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Quaternary of Himalaya

Pradeep Srivastava [a], Vimal Singh [b]

[a] Wadia Institute of Himalayan Geology, 33 GMS Road, Dehradun 248001, India
[b] Department of Geology, University of Delhi, Delhi 110007, India

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ABSTRACT

Tectonically active Himalayan mountains evolves via feedbacks from deep earth and surface processes; the complex interaction of various processes results into the landscape which is dynamic both at longer and shorter time scales. The extreme hydrological events that possibly ride over a long term climate cycle bring the changes in the landscape that impact human societies more closely. These events in the Himalaya frequently cause huge damage to economy and human lives. The geologist community under the umbrella of Himalaya-Karakorum-Tibet (HKT) workshop in its 30th edition convened a special session and deliberated on the subject. This special issue "Quaternary of Himalaya" is an outcome of papers presented and discussion held during this session; it consists of 18 papers in three sub-themes (i) Extreme Events in Himalaya (ii) Paleoglaciation in Himalaya and (iii) Expressions of climate and neotectonics in Himalaya.

1. Introduction

The Himalaya with a mountain front of approximately 2500 km, area of nearly 6,00,000 km^2, peaks reaching above 8 km, convergence rate varying 20-8mm/yr along the length, and spatially variable climatic regimes across and along its strike forms a perfect site to study the interplay of tectonics, climate, and erosion. Interaction of these processes have been investigated at several temporal scales in past (e.g., Lavé and Avouac, 2001; Hodges et al., 2004; Sharma and Owen, 1996; Ray and Srivastava, 2010; Singh and Tandon, 2008; Sinclair et al., 2016). The large scale geomorphology of this mountain chain also decides the regional distribution of precipitation (Bookhagen and Burbank, 2006). However, the Quaternary period, during which dramatic climatic changes have been observed, remains the most challenging and important from society point of view. Today mankind is facing an important threat in terms of Global warming; in past one century most of the glaciers across the globe have shown a retreating trend and the Himalaya are no exception. The Himalaya has extensive glacier cover (which occupies third position in world in terms of volume of ice) which are now threatened by the present climatic changes (e.g., Bolch et al., 2012). Around 800 million people depend upon the rivers originating in these mountain ranges (Webster et al., 2011) to which these glaciers contribute significantly (Wulf et al., 2016). The modern climate of the Indian subcontinent itself came into existence due to the uplift of Himalayan mountain belt. Since the rivers originating in the Himalaya receive significant contribution from the melt water of the glaciers, retreat of glaciers mean noticeable impact on the river discharges. Also, retreating glaciers lead to the formation of melt water lakes at higher elevations that pose threat of catastrophic flood surges down stream (Glacial lake outburst floods or GLOFs) (ICIMOD, 2011). Such hazards pose significant threat to the people living downstream (e.g., Richardson and Reynolds, 2000; ICIMOD, 2011). Apart from climatic and hydrologic hazards, the active mountain belts are always under the risk of earthquakes.

Hundreds of thousands of people have lost their life in hazards (e.g., 2005 Kashmir earthquake, 2015 Gorkha earthquake, 2010 flash flood in Ladakh, 2013 Kedarnath event etc.) in the Himalaya, within past one decade (e.g. Juyal, 2010; Hobley et al., 2012; Singh, 2014; Sundriyal et al., 2015; Ziegler et al., 2014, 2016; Sati and Gahalaut, 2013). This has necessitated need to understand the functioning of geomorphic processes at various temporal and spatial scale in the Himalaya and document the potential hazards and their underlying controls.

2. Rationale for special sessions on (a) Quaternary evolution of HKT and climate-tectonic perturbations and (b) Extreme events in Himalaya

The study of geomorphic processes are very few and have been largely ignored in the Himalaya. To minimize the loss - both lives and infrastructure - that occurs every year in the Himalaya due to natural hazards, it is important to understand the dynamics of the geomorphic processes at different timescales. It requires development of high resolution climate record, investigation of past glacial fluctuations in the Himalaya, understanding of paleoflood records, and mapping of active structures.

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HKT (Himalaya Karakorum Tibet) workshop is an international platform that brings together global earth science community working on different aspects of the Himalaya annually. The 30th edition of HKT was held at Wadia Institute of Himalayan Geology on 6-8 October 2015 and it hosted special sessions on (i) the Quaternary evolution of HKT and climate-tectonic perturbations, and (ii) Extreme events in Himalaya. The deliberations in these sessions focused on (A) long term landscape evolution of Himalaya vis-à-vis climate and tectonic perturbations (B) paleoglaciation, and (C) extreme rainfall events; we invited selected papers for publication in this special issue. It should be noted that on one hand, Quaternary studies provide magnitude and frequency of prehistoric extreme events, and the underlying climatic and environmental conditions through the investigation of the landforms and sediment, whereas on the other hand, the natural hazard research help us to reconstruct large magnitude events that have not occurred in the historic period (Korup and Clague, 2009). Thus, the two special sessions complimented each other and helped raise awareness among the young geoscience community regarding the developments in these areas.

The contributions in this special issue does not essentially cover the entire temporal (Quaternary in this case) and spatial scale of the Himalaya but instead represents some important case studies that adds to the Quaternary and hazards related database of the Himalaya, which is essential for creating a reliable record that could later play its part in predicting terrains response to various tectonic and climatic forcing.

