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Periglacial response to late Cenozoic cooling

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Recent research suggests that late Cenozoic cooling caused an almost worldwide increase in erosion rates and that this increase is most pronounced in glaciated mountain ranges, independent of tectonic activity (Herman, 2013). The obvious suspect behind this increase is the enhanced glacial erosion arising from a colder and more unstable climate. However, since periglacial processes are operating in similar temperature regimes, they might also contribute to, and in some regions dominate, the observed increase in erosion rates.

In order to explore the latter effect, we examine the cold, non-glacial erosion processes and their long-term relations to climate. Our main focus is on the physical breakdown of rock by ice (i.e. frost cracking). In particular, our objective is to answer the following questions: 1) What surface temperatures intensify frost cracking, and 2) what characterize the fundamental interactions between sediment thickness, sediment production, and transport of sediment in cold areas?

We follow the approach of Hales and Roering (2007) and Anderson et al. (2012) and integrate the temperature variation in the subsurface following an annually oscillating surface temperature. We record the periods when bedrock temperatures are in the frost-cracking window (-8 to -3 °C) and water is available along a monotonous temperature gradient. For these periods, we estimate frost-cracking intensity as a function of the temperature gradient and the amount of water in the profile, limited by the distance the water has to flow through cold rock. We explore the sensitivity of frost-cracking rates to variations in both mean annual air temperature and the thickness of a regolith cover. This approach allows us to study the conditions under which a regolith cover is likely to accelerate frost cracking.

First of all, our study sheds new light on the role of the sediment cover. We find that a layer of regolith may accelerate erosion in cold regions, where the presence of surface water drives bedrock cracking during the summer period. In contrast, a very thin or absent regolith cover seems to promote frost cracking in warmer climates, where ice cracks the bedrock surface during the coldest days in winter.

The detailed sensitivity analysis also allows us to couple the frost-cracking model to a long-term landscape evolution model where surface elevation, sediment thickness, and air temperature evolve over time. This enables us to explore the spatial distribution of frost cracking in realistic landscapes, and to study the slow feedbacks between periglacial erosion, sediment transport, and the evolving topography. Thereby we can gain more insight into the role of periglacial processes and the response of periglacial landscapes to long-term climatic cooling.

References

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