouimet et al., 2010; Wilson and Fowler, 2011) and have demonstrated that there has been substantial erosion in this region, but data remain sparse. This study adds new thermochronometric data and their interpretation.

2. Geologic setting

The TRR is a complex region of small lithospheric fragments separated by Late Paleozoic–Mesozoic suture zones (Fig. 2). Their reactivation by strike-slip shear has accommodated some of the Cenozoic deformation. Because of the high-degree of strain localization, Cenozoic shortening, metamorphism and exhumation of rocks from middle crustal depths seem mostly limited to shear zones (Tapponnier et al., 1982; Leloup et al., 2001; Wang and Burchfiel, 1997). Localization occurred in the west along the Gaoligong (Zhang et al., 2012; Lin et al., 2009; Wang et al., 2006) and Chong Shan shear zones (Akciz et al., 2008), and in the east along the northern segments of the Ailao Shan–Red River shear system, specifically the Xuelong Shan and Diancang Shan zones (Gilley et al., 2003; Leloup et al., 2001 and references therein) (Fig. 2). Until ∼26 to 22 Ma transpressional shear along these zones was associated with high-temperature metamorphism and granite emplacement. After ∼22 Ma strike-slip deformation continued during cooling to greenschist facies conditions. Diachronous cooling and exhumation to temperatures below 350 °C occurred earlier in the east, before 15 Ma (Leloup et al., 1993, 2001), and later in the west, continuing until about 10 Ma (Akciz et al., 2008; Zhang et al., 2012). In the west, there was more regional Miocene (∼16 Ma) exhumation of metamorphic rocks (Zhang et al., 2012). After 10 Ma the development of meso- to regional-scale high-angle transtensive faults overprinted the shear zones with brittle deformation. At 4.7 Ma, the movement along the Diancang Shan reversed to right-lateral motion (Leloup et al., 1993). At present,