Geophysical Research Abstracts
Vol. 14, EGU2012-6803, 2012
EGU General Assembly 2012

Frost weathering: Climate control of regolith production and critical zone evolution

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Rock generally displays greater fracture density and reduced strength near the surface than at depth. Relatively few processes can explain this profile of mechanical damage seen in rock. Motivated by weathered rock profiles measured in Gordon Gulch in the Boulder Creek Critical Zone Observatory (Colorado Front Range, USA), we focus on frost cracking as an important weathering process. We use our measurements to guide a model of frost cracking. Although the modern mean annual ground temperature is $\sim$4°C, it was subzero during Pleistocene glacial times. Frost cracking is therefore a plausible mechanism of rock damage. Rock on north-facing slopes in this high elevation catchment ($\sim$2600 m a.s.l.) is more deeply weathered and displays lower tensile strength than rock on south-facing slopes. We present detailed subsurface temperature profile records at sites on both slopes, reaching depths up to 1.5 m, and therefore crossing the mobile regolith – saprolite interface. We augment existing frost cracking models by incorporating daily thermal cycles, snow cover, latent heat, variation in material properties with depth, and limitations imposed by long transport distances for water to the freezing front. The north- and south-facing hillslope asymmetries in critical zone architecture can be explained with differences in mean annual surface temperatures, although moisture differences may also play a role. A temperature-controlled model of rock weathering enables consideration of the effect of climate change on weathered profile development.