U-Th dating of aragonite cement in the Fern Pass rockslide (Northern Calcareous Alps, Austria): implications for minimum-age dating of catastrophic mass movements.

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In the Fern Pass rockslide (Northern Calcareous Alps, Austria), boulders projecting from toma hills guided surface runoff towards their downslope flanks, and retended pore-water flow into small-scale, fluctuating phreatic/vadose diagenetic systems recorded by aragonite and calcite cements. The first generation of aragonite cement indicates a U-Th minimum age of the rockslide event of 4150 ± 100 a. This cementation age fits very well with and provides a minimum constraint on exposure ages for the rockslide event as established by other authors.

The Fern Pass rockslide detached from a East-facing mountain slope of Upper-Triassic carbonates and parted, after run-up onto the opposite valley flank, into a northern and southern branch. Today the rockslide is forested, but shows (oblique-)transversal ridges and toma hills that largely represent the original surface of the flow after freezing. In the upper part of tomas, along the south-facing flank of projecting boulders more than about 4 meters in exposed diameter, layers up to about 20 cm thick of breccia cemented by calcium carbonate are present. Three locations with breccias were sampled.

The diagenetic successions of breccias are quite variable both among and within a location and record fluctuating, phreatic and vadose small-scale settings that, in some cases, were separated by phases of partial dissolution of cements. Phreatic conditions are recorded by isopachous to botryoidal fringes of aragonite cement, by fringes of skalenohaidral calcite spar, and by blocky calcite spar. Vadose cementation is indicated by isopachous to mammillary crusts of micrite to lithic wackestone, and by clotted to peloidal micrite that may show alveolar structures. From the surface of boulders outwards, the diagenetic successions become more incomplete, and all types of cement disappear.

At one location, a botryoidal aragonite cement along a boulder surface was age-dated by the U-Th disequilibrium isochron method to 4150 ± 100 a. Comparison with numerical ages derived by other authors from ^{36}Cl-exposition dating of the rockslide detachment scar, and by ^{14}C-dating of organic material in deposits of rockslide-dammed torrent deposits indicates that the precipitation age of the aragonite to date is the most precise of all proxies of depositional age (cf. contribution by Prager et al., this volume).

Subsequent to freezing, the rockslide was rich in dolomite „powder“ produced by abrasion during the event. Upon atmospheric precipitation, dissolution of the fine-grained clastic dolomite gave rise to calcium-magnesium-bicarbonate pore waters. Along the flanks of toma hills, the downward-percolating pore waters collected and were retended along large projecting boulders, and additional water was supplied by runoff from the boulder surface. This gave rise to temporary, small-scale, phreatic to vadose meteoric diagenetic environments. Upon evaporative concentration of pore waters, immediately adjacent to the boulders, calcium carbonate cements precipitated. Evaporative concentration is supported by presence of breccias only along south-facing boulder flanks, and by exceptionally „heavy“ stable isotope values of oxygen and carbon of the cements. During an early stage, when the rockslide deposit was still rich in dolomite powder vulnerable to dissolution, from magnesium-bearing pore waters moderately to strongly supersaturated for calcium carbonate, the isopachous to botryoidal crust of aragonite precipitated that was age-dated. With progressive vegetation of the rockslide and time lapse, the source of dolomite powder to supply $Ca\text{-}Mg\text{-}HCO_3^-$ pore waters became progressively exhausted. In a later stage, fringes of dog tooth spar and of micritic cements precipitated. The described diagenetic system mainly results from the combined effects of the type of deposit with the position, size and exposition of boulders, in interaction with meteoric pore-water flow.
The age of the aragonite cement close to the age of the rockslide event (as deduced by exposition dating by other authors) indicates that U-Th dated carbonate cement can represent a fairly precise proxy of depositional age. Because the diagenetic conditions within the Fern Pass rockslide are not exceptional, similar breccias may be expected in other rockslides. Age-dating of cemented portions of rockslides by the U-Th method thus may represent a new, hitherto unexploited source for proxy age determination of catastrophic mass failures.