Available online at www.sciencedirect.com
SCIENCE DIRECT®

Earth and Planetary Science Letters 248 (2006) 198 – 208

EPSL

www.elsevier.com/locate/epsl

Rapid exhumation at ~8 Ma on the Liupan Shan thrust fault from apatite fission-track thermochronology: Implications for growth of the northeastern Tibetan Plateau margin

Dewen Zheng, Pei-Zhen Zhang *, Jinlin Wan, Daoyang Yuan, Chuanyou Li, Gongming Yin, Guangliang Zhang, Zhicai Wang, Wei Min, Jie Chen

State Key Laboratory of Earthquake Dynamics, Institute of Geology, China Earthquake Administration, Beijing 100029, China

Received 11 September 2005; received in revised form 13 May 2006; accepted 20 May 2006
Available online 10 July 2006
Editor: R.D. van der Hilst

Abstract

The Liupan Shan Mountain is one of the outermost ranges in northeastern Tibetan Plateau. The onset of its uplift provides insight on whether the plateau grew sequentially outward or broad areas of the plateau deformed simultaneously. The apatite fission-track method can be used to date rapid cooling as the result of unroofing of rocks in response to tectonically induced vertical motion. Fission-track data from apatite in Early Cretaceous sedimentary strata exposed on the hanging-wall of Liupan Shan thrust fault in northeastern Tibet suggest that a late Cenozoic rapid cooling events occurred at 7.3–8.2 Ma or ~8 Ma. This age apparently dates fault activity of the Liupan Shan thrust in response to northeastward growth of the Tibetan Plateau uplift and lateral growth, which continues today. Numerous studies of the Tibetan Plateau suggest that the onset of deformation in eastern and northern margin of Tibetan Plateau occurred in the latest Miocene.

Keywords: rapid cooling; exhumation; Tibetan Plateau growth; fission track

1. Introduction

Understanding when the Tibetan Plateau and its margins attained their current elevations and the mechanics of how the plateau has grown in time are among key issues of continental tectonics [1–3]. The lateral extents of high elevations of the plateau have been related to the onset and intensification of the Asian monsoon and climatic changes in central and eastern Asia [3–5]. The northeastern margin of the Tibetan Plateau, defined as the region bounded by the Kunlun fault to the south and the Altyn Tagh and the Haiyuan faults to the north (Fig. 1), is an area where the plateau is actively deforming and where coeval crustal shortening and left-lateral strike–slip faulting can be related to the northeastward growth of the plateau margin [6–9]. In addition, Harrison et al. [5] and Molnar et al. [3] have suggested that the plateau rose ~1000–2000 m, to its present elevation, near 8 Ma. The timing of deformation and uplift, however, are debated. Based on sedimentary facies changes, paleobotany, and onset of Chinese loess north of Tibetan Plateau, Li et al. [10], Pares et al. [11]

* Corresponding author.
E-mail address: peizhen@ies.ac.cn (P.-Z. Zhang).

0012-821X/$ - see front matter
doi:10.1016/j.epsl.2006.05.023

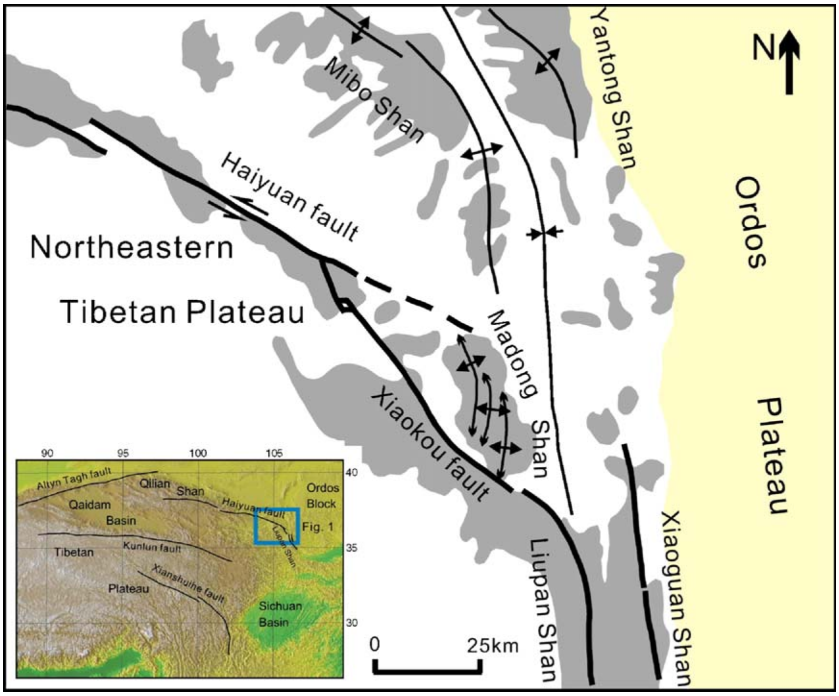

Fig. 1. Tectonic map of the Liupan Shan and Haiyuan region, northeastern margin of Tibetan Plateau. Bold thick black lines are reverse and thrust faults. Double arrows indicating sense of strike–slip motion. Black lines with inward arrowheads are synclines, and those with outward arrowheads are anticlines. Grey areas mark mountains.

and Fang et al. [12] suggest significant uplift (>3000 m) of the Tibetan Plateau ~3–4 Ma. Zhang et al. [13] and Molnar [14], however, argue that phenomena can be ascribed to global climate change from a stable to variable state, implying that uplift occurred both before and after 3–4 Ma. Molnar [15] has recently summarized evidence of late Miocene (about 6–8 Ma) environmental change and concurrent tectonic acceleration around the Tibetan Plateau to show both potential correlations and inconsistencies. Thus, a need exists to obtain more evidence of the onset of tectonic acceleration around the Tibetan Plateau during late Cenozoic time.

The apatite fission-track method can be used to date rapid cooling typically interpreted as the result of erosional unroofing of rocks in response to tectonically induced vertical motion [16–18]. Until recently few observations constrained the timing of growth of the northeastern margin of the plateau. Recently, however, Kirby et al. [2] report the beginning of rapid cooling between 12 and 5 Ma in the Longmen Shan and between 5 and 3 Ma in the Min Shan. In southeastern margin of the Tibetan Plateau, Clark et al. [1] reports surface uplift to have initiated between 9 and 13 Ma. We show a similar development on the northeastern margin of Tibetan Plateau.

2. Geological setting of the Liupan Shan region

The Liupan Shan, a north-trending mountain range, forms the northeasternmost active structure of the Tibetan Plateau margin (Figs. 1 and 2). To the east, the Ordos Plateau has been tectonically stable with very little Cenozoic or Recent deformation [19]. To the west, numerous active strike–slip and thrust faults contribute to the continuing growth of the northern and northeastern margin of the Tibetan Plateau [6,7,9,20–22]. The Liupan Shan separates the eastern edge of the actively deforming northeastern part of the Tibetan Plateau to the west from the stable Ordos block (Figs. 1 and 2). Thus, the timing and style of deformation in the Liupan Shan provide constraints on how the Tibetan Plateau was built and whether it grew synchronously over a broad area or by incremental outward growth.

Rock units exposed in the Liupan Shan area range from Early Ordovician to Recent in age, but Cretaceous and Tertiary rocks form the most extensive outcrops [6,7]. Lower Cretaceous rocks, assigned to the Liupan Shan Group, are the most widely exposed rock units in the study area, and form the main body of the Liupan Shan. These rocks have been divided into five conformable formations whose ages were determined