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Rapid frost weathering and its potential role as a periglacial buzzsaw

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Icy Bay, in the Chugach-St.Elias mountains of southern Alaska, provides an excellent opportunity to 1) document exceptionally rapid breakdown of cobbles on surfaces recently exposed by glacial retreat, 2) examine frost-induced breakdown in light of recent advances in theory, and 3) explore the potential role of periglacial processes in limiting the height of mountain ranges. The latter adds to the current interest in the interactions between topography, tectonics and climate, and in particular, the so-called glacial buzzsaw (Egholm, et al. 2009. Nature, 460, p 884; doi:10.1038/nature08263). This is the notion that the growth of mountains is curtailed by erosion and related effects of glaciers with little or no dependence on the factors that are generally thought to control the height of mountains; height increases with the elevation of the snow line, with little or no influence of uplift and exhumation rates, rock type, and precipitation.

A well-documented retreat of tidewater glaciers in Icy Bay has resulted in a succession of outwash surfaces on which cobbles of diverse lithology were exposed to atmospheric conditions sequentially. Following deposition, initial breakdown rates were determined for each of four distinct lithologies: siltstone, sandstone, greenschist, and granite/gneiss. These rates decrease to negligible values after 10-15 years of exposure. Breakdown is significantly enhanced adjacent to the current shoreline with the fraction of surface cobbles fractured after 30 years ranging from 20% for granite/gneiss to 90% for siltstone.

Theoretical considerations suggest that the susceptibility of a rock type to frost weathering is dictated by its specific surface area and resistance to fracture. These parameters define a threshold zone for frost weathering specific to ambient thermal and moisture conditions in Icy Bay, a conclusion substantiated by independent experimental evidence. This result, coupled with the fact that this and other studies have shown enhanced rock breakdown under relatively mild climatic conditions, suggests the importance of unfrozen water migration in frost weathering under natural conditions and a significantly greater spatial importance of frost weathering than previously recognized.

The rate of frost weathering should be maximized for temperatures between -3 to -10°C and in the presence of abundant moisture. These conditions ought to define an elevation interval in mountainous landscapes most conducive to frost weathering. Climatic fluctuations ought to drive large altitudinal changes in this interval causing variations in affected land area. Frost weathering appears to be significantly faster than other subaerial weathering mechanisms, and probably contributes significantly to the rapid exhumation documented in the Icy Bay region (Berger, A.L., et al. 2008. Nature Geoscience,1, 793-802.)