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Using Soil stratigraphic observations to constrain TCN depth profile ages of relict alluvial fan surfaces in the Sonoran Desert, USA

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Interpretations of surface exposure ages derived from the accumulation of cosmogenic isotopes commonly are hampered by a lack of field documentation that is necessary to identify and constrain if any post-depositional surface modifications have occurred (e.g. surface erosion, burial) that will impact age interpretations. Previous authors have discussed these issues, but the community still has not fully adopted the practice of interpreting surface exposure ages in conjunction with detailed soil stratigraphic observations. We employ this “novel” approach by documenting a soil chronosequence from the Gould wash alluvial fan sequence near Cibola, AZ to demonstrate how soil stratigraphy can provide constraints for the relative stability of depositional surfaces and can influence interpretations of TCN ages.

The Cibola chronosequence represents a range of alluvial fan ages that extend well beyond those commonly observed in the desert southwestern US (typically <100 ka) and provides evidence for extended periods of surface stability. We identified seven different alluvial fan surfaces within the sequence, documented their soil morphological and chemical properties, and dated four of the fan surfaces with ^{36}Cl depth profiles. Fan deposits largely consist of volcaniclastic alluvium derived from the local Trigo Peaks and distal Castle Dome mountain blocks and show both a reduction of bar-and-swale surface topography and an increasing expression of desert pavement with relative surface age. The soil profiles consist of Av-Bk-BCky-Cky-Ck vertical horizon sequences (~125-cm thick) in the youngest fan units to Avk-Btky-Bkym-Bky-BCky-Cky-C (~400-cm thick) in the oldest fan unit that reflect systematic changes in soil thickness, structure, rubification of B horizons, and relative accumulations of eolian derived silt, clay, and salts as a function of relative surface age.

Chlorine-36 depth profile analysis yielded variable fan ages that are largely controlled by the magnitude of allowable erosion. Model results for which input data were parameterized to optimize unconstrained erosion rates indicate surface exposure ages of 46 (2A), 114 (2B), 268 (3A), and 386 (4A) ka. These are associated with best-fit erosion rates of 0-6 mm/kyr that indicate 0-136 cm net erosion. By comparison, results for which erosion rates were constrained to ~1 mm/kyr based on soil stratigraphic observations yielded exposure ages of 41 (2A), 114 (2B), 209 (3A), and 287 (4A) ka, resulting in differences of 10-25% of the unconstrained ages. The systematic morphological trends observed in the soil profiles do not support inferences of net erosion exceeding 30 cm and therefore cannot support the results from unconstrained parameter optimization. Although statistical optimization schemes provide better model fits to the data as indicated by chi-shared minimization routines, current models cannot account for field observations or for inferred constraints on surface modifications based on cosmogenic isotope concentrations alone. That task is better suited for and required by the sampling protocol to achieve more reliable surface exposure dates.