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The leading edge of the Greater Himalayan Crystalline complex revealed in the NW Indian Himalaya: Implications for the evolution of the Himalayan orogen : COMMENT

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Notes

The leading edge of the Greater Himalayan Crystalline complex revealed in the NW Indian Himalaya: Implications for the evolution of the Himalayan orogen: COMMENT and REPLY

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Webb et al. (2007) have described the structural evolution of the northwest Indian Himalaya after studying a small area around the Rohtang La. I am glad that the authors have corroborated some of our conclusions (Dubey et al., 2004), but I would like to draw attention toward the following points.

1. The Chail-Jutogh rocks are well exposed south of the Kulu (Rampur) window (Pilgrim and West, 1928; and all the important geologic maps published since then). However these rocks are wrongly marked by Webb et al. as Late Proterozoic rocks (PtTHS) under the Tethys Himalayan sequence (THS) in their Figure 2. Moreover, the root of the klippen rocks does not lie north of the Kulu (Rampur) window, but north of the Shali Formation, south of the window. Hence, the total displacement determined by the "klippe to fenster method" is ~40 km (Pilgrim and West, 1928; Dubey and Bhat, 1991) and not >100 km as mentioned by Webb et al.

2. The structural evolution of the area cannot be interpreted in isolation, as this is controlled by the development of the Kangra recess lying immediately south of the area (Fig. 1). The following significant points deserve special attention (details in Dubey et al., 2004):

i. The initial geometry of the Kangra recess is shown in Figure 2A. The strike-slip component of the oblique thrust ramp led to its propagation by extending its length (fault f, Fig. 2B). Similar fault propagation is visible in the geologic map of the region marking the boundary between the Chail Formation and the THS (Fig. 1; see also Figure 5.1 in Thakur, 1992). The initial gentle dip of the leading frontal ramp led to large-magnitude displacement, and rocks from the deeper level (Chail Formation) crop out on the surface. However, the steeper dip of the trailing frontal ramp led to a small amount of thrust displacement; hence, rocks occurring at the upper levels in the succession (THS) outcrop on the surface.

ii. Webb et al. have described the occurrence of the Greater Himalayan Crystalline complex (GHC) over the Lesser Himalayan sequence (LHS) in the central Himalaya, and the Tethys Himalayan sequence (THS) over the LHS in the western Himalaya. The variation was attributed to "an eastward increase in the magnitude of exhumation resulting in differential preservation of past orogenic architecture" (Webb et al., 2007, p. 958). The along-strike variation of Himalayan geology was assigned to a consequence of "spatially varying erosion" and the possibility of a change in deformation mechanism was negated (p. 958). As the matter is already described by

