Relation between slab-bending-related hydration and earthquake swarms in subduction zones

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Slab-bending-related faults and their hydration are known to strongly influence fluid distribution in subduction zones [Worzewski et al., 2011]. Recent studies have shown that slab-bending-related hydration also has a strong influence on seismicity in subduction zones. For example, Ranero et al. [2005] found that intermediate-depth (70—350 km) intraplate earthquakes are especially active in subduction zones with well-developed bending-related faults. Nishikawa and ide [2015] and Shillington et al. [2015] found positive correlations between the curvature of incoming plate before subduction, the pervasiveness of bending-related faults, and the seismicity rate of interplate earthquakes in subduction zones. These correlations suggest that expelled fluid from hydrated bending-related faults reduce the strength of intraplate faults and plate interface, and increase the seismicity rates.

An earthquake swarm, which is an increase in seismicity rate without a clear mainshock and does not follow the Omori’s law [Utsu, 1961], also may be related with slab-bending-related hydration. Poli et al. [2017] found that a spatial clustering of earthquake swarms in central Chile trench shares similar orientation with slab-bending-related faults, and suggested that expelled fluids from hydrated bending-related faults might facilitate earthquake swarms. Therefore, it is also possible that variations in earthquake swarm activity in world’s subduction zones [Holtkamp and Brudzinski, 2011] are related with variations in slab-bending-related hydration. Here we detected earthquake swarms in world’s subduction zones and compared the swarm activity with the curvature of incoming plate before subduction, which is known to correlate with the pervasiveness of slab-bending-related faults and the intensity of slab-bending-related hydration [Faccenda, 2014].

We divided world’s subduction zones into 100 half-overlapping study regions. Each region is bordered by a trench section of about 500 km and extends 200 km in the direction of plate motion [Ide, 2013]. In each region, we extracted earthquakes with M 4.5 during 1995-2009 in the ANSS catalog. We applied the space-time ETAS model [Zhuang et al., 2002] to seismicity in each region and detected anomalous increases in seismicity rates that do not follow the Omori’s law as earthquake swarms. Then, we compared the swarm activity and the curvature of incoming plate before subduction. Here we fitted cubic functions to the topography of outer-rise regions (< 100 km from trench) [Smith and Sandwell 1997] and calculated the curvature of incoming plate before subduction. As a result, we found that the number of swarm events, the number of swarm events per 1-m plate motion, and the ratio of the number of swarm events to all observed events positively correlate with the curvature of incoming plate. The swarm activity is especially high in subduction zones with a large plate curvature and thus strong bending-related hydration.

These results are consistent with the interpretation of Poli et al. [2017]. Expelled fluids from hydrated bending-related faults may facilitate earthquake swarms in subduction zones with a large plate curvature. Furthermore, slow slip events (SSEs), which often trigger earthquake swarms in subduction zones [e.g, Sagiya, 2004], are known to occur in regions with abundant fluid [e.g., Kodaira et al., 2004]. It might be possible that slab-bending-related hydration also has some relation to SSE activity at seismogenic depths in subduction zones. In fact, expelled fluids from hydrated bending-related faults can facilitate decoupling and aseismic slip on the plate interface [Moreno et al. 2014].

Our results reveal the relation between slab-bending-related hydration and earthquake swarm activity in world’s subduction zones. To understand variations in the characteristics of seismicity among world’s subduction zones, it is important to further clarify the role of slab-bending-related hydration in seismicity.

Keywords: Slab-bending-related fault, Earthquake swarm, ETAS model, Hydration, Slow slip, Seismicity