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Late Quaternary tectonic landforms and fluvial aggradation in the Saryu River valley: Central Kumaun Himalaya

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ABSTRACT

The present study has been carried out with special emphasis on the aggradational landforms to explain the spatial and temporal variability in phases of aggradation/incision in response to tectonic activity during the late Quaternary in the Saryu River valley in central Kumaun Himalaya. The valley has preserved cut-and-fill terraces with thick alluvial cover, debris flow terraces, and bedrock strath terraces that provide signatures of tectonic activity and climate. Morphostratigraphy of the terraces reveals that the oldest landforms preserved south of the Main Central Thrust, the fluvial modified debris flow terraces, were developed between 30 and 45 ka. The major phase of valley fill is dated between 14 and 22 ka. The youngest phase of aggradation is dated at early and mid-Holocene (9–3 ka). Following this, several phases of accelerated incision/erosion owing to an increase in uplift rate occurred, as evident from the strath terraces. Seven major phases of bedrock incision/uplift have been estimated during 44 ka (3.34 mm/year), 35 ka (1.84 mm/year), 15 ka (0.91 mm/year), 14 ka (0.83 mm/year), 9 ka (1.75 mm/year), 7 ka (5.38 mm/year), and around 3 ka (4.4 mm/year) from the strath terraces near major thrusts. We postulate that between 9 and 3 ka the terrain witnessed relatively enhanced surface uplift (2–5 mm/year).

1. Introduction

The dynamic Himalayan terrain is controlled by tectonic and climatic processes (Valdiya, 2001; Ray and Srivastava, 2010). These processes include orogenesis, vertical tectonic motion, erosion, glacial activity, and high monsoon precipitation (Montgomery, 2001). The interaction between these two processes has resulted in the formation of some southward younging thrusts namely, Main Central Thrust (MCT), which brings the Higher Himalayan Crystallines (HHC) into contact with the Lesser Himalaya (LH), and the Main Boundary Thrust (MBT) that marks a contact between LH rocks and Siwalik in the Kumaun Himalaya. However, in the NW Himalaya, Subathu and Dharamsala rocks occur between the LH and Siwalik along the MBT (Thakur et al., 2014). Similarly, in the Arunachal Himalaya, Gondwana rocks occur in patches along MBT. The LH rocks come over the Siwalik only where the Bomdila Thrust overlaps the Gondwana by overthrusting (Tripathi et al., 1978; Kumar, 1997). The Himalayan Frontal Thrust (HFT) brings the Siwalik over the Ganga plain (Nakata, 1972; Srivastava and Misra, 2008). Tectonic deformations in the HHC and LH zones occur between the MCT and MBT caused by formation of out-of-sequence thrusts (Bookhagen, 2004; Hodges et al., 2004; Thiede et al., 2004; Bookhagen et al., 2005; Wobus et al., 2005). The southward progression of deformation of the Himalayan orogen suggests that the mountain front defined by the HFT is tectonically active (Nakata, 1972; Valdiya, 1990; Lave and Avouac, 2000). The spatial- and temporal-scale variations in such a dynamic system are intimately related to the evolution of tectonically active landscapes (Montgomery and Brandon, 2002). Slope morphology, aggradation, incision, and erosion rates are being challenged by recent work on erosional processes and tectonic forcing (Beaumont et al., 1991; Montgomery et al., 2001; Juyal et al., 2010; Ray and Srivastava, 2010). Srivastava and Misra (2008) suggested that terrace aggradation was associated with strengthened monsoon supported by tectonics. Aggradation and associated incision in the Himalayan river valleys may be controlled by the underlying geological structures and sufficient sediment discharge (Hancock and Anderson, 2002; Bookhagen et al., 2005; Bridgland and Westaway, 2007; Juyal et al., 2010). However, attention should be paid to fluvial aggradation and incision near major geological structures to understand river dynamics and long-term vertical tectonic uplift.

The central Kumaun Himalayan region has been hit by large to moderate earthquakes (Valdiya, 1984). During the last few decades the epicenters of these earthquakes were mostly restricted to the central sector of the Himalayan region (Paul et al., 2010; Pathak et al., 2013; Fig. 1). The latest is the Chamoli earthquake (Mw 6.3) of 28 March 1999, which occurred in the vicinity of MCT (Kayal, 1996, 2001). This region

