Hydration- and dehydration-induced rheological heterogeneities on the deep subduction interface, and possible relationships to episodic tremor and slow slip

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Episodic tremor and slow slip (ETS) is observed in several subduction zones down-dip of the locked megathrust, and may provide clues for preparatory processes before megathrust rupture. Exhumed rocks provide a unique opportunity to evaluate the sources of rheological heterogeneity on the subduction interface and their potential role in generating ETS-like behavior. We present data from two subduction interface shear zones representative of the down-dip extent of the megathrust: the Condrey Mountain Schist (CMS) in northern CA (greenschist to blueschist facies conditions) and the Cycladic Blueschist Unit (CBU) on Syros Island, Greece (blueschist to eclogite facies). Both complexes highlight the propensity for fluid-mediated metamorphic reactions to produce strong rheological heterogeneities:

In the CMW, hydration reactions led to progressive serpentinization of peridotite bodies that were entrained from the overriding plate and underplated along with oceanic-affinity sediments. The margins of each peridotite-serpentinite lens show extreme strain localization accommodated by dislocation glide and minor pressure solution in antigorite, whereas lens interiors show evidence for more distributed, alternating, frictional-viscous deformation, with abundant crack-seal veins occupied by antigorite, brucite and oxides that are in some places also ductilely sheared. Deformation in the surrounding metasedimentary matrix was purely viscous.

In the CBU on Syros Island, dehydration reactions in MORB-affinity basalts, subducted and underplated with oceanic and continental-affinity sediments, led to progressive development of strong eclogitic lenses within a weaker blueschist and metasedimentary matrix. The eclogite lenses are commonly coarse-grained and massive and show brittle deformation in the form of dilational and shear fractures/veins filled with quartz, white mica, glaucophane and/or chlorite. Brittle deformation in the eclogites is coeval with ductile deformation in the surrounding blueschist and metasedimentary matrix, indicating concurrent frictional-viscous flow.

Although we cannot easily distinguish transient deformation processes in exhumed rocks, we can use the following three approaches to assess whether these heterogeneities could have generated
deformation behaviors similar to deep ETS: 1) We measure displacements within, and dimensions of the heterogeneities in outcrop/map-scale to estimate the maximum possible seismic moment that would be released when the frictional heterogeneities slip; 2) We compare deformation mechanisms inferred from field and microstructural observations to their expected mechanical behavior from rock deformation experiments; and 3) We use seismo-thermo-mechanical modeling to examine expected slip velocities and moment-duration ratios for frictional-viscous shear zones that are scaled to observations from nature and the lab.

All three approaches suggest that frictional-viscous heterogeneities of the types and length-scales we observe in the exhumed rock record are compatible with ETS as documented in modern subduction zones.