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Tectonometamorphic discontinuities within the Greater Himalayan Sequence in Western Nepal (Central Himalaya): Insights on the exhumation of crystalline rocks

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ABSTRACT

The core of the Greater Himalayan Sequence in the Mugu-Karnali area (Western Nepal) is affected by a thick shear zone with development of nearly 4 km of mylonites (Mangri shear zone). It is a contractional shear zone showing a top-to-the-SW and WSW sense of shear. The shear zone developed during the decompression, in the sillimanite stability field, of rocks that previously underwent relatively high-pressure metamorphism deformed under the kyanite stability field. P–T conditions indicate that the footwall experienced higher pressure (1.0–0.9 GPa) than the hanging wall (0.7 GPa) and similar temperatures (675°–700 °C). U–Pb in-situ dating of monazites indicate a continuous activity of the shear zone between 25 and 18 Ma. Samples from the lower part of the Greater Himalayan Sequence underwent similar ductile shearing at ~17–13 Ma. These ages and the associated P–T–t paths revealed that peak metamorphic conditions were reached ~5–7 Ma later in the footwall of the shear zone with respect to the hanging-wall pointing to a diachroneity in the metamorphism triggered by the shear zone itself.

Mangri Shear Zone, with the other recently documented tectonic and metamorphic discontinuities within the Greater Himalayan Sequence, point to the occurrence of a regional tectonic feature, the High Himalayan Discontinuity, running for more than 500 km along the strike of the Central Himalayas. It was responsible of the exhumation of the upper part of the Greater Himalayan Sequence starting from 28 Ma, well before the activation of the Main Central Thrust and the South Tibetan Detachment.

Our data point out that exhumation of the Greater Himalayan Sequence was partitioned in space and time and different slices were exhumed in different times, starting from the older in the upper part to the younger in the lower one.

1. Introduction

Plate tectonics well-accounts for the occurrence of high-pressure metamorphism in collisional settings. However, the mechanisms explaining the exhumation of deep seated metamorphic rocks are not well-explained by the paradigms of plate tectonics and are nowadays debated. One of the main problem to face is the occurrence of HP or UHP rocks exhumed in the same collisional cycle in which they formed in still contractional tectonics. This is the case in the Alps and in the Himalayas (Platt, 1993). Their occurrence ruled out two of the main mechanisms generally adopted for the exhumation of deep-seated rocks such as erosion and extensional tectonics. In the nineties the discovery of thrusts and normal faults active on the same vertical section, in a still active collisional belt, leads to the formulation of a new model of extrusion both by observation in the Himalayas (Hodges et al., 1992) and analogue modelling (Chemenda et al., 1995). This one was the first model able to explain rapid syn-convergence exhumation of deep seated rocks in the Himalayas.

The Himalayan belt, derived from the collision at ~55 Ma between India and Asia, is the most classical example of continent–continent collisional belt and it is a natural laboratory where several exhumation mechanisms were first described, so that it is the best place to test some of the generally accepted exhumation models.

Several first-order tectonic discontinuities have been recognised in the Himalayas that from bottom to top are: Main Frontal Thrust, Main Boundary Thrust, Main Central Trust (MCT) and South Tibetan

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Detachment (STD) (Gansser, 1964; Le Fort, 1975; Hodges, 2000 with references). The belt is characterised by the impressive continuity of these main structural discontinuities and tectonic units for nearly 2500 km. Among these the MCT and STD bound the Greater Himalayan Sequence (GHS), containing the most metamorphic rocks of the Himalayas.

The main tectonic models proposed for the exhumation of GHS are (Fig. 1):

1) channel flow (Beaumont et al., 2001), in which the GHS represents a partially molten lower/middle crust (hot-channel) that tunnels southwards during the Eocene–Oligocene, a process driven by the lateral pressure gradient created by the gravitational potential difference between the Tibetan plateau and its margins. In this model MCT and STDS are contemporaneous and remain parallel and sub-horizontal;
2) wedge extrusion in which the GHS extruded southwards as a northward-tapering wedge, by combining thrust along MCT at its base and extension along STDS at the top of the unit, as: a) a rigid wedge (Hodges et al., 1992), b) a ductilely deformed wedge undergoing simple shear (Grujic et al., 1996), or c) a wedge deformed by non-coaxial general flow (Vannay and Grasemann, 2001);
3) channel flow followed by extrusion (Godin et al., 2006) in which the hot-channel is finally exhumed to the surface by extrusion, with the geometry of model 1), and enhanced by focused erosion at the topographic front of the orogen;
4) wedge insertion (Webb et al., 2007) in which the GHS is regarded as a wedge but differently from model 1), it has a southward-tapering geometry and the STDS is regarded as a back-thrust;
5) critical taper wedge (Kohn, 2008) in which the Himalayas are considered as a Coulomb wedge (Davis et al., 1983; Platt, 1993) undergoing overall shortening when the wedge was thinned and undergoing extension when the wedge was overthickened. In this model the contemporaneous shearing along the STDS and MCT is not required.

According to the above proposed models of exhumation most of the attention of the researchers was paid to the bounding shear zones and faults of the GHS. As a consequence during the last decades less attention has been put on the internal structure of the GHS and, moreover, faults and/or shear zones recognised within its core has been mainly regarded as out-of-sequence thrusts (see Mukherjee et al., 2011 for a review): Central Himalayas: Kalopani shear zone (Vannay and Hodges, 1996) and Modi Khola shear zone (Hodges et al., 1996) and in Bhutan Himalayas: Kakhtang thrust (Daniel et al., 2003; Davidson et al., 1997) and Laya Thrust (Grujic et al., 2012).

