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Tectono-geomorphic study of the Karewa Basin of Kashmir Valley

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ABSTRACT

The Karewa Basin nestled between the Pir Panjal Range and the Great Himalayan Range, in Northwest India, has been studied to understand its tectono-geomorphic evolution on the basis of geomorphic indices and morphotectonic parameters supported by the field evidences. Satellite data, topographic maps and digital elevation model (DEM) were used to extract various parameters at various spatial scales. Four watersheds, representative of the entire Karewa Basin, were chosen for detailed studies on the basis of the researchable evidence of the complete sequence of the stratigraphic record and the preservation of geomorphic landscapes. The integrated analysis of the geomorphic and morphometric data provides evidence of the relative variations in the tectonic activity among the watersheds. Geomorphic indices suggest a relatively high degree of tectonic activity along the Pir Panjal side of the Karewa Basin. This variation in the relative degree of tectonic activity is consistent with the field evidence, fault/lineament locations and the landscape geometry of the Karewa Basin. Based on the results from this study, it is suggested that Late Quaternary climate changes, tectonic uplift and erosion of the Pir Panjal Range and changing geometry of the Karewa Lake have played a key role in the evolution of the geomorphic landscape of the Kashmir Valley.

1. Introduction

Tectonic geomorphology describes the relationship between topography and geomorphic features generated by tectonic and erosion processes (Burbank and Anderson, 2001). The most common goal of tectonic geomorphology is to use Quaternary landforms to infer the nature, patterns, rates, and history of near-surface tectonic processes. However, a major conundrum being faced is how to extract tectonic information from the existing topography (Wang et al., 2009). Currently, digital elevation models (DEMs) are the main source for the extraction of different geomorphological and topographic features depending on altitude and its spatial distribution and variation (Felicisimo, 1994; Romshoo et al., 2012). DEMs and remotely sensed satellite imagery are widely used for morpho-tectonic analysis and for studying the role of surface processes in landscape evolution (Duncan et al., 1998; Bishop et al., 2001, 2003; Kaab et al., 2002; Kamp et al., 2005; Seong et al., 2009). Availability of the High-resolution global digital elevation models (DEMs), as well as rapid advancement in the field of computing technology, provides new opportunities in quantitative analysis in morphotectonics (Cheng et al., 2004). Additionally, the advancement in geomatics provides opportunities to enhance, manipulate, and integrate digital remotely-sensed data with several types of geospatial and non-spatial information like topography, drainage, geology, and lithostratigraphy that in turn appreciably improves the interpretation of the extracted information related to geomorphologic, tectonic and geological processes (Bishop et al., 2003).

The Kashmir Valley provides an opportune geographical setting to systematically study landforms produced or modified by active tectonic processes and to deduce spatial variations of Quaternary deformation and active tectonics in the region. The valley exhibits great internal variation in the relief and continuity of mountain fronts. The relatively young and active tectonic features are supposed to be readily preserved in the present topography. Some workers have already documented tectonics, active surface faulting and historical seismicity in this Himalayan basin (Ganju and Khar, 1984; Ahmad et al., 2013; Bilham and Bali, 2013; Dar et al., 2013a, 2013b; Schiffman et al., 2013; Shah, 2013). However, none of these studies have used a systematic analysis of landforms to define patterns of the relative rates of tectonic activity and the consequent landscape evolution in the region. The geomorphologic studies of this region are revealing as the signatures of various processes related to the tectono-geomorphic evolution are clearly evident and are well preserved. Geomorphic indices are widely used in the evaluation of active tectonics because they provide rapid insight concerning specific areas within a region which are

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undergoing adjustment to relatively rapid, and even slow rates of active tectonics (Keller, 1986; Ramírez-Herrera, 1998; Ahmad et al., 2013; Bhat et al., 2013). Quantitative measurements and the calculation of geomorphic indices have been previously tested as valuable tools in various tectonically active areas around the world (Bull and McFadden, 1977; Rockwell et al., 1984; Keller, 1986; Silva et al., 2003; Zovoili et al., 2004; Dehbozorgi et al., 2010). Further, the analysis of drainage pattern can provide important clues towards understanding the Quaternary tectonic activity of any region at both regional and local scales (Goldsworthy and Jackson, 2000). This paper reports the results of a geomorphic study based on geomorphic indices and field based geomorphic evidences. It is hoped that the information generated in this study shall help to improve the understanding and interpretation of the tectono-geomorphic evolution of the Karewa Basin of Kashmir Valley.

