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From source to sink: Unravelling the complex in situ cosmogenic 10Be-14C signature in eroding bedrock surfaces and river sediment from the Bolivian Altiplano

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Sediment storage is a critical component of fluvial sedimentary systems. By interrupting transport processes, intermittent sediment storage can effectively decouple source from sink and buffer the transmission of signals of environmental change (e.g., in climate, vegetation, human impact) through the fluvial system. Combined in situ cosmogenic 14C-10Be analysis in fluvial sediment provides a unique method to simultaneously assess sediment transit times (in situ 14C signal) and long-term sediment production rates from bedrock erosion (10Be signal). The key is the much shorter half-life of in situ 14C compared to 10Be which causes a rapid decrease of the in situ 14C concentration when sediment is buried during sediment storage and creates an offset to 10Be.

Here, we use the in situ 14C-10Be chronometer to determine changes in surface erosion and estimate absolute rates of sediment transfer in a catchment on the Bolivian Altiplano. Previous research in the study area has found a significant offset in the in situ 14C-10Be inventories from river sediments with much lower in situ 14C concentrations than expected from the 10Be content for steady-state conditions. This offset has been interpreted to reflect sediment storage over the past 11-20 ka [1]. Additional analyses of in situ 14C and 10Be in a dense network of sediment samples from the main channel and tributaries agree with previous data and yield very low in situ 14C concentrations that suggest an increase in storage duration by a few ka with downstream distance. However, analyses of in situ 14C-10Be in hilltop samples from the eroding source area reveal an almost as large offset as in the river sediments. Such complex in situ 14C-10Be inventories in the source area have a severe impact on the quantification of sediment storage times and strongly challenge previous data interpretation.

The most straightforward explanation for the in situ 14C-10Be offset at hilltop locations is a change in denudation rate during the Holocene. Using a simple model of a rapid, one-step denudation rate change, a minimum increase by a factor of 30-40 at about 4-6 ka ago is required to approach the measured in situ 14C-10Be concentrations. This corresponds to the Mid-Holocene shift towards wetter climate in the Eastern Andes as proposed from paleolake deposits [2]. Assuming that fluvial sediments inherit a complex 10Be-14C signal from the source area, the estimated duration of total sediment storage reduces to 1-5 ka and is, thus, much shorter than previously assumed. These time spans correlate well with ages of 2-3 ka obtained for fluvial terraces in the study area by radiocarbon and 10Be depth profile dating.

Our data allows tracing the spatial pattern of sediment storage and quantify individual storage durations during source-to-sink sediment transfer through the catchment. We further highlight the potential of the in situ 14C-10Be chronometer to determine the magnitude and timing of changes in surface erosion in the past and, thus, to identify transience in eroding landscapes.

[1] Hippe et al., 2012 – Geomorphology 179 – pp. 58-70.
[2] Rigsby et al., 2005 - J Quaternary Sci 20 – pp. 671-691.