However, recent works identified several ductile shear zones in the core of the GHS active before the activation of the MCT (Fig. 2): Sikkim (Rubatto et al., 2012); Eastern Nepal: High Himalayan Thrust (Goscombe et al., 2006; Imayama et al., 2012); Western Nepal: Tojiem shear zone (Carosi et al., 2007, 2010) and metamorphic discontinuity between upper and lower GHS (Larson et al., 2010; Yakymchuck and Godin, 2012).

These findings shed new light on the internal structure of the GHS and even on exhumation mechanisms of the unit itself. The shearing along shear zone within the GHS affected the metamorphic evolution of the two portions of the GHS separated by the shear zone itself causing its early exhumation, some Ma before the onset of MCT activity and, consequently, before the classical activation of extrusion/channel flow mechanisms of exhumation (Carosi et al., 2010).

In this view the occurrence, geometry, kinematics, extension and timing of shear zones in the core of the GHS is crucial in the discussion of the exhumation mechanisms.

Recent field works, in the remote region of Mugu-Karnali (Western Nepal), allowed to recognise one of the thickest shear zone within the GHS: the Mangri shear zone localized in its core, showing a thickness of ~4 km.

The aim of this paper is to describe the geometry, the kinematic, the P and T evolution of the Mangri shear zone in the crystalline rocks of the Central Himalayas, as well as its timing by U–Pb in-situ analyses on monazite, and to discuss the new results in the light of the most popular models for the exhumation of deeply seated metamorphic rocks in the Himalayas.

2. Geological outline

The Himalayan orogen (Fig. 2) is divided into four tectonic units from south to north: Sub-Himalayas molasses, Lesser Himalayan Sequence, Greater Himalayan Sequence and Tibetan Sedimentary Sequence. These units run parallel to the belt for more than 2400 km and are bounded by the Main Frontal Thrust, Main Boundary Thrust, Main Central Trust and South Tibetan Detachment (Hodges, 2000 and references therein).

The Lesser Himalayan Sequence (LHS) is made by impure quartzite, marble, phyllites, orthogneisses and metabasaltic rocks. These rocks are affected by a greenschist to lower amphibolite facies metamorphism (Hodges, 2000; Upreti, 1999). The LHS is subdivided in two

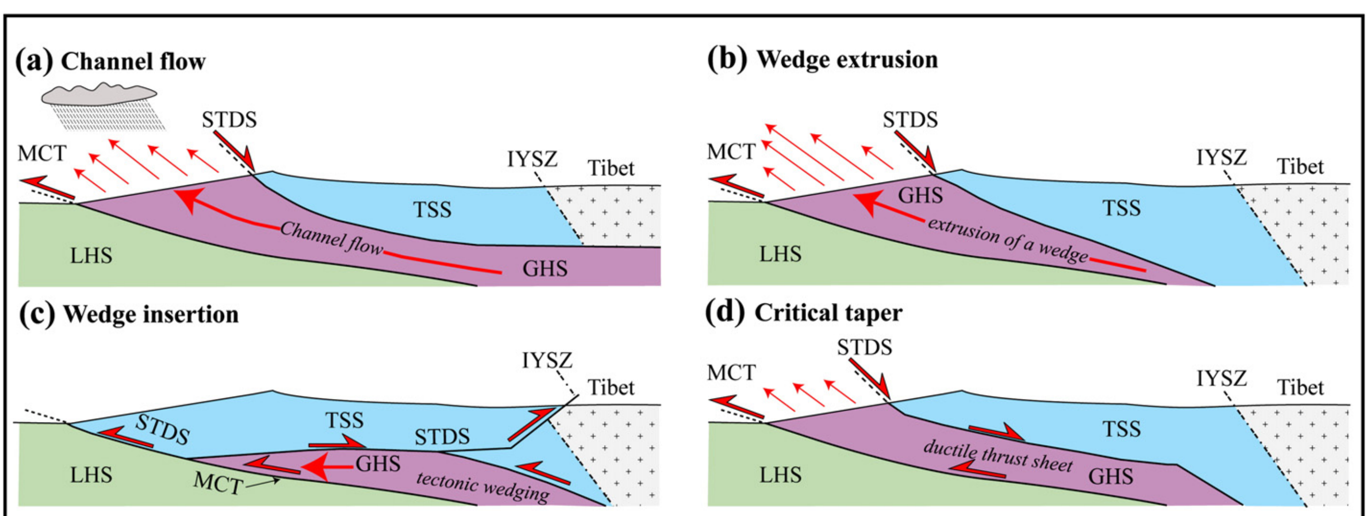

Fig. 1. Schematic drawings of main current tectonic models for exhumation of GHS rocks between the Main Central Thrust (MCT) and the South Tibetan Detachment System (STDS). a) Channel flow: b) wedge extrusion; c) wedge insertion; d) critical taper (IYSZ: Indus–Yarlung Suture Zone). (TSS: Tethyan sedimentary Sequence; GHS: Greater Himalayan Sequence; LHS: Lesser Himalayan sequence).