Future tasks in the studies of subduction-zone rheology

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Recent geodetic and seismological studies have been revealing a wide variety of behavior of subducting plate boundaries ranging from great earthquakes to slow slip. Rheology of subduction zone has to be established to understand the origin of the diverse behavior. An IODP project on the drilling into seismogenic zone in Nankai Trough is going to start in a few years, and we must promote integrated studies linking analyses of natural faults (deformation mechanisms, fluid flow and constituent materials in fault zones), laboratory experiments to determine frictional and transport properties of faults, theoretical and numerical analyses of fault motion, and geodetic and seismological analyses of fault behavior. This presentation will review the current status and futures tasks in fault constitutive properties associated with subduction-zone rheology with emphasis on the following three topics.

(1) Fault constitutive laws in the brittle, intermediate and fully plastic regimes

Mode of deformation changes from brittle, through intermediate and to fully plastic deformation along shallow to deep subducting plate boundaries. Most modeling of earthquakes along subducting plate boundaries is based on a change from velocity weakening to velocity strengthening in steady-state friction in the brittle fault constitutive law as the lower bound of seismicity. However, a constitutive law combining frictional and flow properties needs to be used. High-temperature shearing experiments on halite shear zones have revealed slow stick-slip events lasting for a few seconds and stops gradually near the bottom of the seismogenic zone, although ordinary stick-slip in the same machine last for a few ms. Low-frequency earthquakes and associated slow slip, as revealed by Obara recently, may be characteristic of fault behavior at the very base of seismogenic zone.

(2) Constitutive properties of phyllosilicate-rich fault zones

Phyllosilicate minerals such a clay minerals have only one slip system, so that fault zones containing those minerals have some flow property mixed with frictional property. However, their properties are so subtle that those two properties have not been separated yet. The difficulty will be illustrated with several examples. Montmorillonite-illite transition as a cause for the onset of seismicity at the shallow end of seismogenic zone has been established based on laboratory experiments. Understanding the behavior of mixed clay and granular minerals is critical to this problem.

(3) Effects of solution-precipitation and reaction processes

Solution-precipitation processes have two contrasting effects on fault behavior; i.e., one to promote seismic behavior by enhancing strength recovery of faults during interseismic period, and the other to suppress the seismic motion by inducing viscous behavior via solution-precipitation creep. How to combine those effects is a difficult, but an essential and important task in establishing subduction-zone rheology. Effects of chemical reactions still remain to be explored.