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Paleo-erosion rates versus paleo-erosion processes from cosmogenic nuclide concentrations in sedimentary archives

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Paleo-erosion rates derived from cosmogenic nuclide concentrations in sedimentary archives are commonly observed to differ from modern rates, in some cases by several orders of magnitude. However, the meaning of these rates can be unclear when we consider the averaging timescale (and presumed lag) of the cosmogenic nuclide technique in recording erosion rates, grain-size dependencies in nuclide concentrations, and assumptions inherent to the detrital approach. These issues can complicate our ability to interpret landscape response to past climate change from cosmogenic nuclides.

In general, the cosmogenic nuclide concentration in sediment is inversely related to the catchment mean erosion rate. However, several studies, including ours from the Central Andes, have suggested that low nuclide concentrations from fill terrace sediment coupled with a strong grain-size dependence in nuclide concentrations point to a greater importance of landslide activity in the past. In such settings, cosmogenic nuclide concentrations may provide clear signals of changes in erosion processes, but are difficult to interpret in terms of changes in erosion rates.

These complications may be reduced in low-relief catchments, where landsliding is unlikely. Such is the case for the semi-arid Baragoi catchment of East Africa, which was affected by a wetter climate during the African Humid Period (ca. 15-6 cal. kyr BP). From that time period, we calculate paleo-erosion rates from cosmogenic nuclides within deltaic sediments that are up to 7x faster than modern rates. Moreover, erosion rates rise rapidly near the onset of wetter climate conditions, then drop to near-modern rates well before the return to semi-arid conditions. Given that the averaging timescale of our samples is 8 to 46 kyr, to match the rapid observed rise in erosion rates with a 1D model of cosmogenic nuclide accumulation requires an increase in erosion rates several hundred times higher than the initial (pre-delta formation) erosion rate. However, after achieving such a low concentration (high erosion rate), it is impossible within the model scenario to return to the high concentrations (low erosion rate) that we find shortly afterwards, again as a result of the technique's long averaging timescale. Hence, we can only explain the observed change in nuclide concentrations by invoking a change in erosion patterns, most likely associated with a change from soil creep to the formation of rills and gullies as climate became wetter. Such localized excavation of sediment could result in a pulse of low-concentration sediment. Later, after the persistently wet climate led to denser vegetation cover, a return to soil creep would have removed sediment more evenly across the landscape, explaining the rapid return to high-concentration material. While this case study provides a compelling argument that cosmogenic nuclides can record changes in erosion processes even in low-relief catchments, it further illustrates the potential difficulties in using such data to quantitatively reconstruct changes in erosion rates.