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Strength of the M9 Tohoku Earthquake generating fault

SHIMIZU, Ichiko[1*]

[1]Department of Science, University of Tokyo

The 2011 off the Pacific coast of Tohoku Earthquake with a magnitude (M) of 9.0 (the M9 Tohoku Earthquake) occurred at an intermediate depth (approximately 24 km) on the subducting plate interface, whereas the usual Miyagi-oki earthquake had been expected to occur at the down-dip side. A huge area of the plate interface, including asperities of the M7-class Miyagi-oki earthquakes and their surroundings, was ruptured at the mainshock, although the surroundings were previously assigned as stable sliding regions. The interplate coupling of the source region of the M9 earthquake had been believed to be weak because small repeating earthquakes were rarely occurred, but new estimates suggest high coupling coefficients in this region (Uchida & Matsuzawa, 2011, EPS). Now the questions arise: ”What is the difference between the asperities of the usual Miyagi-oki earthquakes and the source region of the March 11 event, and why the M9 earthquake occurred at the region where small repeating earthquakes are almost absent”.

Geophysical observations (Ito et al., 2005, GRL; Miura et al., 2005, Tectonophysics) suggest the existence of subducted seamounts at the neighborhood of the hypocenters of the M9 Tohoku Earthquake and the 1978 Miyagi-oki Earthquake. It is possible that ruptured seamounts at the depth behave as regular asperities and that uncollapsed seamounts at shallower parts act as barrier against frictional sliding.

Assuming the upper surface materials of the subducting slab to be siliceous sediments with the thickness of 2-3 km and seamounts of basaltic compositions, the strength envelope for the interplate thrust fault in NE Japan was drawn. A dislocation creep flow law of fine quartz rocks was applied for the rheology of siliceous sediments. The occurrence of repeating earthquakes at deep regular asperities is well accounted for by rheological contrast between basaltic (or gabbroic) rocks and wet quartz. The hypocenter of the M9 earthquake corresponds to the upper limit of the brittle-ductile transitional zone of wet quartz. The failure of this high-strength zone was possibly triggered by the collapse of the subducted seamount. The propagation of the coseismic slip to the down-dip part of the thrust fault is understood by the velocity-dependence of viscous/frictional properties in the brittle-ductile transitional zone.

Keywords: The 2011 off the Pacific coast of Tohoku Earthquake, asperity, rheology, subduction zone, frictional law, seamount