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The role of structural diagenesis in faulting and fracturing of upper crustal rocks

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Fluid flow in fractured rock is increasingly important in recovering water and hydrocarbon supplies and geothermal energy, in predicting flow of pollutants underground, in engineering structures, and in understanding large-scale crustal behavior. Structural diagenesis, the study of the relationships between deformation or deformational structures and chemical changes to sediments, can help unlock knowledge about the low-temperature realm of sedimentary basins that is of great intrinsic and practical interest. The effects of structural diagenetic interactions on fault and fracture attributes are illustrated by meter- to decimeter-displacement oblique-slip faults cut latest Precambrian lithic arkose to feldspathic litharenite and Cambrian quartz arenite sandstones in NW Scotland. Despite common slip and thermal histories during faulting, the two sandstone units have different fault-core and damage-zone attributes, including fracture length and aperture distributions, and location of quartz deposits. Fault cores are narrow (less than 1 meter), low-porosity cataclasite in lithic arkose/feldspathic litharenites. Damage zone-parallel opening-mode fractures are long (meters or more) with narrow ranges of lengths and apertures, are mostly isolated, have sparse quartz cement, and are open. In contrast, quartz arenites, despite abundant quartz cement, have fault cores that contain porous breccia and dense, striated slip zones. Damage-zone fractures have lengths ranging from meters to centimeters or less, but with distributions skewed to short fractures, and have power-law aperture distributions. Owing to extensive quartz cement, they tend to be sealed. These attributes reflect inhibited authigenic quartz accumulation on feldspar and lithic grains, which are unfavorable precipitation substrates, and favored accumulation on detrital quartz. In quartz breccia, macropores >0.04 mm wide persist where surrounded by slow-growing euhedral quartz. Differences in quartz occurrence and size distributions are compatible with the hypothesis that cement deposits modify the probability of fracture reactivation. Existing fractures readily reactivate in focused growth where quartz accumulation is low and porosity high. Only some existing, partly cemented fractures reactivate and some deformation is manifest in new fracture formation in partitioned growth where quartz accumulation is high. Consequences include along-strike differences in permeability and locus of fluid flow between cores and damage zones and fault strength.