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Formation of paleovalleys in the Central Himalaya during valley aggradation

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ABSTRACT

The formation of paleovalleys in mountainous regions is considered to result from extreme events such as landslides and glacial or landslide lake outburst floods. According to IPCC (2012) the extreme events are rarest of the rare weather/climatic events when the climate/weather variable is significantly above or below the defined threshold value. The present study suggests that paleovalleys can also form during years long periods of valley aggradation. A series of paleovalleys thus formed runs parallel to the present river course. In this study, we suggest that paleovalleys in the Alaknanda valley of the Central Himalaya have formed in two ways: 1) major valley aggradation and 2) local events of landsliding and lake breaching. Most of the paleovalleys in the Alaknanda valley formed during a major valley aggradation phase (between 15 and 8 ka). Paleovalleys formed due to local landsliding also formed around 8 ka. Local landslides were triggered due to high rainfall in lower valley reaches during unstable climatic conditions. Therefore, the formation of paleovalleys both by regional and local mode within 15–8 ka indicates that the valley was receiving excess sediment from upper catchment as well as from lower reaches during this period. This phase of excess sediment supply and valley aggradation coincides well with post glacial climatic amelioration. Therefore the study underlines the role of climate in the time scales of 10^3 years in shaping the landscape of an active mountain like the Himalaya. The role of other landscape changing agencies such as tectonics and erosion is not accounted in the present study.

1. Introduction

First generation sequence stratigraphy model suggests that the valley aggradation and degradation is directly related to its base level change (Wilgus et al., 1988). Paleovalleys represent abandoned or paleo river courses which are important for understanding both first generation sequence stratigraphy in large alluvial tracts (Boyd et al., 1989) and the geomorphic evolution of mountainous regions (Ouimet et al., 2008). The formation of paleovalleys in the Himalaya are thought to form as a result of increased precipitation conditions, triggering of landslides and enhancing sediment in the river system (Pratt et al., 2002). Paleovalleys are generally associated with epigenetic gorges. Epigenetic gorges are formed when the river incises bedrock during lateral shifts of its course in response to river blockage or aggradation episodes (Ouimet et al., 2008). This process results in the formation of a preserved valley adjacent to an epigenetic gorge filled with sediments. Sedimentological and chronological analyses of these sediment fills, thus, bear the potential to unravel the climate-tectonic causes of channel reorganization. According to Korup et al. (2006) the geomorphic evolution of high gradient fluvial system on the 10–10^4 y timescale is controlled by large scale landslides that block the river channel and eventually give rise to “bypass gorges” (paleovalleys). The understanding of such features is very limited for the Himalayan fluvial system and published examples from Nepal imply local (landslide) and single catastrophic (lake breaching) events as overriding causes of their formation (Pratt et al., 2002; Pratt-Sitaula et al., 2007). For example, in the Marsyandi River of Nepal, the process of forming an epigenetic gorge incised ~70 m of bedrock at a rate of 13 mm/yr. This gorge formation and river shifting was attributed to a large landslide (Pratt-Sitaula et al., 2007). Therefore, channel reorganization that may be in response to landslides and/or rapid aggradation phases

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may result in some of the fastest rates of observed bedrock erosion and landscape evolution, but these incision rates are not necessarily equivalent to rates of rock uplift (Pratt et al., 2002; Ouimet et al., 2008).

Therefore, paleovalleys are also important for understanding: (i) the geomorphic evolution of mountain river systems, (ii) the phases and hot spots of high sediment input and (iii) potential changes in channel network vis-à-vis climate and tectonics of the river basin. Paleovalleys formed in a sediment transport zone are also crucial for understanding sediment preservation, which in turn helps to understand the source to sink sediment relations (Blum et al., 2013). In the present study, a series of exceptionally preserved paleovalleys has been reported from the Alaknanda River sediment transportation zone in the Lesser Himalaya (Fig. 1A). In the Higher Himalaya, the Alaknanda River course is confined to a gorge due to relatively higher uplift rates, which presumably does not allow sufficient residence time or accommodation space for widespread sediment deposition. For this reason, all paleovalleys are confined within the ~80 km stretch of the Lesser Himalayas, and are less expected to be found in the Higher Himalaya. Present study on these paleovalleys suggests that rapid sedimentation in the valley occurred during climatic amelioration phases forming paleovalleys and river terraces simultaneously. To support this, we present data on the geomorphic configuration, sedimentological character, sediment source, flow velocity and chronology.

