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Quantifying the effect of landslide-derived sediments on detrital thermochronology

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Analysis of modern river sediment using detrital thermochronology can provide a record of tectonic activity, surface denudation and sediment transport by surface processes. Ideal sediment samples contain datable mineral grains that represent bedrock exposed in the entire catchment. However, in steep mountainous catchments in active orogens, where detrital thermochronology is advantageous, bedrock landslides can produce a significant fraction of basin sediment. Individual landslides contribute sediment from a restricted region within the catchment and may invalidate the assumption that the sediment sample represents the entire drainage area. We use a simple numerical model of landslide sediment production in combination with the 3D thermokinematic and thermochronometer age prediction software Pecube to determine the magnitude of the influence of landslides on modern river sediment samples. Model landslides are distributed randomly in the catchment following a defined frequency-magnitude relationship and the rate of landslide sediment production is scaled to a defined rock exhumation rate. A sample of n ages is selected at random from the catchment mouth after $1-1000$ years of sediment accumulation to simulate variable sediment residence times within the catchment. Sub-basins are also sampled to determine the influence of landslides as a function of basin area.

Bedrock landsliding strongly affects catchment detrital cooling age distributions, particularly for shorter sediment residence times. We focus on the Nyadi drainage basin in the central Nepal Himalaya, where published detrital muscovite ^{40}Ar/^{39}Ar cooling age distributions from samples collected five years apart differ in spite of having a sufficient number of dated mineral grains to record the basin age distribution ($n = 34$ and $n = 111$). Using a Monte Carlo method, we compare the observed age distributions to 10,000 predicted age distributions of n randomly selected ages and find $\sim$97% of the predicted age distributions are statistically equal to one observed age distribution, but only 0.1% are equal to the other. This suggests the sampled sediment does not reflect spatially uniform basin denudation, but may be biased by landslides. Using the landslide sediment production model with a 1-year sediment residence time, only 0.2% of the predicted age distributions are equal to the observed distribution that was previously fit well by uniform basin sediment production. Increasing the residence time to 10 or 100 years improves the fit, with $\sim$8% and $\sim$40% of the respective predicted age distributions equal to the observed. Predicted sub-basin age distributions with and without landslide sediment production reveal a surprising trend; $>$70% of the predicted age distributions are statistically equal regardless of the residence time for basin areas $<$25 km^2. This is because small drainage basins have smaller age ranges, yielding predicted age distributions that are similar regardless of the source of sediment in the basin. This may not be true for basins with slower long-term denudation rates. Lastly, simple mixing of fluvial (uniform) and landslide sediment production suggests landslides affect basins when $>$20% of sediment is produced by landslides with a 1-year residence time, and landsliding impacts basins with 10 or 100 year residence times when $\sim$30% and $\sim$70% of sediment is produced by landslides, respectively.