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Runaway slip to the trench due to rupture of highly pressurized megathrust beneath the middle trench slope

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In plate subduction zone, enormous earthquakes occur repeatedly on the plate boundary, which is facing surface between subducting sediments and basal rocks. The subducting rocks have been presumed to supply water to the plate boundary during subducting, which has much effect on deformation processes and earthquakes in the subduction zone. To clarify the relation between dehydration, deformation and earthquakes along subduction zone, we discussed diagenesis and deformation processes of ribbon cherts embedded in a Jurassic accretionary complex, central Japan, and evaluated the dehydration region in the Japan Trench through numerical simulation.

The diagenesis and deformation processes of ribbon cherts were investigated in detail to gain a better understanding of the mechanical behavior of the plate boundary at depth in cold subduction zones. The analyzed cherts record two stages of deformation: (1) map- to outcrop-scale ductile folding, and (2) subsequent brittle faulting. The ductile deformation was facilitated by silica dehydration?precipitation, and is represented by multiple stages of vein networks. The folds are cut by brittle faults, indicating lithification and the concurrent mechanical transition from ductile to brittle behavior. Slip zones along the faults are typically filled with brecciated chert in a chlorite matrix. Geothermometry analysis of the matrix chlorite suggests that faulting occurred following the completion of opal-CT to quartz transition reaction. This is also confirmed by the kinetic simulation of silica conversion reactions. The results suggest that ductile deformation of thick pelagic deposits with abundant fluids results in an aseismic plate boundary, whereas chemical diagenesis of the deposits, producing crystalline cherts, results in strong interplate coupling in cold subduction zones such as the Japan Trench.

Based on the upper results and discussion, the gigantic 2011, March 11 Mw 9 Tohoku earthquake is examined from the viewpoint of the pre-seismic forearc structure, the seismic reflection properties of a megathrust around the usual up-dip limit of the seismogenic zone, the thermal state of a shallow subduction zone, and the dehydration of underthrust sediments.At the Japan Trench the Pacific Plate is subducting westward beneath the northeast Japan at a dip angle of 4.6 deg. The middle and lower slopes dip eastward at angles of ~2.5 and ~8.0 deg, respectively. The forearc prism beneath the middle and lower slopes is inferred to be in extensionally and compressively critical states, respectively, based on the presence of clear internal deformation features and on the occurrence of aftershock earthquakes. The rapid uplift of the forearc that caused the 2011 Tohoku tsunami may have been associated with this internal deformation of the prism. The critical state of the prism indicates that the effective basal friction (mub') of the plate boundary megathrust is <0.03 for the middle prism and >0.08 for the lower prism. The megathrust, especially under the middle slope, is characterized by a prominent reflector with negative polarity; i.e., a landward-increasing wave amplitude. This observation suggests that the megathrust hosts highly pressurized fluids. Underthrust sediments in this part of the Japan Trench are dominated by pelagic and siliceous vitric diatomaceous silt with clay. The dehydration kinetics of opal-A to quartz, the clay transformation of smectite?illite, and the thermal structure of the Japan Trench suggest that maximum dehydration of the sediments would take place at 50?60 km horizontally from the deformation front, where the temperature along the megathrust is 100?120C. The zone of maximum dehydration coincides with the prominent seismic reflector that has negative polarity. We hypothesize a possible free slip along this portion of the megathrust during the 2011 Tohoku earthquake, caused by anomalously high fluid pressure resulting from fluid accumulation over centuries.

Keywords: underthrust, sediment, dehydration, excess pore pressure