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High-speed deformation by pressure solution creep along fault zones in upper crust

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The author has studied exhumation tectonics of metamorphic rocks for a long time, and recently recognized that deformation processes and mechanisms in metamorphic rocks during exhumation into upper crustal levels across the brittle-ductile transition zone provide us with clues to unravel those of inland earthquakes. For example, the Sambagawa metamorphic rocks, southwest Japan experienced pervasive normal faulting under nearly arc-normal extension at D2-phase, which occurred during the exhumation stage when they were elevated to upper crustal levels across the brittle-ductile transition zone. These normal faults formed at D2-phase are characterized by quartz sclikenfibre on fault plane, the displacement rate along which was perhaps controlled by pressure solution creep, and hence not accelerated to generate earthquakes (i.e. stable sliding). Other microstructures such as shear bands defined by alignment newly grown muscovite and chlorite, strain fringe with large aspect ratios, random c-axis fabric in quartz aggregates, etc. all indicate that the rate of pressure solution creep was fairly high.

In fact, the brittle strength shown in crustal strength profile so far constructed is that needed to generate earthquakes. However, while this critical differential stress only occurs once per a few thousand years at the time of earthquake in seismogenic fault zones, the stress during inter-seismic periods is far below this value. It has been considered that pressure solution creep occurs at such low differential stress conditions. Then, the point of discussion is how fast pressure solution creep or reaction-controlled creep occurs under these conditions in nature. If pressure solution proceeds so fast in fault zones, the differential stresses cannot be elevated to generate earthquakes. In reality, the structure of seismogenic fault zones is heterogeneous, which consist of very fine-grained mature fault rocks with numerous microfaults defined by development of aligned muscovite and chlorite (i.e. phyllosilicates), and relatively undeformed coarse-grained protolith not metamorphosed and deformed extensively. In these cases, while grain-size sensitive pressure solution creep occurs at higher rate in the former rocks, also assisted by a low coefficient of internal friction in phyllosilicate minerals (e.g., Bos and Spiers, 2002), stress becomes built up, leading to the generation of earthquakes in the latter rocks. This process is repeated, which explains the repetition of inland earthquakes. Since the undeformed rocks in fault zones can be correlated with asperities in subduction zones, this model can be called 'asperity model' for generation of inland earthquake (e.g. Jefferies et al., 2008).

Keywords: pressure solution creep, fault zones, repetition of inland earthquakes, strength profile of the continental crust, reaction softening, asperity