Geophysical Research Abstracts
Vol. 16, EGU2014-14767, 2014
EGU General Assembly 2014

Landscape evolution by subglacial quarrying

Sofie V. Ugelvig (1), David L. Egholm (1), and Neal R. Iverson (2)

(1) Department of Geoscience, Aarhus University, Denmark, (2) Department of Geological and Atmospheric Sciences, Iowa State University, USA

In glacial landscape evolution models, subglacial erosion rates are often related to basal sliding or ice discharge by a power-law. This relation can be justified for bedrock abrasion because rock debris transported in the basal ice drives the erosion. However, a simple relation between rates of sliding and erosion is not well supported when considering models for quarrying of rock blocks from the bed.

Iverson (2012) introduced a new subglacial quarrying model that operates from the theory of adhesive wear. The model is based on the fact that cavities, with a high level of bedrock differential stress, form along the lee side of bed obstacles when the sliding velocity is to high to allow for the ice to creep around the obstacles. The erosion rate is quantified by considering the likelihood of rock fracturing on topographic bumps. The model includes a statistical treatment of the bedrock weakness: larger rock bodies have lower strengths since they have greater possibility of containing a large flaw [Jaeger and Cook, 1979]. Inclusion of this effect strongly influences the erosion rates and questions the dominant role of sliding rate in standard models for subglacial erosion.

Effective pressure, average bedslope, and bedrock fracture density are primary factors that, in addition to sliding rate, influence the erosion rate of this new quarrying model [Iverson, 2012]. We have implemented the quarrying model in a depth-integrated higher-order ice-sheet model [Egholm et al. 2011], coupled to a model for glacial hydrology. In order to also include the effects of cavitation on the subglacial sliding rate, we use a sliding law proposed by Schoof (2005), which includes an upper limit for the stress that can be supported at the bed.

Computational experiments show that the combined influence of pressure, sliding rate and bed slope leads to realistically looking landforms such as U-shaped valleys, cirques, hanging valleys and overdeepenings. Compared to model results using a standard erosion rule, where erosion rate scales with basal sliding, the quarrying model produces valleys that are wider and have more flattened valley floors with several shallow overdeepenings. The overdeepenings are stabilized by hydrology because of the strong influence of effective pressure on quarrying rate. For melt water to escape the overdeepening, the average water pressure must rise as the overdeepening grows, and this keeps the effective pressure low and prevents the overdeepening from growing infinitely. In addition, the strong influence of effective pressure indicates that erosion rate depends strongly on ice thickness. This could associate to sudden jumps in erosion rate and fjord formation along margins that experienced periodic ice sheet configurations in the Quaternary.

Egholm, D. L. et al. Modeling the flow of glaciers in steep terrains: The integrated second-order shallow ice approximation (iSOSIA). Journal of Geophysical Research, 116, F02012 (2011).

Iverson, N. R. A theory of glacial quarrying for landscape evolution models. Geology, v. 40, no. 8, 679-682 (2012).

Schoof, C. The effect of cavitation on glacier sliding. Proc. R. Soc. A , 461, 609-627 (2005).

Jaeger, J.C., and Cook, N.G.W. Fundamentals of rock mechanics: New York, Chapman and Hall, 593 p. (1979)