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Dynamic interactions between fluid and earthquake faulting in the subduction thrust

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Studies of exhumed plate boundary faults in ancient accretionary complexes provide an invaluable opportunity to understand the dynamic processes of earthquake faulting in subduction zones. The ancient subduction thrust in the upper part of seismogenic depths (4-6 km) is well exposed in the Late Cretaceous-early Tertiary Shimanto accretionary complex of eastern Shikoku, which constitutes a duplex structure developed during the underplating of subducted melange and the topmost part of the oceanic crust (basalt). The fault zone is 20 m thick and is composed of foliated cataclasites derived from basalt and ultracataclasites derived primarily from basalt and secondarily from melange. The internal structure of the fault zone indicates that the slip was concentrated along the narrow (2-20 cm thick) ultracataclasite layer. This layer is continuous along the strike and has locally changing dips from subvertical to moderately dipping. Several characteristic deformational features have been identified in the ultracataclasite layer. One is the fluidization of ultracataclasites, which is characterized by the homogeneous texture of ultracataclasites, the injection of ultracataclasites into melange, and the mixing of ultracataclasites derived from basalt and those derived from melange. Fluidized ultracataclasites occurred regardless of the dips of the ultracataclasite layer. Others are marked by the implosion breccias and the discrete slip surface. The implosion breccias are distributed only in the moderately dipping ultracataclasite layer that represents a dilational jog in a thrust system. The implosion breccias, in which angular fragments of ultracataclasites are included in the calcite matrix, are commonly incorporated into the fluidized ultracataclasites; this is indicative of temporal changes in the cohesion of ultracataclasites. The discrete slip surface is sharp and smooth, and it juxtaposes contrasting ultracataclasite components. The silica layer with a thickness of less than 100 microns is locally developed along the discrete slip surface, which is composed of microcrystalline quartz crystals. Observations of the silica layer by transmission electron microscopy identified spherical silica cores (10-100 nm in diameter) overgrown by clear quartz rims. These features suggest the hydrothermal precipitation of amorphous silica along the discrete slip surface, which may possibly reduce the dynamic friction, and the textures of the silica layer may represent a subsequent crystallization. The characteristics deformations including the fluidization and implosion brecciation suggest that the ultracataclasite layer was the locus of earthquake rupture. The fluidization of the incohesive ultracataclasite could lead to rupture propagation. In contrast, the passage of the rupture along the cohesive ultracataclasite likely occurred along the discrete slip surface, which may accompany the implosion brecciation associated with depressurization at dilational jog (i.e., stopping of rupture) and/or the precipitation of amorphous silica gel (i.e., lubrication of the rupture surface). Our new observations of the ultracataclasite layer suggest that the rupture behavior in the upper part of the seismogenic depths was complex, and it depends on the cohesion of ultracataclasites during earthquake faulting.