Using a paleo perspective to decipher climate controls on erosion and landscape evolution

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Today, topograpic, erosion, and climate data are measured in abundance but the role of climate in modulating sediment production and landscape evolution remains unclear. Studies that quantify climate controls on denudation by analyzing multiple study areas with varying temperature and precipitation are hampered by site-to-site variations in topography, substrate, and vegetation, as well as uncertainty in the state of landscape adjustment. These contingencies can obscure how climate influences landscape dynamics. Alternatively, sedimentary records at a given location provide a means to track how climate variations influence sediment flux and weathering rates and mechanisms.

At our forested, steepland field site in western Oregon, we used a 50,000-yr sedimentary archive that accumulated in a landslide-dammed lake to document how erosion rates track environmental change. In such unglaciated settings, increased sediment production inferred during the last glacial maximum (LGM) has commonly been attributed to changes in precipitation and vegetation. By combining a mechanistic frost weathering model with a regional LGM paleoclimate reconstruction, paleovegetation data, and a cosmogenic paleoerosion sedimentary archive, we demonstrate that frost-driven sediment production was pervasive at our site during the LGM, resulting in a 2.5x increase in erosion relative to modern rates. Both paleoclimate simulations and paleovegetation data indicate drier conditions during the LGM across our study domain, such that temperature, rather than precipitation, may be the dominant driver of geomorphic processes during glacial intervals in many mid-latitude regions.

Our results imply that broad swaths of continental landscapes experienced accelerated sediment production via frost processes during glacial intervals, inviting a re-evaluation of what constitutes a steady-state landscape. Other climate dependencies will apply elsewhere, but the coupling of process theory and climate reconstructions with well-characterized sedimentary records will help resolve the enigmatic role of climate fluctuations.