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Theoretical cosmogenic nuclide concentration in river bed load clasts: Does it depend on clast size?

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Terrestrial Cosmogenic Nuclides (TCN) have been widely used to date the exposure of alluvial surfaces and to estimate catchment-scale erosion rates. However, TCN concentration differences in samples of different grain sizes remain to be fully understood. In order to explore the possibility that river processes generate such differences, we develop a numerical model to calculate along-stream clast-scale TCN concentrations. Using the hillslope model, there is a progressive detachment of successive clasts of specific sizes followed by their instantaneous fall into the river. In the river, transport velocity and TCN concentration evolution in a clast depend 1) on the probability of being trapped in the sediment mixing layer of the river or within an adjacent terrace; 2) on its size which decreases downstream by attrition. The size-dependent transport law corresponds to the partial transport state in a river. We model the distribution of TCN concentrations in different clast size fractions in the 0-5 cm radius range for catchments in steady state erosion, and for catchments experiencing sedimentation.

We propose that clast attrition tends to increase the variance of TCN concentrations of the small clast size fractions because these fractions incorporate initially big clasts that travelled a long distance in addition to small clasts contributed near the outlet. We obtained numerous clast size-TCN concentration correlations, positive or negative, the significance of which depends on the initial clast size distribution, hillslope erosion rate, river length and lithology. For an equilibrium catchment, even large, we found that the addition of TCN concentration acquired during river transport is negligible compared to TCN concentration acquired on a hillslope, although a clast size- TCN concentration relationship can result from or be modified by clast attrition. On the contrary, aggrading catchments may show a significant clast size-dependent TCN concentration increase during river transport. This may introduce a small bias in the TCN-derived catchment erosion rate, but it could be used positively to quantify the mean transport velocity of clasts of different sizes over thousands of years. In addition, the lack of correlation between TCN concentration and clast size does not imply that the mean transport velocity is the same for all clast size fractions. Overall, our study provides an alternative explanation for observed clast size-dependent TCN concentrations and brings to the fore the need for measuring TCN concentration in larger clast size fractions than is usually done. To see if the byproducts of abrasion dilute or increase the TCN concentration of sand, all products should be included in a future study.