Subduction of buoyant oceanic plateaus and intraslab high-angle normal-fault earthquakes

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Shallow normal-fault earthquakes at subduction zones usually occur either in the forearc of overriding plates, in the outer rise region of incoming plates or within deeply subducting plates. These normal-fault events are typically induced by plate bending and/or volume reduction (densification) associated with metamorphic dehydration and tend to avoid a source region of megathrust earthquakes along the plate interface at typical seismogenic depths (e.g., 10-30 km). This spatial relationship between reverse-fault and normal-fault events reflects the fundamental stress regime caused by plate subduction and thus seems true for most of the subduction zones worldwide. In that sense, an earthquake sequence that occurred in 1995 in the northern Ryukyu (Nansei-Shoto) subduction zone seems weird. This activity was initiated by the main shock with a moment magnitude of 7.1 and was followed by several large aftershocks with a magnitude greater than 6.0 within 24 hours. Surprisingly, aftershock distributions constrained by ocean bottom seismograph data indicate that conjugate faults with very high dip angles of up to 80° ruptured the subducting slab (Yamada et al., 1997). The source region is characterized by collision/subduction of the Amami Plateau, a large-scale oceanic plateau developed on the incoming Philippine Sea plate. Based on the spatial coincidence, previous studies hypothesized that a subducting seamount in the flank of the Amami Plateau played a role in generating the large intraslab normal-fault earthquakes (Kasahara and Sato, 1997), but fine-scale structural information was necessary to test this hypothesis.
Based on active source seismic imaging, we present structural evidence for large normal-fault events almost vertically intersecting the subducting slab. The seismic reflection images reveal that the plate interface is a few kilometers displaced along one of the faults of 1995 events and that a large seamount with a relative height of 1-2 km is located updip of their source region. These results suggest that a lateral variation in buoyancy force acting on the slab can sufficiently produce an extensional stress regime in a semi-vertical direction leading to large near-vertical normal-fault earthquakes within the subducting plate.
In the study area, another large earthquake with magnitude of around 8 named the Kikai-jima earthquake occurred in 1911. The previous study proposed that this event may have been a shallow interplate earthquake (Goto, 2013), but its potential source region may overlap the regions with large-scale structural heterogeneities along the plate interface including the seamounts and vertical displacements, which are likely to inhibit stress accumulation leading to a high-speed rupture. Alternatively, we point out another possibility that the Kikai-jima earthquake was also a high-angle normal-fault earthquake within the subducting slab similar to the events in 1995.

Keywords: Seamount subduction, Normal-fault earthquakes, MCS reflection