Geologic constraints on the geometry composition and structural evolution of the shallow subduction interface and frontal prism in the Japan Trench

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We present ^{10}Be concentration data and structural analyses of sediment cores and seismic data from the Japan Trench that provide insight on the geometry, composition, and evolution of the upper ~10-30 km of the plate boundary interface that experienced slip to the trench during the 2011 Tohoku-oki earthquake. We measured meteoric ^{10}Be concentrations in 24 samples across the frontal prism, décollement, and underthrust sediments from IODP Exp 343 Site C0019 (JFAST), and integrate these data with visual core descriptions, resistivity logs, and high-resolution multi-channel seismic profiles collected by JAMSTEC. Our data provide constraints on four key properties of the shallow subduction interface. First, our data show that the frontal prism contains an abundance of sediment with a high ^{10}Be concentration (>8 x 10^8 atoms/g) and young ^{10}Be ages (<1-2 Ma). When compared to ^{10}Be concentration data from the forearc slope and incoming plate, it is clear that the sampled frontal prism material cannot be sourced from reworked slope sediments, but must consist of recently accreted incoming plate sediment. These results are consistent with seismic profiles that show imbrication of sediments near the trench, and a dé collement located near the base of the incoming sediment section. Over geologic timescales, these data imply that the décollement may localize at or near a frictionally weak, smectite-rich clay layer near the base of the incoming sediment section, with relatively efficient sediment accretion (~50-90%) and minimal sediment subduction, even in the presence of horst-and-graben topography on the incoming plate. Second, within the frontal prism, ^{10}Be data show pervasive apparent thrust and normal faulting, at a spacing of 10s of meters, that likely reflects multiphase deformation of the frontal prism and décollement zone in response to the subduction of horst and graben topography. Such a complex deformation history may contribute to the chaotic nature of seismic refection data across the frontal prism and the lack of a mature imbricate thrust system commonly found in other accretionary margins. Third, our data also highlight the structural complexity that occurs within the plate boundary fault zone. Numerous age and ^{10}Be concentration inversions within the plate boundary decollement zone and underthrust sediment sequence require the presence of multiple discrete faults developed in both biogenic muds and smectite-rich clays. These data are consistent with trace element geochemistry and thermal maturation data that suggest multiple fault horizons, developed in a range of lithologies, have hosted seismogenic slip to the trench in past events. Finally, comparison of the seismic profiles at the JFAST site with those along strike highlights significant along-strike variability in décollement geometry and composition, and in the relative fluxes of accreted versus subducted sediment, at km to 10s-of-km length scales. The style of deformation appears to be a function of the offset of lower plate extensional structures relative to the local sediment cover thickness, and may contribute to small scale heterogeneities in the physical and mechanical properties of the shallow decollement. Collectively, these data suggest that the presence of frictionally weak clays may help localize plate boundary slip and promote sediment accretion over geologic time scales, but that the geometry, composition, and frictional properties of the shallow decollement and adjacent sediments vary over short spatial scales and between seismogenic events.

Keywords: meteoric 10Be, shallow decollement, Japan Trench

