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Episodic exhumation of the Greater Himalayan Sequence since the Miocene constrained by fission track thermochronology in Nyalam, central Himalaya

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ABSTRACT

The Greater Himalayan Sequence (GHS), which makes up the core of the Himalayan orogen, has an uppermost tectonic contact defined by the South Tibetan Detachment System (STDS) and a lower tectonic contact defined by the Main Central Thrust (MCT). The GHS occurs as one of the most important tectostratigraphic units for deciphering processes related to tectonic and climatic exhumation across the orogen. Zircon and apatite fission track (ZFT, AFT) dating were carried out along a transect in Nyalam, central Himalaya in southern Tibet to constrain cooling driven by orogenic process since the middle Miocene. The hanging wall of the STDS yields an essentially unreset Jurassic ZFT age in the Jurassic strata. However, below the STDS within the GHS there is a clear and distinct thermal signal of cooling related to exhumation. In the footwall and within the GHS, the rocks have ZFT ages of middle Miocene to Pliocene, and AFT ages of late Miocene to Quaternary that get younger downward and away from the STDS. In combination with thermal structure modeling, a two-part episodic model, which is widely compatible with existing thermochronological data, is proposed for cooling and exhumation of the GHS since the middle Miocene: [1] middle Miocene; and [2] Pliocene to Quaternary (Recent). The middle Miocene cooling is suggested to have resulted from a rapid tectonic unroofing by down-to-the-north slip on the STDS. The tectonic exhumation was also recorded by several other thermochronological systems (e.g. biotite $^{40}Ar/^{39}Ar$) with concordant middle Miocene cooling ages in different structural positions across the GHS. Post middle Miocene ZFT and AFT cooling ages in the lower part of the GHS suggest accelerated cooling by climate-enhanced erosional exhumation, which was initiated in the late Miocene to Pliocene and was dramatic in the Quaternary to Recent. Thermochronological data and modeling further imply that the present Himalayan topographic front may have been shaped essentially by surface erosion since the late Miocene, when the Himalayan divide might have been some 20–30 km to the south of its present position. However, these data do not preclude the possibility that the intense erosional exhumation may have triggered rock uplift to approach and/or maintain a steady topography in the GHS.

1. Introduction

The Himalayan orogen has formed since the Eocene due to closure of the Tethyan Ocean driven by convergence of the India and Asian plates (Searle et al., 1987; Beck et al., 1995). The first-order structure of this spectacular orogenic belt is characterized by continental collision accompanied by regionally extensive along-strike faults that accommodate both contraction and extension (Burchfiel et al., 1992; Hodges et al., 1992; Wu et al., 1998; Yin, 2006). Traditionally the Himalayan Orogen is divided by orogen-parallel faults into three major tectostratigraphic units: the Tethyan Himalayan Sequence (THS), Greater Himalayan Sequence (GHS) and Lesser Himalayan Sequence (LHS). The GHS constitutes the core of the Himalayan orogen and the top of this sequence is defined by the extensional South Tibetan Detachment System (STDS) while the bottom is defined by the Main Central Thrust (MCT). A widely held view is that there has been simultaneous motion on the STDS and MCT and therefore southward extrusion of the GHS might driven by ductile flow in the lower crust and significant near-surface exhumation (Hodges et al., 1992; Dezes et al., 1999; Beaumont et al., 2001; Harris, 2007).

The timing of movement on these key boundary faults is debated and poorly known. For example, new chronologies in the central and western Himalaya support a Pliocene–Quaternary activation for the MCT (Jain et al., 2000; Catlos et al., 2001, 2002; Holland et al., 2003; Robert et al., 2009), while little evidence has been identified for Pliocene slip on the STDS. As such, a few workers have suggested that the GHS might have been variably extruded both spatially and

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temporally (i.e. Burbank, 2005; Harris, 2007). Intense surface denudation and exhumation of rocks in the greater Himalaya are considered to be dynamically linked with fault movement (Beaumont et al., 2001; Wobus et al., 2003, 2005; Harris, 2007). However, evidence for the link and mechanisms for this dynamic interaction remain poorly resolved. A comprehensive low-temperature thermochronological evolution of GHS bounded between STDS and MCT is thus essential for understanding and examining both boundary fault activation and surface processes that drive exhumation of rock through erosion, which is largely related to uplift and dramatic climate change that has resulted in intense glaciation.

In this paper, we present new zircon and apatite fission track (ZFT and AFT) ages from rocks taken along a north–south trending transect from the THS to GHS in the Nyalam area (28°N, 86°E; Figs. 1 and 2). This transect crosses the root zone of the GHS and is located in the central Himalaya ~90 km to the west of Mt. Everest (Qomolangma). Based on existing thermochronological data and thermal structure modeling, we address tectonic and climatic exhumation processes of the GHS since the middle Miocene.

