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Initial geometry of western Himalaya and ultrahigh-pressure metamorphic evolution

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Abstract

Ultrahigh-pressure metamorphic rocks on both sides of the western Himalayan syntaxis show different P–T–t paths. The Kaghan unit was metamorphosed under the UHP conditions significantly later (∼46 Ma) than the Tso Morari unit (∼53 Ma), implying that the Tso Morari was subducted earlier (∼57 Ma) than the Kaghan unit (∼52 Ma). The age difference likely reflects the initial shape of Greater India, with the Kaghan unit located greater than 300 km south of the Tso Morari before the collision of two continents. We calculate the dip of the subducting plate using two independent methods. The results show gentle dipping subduction east of the western syntaxis, and steep subduction west of the syntaxis since the time of India–Eurasia collision to the present time. We propose that the steep subduction in the western part is likely related to the proto-Chaman and Karakorum faults along which the Indian plate moved northward. In the eastern part, the overlying Eurasian plate extruded to east, which allowed gentle dipping subduction of the Indian continent. Although the main period of eastward extrusion of the Eurasian continent occurred between 30 and 15 Ma, our results suggest that this was likely taking place since the early India–Asia collision. Using those geometrical constraints, a 3D image of the slab is reconstructed in the western part, showing the sharp bending of the western syntaxis along the proto-Chaman fault. This bending resulted in the warping of the slab surface to form a conical fold with a north-dipping axis located near the western syntaxis.

Keywords: Subduction geometry; UHP metamorphism; Himalaya; Tectonics

1. Introduction

One of the crucial questions in the India–Eurasia collision concerns the geometry of the Indian plate prior to continental subduction, particularly on its western part (e.g., Ali and Aitchinson, 2005 for review). P–T–t evolution of ultrahigh-pressure (UHP) metamorphic rocks have provided such information related to the geometry of many convergent margins (Ernst, 2001). Northwestern Himalaya has two major UHP units; the Kaghan unit in northern Pakistan and the Tso Morari unit in northern India. The two are considered to have developed contemporaneously during the early subduction of the Indian continent in Paleocene-Eocene time (O'Brien et al., 2001; Kaneko et al., 2003) but recent age determinations show different PTt evolution of the two units. We estimated the dip of the subducting Indian continent for the two areas between 55 and 40 Ma using two different methods. One is based on the trigonometric calculations using the horizontal displacement of the Indian continent and the depth of the UHP units during their subduction and subsequent exhumation (Guillot et al., 2004) and the second method uses the bending of the Indian plate during the same period as has recently carried out by Leech et al. (2005). This paper presents the results, and discusses the initial geometry of the Greater India and the collision between the India and Eurasia continents during the Paleogene.

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2. Geological setting

Along the Himalayan belt, two units of UHP rocks have been recognized (Fig. 1). The occurrence of HP rocks were reported in the Kaghan valley southwest of the Nanga Parbat spur in northern Pakistan by Pognante and Spencer (1991) and they are now considered to be UHP rocks based on the discovery of coesite in this unit by O'Brien et al. (2001). The second occurrence is in the Tso Morari unit in eastern Ladakh, NW India (Guillot et al., 1995, 1997; de Sigoyer et al., 1997). It is now recognized as a UHP unit based on the discovery of coesite by Sachan et al. (2004). Both units represent distal parts of the NW Indian continental margin that were subducted to a depth of 100 km for the Kaghan unit (O'Brien et al., 2001) and most likely 130 km for the Tso Morari unit (Mukherjee and Sachan, 2003). The third and fourth occurrences of an eclogitic unit is reported by Le Fort et al. (1997) in the Indus suture zone, east of the western syntaxis and by Lombardo and Rolfo (2000) in the MCT zone, Central Nepal. The rocks in these units are extensively retrograded at unknown age, and are therefore, not included in the following discussion (Fig. 2).

2.1. Tso Morari unit

The Tso Morari unit in eastern Ladakh is separated from the higher Himalayan crystallines by the Zanskar synclinorium (Guillot et al., 1997). The unit contains hectometric lenses of eclogites in Cambro–Ordovician gneisses overlain by upper Carboniferous to Permian metasedimentary rocks (Colchen et al., 1994; de Sigoyer et al., 2004). The metamorphic condition of the eclogites is estimated up to 3.9 GPa and 750–850 °C (Mukherjee and Sachan, 2003) and dated at ~55 Ma by isotope methods (de Sigoyer et al., 2000; Table 1). Although the age of ~55 Ma is significantly different from the peak metamorphism age of ~46 Ma for the Kaghan unit (Kaneko et al., 2003), the onset of the subduction was considered synchronous both west and east of the western syntaxis probably because of large uncertainty in the peak metamorphic age of the Tso Morari unit. However, recent geochronological studies confirm the age difference of metamorphism between the two units. First, Schlup et al. (2003) obtained a $^{40}Ar/^{39}Ar$ phengite age of 53.8 ± 0.2 Ma from a Tso Morari gneiss which is interpreted as a cooling age. Second, Leech et al. (2005) obtained the UHP metamorphic age of 53.3 ± 0.7 Ma based on a U–Pb zircon SCHRIMP age from a quar-

