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Headwall erosion rates from cosmogenic ^{10}Be in supraglacial debris, Chhota Shigri Glacier, Indian Himalaya

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Debris-covered glaciers are widespread within the Himalaya and other steep mountain ranges. They testify to active erosion of ice-free bedrock hillslopes that tower above valley glaciers, sometimes more than 1 km high. It is long known that debris cover significantly reduces surface ablation rates and thereby influences glacial mass balances; but its dynamic evolution along with climatic and topographic changes is poorly studied. Better understanding the coupling of ice-free bedrock hillslopes and glaciers in steep mountains requires means to assess headwall erosion rates. Here, we present headwall erosion rates derived from ^{10}Be concentrations in the ablation-dominated medial moraine of the Chhota Shigri Glacier, Indian Himalaya. We combine our empirical, field-based approach with a numerical model of headwall erosion and glacial debris transport to assess permissible patterns of headwall erosion on the ice-free bedrock hillslopes surrounding the Chhota Shigri Glacier.

Our five samples, each separated by approximately 500 m along the glacier, consist of an amalgamation of $>$1000 surface clasts with grain sizes between $\sim$1 and $\sim$30 mm that were taken from the medial moraine. Our results show that ^{10}Be concentrations increase downglacier from $\sim 3\times10^4$ to $\sim 6\times10^4$ atoms g^{-1}, yielding headwall erosion rates of $\sim$1.3-0.6 mm yr^{-1}. The accumulation of ^{10}Be during debris residence on the ice surface can only account for a small fraction ($<$20%) of the downglacier increase. Other potential explanations include (1) heterogeneous source areas with differences average productions rates, and (2) homogeneous source areas but temporally variable headwall erosion rates.

We use the ^{10}Be-derived headwall erosion rates to define debris supply rates from ice-free bedrock hillslopes in the numerical ice model iSOSIA. Headwall debris that is deposited in the ablation zone of the ice surface becomes englacial, is passively advected with the ice and emerges in the ablation zone where it forms supraglacial debris cover that influences surface melting. Preliminary results show that the model reproduces the actual medial moraine of the Chhota Shogri Glacier quite well.

We conclude that the observed ^{10}Be concentrations in the medial moraine of the Chhota Shigri Glacier yield reasonable headwall erosion rates, and that the systematic downglacier change in the concentration may reflect a changing erosion rates through time. Combining the ^{10}Be results with the numerical model we are presently exploring new avenues to test simple models of debris production by frost cracking, e.g., spatially uniform versus temperature dependent.