Catchment-wide erosion rates, glaciation, and topography of the central ladakh Range, India

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Introduction

Researchers have hypothesized that erosional unloading can influence rate and style of tectonic deformation, but this hypothesis remains controversial, and rates of erosion and sediment transfer need to be quantified to help test these models. The central Ladakh Range, located in the Transhimalaya of northern India, is an ideal setting to examine these models because the range has contrasting styles of deformation, unroofing history, and geomorphology on its northern and southern sides. The asymmetric topography and morphology of the Ladakh Range suggests that erosional unloading affects rock uplift on the northern side of the range. In this study, we aim to test this idea by comparing catchment-wide erosion rates, long valley profiles, equilibrium-line altitude's (ELAs), and basin statistics across the central Ladakh Range using ^{10}Be TCN methods, and morphometric analysis.

Previous work

Based on thermochronology data from zircon and apatite (U–Th/He) and apatite fission-track methods (AFT), Kirstein et al. (2006; 2009) argue that the central Ladakh Range has been tectonically tilted southward, which resulted in higher elevations on the northern side of the mountain range during the Late Palaeogene (Fig. 1). Using strath terrace incision rates, Dortch et al. (2011) argue the northern side of the range is actively uplifting at 0.6±0.1 km/Ma. Morphometric analysis of digital elevation models (DEMs) (Jamieson et al., 2004) shows that catchments on the southern side of the central Ladakh Range are significantly shorter, narrower, and have a lower mean elevation than the equivalent catchments on the northern side of the range. Owen et al. (2006) and Dortch et al. (2010) used ^{10}Be TCN dating to show that the most extensive preserved late Pleistocene glacial advances extended ~33 km at ~ 160 ka on the northern side and ~ 18 km during marine isotope stage (MIS)-8 on the southern side of the range. Morphostratigraphic correlation demonstrates that advances on the northern side of the mountain range were twice as extensive as those on the southern side, albeit still restricted to their valleys (Owen et al., 2006; Dortch et al., 2010).

Results

^{10}Be TCN analysis of 13 fluvial sediment samples from active channels in 6 catchments across the Ladakh Range constrains erosion rates for catchments on the northern side of the mountain range to 56±12 – 74±11 m/Ma, while rates for catchments on the southern side are 20±3 – 39±8 m/Ma. Minimum elevation from swath analysis shows that the range divide is shifted to the south by 3.5-11.8 kilometers (Fig. 2). Maximum elevation is unusually uniform and dips toward the southern side of the range. Moreover, maximum elevation and relief are strongly correlated with proximity to the Karakoram Fault. Elevation vs. catchment size statistics show a nearly parallel positive trend of maximum (R^2=0.86) and average (R^2=0.39) elevation increasing to the north side of the range. The ELAs of the 382 contemporary glaciers are remarkably consistent across the region, with an average of 5455±130 m. However, there is a distinct ELA gradient increasing to the north that closely follows the distribution of the highest topography, which suggests that glacier headwall height controls topography (Fig. 2).

The higher erosion rate to the north likely relates to tectonic tilting of the Ladakh Range, active rock uplift on the northern side of the range along the Karakoram Fault, and increased glaciation. The nearly parallel maximum and average elevations across the range suggests that greater erosion on the northern side of the range is not keeping pace with rock uplift. This is confirmed by catchment-wide erosion rates on the northern side of the range that are an order of magnitude slower (60-70 m/Ma) than rock uplift 600 m/Ma (Dortch et al., 2011a). Thus, we preclude the possibility of long-term denudational unloading from having a significant influence on the tectonic tilting of the range. Moreover, because rock uplift is outpacing erosion and maximum topography follows the conditions of the glacial buzzsaw hypothesis, the average elevation must be increasing and will continue to do so until limited by the ELA as long as the northern side of the range remains tectonically active. Therefore, we suggest that the central Ladakh Range is a transient landscape moving toward a state of equilibrium between topography and glaciation.

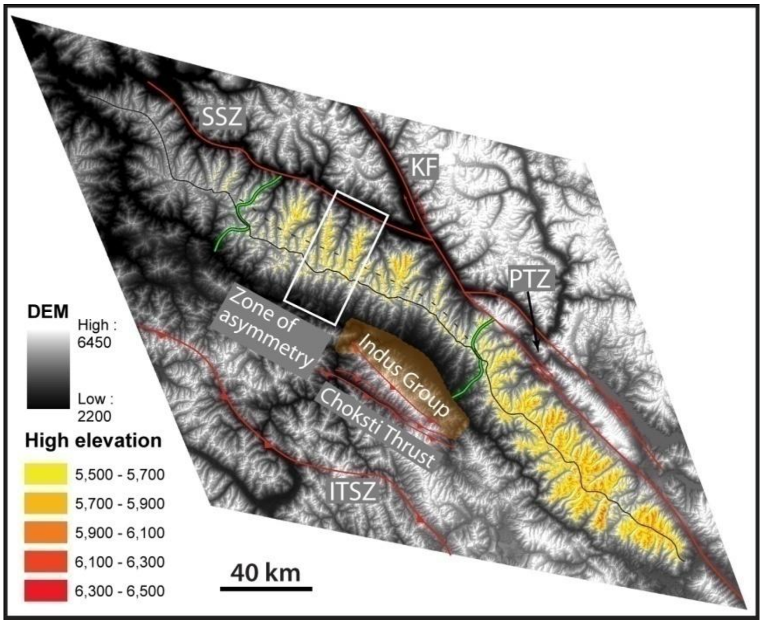

Figure 1. SRTM DEM highlighting the unequal distribution of high elevation across the central Ladakh Range. Topography with elevation > 5,500 m decreases dramatically with distance away from the Karakoram Fault. The asymmetric central Ladakh Range is marked by green lines. White box shows the location of the example swath profile in Figure 2.

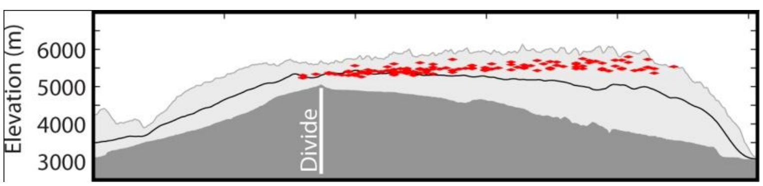

Figure 2. Swath profiles of the central Ladakh Range coded by boxes. Minimum elevation shown in dark gray and maximum elevation marked by medium gray line. Light gray between maximum and minimum elevations is relief. Average elevation marked by black line. Equilibrium-line elevations for contemporary glaciers are marked by red diamonds. Elevation error (± 20 m) and distance error (± 0.25 km) do not extent beyond red diamonds.

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