2. Geotectonic setup of the study area

The Kashmir Valley occupies an oval shaped basin between Pir Panjal Range in the southwest and the Great Himalayan Range of north Kashmir in the northeast. Wadia (1931) described the thrust-bounded basin, as 'Kashmir Nappe Zone' comprising the rocks of Paleozoic–Mesozoic marine sediments, with Precambrian basement thrusted along a regional tectonic plane viz., Panjal Thrust over the younger rocks of the autochthones belt. The 'Kashmir Nappe' forms two major axes of orogenic upheaval along the Pir-Panjal and the Great Himalayan Ranges (Fig. 1a). The structural disposition and the geographical location of the Kashmir Nappe is the resultant effect of the Great Himalayan Orogeny. Southwest of the Pir Panjal Range, there is a complex pattern of faulting with the superposition of several thrusts including from northeast to southwest, the MCT/Panjal, MBT/Murree, Riasi, and Kotli thrusts (Thakur et al., 2010). These faults are considered to be imbrications of the northward rooted basal décollement known as Main Himalayan Thrust (Schelling and Arita, 1991; Brown et al., 1996; DeCelles et al., 2001). The southern-most deformation front of Kashmir Himalaya is defined by an active fold belt known as Suring-Mustgarh anticline that extends from river Beas in southeast to Jhelum in the northwest rather than by an emergent thrust. Burbank and Johnson (1982) revealed that Kashmir Valley is experiencing uplift along its southwestern margin. The valley possesses almost complete stratigraphic record of rocks of all ages ranging from Archean to Recent (Fig. 1b). The valley is filled with Plio-Pleistocene fluvio-glacio-lacustrine sediments up to 1300 m thick which are generally known as the "Karewa" or the "Karewa Group" (De Terra and Paterson, 1939; Bhatt and Chatterji, 1976; Bhatt, 1976, 1982; Kotlia et al., 1982; Kotlia, 1985). These sediments preserve the record of past four million years in which the sedimentation is controlled by fluvial activity; climate change and the Pir Panjal uplift (Bhatt, 1982; Gardner, 1989). The loessic sediments of Dilpur Formation occur as blanket sediments to the Karewa Group. These sediments are distributed throughout the Kashmir Valley covering an area of about 500 km^2, representing the present day landscape of the valley.

3. Materials and methods

The study area, Karewa Basin of Kashmir Valley, has been divided into twenty-four watersheds. However, only four watersheds, three on the Pir Panjal side (Romushi, Dudhganga and Ningli Watersheds) and one on the Himalayan side (Lidder Watershed) of the Karewa Basin have been selected for the detailed morphotectonic and geomorphic studies (Fig. 2). These watersheds were selected on the basis of their representativeness of the entire Karewa Basin, evidence and completeness of the stratigraphic record and the preserved record of the geomorphic landscapes. Using watershed as a basic unit in morphotectonic analysis is the most logical choice because all hydrologic and tectono-geomorphic processes occur within the watershed (Romshoo et al., 2012). Moreover, the development of a landscape is synonymous to the development of individual drainage basins of which it is composed (Singh, 1980). Thus, the morphometric characteristics at the watershed scale may contain some important information regarding its formation and development. In addition, obtaining quantitative geomorphic indices and morphotectonic parameters at watershed scale will allow more direct and meaningful inference of the tectono-geomorphic processes for the Karewa Basin. The various morphometric parameters used in this study are shown in (Table 1). The measurements of these parameters were calculated from topographic maps, ASTER DEM of 30 m resolution and Landsat TM imagery. Longitudinal river profiles were plotted at 10 times vertical exaggeration in order to isolate anomalous patterns in channel profiles attributable to tectonic activity.

4. Results and discussion

The analyses of mountain fronts and drainage systems provide reliable information on the long-term evolution of the landscape. Drainage basin development is mostly effected by the tectonic activity that can be described both qualitatively and quantitatively by studying the patterns and geometries of the drainage network and the configuration of landforms. The various studies on morphometric analysis of drainage basins indicate that morphometric and morpho-tectonic parameters and indices like drainage density, bifurcation ratio (Rb), circularity ratio, mountain front sinuosity (S_{mf}), drainage basin asymmetry factor (AF), and Stream Length-Gradient Index (SL) in combination with river profile analysis greatly help in the identification of the overall terrain characteristics of the basin (Miller, 1953; Hack, 1973; Bull and McFadden, 1977; Singh, 1980; Keller and Pinter, 2002; Dar et al., 2013a, 2013b). The morphometric indices are influenced by factors such as tectonics, lithology, climate and vegetation of the study area.

4.1. Drainage density (D)

Drainage density is an important parameter in knowing the level of dissection of a landscape due to the action of the fluvial systems and is a good measure of the fineness of the basin topography. Rock types, vegetation cover, amount of slope are some of the parameters, which influence drainage density. The drainage density values for the studied watersheds range from 1.39 (Ningli) to 2.35 (Lidder) indicating moderate to high drainage density (Table 1). The Pir Panjal side of the Kashmir Valley, with appreciable Karewa deposits, descends through a long gentle slope towards the valley floor as opposed to the short and moderately steep slopes on the Himalayan side. The drainage network is thus most extensive towards the Pir Panjal side, which is characterized by the gently dipping Karewa sediments (Fig. 3). The comparative analysis of the four representative drainage systems indicate that the drainage patterns have undergone varied changes due to the differential tectonic activities on the Pir Panjal and Great Himalayan sides of the Kashmir Valley and is also evident from the clear drainage divides observed in the area. The magnetic polarity studies also suggest that the flow direction of the drainage pattern has changed from northeast at ca. 4.18–1.07 Ma to northwest around <1.07 Ma pointing to the emergence of the River Jhelum (Basavaiah et al., 2010).