Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SSS30-21 Room:Main Hall Time:April 28 17:00-17:15

Seismicity rate variations in subduction zones related to forearc topography

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There are clear variations in seismicity among subduction zones worldwide in terms of such as the frequency of earthquake occurrence and maximum earthquake magnitude. These variations have been attributed to differences in tectonic properties in subduction zones, such as relative plate velocity and subducting plate buoyancy. For example, Ide [2013] demonstrate proportionality between relative plate velocity and background seismicity rate — the frequency of seismic events excluding aftershocks. Given that earthquakes occur to release strain in the crust accumulated by relative plate motion, we can intuitively understand this proportionality.

The overriding plate is also an important control on earthquake occurrence in subduction zones. Seismological observations and studies of tectonics have suggested the relationship between forearc topography and frictional properties on the plate interface, such as interplate locking and pore fluid pressure. Given this relationship, variations in forearc topography may reflect differences in frictional properties on the plate interface among subduction zones worldwide. However the relation between forearc topography and variations in seismicity among subdcuction zones is still unclear. In this study, we compare forearc slope and background seismicity rate in subduction zones worldwide. The forearc slope is based on Smith and Sandwell [1997], and the background seismicity rate is estimated using the epidemic type aftershock sequence (ETAS) model [Ogata, 1988]. We show the correlation between forearc slope and background seismicity rate. Subduciton zones with steeper forearc slopes have higher seismicity rates. Furthermore, subduction zones that are outliers of the proportionality between relative plate velocity and background seismicity rate [Ide, 2013], such as Cascadia and South Chile trench, also appear to obey this correlation.

According to the critical taper theory [Davis et al., 1983; Dahlen, 1984], which explains the relationship between forearc topography and frictional properties on the plate interface, and sand box experiments [e.g., Gutscher et al., 1996], steep forearc slope is associated with high basal friction. When we take these studies into account, our results suggest that the seismicity rates are high in subduction zones with steep slopes and high basal friction. This can be explained by considering erosion and accretion processes and geometrical irregularities on the plate interface. Erosional margins tend to have steeper forearc slopes [Clift and Vanucchi, 2004]. Because of thin trench sediments in erosional subduciton zones, geometrical irregularities on the subducting plate are not smoothed. Such irregularities may cause high basal friction at the tip of the forearc wedge and steepen the forearc slope. In the seismogenic zone, these irregularities act as numerous small asperities, and these asperities result in many seismic events in the erosional subduction zone. In contrast, accretionary margins generally have gradual slopes. Thick trench sediments smooth subducted seafloor, and it results in low basal friction at the tip of the forearc wedge and the gradual forearc slope. The smoothed plate interface may act as one large asperity in the seismogenic zone, and fewer earthquakes occur in the accretionary subduction zone. Furthermore, these variations in number and size of asperities among subduction zones worldwide may cause differences in megathrust earthquake occurrence.

Our results reveal the relation between forearc topography and seismity, and suggest that the frequency of seismic events in subduction zones is controlled by not only the mechanical factors such as relative plate velocity and the strain accumulated in the crust, but also the material factors such as erosion and accretion processes, trench sediments, and geometrical irregularities on the plate interface.

Keywords: seismicity rate, subduction zone, forearc topography, erosion and accretion, asperity