Catena 199 (2021) 105103

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

# Late Quaternary tectono-geomorphic forcing *vis-a-vis* topographic evolution of Indus catchment, Ladakh, India

Debarati Nag [a], Binita Phartiyal [a,*], Mallickarjun Joshi [b]

[a] Birbal Sahni Institute of Palaeosciences, 53-University Road, Lucknow 226 007, UP, India
[b] Department of Geology, Banaras Hindu University, Varanasi 221005, UP, India

ARTICLE INFO

*Keywords:*
Ladakh
Indus suture zone
Neotectonics
Geomorphology
Late Quaternary

ABSTRACT

The Indus River valley has frequently reorganized itself to attain geomorphic equilibrium during the Late Quaternary. In this regard, significant advances have been made towards the understanding of the response of landform/ landscape to climate (exogenic) forcings. However, advancements in geomorphic studies on the upper Indus basin focusing on recent tectonics (endogenic) are lacking, thus implementing a partial picture of landscape evolution. This article attempts to synthesize geomorphic indices of active tectonics to understand the prevalence of neotectonic activity in the Ladakh area. A combination of geomorphic field data, morphometric analysis and previously published incision rates, denudation rates, the chronology of landform features and soft-sediment deformation structures are used to suggest the region is undergoing differential tectonic activity. Based on morphometric parameters and landform characteristics, the region is divided into three differentially uplifted morphotectonic segments. The neotectonic activity is inferred to be the response to the thrusting of Indus Molasse over the rigid Ladakh Batholith along with oblique convergence of the Indian plate in the study area. This led to the development of a system of back thrust (Stok Thrust) and cross-cutting minor strike-slip faults. Recurrent tectonic activity largely responding to the differential movement along this system of thrust fault is recorded at 50 ka, 35 ka and 21 ka (Last Glacial Maxima) through lower Greenlandian (~11 ka) to middle Northgrippian (~6 ka), while the climatically induced topographic changes are marked between ~13 and 12 ka.

## 1. Introduction

Indus Suture Zone (ISZ) marks the collisional imprint between the northward moving Indian plate against the Eurasian plate. The development of the Indus basin along the ISZ is characterized by S to SW directed early thrusting followed by the post collision (~50 Ma) vertical tectonics evidenced by abundant normal faulting and marked variations in bed thickness that reflect rapid deepening and consequent infilling of the basin (Bassoulet et al., 1983; Searle et al., 1990). During the late Tertiary, ongoing compression shortened the basin by several kilometers in response to the N to NE directed backthrusting (Searle et al., 1990). In the Quaternary times, the Indus river valley along the ISZ in the Ladakh region shows the development of multiple level terraces, large alluvial fans, landslide-dammed lakes and extensive deformed lake sediments (Phartiyal et al., 2005, 2013, 2015; Clift and Giosan, 2014; Blöthe et al., 2014; Nag and Phartiyal, 2015; Nag et al., 2016; Kumar and Srivastava, 2017). Several studies in the Indus valley attempted to chronologically constrain the preserved sediments in the valley fill to reconstruct the landscape development, climate-tectonic forcings, influence of precipitation induced surface runoff and erosion flux at millennial time scales (Sharma et al., 1998; Sant et al., 2011a, 2011b; Clift and Giosan, 2014; Munack et al., 2014; Blöthe et al., 2014; Mujtaba et al., 2017). The ISZ which is referred to as essentially inactive in terms of tectonics (Dortch et al., 2011a), the formation of these Quaternary deposits is attributed to the increased climate variability, Quaternary glaciations and potentially to wetter monsoon phases (Kumar and Srivastava, 2017, Jonell et al., 2018).

However, this hypothesis seems to be at odds with the recent report of tectonically active Stok thrust that passes through the region (Sinclair et al., 2017; Kumar et al., 2020). Considering the location of the study area on the leeward side of the Indian Summer Monsoon (ISM), Mid Holocene monsoon intensification, meager denudation rates since ~430 ka (Deitsch et al., 2015) and the continued tectonic activity along the Stok thrust since ~45 ka (Sinclair et al., 2017) call for an assessment of the relative contributions of climate driven surface processes *vis a vis* neotectonics in the topographic evolution of the Indus valley. In view of

* Corresponding author.
*E-mail address:* binita_phartiyal@bsip.res.in (B. Phartiyal).

https://doi.org/10.1016/j.catena.2020.105103
Received 18 May 2020; Received in revised form 4 December 2020; Accepted 12 December 2020
Available online 28 December 2020