# The Role of Mantle Wedge Serpentinization in ETS and Seismic Rupture Along the Megathrust

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In warm subduction zones such as Cascadia, Nankai, and Mexico, the megathrust seismogenic zone is confined to a shallow depth. Some distance farther downdip and around the mantle wedge corner (MWC), there may be concurrent deep tremor and short-term slow slip (ETS). Most other subduction zones are colder, and seismic slip can propagate farther downdip and much beyond the MWC. Instead of tremor in a separate ETS zone, high-frequency energy (HFE) may be radiated from the deepest part of the seismic slip zone. Here we draw parallels between ETS and HFE and speculate on their possibly similar petrologic conditions. In a way, ETS resembles a slow-motion picture of HFE-radiating deep rupture, and vice versa.

The ETS zone in warm megathrusts exhibits a transitional behaviour between stable and unstable friction. The slow slip is driven by the shear motion of neighbouring viscous segments updip and downdip (Gao and Wang, 2017). The slip shows slight fault weakening (small stress drop) that does not lead to seismic rupture. Tremor appears to reflect the presence of numerous seismogenic small "asperities" in the slip zone.

The deepest part of the rupture zone of colder megathrusts also exhibits a transitional behaviour between stable and unstable friction. It may undergo transient creep (Mavrommatis et al., 2014) and may host small and medium size earthquakes. Its slip during a great earthquake is driven by its highly seismogenic (stick-slip) updip neighbour. The slip shows slight fault strengthening (small stress increase) that does not fully inhibit the ongoing seismic rupture. HFE radiation appears to reflect the presence of numerous more seismogenic small "asperities" in the deepest part of the slip zone.

As inferred from thermo-petrologic models, the ETS zone and the HFE zone are both rich in serpentinites. Fluids from the dehydrating slab cause the serpentinization of the bottom part of the mantle wedge to form serpentine, talc, and other hydrous minerals. These hydrated materials are incorporated into the megathrust fault zone and affect its shear and slip behaviour. In warm subduction zones, the fault zone at the MWC is expected to include a mixture of antigorite (a high-T serpentine mineral) and talc. The very high pore fluid pressure in this area gives rise to frictional behaviour of the fault that would otherwise exhibit viscous behaviour under the same thermal condition, which is proposed to be responsible for the short-term SSEs (Gao and Wang, 2017). In colder subduction zones, the fault zone is expected to include a mixture of lizardite/chrysotile (low-T serpentine minerals) and talc at the MWC but a mixture of antigorite and talc farther downdip. In contrast to lizardite or lizardite-talc mixture, antigorite (Takahashi et al., 2011) and antigorite-talc mixture (Moore and Lockner, 2011) may facilitate unstable slip under certain conditions. Antigorite or antigorite-talc lenses or patches in the highly heterogeneous and foliated fault zone may act as small asperities. We speculate that tremor or HFE are caused by the activation of these asperities in slow slip or seismic rupture, respectively.

References:
Gao, X., and K. Wang (2017), Rheological separation of the megathrust seismogenic zone and Episodic Tremor and Slip, Nature, 543, 416–419.

Mavrommatis, A. P., P. Segall, and K. M. Johnson (2014), A decadal-scale deformation transient prior to the 2011 *Mw* 9.0 Tohoku-oki earthquake, *Geophys. Res. Lett.*, *41*, 4486–4494.
Moore, D. E., and D. A. Lockner (2011), Frictional strengths of talc-serpentine and talc-quartz mixtures, J. Geophys. Res., 116, B01403.
Takahashi, M., et al. (2011), On the transient response of serpentine (antigorite) gouge to stepwise changes in slip velocity under high-temperature conditions, J. Geophys. Res., 116, B10405.

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