3. Outcome of the sessions and special issue

3.1. Extreme events

Indian Summer monsoon has profound effect on the surface processes in the Himalaya (Bookhagen and Burbank, 2006). The precipitation in the Himalaya has varied over millennial, centennial and decadal scale which is evident from the landscape imprints and varying sedimentation rates (e.g., Bookhagen and Burbank, 2006). The monsoonal variation occurs both across and along the length of the Himalaya, with the eastern Himalaya receiving maximum rainfall and northwestern Himalaya receiving relatively less rainfall (Bookhagen and Burbank, 2006). It has been demonstrated that during enhanced monsoonal circulation deeply incised valleys oriented parallel to the Himalayan orogen provides pathways to the moisture laden wind to be carried in the rain shadow arid regions and cause precipitation which in turn result in enhanced erosion (Bookhagen and Burbank, 2006). However, Sharma et al., (2017–this issue) demonstrate through the investigation of Oxygen, Strontium isotope and Deuterium characteristics of the Indus River water system that ~70% of its water budget is imparted by SW monsoon driven precipitation; this implies that even during normal monsoon years it is SW monsoon which dictates hydrology of the Ladakh Himalaya.

The record of past floods for the Alaknanda-Mandakini Rivers (Garhwal Himalaya), the Indus River (Ladakh, NW Himalaya) and the Brahmaputra River (NE Himalaya) indicate that (i) The Alaknanda-Mandakini Rivers experienced large floods during the wet and warm Medieval Climate Anomaly (MCA); (ii) the Indus River experienced at least 14 large floods during the Holocene climatic optimum, when flood discharges were likely an order of magnitude higher than those of modern floods; and (iii) the Brahmaputra River experienced a megaflood between 8 and 6 ka. Magnetic susceptibility of flood sediments indicates that 10 out of 14 floods on the Indus River originated in the catchments draining the Ladakh Batholith, indicating the potential role of glacial lake outbursts (GLOFs) and/or landslide lake outbursts (LLOFs) in compounding flood magnitudes. Collectively, this new data indicate that floods in the Himalaya largely occur during warm and wet climatic phases and implies that the Indian Summer Monsoon front may have penetrated into the drier Ladakh Himalaya during the Holocene climatic optimum (Srivastava et al.- 2017–this issue).

June 2013 witnessed the largest flood of millennium in Garhwal Himalaya (Wasson et al., 2013). Agnihotri et al. (2017–this issue) present the plausible forcing factors responsible for such an extreme event. Investigation of around hundred year rainfall and air temperature data shows an increasing upward trend in June–July rainfall and a significant increase in the pre monsoon air temperature since 1997. The analysis also points that the monsoonal rainfall (June, July, August, and September; JJAS) co-varying with interannual variability in Eurasian snow cover (ESC) extent during the month of March. This work (Agnihotri et al., 2017–this issue) contemplated enhancing tendency of anomalous high rainfall events during negative phases of Arctic Oscillation.

Interaction of extreme rainfall and the high relief Mountains is research field that interests planers, policy makers and the society at large. Extreme events destabilize the slopes, create landslides and block, aggrade and incise the rivers anomalously (e.g., Devrani et al., 2015). Poonam et al. (2017–this issue) studied pre-and-post event imagery data of the Mandakini valley and identified landslide-prone zones in the region. The study also shows that in terms geomorphic change, and loss of life and economy, June 2013 was the most disastrous event in several centuries in the region. In another study Mehta et al., (2017–this issue) quantify the volume of sediment deposited in the low gradient headstream reaches and volume of sediment evacuated from the high gradient reaches of the Mandakini river during the June 2013 Kedarnath event in the Alaknanda basin of the NW Himalaya. This study also shows that the moraine-dammed Chorabari Lake which was breached during June 2013 event, released ~ 6.1×10^5 m^3 of water with an average rate of ~ 1429 m^3/s (discharge of lake).

During September 2014 an unusual rainfall event occurred in western Himalaya when ~488.2 mm rainfall occurred in 24 h over a wide spread region in Jammu and Kashmir. This Extreme rainfall event triggered large number of landslides and flash floods in the region that buried several villages. A spatio-temporal study on landslides vis-à-vis rainfall events indicated that orography of the western Himalaya played important role in landslide and flash flood distribution where most event occurred on the windward side (Kumar et al. 2017b–this issue). This study (Kumar et al. 2017b–this issue) presents details of major landslides caused by the September 2014 event and emphasises on the need of a dense network of hydro-metrological stations in the western Himalayan region.

Inter-governmental Pannel on Climate Change report (IPCC, 2012) indicates that frequency of extreme hydrological events, in the scenario of global warming, over Himalaya is likely to increase and thus it demands much deeper understanding of (i) the frequency of extreme events, (ii) interaction of these events with fragile Himalayan landscape, and (iii) the predictability of high risk zones in the Himalaya. It also requires a detailed documentation of these extreme events that rather lacks in Indian scenario, and with the papers presented in here and published earlier, the 2013 event becomes the most documented extreme hydrologic event in the Himalaya.

3.2. Paleoglaciation in Himalaya

Himalayan glaciers are known to be sensitive to environmental temperature, strength of SW and Westerlies driven monsoon. Large number of studies on the modern glacial fluctuations suggest anthropogenically mediated global warming to have played overwhelming role in the rapid depletion of the glaciers. The evaluation of glaciers in the Chandra basin (located in the Himalaya of Himachal Pradesh) using a multi-parametric approach shows that Sakchum and Bara Shigri glaciers are retreating at a rate of 11 and 15 $m\ a^{-1}$ respectively, while Chhota Shigri Glacier is retreating at relatively slower rate (4 $m\ a^{-1}$) (Garg et al., 2017–this issue). It is also suggested that mutual variation of glacier parameters together with nano-climatic factors exercise a great control on glacier response. Similarly, a retreat of ~ 480 - 2000 m is reported for the