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Active Uplift, Surface Relief and Mass Redistribution Drive Drainage Growth

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Abstract

Continued convergence of the Indian and Eurasian plates have causes active uplift, development of surface relief and redistribution of mass that drive drainage growth and reorganization. Investigations of drainage basin morphology and drainage network morphometry have been the most insightful into the mountain building and relief development processes. Present investigations reveal that two modes of drainage basin/network growth exist. The 'mouthward growth' is more prevalent and dominant mode within larger basins. In contrast, the head-ward growth mode is restricted spatially to very small basins and to very narrow zones.

Introduction

The Himalayan mountain belt formed under the influence of huge compressive forces of plate tectonic origin. It has given rise to an ensemble of geological structures (Figure 1). Most of these structures, eg. thrust faults and folds, tend to absorb part of this compression and result in crustal thickening manifested by topographic build-up. As the topography builds up, surface relief tends to increase and interact with the surface processes, mainly drainage system. Evolution and growth of drainage are part of the whole process. Drainage basins are spread over different spatial scales and have been used to gauge subtle uplifts along small active faults traces and also along large spreading fault-related folds (ridges) etc. Therefore, drainage analysis has become the most integral part of active tectonic studies and has been the most insightful one as well. In this study we look into the drivers of drainage growth in an actively uplifting area. At the same time we also investigate the mode by which drainage basins grow over time. In the same context, we investigate the growth of drainage basins and its relationship with the surface relief.

Study area

The Sub-Himalayan zone is the outermost southern litho-tectonic unit of the Himalayan orogen (Figure 2). It is a terrain of low lying hills composed mainly of Siwalik rocks that are thrusted/uplifted in the hanging wall of the Himalayan Frontal Thrust (HFT). The Siwalik sediments were deposited since the Miocene times and the deformation post-dates that. Recent investigations demonstrate that these hills actively absorb a part of the India-Asia convergence by active faulting/thrusting and fault-related folding. The average uplift rates in NW India, deduced through dating of terrace materials, are about 4-6 mm/yr (Kumar et al., 2006). This active uplift constantly builds the topography and renders itself to the surface processes. Surface processes constantly erode the uplifting landscape through evolution and growth of drainage network and basins. Therefore, these hills are best suited to investigate drainage network evolution and growth of drainage basins.

Results

Our investigations reveal that in areas where surface relief tends to vary gradually, the drainage basins evolve by elongation and coalescence of adjoining drainage lines, downstream. In this way, basins tend to grow both in length and width, often maintaining their elongation ratios (Singh, 2008). This mode is known as 'mouth-ward growth'. In contrast, where the gradual surface relief is disrupted by abrupt rise of topographic ridges, mass is constantly added within the drainage basin area. This disrupts and/or limits the 'mouth-ward growth' of drainage basins. In order to maintain the elongation ratio, coalescence with adjoining basins is therefore not possible. However, the local increase in surface slope along these ridges motivates the drainage basins to defy the usual mode i.e. 'mouth-ward growth' and look for alternative modes i.e. grow in the head-ward direction. Here the streams tend take advantage of increased slope and begin to grow head-ward. This mode is known as 'head-ward growth'.

Conclusions

Our investigations demonstrate that the two modes exist in actively uplifting areas and usually operate in tandem. However, spatially the mouth-ward growth is more prevalent and dominant mode within larger basins. In contrast, the head-ward growth mode is restricted spatially to very small basins and to very narrow zones. In conclusion, both these modes of drainage basin growth, together, play a dominant role in redistribution of mass in actively uplifting areas to adjoining depo-centres through drainage basin reorganization.

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Figure 1: a) Himalayan orogen showing the major thrust faults (MCT: Main Central Thrust; MBT: Main Boundary Thrust; HFT: Himalayan Frontal Thrust) and meizoseismals zones of the major historical earthquakes (black dotted lines with dates). White arrows indicate the India – Asia convergence (DeMets *et al.*, 1990). The box represents the investigated area also shown in the inset map representing the broader geodynamic setting. (b) Generalized geological section across the Himalaya. Legend: 1) Indian crust; 2) Precambrian crystallines; 3) Upper Precambrian, Palaeozoic and younger sediments; 4) Tertiary-Quaternary molassic sediments; 5) Quaternary sediments. Modified from Powers *et al.* (1998).

