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Review Article

Active faulting, mountain growth, and erosion at the margins of the Tibetan Plateau constrained by in situ-produced cosmogenic nuclides

Ralf Hetzel *

Institut für Geologie und Paläontologie, Westfälische Wilhelms-Universität Münster, Correnssstraße 24, D-48149 Münster, Germany

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A B S T R A C T

The India–Asia collision zone is a key area for understanding continental plateau formation and mountain building. Two fundamental questions in this context are how the northeastward motion of India is partitioned between strike–slip and thrust faults and how mountain building is counteracted by erosion. Cosmogenic nuclides allow us to address these questions, because they provide age constraints on tectonically offset landforms and constraints on erosion rates. After considerable debate on whether or not major strike–slip faults move at high rates of up to 20–30 mm/yr and absorb most of the continental deformation, it now appears that the three largest faults (Altyn Tagh, Haiyuan, Kunlun) have millennial slip rates of no more than 8–13 mm/yr, consistent with rates of elastic strain accumulation determined by geodetic methods. Furthermore, a significant portion of the lateral slip on these faults is transferred to thrust faults within the collision zone. Both observations indicate that the eastward tectonic escape of material along these faults is less important than often assumed. With respect to mountain building and erosion, cosmogenic nuclide studies show that thrust faults at the northeastern and eastern margins of Tibet (Qilian Shan, Longmen Shan) have vertical slip rates of ~0.3 to ~2 mm/yr while catchment-wide erosion rates vary from ~0.02 to ~1.0 mm/yr, with high-relief areas eroding significantly faster than the plateau interior and growing mountains in the foreland. The deeply incised regions have apparently reached an erosional steady-state, in which rock uplift is balanced by erosion. River terraces at active mountain fronts document repeated changes between sediment deposition and fluvial incision. During the Quaternary, incision and terrace formation occurred predominantly at glacial–interglacial transitions but also during interglacial periods. Hence, flights of terraces at the fault-bounded mountain fronts record the interplay between sustained rock uplift and a temporally variable climate.

Contents

* Tel.: +49 251 83 33 908; fax: +49 251 83 33 933.
E-mail address: rahetzel@uni-muenster.de.

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1. Introduction

1.1. Tectonic setting and geomorphology of the Tibetan Plateau

The Tibetan Plateau constitutes the largest and highest continental plateau on Earth with an east–west extent of ~2500 km and a mean elevation of ~5 km (Fig. 1). The current size, shape, and height of the plateau are mainly the result of the continent–continent collision between India and Asia (e.g. Dewey et al., 1988; Hetzel et al., 2011; Molnar and Tapponnier, 1975; Royden et al., 2008; Tapponnier et al., 2001; Yin and Harrison, 2000), although the southern and central part of the plateau may have had a significant elevation before the continental collision (e.g. Kapp et al., 2007; Murphy et al., 1997). The exact timing of the collision is still not fully resolved — most studies have determined an age between 55 and 50 Myr for the onset of collision (e.g. Liebke et al., 2010; Najman et al., 2010; Patriat and Achache, 1984; Rowley, 1996; Zhang et al., 2012a). Other active mountain ranges in Central Asia that have formed as a result of the India–Asia collision include the Himalaya, the Pamir, the Tien Shan and the Altai (Fig. 1). In this vast region, many tectonically active faults have been documented over the past decades (e.g. Rothery and Drury, 1984; Styron et al., 2010; Tapponnier and Molnar, 1977; Tapponnier et al., 2001; Taylor and Yin, 2009).

In the following, I briefly describe the main tectonic faults and structures that characterize the different margins of the Tibetan Plateau. The northern plateau margin is defined by the longest strike–

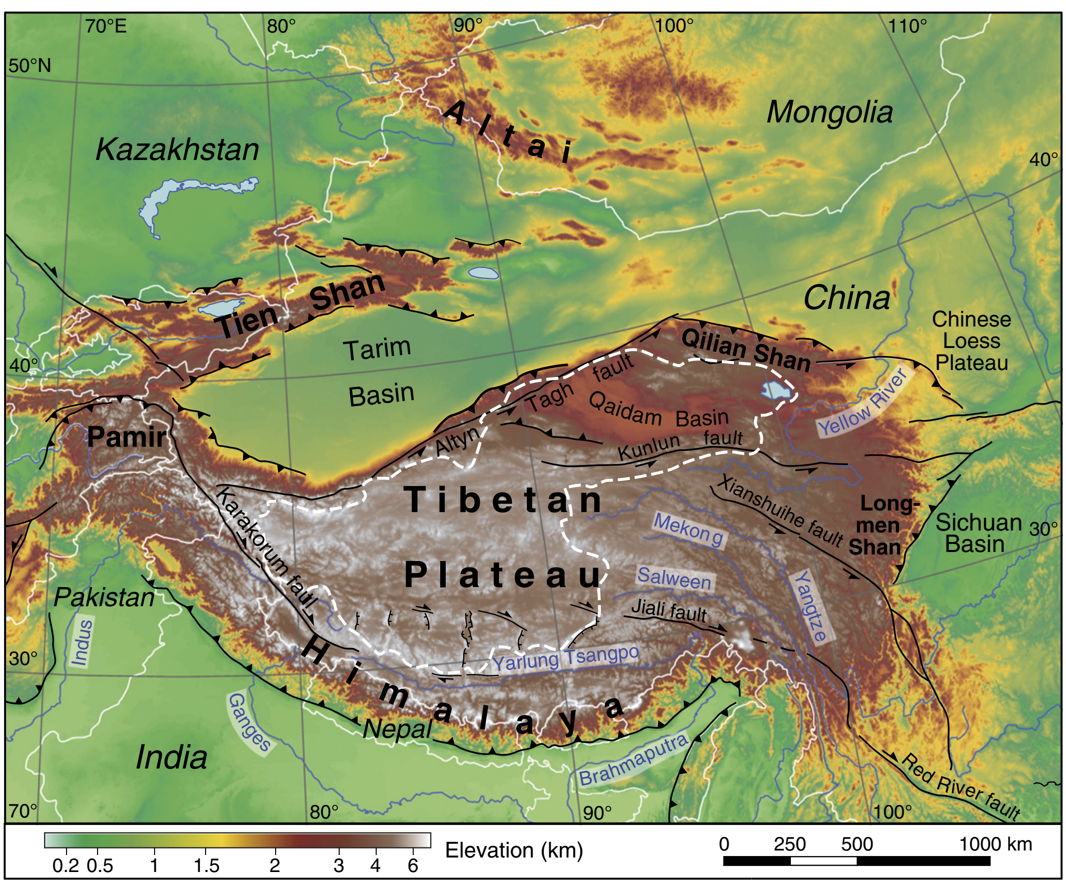

Fig. 1. Map of Central Asia showing the Tibetan Plateau and other active mountain belts that formed as a response to the continent–continent collision between India and Asia. The white dashed line indicates the extent of the internally drained part of the Tibetan Plateau (modified from Liu-Zeng et al., 2008). The major faults shown were adopted from Armijo et al. (1989), Styron et al. (2010), Tapponnier and Molnar (1977), Tapponnier et al. (2001), Taylor and Yin (2009).