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Petrological constraints on ultra-high pressure metamorphism and frictionite formation in a catastrophic rockslide: The Koefels event (Eastern Alps).

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The P-T conditions in extremely-rapid gravity-driven rockslides are difficult to constrain from the descended rock mass itself. Here, we report mineralogical observations from the Koefels rockslide and their interpretation. The Koefels event – happened between 9527-9498 cal BP – comprises 3.9 km^3 mainly of muscovite + biotite-bearing orthogneiss, and is one of the few large rockslides in silicate-bearing rocks worldwide. Detached by collapse of a valley flank, the rockslide impacted the opposite valley flank: While the lower part of the mass was sharply stopped, the overriding part propagated farther. This led to shear localization along discrete planes and, in consequence, to transient melting by frictional heating. The resulting frictionites comprise thin glassy levels with floating crystal fragments. The bulk composition of the glassy melt corresponds to the composition of the orthogneiss.

In the frictionites, ultra-high pressure metamorphosed quartz (UPQ) occurs next to unaffected quartz in a glassy matrix. Micro-Raman spectroscopy of unaffected quartz yielded an intense A1 Raman mode at 464 cm^{-1} ; UPQ shows a shift of this band down to 460cm^{-1}, with some grains showing an internal gradient of up to 3 cm^{-1} from the core (463cm^{-1}) to the rim (460 cm^{-1}). Some UPQ are rimmed by lechatelierite (SiO_2 glass), which never surrounds unaffected quartz grains. Until now lechatelierite formation in frictionites was considered to be a function of temperature only (Heuberger et al. 1984). Because lechatelierite only rims UPQ with outward decreasing band numbers, we interpret lechatelierite formation to be mainly pressure-driven. The completely molten matrix and the lack of glassy rims at the edges of normal quartz indicates minimum temperatures of 900°C. Experimental investigations have shown that the shifted A1 mode of UPQ equilibrates to 464 cm^{-1} at 1100°C, thus giving an upper limit of the temperature range. The Raman shift of the A1 mode and the presence of lechatelierite strongly suggest that a pressure >23 GPa was attained (cf., McMillan et al. 1991, Fritz et al. 2011, Kowitz et al. 2013).

The UPQ and lechatelierite rims formed by grain collisions during initial shear localization, when the shear plane was relatively cool. Next, upon rapid frictional heating the glassy frictionite matrix formed and became locally injected into lechatelierite rims. Once formed, the melt

prevented high-energy grain collisions. Unaffected quartz (which nevertheless may have seen pressures up to 22 GPa) in the frictionites perhaps escaped UHP overprint due to position in local pressure shadows and/or was sheared out from the adjacent caciritic rock mass into the melt. Our results help to better constrain numerical simulations of P-T-conditions in rockslides. Since our investigation only provides limiting estimates the actual P-T conditions in deep shear levels of rockslides exceeding the volume of the Koefels event might be even higher.

References:

Fritz et al. 2011: International Journal of Impact Engineering, 38:440

Heuberger et al. 1984: Mountain Research and Development, 4:345

Kowitz et al. 2013: Earth and Planetary Science Letters, 384:17

McMillan et al. 1992: Physics and Chemistry of Minerals, 19:71