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Deformation structures in the frontal prism near the Japan Trench: Insights from sandbox models

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Subduction of bathymetric features in the oceanic plate, e.g., seamounts, aseismic ridges, volcanic plateaus has a strong influence on the development of morphological features and deformation structures in the overriding plate. For example, the subduction of seamounts correlates to a steeper surface slope in the inner wedge than that in the outer wedge. Conversely, the subduction of aseismic ridges causes the development of a steep outer wedge slope and with almost flat inner wedge. Despite the dominance of horst-and-graben structure at many trenches, its influence on frontal wedge growth remains relatively unexplored. We have used sandbox experiments to explore the mechanics of the frontal prism structures near the Japan Trench documented by seismic reflection data and new borehole from IODP Expedition 343 (JFAST). This study investigated the effects of down-dip (normal to trench axis) variations in frictional resistance along a decollement on the structural development of the frontal wedges near subduction zones. Interpretation of seismic reflection images indicates that the wedge has been affected by trench-parallel horst-and-graben structures in the subducting plate. We performed sandbox experiments with down-dip patches of relatively high and low friction on the basal decollement to simulate the effect of variable coupling over subducting oceanic plate topography. Our experiments suggest that high frictional resistance on the basal fault can produce the internal deformation and fault-and-fold structures observed in the frontal wedge by the JFAST expedition. Subduction of patches of varying friction cause a temporal change in the style of internal deformation within the wedge and gave rise to two distinctive structural domains, separated by a break in the surface slope of the wedge: (i) complexly deformed inner wedge with steep surface slope, and (ii) shallow taper outer wedge with a sequence of imbricate thrusts. Our experiments further demonstrate that the topographic slope-break in the wedge develops when the hinterland part of the wedge essentially stops deforming internally, leading to in-sequence thrusting with the formation of an outer wedge with low taper angle. For a series of alternate high and low frictional conditions on the basal fault the slope of the wedge varies temporally between a topographic slope-break and a uniformly sloping wedge.