Occurrence of normal-type earthquakes and stress loading model under Boso Peninsula, Japan

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Boso Peninsula, Japan, was formed by the interaction of the Philippine Sea, Eurasian and Pacific plates around the trench-trench-trench Boso triple junction. Normal-type earthquakes are persistently observed in the subducting Philippine Sea slab under the peninsula at depth of ~30 km, including a recent (2019) Mw4.9 earthquake which caused shaking throughout the Kanto region (greater Tokyo). Such shallow intra-plate earthquakes are potentially hazardous to this heavily populated region, yet their mechanism is poorly understood, compared with the outer rise earthquakes or intermediate deep earthquakes within slabs. In the previous study, we modeled long-term deformation due to steady subduction of the Pacific and Philippine Sea plates (Hashima et al., Tectonophysics, 2016). Here, we calculate stress rates in the Philippine Sea slab and the surrounding area, using our subduction model, to explain the generation of the regional stress field and its effect on earthquake occurrence.

In our model, the subduction of the Pacific and Philippine Sea plate is expressed by the steady slip (dislocation) on the plate interfaces. The collision of the Izu Peninsula is expressed by slip-rate deficit. The area of the slip-rate deficit is determined to satisfy the long-term deformation data obtained by geological and geomorphological methods. Then, slip-rate deficit turned out to be distributed on the northwest side of the Izu Peninsula.

Using this optimum model, we obtained all-around horizontal extensional stress rates under Boso Peninsula both above and below the Eurasian-Philippine Sea plate interface. In broader view, the stress rates are northwest-southeast compression in the collision zone around Izu Peninsula, strike-slip type in the Philippine Sea plate to the south, and horizontal extension in the Eurasian plate north of Boso Peninsula.

We apply our calculated stress rates to the nodal planes of the observed earthquakes to calculate the Coulomb failure function (ΔCFF). These calculated ΔCFFs are generally positive on normal-type earthquakes under Boso. This result indicates that modeled intra-plate stress pattern is consistent with earthquake occurrence as the stress release process. The ΔCFFs are also consistent with earthquakes in adjacent seismically active areas: the Izu collision zone, the interior of the Philippine Sea plate, and in seismic swarms in the Eurasian plate northeast of Boso Peninsula, which further supports our stress loading model.

To reveal the individual contributions of the Philippine Sea and Pacific subduction and the Izu collision, we decomposed the calculated stress rates. The collision effect is negligible on Boso Peninsula. The subduction of the Pacific plate creates east-west extension, while that of the Philippine sea plate creates north-south extension. Both subduction together creates the characteristic all-around extension under Boso Peninsula.

Keywords: Boso Peninsula, Stress loading, Coulomb stress, Plate subduction, Philippine Sea Plate

