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Out-of-Sequence Thrust in the Higher Himalaya- a Review & Possible Genesis

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An out-of-sequence thrust (OOST) has been established inside the Higher Himalaya by previous workers more frequently from Nepal- and Bhutan Himalaya. The OOST lies between the South Tibetan Detachment System-Upper (STDSU) and the South Tibetan Detachment System-Lower (STDSL). The thrust has been recognized as the Kakhtang Thrust in Bhutan (Grujic et al., 2002 and references therein); Khumbu Thrust (Searle, 1999), Modi Khola Shear Zone (Hodges et al., 1996), Kalopani Shear Zone (Vannay and Hodges, 1999), Toijem Shear Zone in Nepal (Carosi et al., 2007), Chaura Thrust (Jain et al., 2000)- also designated as the Sarahan Thrust (Chambers et al., 2008) in the western Indian Himalaya in Sutlej section, Zimithang Thrust in the eastern Indian Himalaya (Yin et al., 2006), as 'physiographic transition' in Marsyandi valley, Nepal (Burbank et al., 2003). We note that considering the upper strand of the Main Central Thrust (the MCTU) as the lower boundary of the Higher Himalaya, the physiographic transition has also been referred to lie in the Lesser Himalaya.The period of activity of the OOST was 22.5-18.5 Ma (Hodges et al., 1996), 14-10 Ma (Grujic et al., 2002), 4.9-1.5 Ma (Jain et al., 2000), and from Late Pliocene to even Holocene Period (Burbank, 2005). The out-of-sequence thrusting was followed after the initiation of channel flow at $\sim$ 15 Ma in the Higher Himalaya with a maximum delay of $\sim$ 13 Ma. However, in the Bhutan Himalaya, the thrusting continued along with the extensional ductile shearing in the STDSU at 11-10 Ma (Hollister and Grujic, 2006). The OOST in the Higher Himalaya lies inside the zone of the top-to-SW sense of ductile shearing. The OOST, at Kakhtang, Toijem, and Chaura are ductile shear zones with a top-to-SW sense of shearing. The OOST merges with the MCT and the Main Himalayan Thrust (MHT) at a depth of 30 km or more and either runs 200-300 km beneath the Tibetan plateau (Grujic et al., 2002; Hollister and Grujic, 2006). The hanging wall side of the OOST is more dominant with migmatites and leucogranites (Searle, 1999; Yin et al., 2006; Carosi et al., 2007; Grujic et al., 2002; Hollister and Grujic, 2006), but the footwall side does contain these rocks (Hodges et al., 1996; Chambers et al., 2008). The thickness of the OOST are 50 m (Carosi et al., 2007), >150 m (Yin et al., 2006), 3-6 km (Searle, 1999) and $\sim$ 1.5 km (Vannay and Hodges, 1996). A number of hypotheses have been put forward to explain the genesis of the OOST. These are (i) a disparity in erosion rates triggered mainly by a spatial variation in the intensity of rainfall (Wobus et al., 2005). (ii) The lower boundary of the channel flow extrusion defined the OOST (Hollister and Grujic, 2006). (iii) As a result of a heterogeneous velocity profile of channel flow extrusion across lithologic discontinuity (Carosi et al., 2007). The granitic melt at depth in some way led to this thrusting (Swapp and Hollister, 1991). Had channel flow been the extrusion mechanism of the Higher Himalaya, the genesis of the OOST might somehow be related to this extrusion. In this work, a channel flow box was prepared and polydimethylsiloxane was used as the model material. A channel flow was generated in the horizontal channel and was allowed to extrude through an inclined channel similar to the Higher Himalaya (Mukherjee, 2007). In different considerations, the walls of the Higher Himalaya are parallel and diverging-up. A late formed blind thrust plane forms at the corner joining the inclined and the horizontal wall and crops to the surface much later to the initiation of channel flow. On the basis of its late arrival to the surface than the channel flow and its relative position in the model Higher Himalaya, the thrust is comparable with the OOST. This means that (i) climatic factors nor lithologic discontinuity were a trigger to the OOST; and (ii) the OOST is a delayed product of channel flow that initiated at a sub-horizontal channel below the Tibetan plateau and extrude the Higher Himalaya.

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