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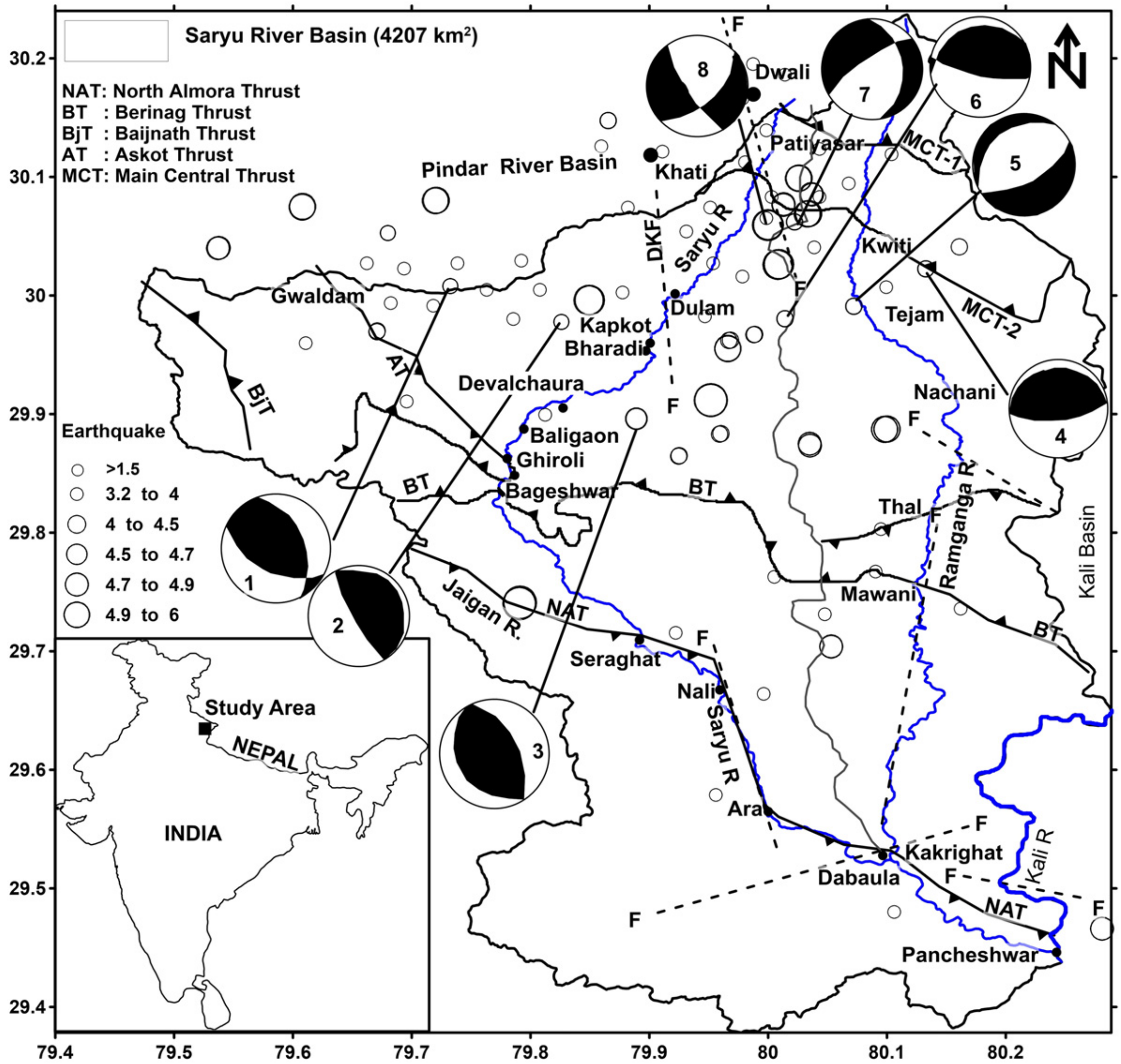

Fig. 1. Location and drainage map of the study area (~4207 km^2). Earthquake epicenters are plotted by different sizes of circles (source: earthquake catalogue of IMD, location of focal mechanism after Mahesh et al., 2015).

absorbs about 30% of the convergence (Molnar and Tapponnier, 1975) with an average rate of 17.7 ± 2 mm/year (Molnar, 1990). Some studies pertain to drainage basin analyses of the Himalayan hinterland (Seeber and Gornitz, 1983; Gupta, 1997; Joshi et al., 2007; Kothyari and Pant, 2008; Phartiyal and Kothyari, 2011; Kothyari, 2014) and the frontal part of the Himalaya (Malik and Mohanty, 2007; Malik et al., 2014; Luirei et al., 2015).

The aim of the present investigation along the Saryu River is to explain the timing of fluvial aggradation and incision in response to vertical tectonic forcing during the Quaternary and Holocene. The Saryu River, a major tributary of the Kali River, has a basin area of 4027 km^2 in the central Kumaun Himalayan region. The fluvial terraces at nine locations along the 135-km section of the Saryu River between Dulam and Dabaula (Fig. 1) were studied to understand the geomorphic development within the zone of major structural discontinuities. These sites are located in different tectonic domains that were subjected to differential uplift during the Quaternary and Holocene. To achieve the above objectives, the geomorphology and terrace sedimentology were studied and supported by optical dating. The areas of anomalous uplift/incision were identified using conventional morphometric techniques.

2. Geological background

The Saryu River flowing through tectonically active terrain drains through the Himalayan thrust belts (Valdiya, 1980). These thrusts are southward younging, with the Himalayan Frontal Thrust (HFT) being the youngest (Nakata, 1972; Thakur, 2004; Kothyari, 2014). In the upper and middle reaches, the Saryu River flows through the HHC and the LH metasedimentaries (Valdiya, 1980; Fig. 2). The HHC is separated from the Lesser Himalayan crystalline by the Vaikrita Thrust (MCT-1), whereas the Lesser Himalayan crystalline are separated from the metasedimentaries of the Inner Lesser Himalaya by the Munsiyari Thrust (MCT-2; Valdiya, 1980). However, toward the lower reaches the river flows through the synclinally folded Almora Nappe, which represents a large thrust sheet disconnected from its root zone (Valdiya, 1980). The synclinally folded low- to medium-grade metamorphic rocks of the Almora Nappe rest on the LH metasedimentary sequence along a structural discontinuity (Valdiya, 1980; Fig. 2). The Almora Nappe is bounded by the North Almora Thrust (NAT) and South Almora Thrust (SAT). In the NAT zone it comprises the Saryu Formation of Almora Group, slates and quartzites of the Rautgara Formation, quartzite with metabasics