

Structure and composition of the plate boundary decollement in the area of maximum slip during the 2011 Tohoku-Oki earth

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The exceptionally large, shallow slip during the Mw=9.0 2011 Tohoku-Oki earthquake caused the strong impulsive peak of the tsunami, emphasizing the importance of understanding the controls on rupture propagation and slip on subduction megathrusts at shallow depths for hazard mitigation. The structure and composition of the decollement near the trench, which both reflect and contribute to the mechanical behavior of the fault, were investigated during Integrated Ocean Drilling Project Expedition 343. Coring results show that the frontal prism is composed primarily of moderately to steeply dipping mudstones. Two steeply dipping reverse faults containing centimeters thick gouge layers, along with numerous smaller shear fractures, attest to long-term shortening in the prism. The footwall Pacific plate sediments are distinct, consisting of shallowly dipping clay-rich mudstones, laminar pelagic clays and chert. Structural evidence of intense deformation is restricted to a layer of dark brown to orange pelagic clay <5 m thick, which marks the decollement. This decollement clay has a pervasive composite foliation, or scaly fabric, defined by striated, lustrous surfaces enclosing lenses of less fissile material. Extremely narrow, planar discontinuities crosscut this fabric, truncating the foliation and separating domains in the clay in which the foliation orientation and intensity change. The decollement damage zone is <10 m wide in both the overlying frontal prism and down-going Pacific plate. Long-term displacement on the plate boundary fault near the Japan Trench is therefore localized onto a zone <5 m thick. The scaly fabric is indicative of distributed shear across the recovered interval (~1 m), and may represent deformation at interseismic strain rates. However, the sharp discontinuities within the decollement clay result from localized deformation, and are similar to those observed at coseismic slip rates in friction experiments, suggesting they formed at higher strain rates. The presence of poorly lithified clay in the incoming stratigraphic section of the Pacific plate controls both the long-term and coseismic mechanical behavior of the decollement near the Japan Trench.

Keywords: Tohoku-Oki earthquake, Japan Trench, IODP Expedition 343, Megathrust earthquake, Shallow slip