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# Using forward modeling of common geomorphic processes to reconcile discordance in Quaternary geochronometers: a case study from Late Pleistocene-Holocene alluvial fans in southern California

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The progressive increase in precision of new and emerging Quaternary dating techniques provides an opportunity to apply multiple chronometers and sampling strategies to single geomorphic surfaces. Interestingly, however, many constructional geomorphic features (e.g., alluvial fans) dated with multiple chronometers show discordances in dates that far exceed the analytical uncertainties in the individual dating methods. Discordance between dates from cosmogenic Be-10 depth profiles and dates from U-series on pedogenic carbonate, OSL and other cosmogenic techniques are especially common. In particular, attempting to model depth profiles with non-ideal concentration-depth distributions using traditional methods commonly results in age interpretations significantly lower than U-series or clast exposure dates. Here we explore whether these discordances can be reconciled using simple forward models of syn- or post-depositional processes that affect near-surface cosmogenic nuclide inventories. We forward model three scenarios: 1) small-scale incremental deposition, 2) erosion/surface lowering, and 3) bioturbative mixing with allochthonous sand infiltration. For each model an assumed age based on an independent measurement is a required input, and it is possible, though not required, to subtract an initial inherited nuclide concentration. To model small-scale (<m) incremental deposition we adjust deposit thickness and recurrence. These models predict stepped, near-vertical concentration curves and may explain unexpectedly steep nuclide distributions in surfaces that have been exposed for less than ∼10-20 kyr. Straightforward erosion/surface lowering models explain overly steep nuclide distributions in older surfaces. Nuclide concentration curves displaying anomalously low near-surface concentrations or abrupt changes in concentration with depth can be explained by multi-parameter models that incorporate a set erosion rate, near-surface bioturbative mixing depth and turnover rate, and/or the infiltration rate and nuclide concentration of allochthonous sediments. We apply the models to three multiply dated alluvial fans in the Coachella Valley in southern California, USA. All three fans are similar in provenance and morphology but differ in probable age. For two surfaces, U-series pedogenic carbonate dates constrain minimum deposition ages, and for all three surfaces, cosmogenic Be-10 exposure dates from depth profiles and surface clasts (boulders or cobbles) provide additional constraints on deposition. None of the depth profiles exhibit ideal decreases in nuclide concentration with depth, and at one sampling location, varying the clast size analyzed (cobbles vs. sand) produced different concentration-depth distributions. Traditional techniques for depth profile modeling yielded surface exposure ages far younger than the U-series minima and the majority of clast exposure dates; however, by applying the forward models, the depth profile concentrations can be brought into agreement with the U-series and cosmogenic clast dates. In all three cases, only one model or set of parameters adequately reconciles the discordant data, suggesting the possibility that individual geomorphic processes affecting alluvial fan deposition and evolution can be uniquely identified and measured.