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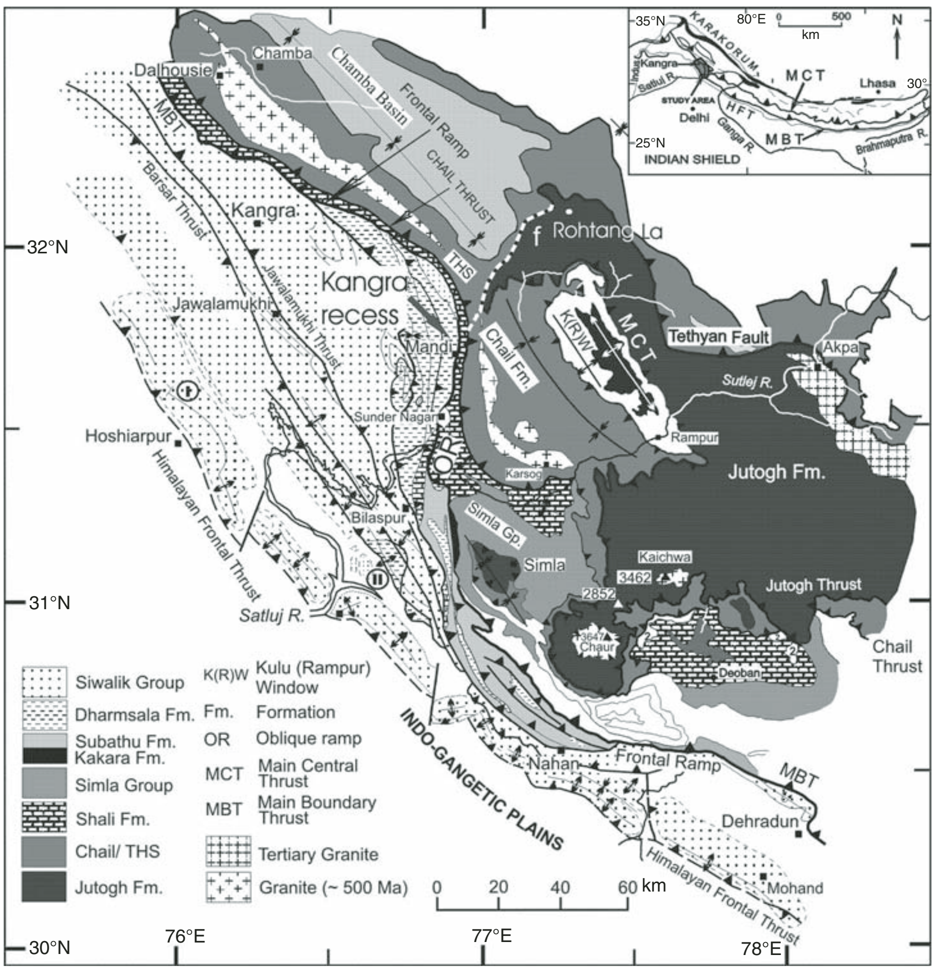

Figure 1. Geological map of a part of the Himachal Himalaya. The propagation and extension of the oblique ramp into the hanging wall, marking the boundary between the Chail Formation and the Tethys Himalayan sequence (THS), is shown by a white broken line. K(R)W—Kulu (Rampur) Window; Fm.—Formation; OR—Oblique ramp; MCT—Main Central Thrust; MBT—Main Boundary Thrust.

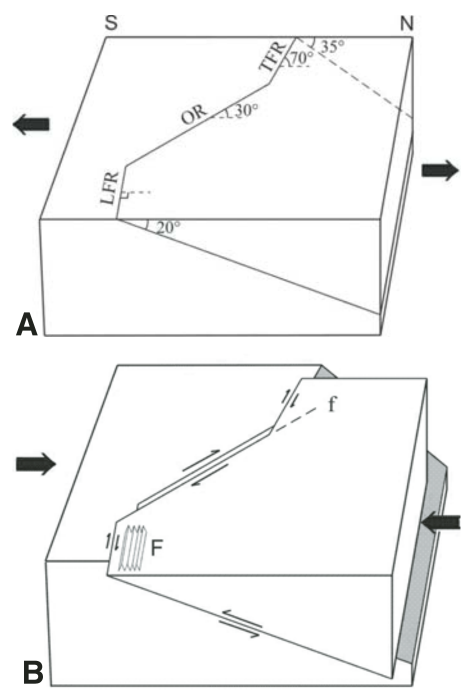

Figure 2. Simplified model showing two stages in the structural evolution of the Kangra recess. A: Geometry of initial fracture. LFR—leading frontal ramp; TFR—trailing frontal ramp; OR—oblique ramp; N-S—north and south directions. Note the variation of dip at the leading and trailing frontal ramps. B: Formation of folds (F), and extension of the oblique ramp fault (f) during the Himalayan orogeny.

Dubey et al. (2004), the conclusions are justified with additions that (1) the structural juxtaposition is a result of a combination of displacement along the thrust and spatially varying erosion, and (2) the structure is controlled by the oblique thrust ramps of the Kangra recess, a key factor ignored by the authors.

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We thank A.K. Dubey for his Comment (Dubey, 2008) and address his arguments.

