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Interpreting a frequency distribution of single-grain cosmogenic ^{21}Ne concentrations in coarse fluvial clasts in terms of spatially variable bedrock erosion rates and/or post-detachment sediment residence times

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Cosmogenic nuclide concentrations (CNCs) in alluvial sediments are now routinely being used to estimate time- and space-averaged catchment-wide denudation rates. Detrital mineral CNCs have the potential, however, to offer considerably more. The rates at which cosmogenic nuclides are produced vary across the landscape, mainly as a function of elevation. Moreover, grains can accumulate cosmogenic nuclides while they are part of the bedrock, prior to detachment, and then at all stages of their transport and storage. Because each grain potentially has a unique history of erosion, transport and storage, the frequency distribution of CNCs in a large numbers of grains leaving a catchment can provide an integrated signature of the catchment's geomorphological characteristics and history. The measurement of CNCs in single-grain samples from the outlet of a catchment has the potential to provide not only information on the average rate of geomorphic processes in the catchment, but also detailed information on the spatial distribution of variations in process rates in the catchment.

The need for relatively large amounts of pure quartz ($\approx 20-30$ g) (and a lengthy and expensive sample preparation process) limits the application of ^{10}Be and ^{26}Al to amalgamated sediments. The measurement of cosmogenic ^{21}Ne, however, requires significantly smaller amounts of quartz, $0.5-1$ g being sufficient to measure 10^6 atoms/g with an uncertainty of $< 10\%$. These advantages allow ^{21}Ne to be measured in single pebbles of vein-quartz. To explore the possibility of using cosmogenic ^{21}Ne in individual clasts to trace the geomorphology of a catchment, we have studied 32 quartzite

pebbles ($16 - 21$ mm diameter) from the active channel of the Gaub River in western Namibia. ^{21}Ne concentrations span two orders of magnitude ($2.6 - 1.6 * 10^8$ atoms/g), and the distribution is highly skewed to lower values.

Our GIS-based numerical model of cosmogenic nuclide acquisition in sediments suggests that the CNC distribution can be interpreted in two fundamentally different ways. In one interpretation, the CNC distribution reflects an environment that is in isotopic steady-state (i.e., with negligible post-detachment nuclide acquisition) and characterised by low and spatially variable bedrock erosion rates that are linearly correlated with local mean topographic gradient and range between ≈ 0.1 and 10 m/Myr. In the second interpretation, the CNC distribution reflects an environment characterised by surface or near-surface exposure times of up to ≈ 4 Myr that are the result of very slow hillslope sediment transport rates (i.e., no isotopic steady-state). Both interpretations are equally plausible. The fact that both the measured ^{21}Ne concentrations and the frequency distribution lend themselves equally well to both interpretations confirms that the assumption of isotopic steady-state needs to be carefully considered before interpreting any detrital grain CNCs. The modelling also demonstrates that analysis of the distribution of CNCs enhances geomorphic interpretation of cosmogenic nuclide data. Using the model, we have both constrained the study area's range of possible erosion rates and sediment residence times, and obtained information on the spatial distribution of these rates.