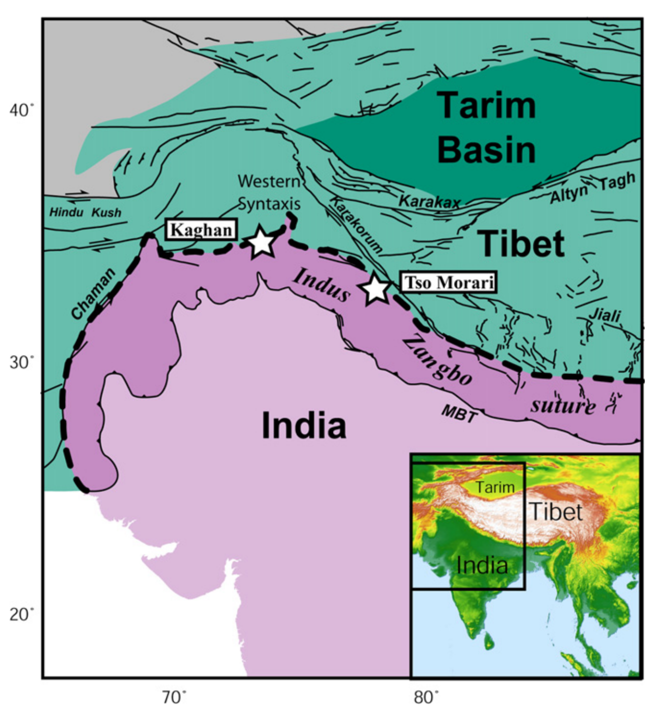

Fig. 1. Schematic map of the NW Himalaya showing the locations of the two UHP units (open stars), Kaghan and Tso Morari (modified after Replumaz and Tapponnier (2003)).

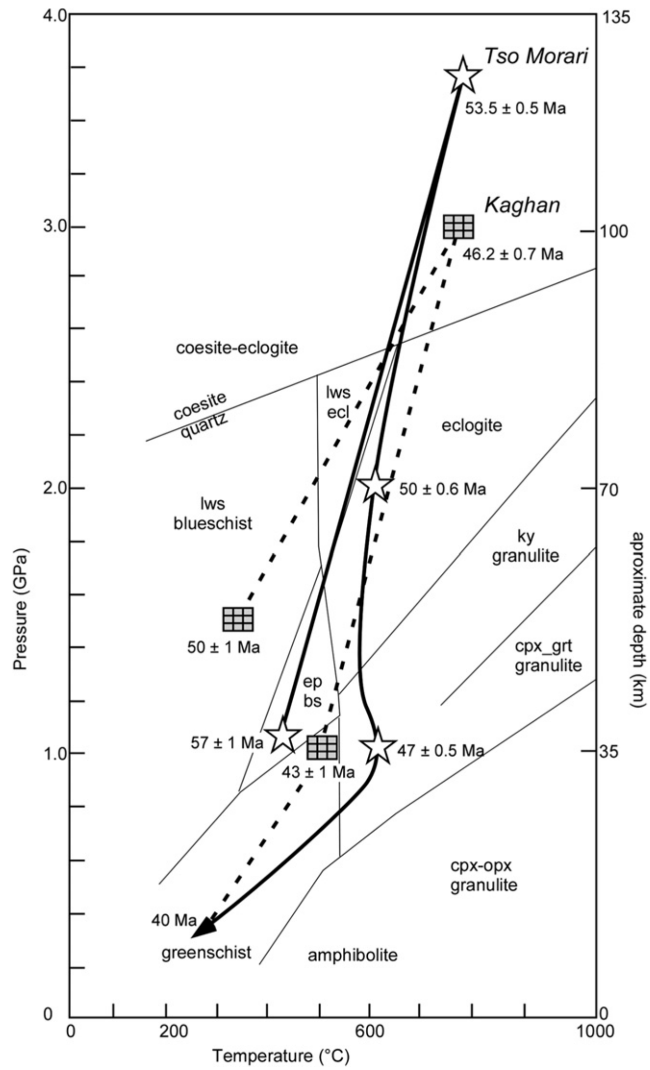

Fig. 2. Pressure–Temperature–time path of the UHP Tso Morari (open stars) and Kaghan units (meshed squares). (see Table 1 for references). Note lower dP/dT gradients and higher peak temperature for the Kaghan unit, probably related to the slower subduction rate. *Abbreviations*: bs, blueschists; cpx, clinopyroxene; ep, epidote; grt, garnet; ky, kyanite; lws, lawsonite; opx, orthopyroxene.