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Earthquakes in subduction zones: An important role of aqueous fluids in earthquake generation

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Recent investigations have shown that slab-origin aqueous fluids play an important role in generation of three main types of earthquakes in subduction zones. Studies on spatial distribution of intraslab earthquakes and tomographic imagings of seismic velocity structure within the Pacific slab provide evidence which supports the dehydration embrittlement hypothesis for generation of intermediate-depth intraslab earthquakes. Investigations of detailed seismic velocity structure in and around the plate boundary zones suggest that interplate coupling is mainly controlled by fluid overpressure there or serpentinization of the mantle wedge right above. Seismic tomography studies show the existence of inclined sheet-like seismic low-velocity zones in the mantle wedge not only in Tohoku but also in other areas in Japan, which perhaps correspond to the upwelling flow portion of the subduction-induced convection system. The upwelling flows reach the Moho right beneath the volcanic areas, suggesting that those volcanic areas are formed by the upwelling flows. Aqueous fluids derived from the slab are probably transported upward through the upwelling flows to reach the arc crust, where they might work to weaken the surrounding crustal rocks and finally cause shallow inland earthquakes.

Generation of the 2011 Tohoku-oki earthquake and its induced seismic activities also seem to be closely related with aqueous fluids. We observed a clear temporal change in stress field near the source area after the earthquake which shows nearly complete stress drop by the earthquake, suggesting that the plate interface is very weak. Temporal change in stress field after the earthquake is also observed for inland areas, suggesting that faults for inland earthquakes are weak as well. The weak faults are probably caused by overpressured fluids. Tomographic imagings in the source area of a large (M7.1) intermediate-depth intraslab aftershock provide evidence for reactivation of a buried hydrated fault in the Pacific slab.

These observations suggest that aqueous fluids expelled from the subducted slab play an important role in the generation of three main types of earthquakes in subduction zones.

Keywords: Subduction zone, aqueous fluids, interplate earthquake, intraslab earthquake, shallow inland earthquake