2. Study area

2.1. Geological setting

The study area is located in the Alaknanda River valley, of the Central Himalaya. The Alaknanda River is a glacier and monsoon-fed river. The catchment of the Alaknanda River lies upstream of the town of Srinagar in the Tethys Himalaya, the Higher Himalaya (HH) and part of the Lesser Himalaya (LH), which are separated from each other by major tectonic units, namely the Trans Himadri Fault (THF) and Main Central Thrust (MCT). The major lithologies of the catchment are: shale, sandstone, fossiliferous limestone of Tethys Himalaya, schist, gneiss, and quartzite of Higher Himalaya and quartzite, meta-sedimentaries, sandstone, shale, phyllite and metabasic dykes of Lesser Himalaya (Valdiya, 1980). Most of the paleovalleys identified in this study are present near Srinagar (5 out of 7) (Fig. 1A), where Precambrian phyllite is the major lithology. The area around Srinagar is traversed by one regional fault known as Tons Thrust (TT) (Ahmad et al., 2000), also called the Srinagar Thrust (Valdiya, 1980) or North Almora Thrust (NAT; Kumar and Agarwal, 1975; Srivastava and Ahmed, 1979), and two local faults, the Kaliasaur Fault and Kirtinagar Fault (Fig. 1A). The Kirtinagar Fault is inferred from lineaments viewed in aerial photography on a local scale (Sati et al., 2007) (Fig. 2A, B).

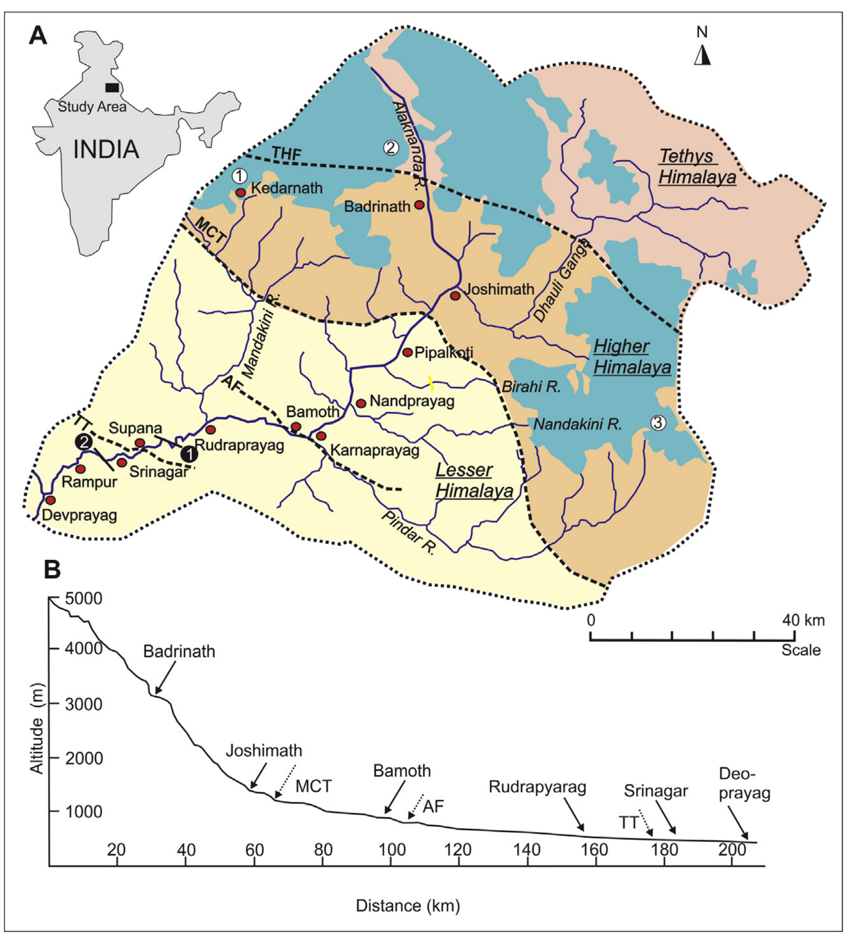

Fig. 1. (A) Map of Alaknanda River catchment showing major locations and regional faults along its course. Present study area around Tons Thrust (named as TT in the map), though paleovalleys at Rudraprayag and Bamoth are also described. Black solid lines across the Alaknanda River represent two local faults: (1) the Kaliasaur Fault and (2) the Kirtinagar Fault. Catchment glaciers namely Chorabari glacier (Mehta et al., 2012), Satopanth glacier (Nainwal et al., 2007) and Pinadari glacier (Bali et al., 2013) are marked as 1, 2 and 3 respectively. The bar across Birahi River is location of source of 1894 and 1970 floods in the valley. (B) Longitudinal profile of Alaknanda River (after Tyagi et al., 2009). Note the change in gradient after MCT particularly at Srinagar.