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Bending-related normal faulting influence on near trench decollement propagation along the Japan Trench

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Geophysical analysis of the great 2011 Mw 9.0 Tohoku earthquake revealed co-seismic rupture to the trench with a combination of uplift and landslides contributing to tsunamigensis. After ~150 seconds of rupture along the main decollement, normal faulting focal mechanisms started to dominate, especially along the outer rise. These bending-related normal faults appear to affect the updip geometry of the decollement, where seismic reflection data show downcutting of the decollement into a local trench graben. We investigate bending-related normal faulting to a maximum of ~70 km seaward of the trench using depth migrated regional 2D seismic lines and trench focused 2D high-resolution seismic lines to understand the incoming plate geometry near the Tohoku earthquake epicenter. We studied two different classes of normal faults: faults that cut the basement, which dominate the outer-rise topography, and faults that cut the sediment section near the trench but do not penetrate the oceanic basalt, which are seen only in the high-resolution images. Basement-cutting, bending-related faults in the Japan Trench are well documented from multiple bathymetric surveys. We use structural reconstructions to constrain dip and basement offsets along those faults. This process revealed dips varying between 50-80 degrees with a general trend of increased displacement towards the trench. Faults within the sediment column exhibit offsets of ~20m or less but with densely spaced populations of ~30 faults within ~2km. From this understanding of bending-related normal faulting, we propose a simple mechanism for the decollement's propagation into the graben using local stress changes. Before the decollement propagates into the trench graben, co-seismic rupture to the fault tip creates large tensional stresses down into the trench graben, promoting secondary crack formation in the damage zone or activation of the near surface sedimentary faults. Furthermore, tensional stresses from the potentially active basement-cutting, graben bounding normal fault also rotate the local stress within the graben. Later in the earthquake cycle, thrust faulting would experience the stress rotation or exploit these weak surfaces to propagate into the graben. These results demonstrate the significance of the incoming bending-related normal faults to the geometry of the updip extent of the megathrust at the Japan Trench.

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