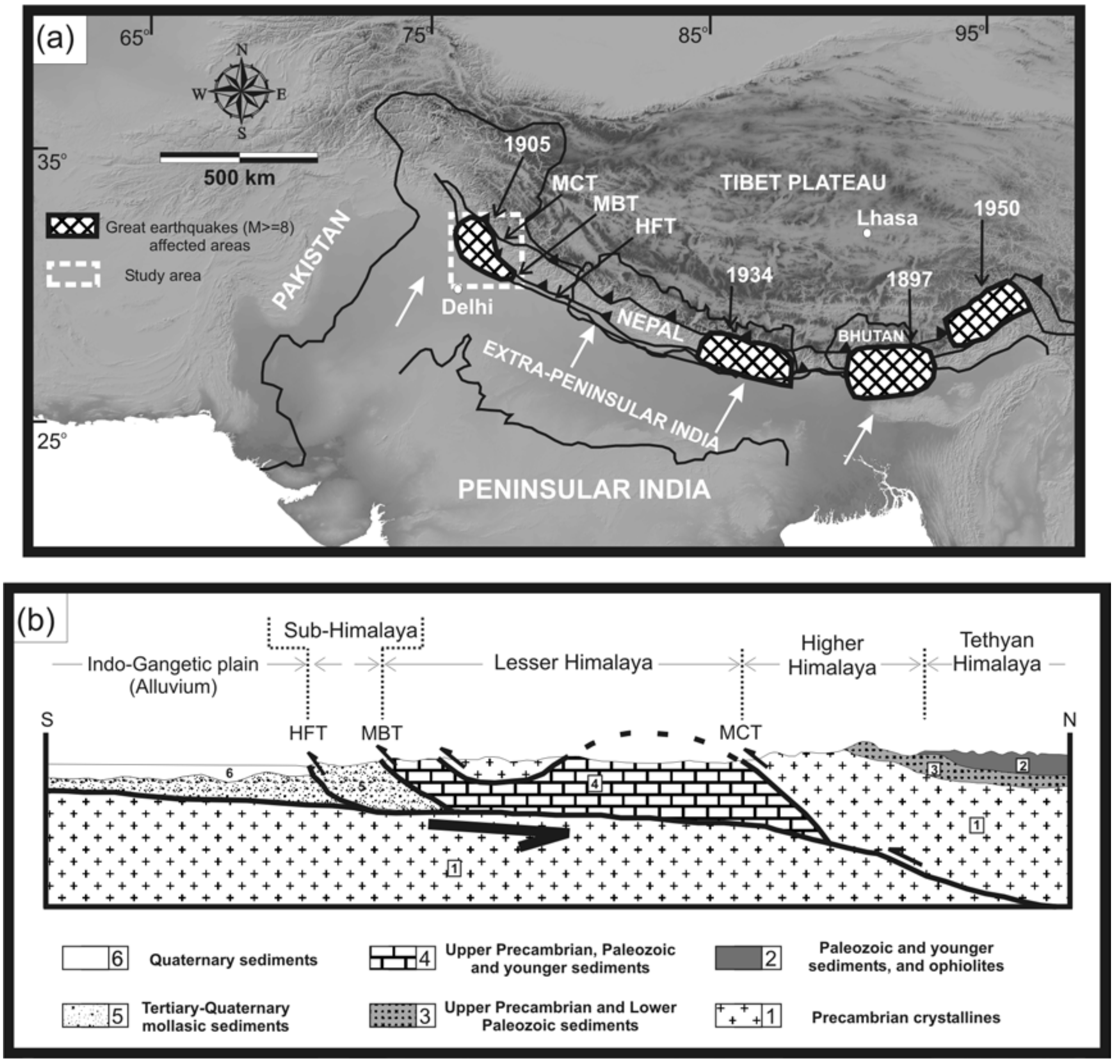

Figure 2: Topography of NW Himalaya, India. The Sub-Himalayan zone bordered by HFT and MBT.