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断層の力学から見た2011年東北沖地震の発生機構
Mechanism of 2011 Tohoku-oki Earthquake in view of Fault Mechanics

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We discuss about the mechanism of the devastating Tohoku-oki earthquake (Mw 9.0, 11 March 2011) in view of the current status of fault mechanics and to point out future tasks for better understanding of megathrust earthquakes in subduction zones. Main points of discussions are listed below.

(1) Erosional boundary and low temperature may cause diversity of seismicity. Subducting plate boundary in Tohoku is a classical erosional plate boundary which allows diverse combinations of rocks in contact at the plate boundary. Subduction zone in Tohoku is also characterized by low temperature although estimated temperature at the bottom of seismogenic plate interface varies from 210 degrees Celsius (Peacock and Wang, 1999, Science) to 400 degree Celsius (Iwamori and Zhao, 2000, GRL). Contacts between oceanic rocks (seamounts and oceanic crust) and basement rocks on the hanging-wall side can be sites of seismic behaviors in view of friction data on granite and gabbro, whereas a shift from velocity-strengthening to velocity-weakening behavior seems to occur at higher temperature for clay-bearing gouge than for granite and gabbro (den Hartog et al., 2012, EPSL). Thus combination of different rock pairs and low temperature can cause diverse behavior ranging from aseismic to seismic behaviors recognized in off-Tohoku areas. However, we definitely need data from friction experiments on representative metamorphic rocks in subduction zones at low to high temperatures.

(2) Seismogenic zones: Seismogenic plate boundary in Tohoku can be divided into three zones; (i) fore-arc accretionary prism (down to about 15 km in depth), (ii) continental crust to oceanic crust interface (about 15-25 km), and (iii) wedge mantle to oceanic crust interface (about 25 to 50-60 km). We will discuss characteristics of those zones in the presentation. Several friction experiments revealed that friction coefficient increases with increasing temperature, and hence frictional strength will be higher in (ii) than in (i). Moreover, high-permeability of fractured rocks in (ii) will low pore pressure there than in (i). Thus high friction and less pore pressure could have been the cause of asperity during the Tohoku-oki earthquake. Sealing of fractures at depths will cause build-up of pore pressure in (iii), but not as high as in Nankai trough, is probably a cause more frequent earthquakes in (iii).

(3) Megathrust earthquake: An important issue raised by this earthquake is how a megathrust earthquake occurs along a plate interface that is not coupled 100%. Earthquake rupture can propagate into velocity strengthening regime if fault weakens dramatically at high slip rates (Noda and Lapusta, 2013, Nature) and this provides a mechanism for megathrust earthquake. However, majority of moderate to large earthquakes do not develop into a megathrust earthquake, so that earthquake modeling including intermediate to high-velocity friction is needed. In particular, the effects of marked velocity-strengthening at the intermediate velocities (Sawai et al., 2012, AGU) on earthquake rupture propagation should be addressed.

(4) Tsunami earthquake and large displacement at shallow plate interface: Dramatic gouge weakening and thermal pressurization probably made it possible for shallow parts to undergo very large displacement and even overshooting. Recent high-velocity experiments (e.g., Faulkner et al., 2010, GRL) demonstrated that wet gouge exhibits almost no peak friction allowing rupture propagation and fault motion very easy. However, the tsunami earthquakes appear to be rather rare events compared with moderate to large earthquakes in Tohoku. We suggest that the bottom part of (i) and the upper part of (ii) above undergo dilatancy upon initiation of fault motion which prohibits easy rupture propagation into shallow plate interface to cause tsunami earthquake.

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