2. Geological background

The STDS in the study area is locally referred as the Nyalam detachment (Burchfiel et al., 1992; Dougherty et al., 1998; Wang et al., 2006), which juxtaposes unmetamorphosed and low-grade Tibetan strata of THS over high-grade metamorphic rocks of GHS, which are mainly composed of pelitic schists and gneisses of Precambrian age (Burg et al., 1984; Burchfiel et al., 1992; Wang et al., 2006; Yin, 2006). The main detachment fault is indicated by a ~400 m-thick mylonite belt at the top of the GHS that has a strong north–northeast-dipping foliation. A normal sense of movement on the detachment is indicated by S–C fabrics and asymmetric augen structures (Wang et al., 2006). In addition, normal sense fabrics also exist across ~8 km in the upper part of the GHS (Wang et al., 2006), where small-scale structures in deformed leucogranites reveal good kinematic indicators of the sense of shear (Scharer et al., 1986; Hodges et al., 1998; Murphy and Harrison, 1999; Searle, 1999).

U/Pb dating of deformed migmatite–granite in the GHS yields a middle Miocene (16.8 ± 0.6 Ma) crystallization age (Scharer et al.,

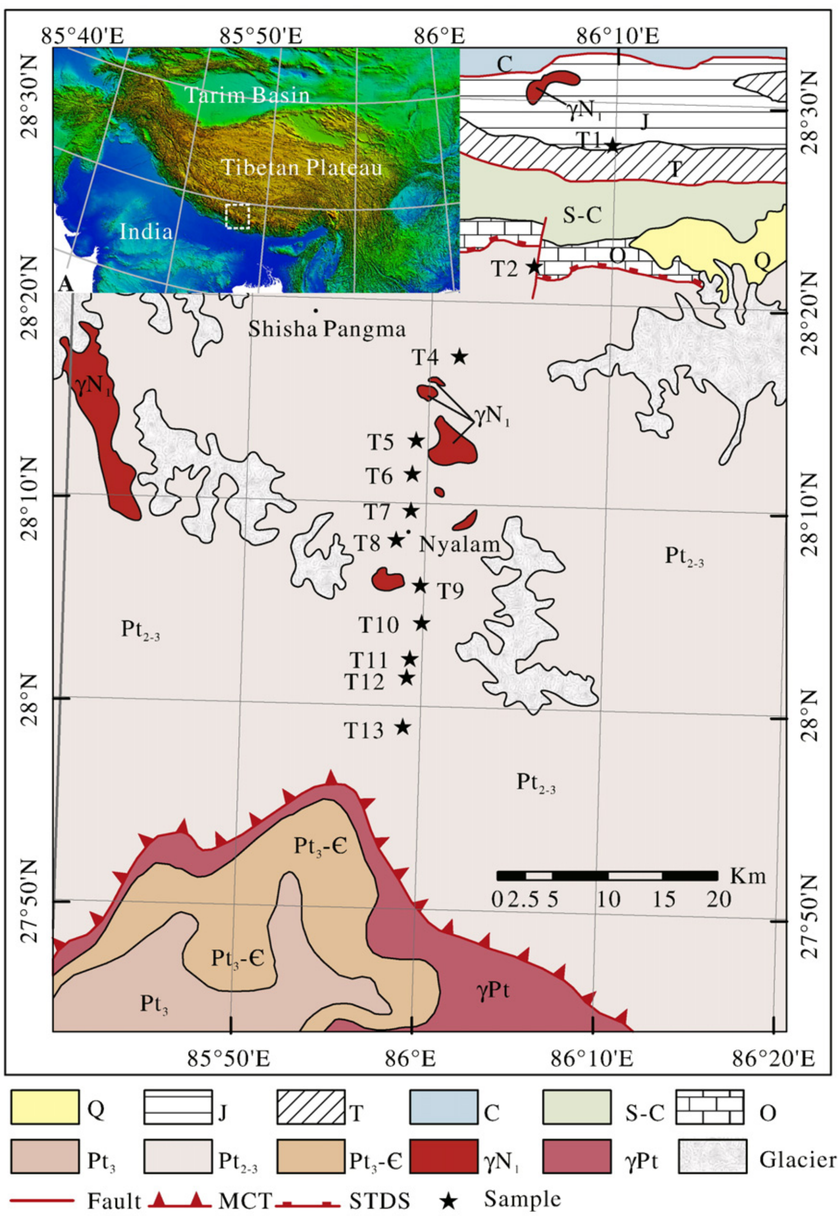

Fig. 1. Simplified geological map of Nyalam area (inset shows location of the studied area in the overall Himalayan orogenic belt). Q is Quaternary; J is Jurassic; T is Triassic; C is Carboniferous; S is Silurian; O is Ordovician; Pt_3 is Neo-Proterozoic; Pt_2 is Meso-Proterozoic; Є is Cambrian; γN_2 is Miocene granite; γPt is Proterozoic granite.