Unlocking the Secrets of Megathrust Earthquakes

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A surge of great earthquakes since 2004 and recent improvement of monitoring networks have resulted in much better characterization and understanding of megathrust earthquake cycles. The new knowledge gives rise to new questions that create opportunities for concerted experimental and theoretical efforts. Here I highlight some of these opportunities. (1) Coseismic slip of the shallowest, near-trench part of the megathrust is poorly known. Present use of seafloor geodetic and tsunami data has not enabled adequate resolution (Fig. 1). Future observations need to be made within 20 km of the trench. (2) Heterogeneous stress drop in great earthquakes, locally large but on average small, is of fundamental importance to rupture mechanics, yet little is known about it. Monitoring and analysis strategies are needed that can characterize stress drop/increase distribution at high resolution. (3) Postseismic monitoring continues to yield new information on mantle rheology, fault friction, and stress transfer. Systematic efforts are needed to investigate how postseismic seismicity, deformation, and other observables (e.g. changes in seismic wave speed and anisotropy) are related to earthquake size and tectonic setting. For mantle rheology, the timing of GNSS site motion reversal is a key observable. (4) Understanding interseismic deformation remains a major challenge and requires fundamental changes to conceptual framework and monitoring strategy. Interseismic stress relaxation due to mantle viscoelasticity is vitally important but is routinely ignored. Locking state of many megathrusts including Cascadia is not well constrained due to lack of near-trench monitoring. (5) The relation of slow slip events (some with tremor) with earthquakes needs to be investigated. Some of them may reflect spatial transition between seismic and aseismic parts of a fault, but some are simply creep pulses in a creeping fault that does not produce great earthquakes. (6) Petrologic and structural conditions for great earthquakes need multidisciplinary studies. It is clear that great earthquakes are produced by weak faults, yet creeping faults can be stronger or weaker depending on the creeping mechanism. Large geometrical irregularities such as seamounts lead to strong creep. Their roles in stopping or generating earthquakes of different sizes are critically important to assessing seismic and tsunami hazards.

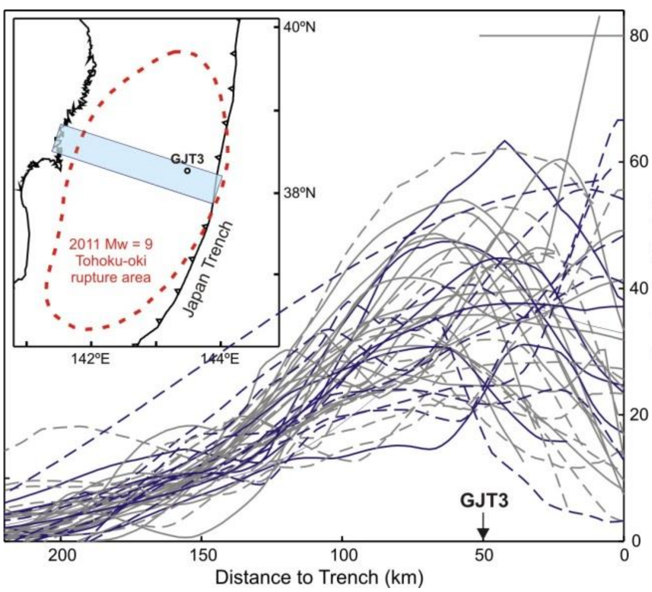

Fig. 1. Fault slip distribution along corridor in inset from 45 published rupture models for the Tohoku-oki earthquake. Models that used seafloor GPS data are shown with solid lines. Models that used tsunami data are shown in blue. GJT3 is the seafloor GPS site nearest to the trench.