Fluvial Sediment Aggradation and Incision in NW Sub-Himalaya

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Alluvial fans are important recorders of temporal variations in sediment delivery from adjacent mountains. Over the last few hundred thousand years, sediment delivery from the Himalayan orogen to its foreland has varied significantly. Variation in sediment delivery toward the foreland resulted into alluvial-fan sedimentation, and in some cases, transient storage in intermontane basins, followed by re-incision and evacuation of sediment to lower elevation sectors. Existing models on sediment transport favour that, on longer timescales of millions of years, tectonic reorganization within the orogenic wedge is the main driver of sediment delivery. In contrast, on shorter timescales involving tens to hundred thousand years, climatic change may play an important role in high-frequency changes in the sedimentary system. In the Himalayan realm climate-driven processes may include variations in monsoonal strength or glacial/ interglacial oscillations, which may trigger fluvial-glacial deposition and incision, voluminous mass movements and other slope-related processes, as well as transient sediment-storage and routing of sediments to the foreland. However, these changes are short-lived and the question has not been answered if voluminous intermontane basin fills in the region of the Sub-Himalaya are related to long-term tectonic or more short-term climatic oscillations. Moreover, detailed stratigraphic information, chronologies of late Pliocene to Quaternary sediment aggradation and incision cycles and knowledge about the degree of connectivity of Himalayan rivers are lacking.

In this study, we decipher the wedge-top basin sediments of the intermontane Kangra basin within the Sub-Himalaya of NW Himachal Pradesh, India. To document the spatiotemporal tectono-sedimentary evolution of the Kangra basin, we used a variety of methods, including structural and geomorphic field mapping, provenance analysis and lithological description, morphometric analysis, and surface-exposure dating of fluvial terraces using cosmogenic radionuclides.

The inferred Pleistocene alluvial fill of the Kangra basin unconformably overlies the Neogene Siwalik sediments and is represented by coalesced alluvial-fan segments. The fans are predominantly made up of debris flow and stream-flow sediments *(Sah & Srivastava, 1992)* and can be sub-divided into two major parts: the western Rait-Rihlu fan and the higher Kangra fan. The sources of the sediments of the basin-fill are Lesser Himalayan low-grade metamorphics, granites, quartzites from Sub-Himalaya, and reworked Siwalik sediments. The catchment of these fans is bounded by the ~5-km-high Dhauladhar range in the north; low-temperature thermochronology suggests that the range has existed since 6-7 Ma *(Deeken et al., 2011)*, which in turn indicates a well-constrained source of the sediments. The Siwalik units reflect a gravel-progradation sequence, which has been subjected to fault-propagation folding, involving a NW-SE striking Jwalamukhi thrust. This has resulted in the uplift and tilting of the Siwalik units, as well as confining the fill of the piggy-back basin to the north of the thrust (*Brozovic & Burbank, 2000; Srivastava et al., 2009*). Previous studies have suggested that the filling of the basin or the generation of the fans might have happened in different phases, although this is still inconclusive. The most recent phase of aggradation is characterized by a single, large uninterrupted sequence of (> 100 m thick) fluvial boulder conglomerates (Neogal beds). Clast counts show that the conglomerates contain >60% granitic clasts unlike the quartzite-dominated Upper Siwalik conglomerates. Following the sedimentation, rivers started to re-incise the basin-fill. Combining field observations, DEM and satellite imagery analysis, we identified at least five distinct terrace levels with average elevations of 190±10m, ~110± 10m, 60± 10m, 40± 5m and ~5-10m above the present riverbed, which indicates the onset of distinct re-incision phases observed in the basin.

The present-day Kangra basin is drained by three river systems, all originating in the Dhauladhar range and traversing the Main Central Thrust and Main Boundary Thrust at the foot of the range, as well as the Siwalik fold-thrust system. In the field, we have documented several sub-parallel paleo-valleys trending NE-SW near a south-westerly flowing river. These valleys are characterized by very narrow valley floors, ~80m deep, steep-walled gorges incised into bedrock, and big granite boulders on the floor – similar to the conditions observed along active channels.

The growth of the fold-and-thrust belt or the focused rock uplift of the Siwalik strata while moving over the fault-ramp of Jwalamukhi thrust is revealed through river-profile analysis. The hanging wall of the thrust is characterized by knickpoints and steepened stretches along longitudinal river profiles. Interestingly, a few of the higher terraces near the southern margin of the basin have a north-easterly tilt toward the south-westerly flowing river. We interpret this to indicate ongoing tectonic shortening within Sub-Himalaya supporting the notion of important tectonic forcing of the fluvial network in this part of the Sub-Himalaya.

To obtain a chronology of the basin-fill processes, re-incision phases, and associated terrace formation, we have embarked on surface-exposure dating of the terrace surfaces using cosmogenic radionuclides. It is expected that these results will elucidate the timing of the tectonic basin-forming processes and the superposed short-term climate-driven oscillations in sediment accumulation and episodes of changed fluvial connectivity, potential stream captures, and protracted tectonic deformation of the fluvial system.

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