1. We interpret the metasedimentary rocks to the south of the Kulu Window as Late Proterozoic rocks of the Tethyan Himalayan Sequence (Webb et al., 2007, our Fig. 2) on the basis of local lithological, structural, and metamorphic observations at the western end of the window. Dubey comments that "all important geologic maps" of the region show those rocks as the distinct Chail and Jutogh Formations. However, our reading of the literature reveals no such uniformity. Most map interpretations involve one of three tectonic schemes: (A) the rocks are divided into the Greater Himalayan Crystalline (GHC) complex rocks and Late Proterozoic Tethyan Himalayan Sequence rocks (e.g., DiPietro and Pogue, 2004); (B) the rocks belong to a single "Higher Himalayan Crystalline" unit equivalent to the GHC without lithologic or structural distinction from the Late Proterozoic Tethyan Himalayan Sequence rocks (e.g., Frank et al., 1995); or (C) the rocks are divided into the Jutogh Thrust Sheet and the underlying Chail Thrust Sheet (Thakur and Rawat, 1992). The Jutogh Thrust Sheet is commonly interpreted as either structurally continuous with the Greater Himalayan Crystalline complex (Thakur and Rawat, 1992) or structurally beneath that unit (Bhargava et al., 1991). The Chail Thrust Sheet is commonly drawn continuously with the Late Proterozoic Tethyan Himalayan Sequence rocks to the northwest (Thakur and Rawat, 1992).

We estimated a minimum slip of >100 km along the Main Central thrust based upon the distance of fault exposure in the NE-SW transport direction from the northeastern margin of the Kulu Window to the Simla Klippe (Webb et al., 2007, our Fig. 1). Dubey argues that the klippen rocks are underlain by the Chail and Jutogh thrusts and have traveled only ~40 km to the southwest. However, a >100 km minimum slip estimate for the Main Central thrust and the klippen rocks is robust for most proposed map patterns, including the map presented by Dubey (2008, his Fig. 1). The slip estimate is valid for the tectonic and related lithologic division schemes (A) and (B) discussed here, because all structural units proposed for the klippen rocks are above the Main Central thrust. Many scheme (C) maps (see Dubey's Fig. 1) show the Jutogh rocks to be parts of the Greater Himalayan Crystalline complex, such that the Jutogh thrust and Main Central thrust are different segments of a single structure. Excepting minor differences, such schemes have the same ~100 km minimum displacement along the Jutogh/Main Central thrust. The Chail rocks of the Simla Klippe have a similar minimum displacement: as Dubey has drawn the Chail thrust, it is exposed at ~40 km to the northeast of Simla, buried and folded further to the northeast, and reappears as the Southwestern margin of the Kulu Window.

2. Dubey claims a major role for his proposed evolution of the Kangra recess of the Main Boundary thrust (Dubey et al., 2004). The Main Boundary thrust generally carries pre-Cenozoic units over deformed foreland strata (see Dubey's [2008] Fig. 1). In the Dubey et al. (2004) model, this structure features planar thrust and oblique segments with static dips ranging from 20° to 35°. Space problems are addressed by breaking the hanging-wall block with new faults which are drawn as extensions of Main Boundary thrust segments. In his Comment, Dubey applies this idea further by reinterpreting a fault segment which was originally inferred by Thakur (1992, his Fig. 5.1). Thakur draws the segment as a north-trending strand of the South Tibet detachment which merges with the Main Central thrust to the south. Dubey reinterprets the segment as a "space problem" fault in the Chail thrust hanging wall. However, the fault segment has never been observed, despite detailed mapping of the area in question (e.g., mapping of Frank et al. [1973, 1995], Thöni [1977], Vannay and Steck [1995], and Webb et al. [2007]). Thakur (1992) presumably inferred this segment because a merger of the South Tibet detachment with the Main Central thrust resolves local and orogen-scale geometric problems (presented by Yin [2006] and Webb et al. [2007]). Our mapping shows that Thakur's (1992) implicit idea is correct but that the local South Tibet detachment geometry is mistaken (Webb et al., 2007).

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