Transition tectonics between the Southwest Japan and Ryukyu arcs appeared in crustal deformation fields

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The tectonics on the Kyushu island of Japan has brought attention by the occurrence of the 2016 Kumamoto earthquake (Mw 7.1). The Beppu-Shimabara rift zone, where the earthquake occurred, is located on the extension of Median Tectonic Line in the Southwest Japan arc and the Okinawa Trough, the backarc basin of the Ryukyu arc, and the relation to their activities has been proposed. Around the Kyushu island, Mj 7.1 earthquake occurred off the southwest coast in 2015. The southern part of the Korean peninsula suffered by the Gyeongju earthquake in 2016, which scaled the maximum magnitude (Mw 5.4) ever observed, and the Pohang earthquake in 2017, which has the similar magnitude. To reveal the mechanism of the activities of these intra-plate earthquakes, it is necessary to model the stress loading mechanism on source faults due to subduction of the Philippine sea plate. The model can be satisfactorily constrained by the dense observation network of regional crustal deformation of the GSI of Japan. There have been several analysis studies on crustal deformation focusing on the coupling (slip-rate deficit) at the Nankai Trough. However, little attention has been given to the trench retreat of the Ryukyu trench. In the present study, we constructed a three-dimensional finite element model to reveal the overall plate interface process on the upper surface of the Philippine sea plate from the Nankai trough to the Ryukyu trench, and to understand the crustal activities around the boundary zone between the Southwest Japan and the Ryukyu arcs including the Kyushu island. Then, we estimated the effect of the trench retreat at the Ryukyu trench by analysis of the regional crustal deformation fields.

Our model contains the region of 3700 km x 4600 km including the Nankai trough and the Ryukyu trench. The bottom of the model is taken at the depth of 700 km to consider the whole upper mantle. The geometries of the Pacific and Philippine sea slabs under the Northeast Japan –Izu Bonin arcs, and the Southwest Japan –Ryukyu arcs, respectively, are incorporated following the previous studies. The model region is divided into 1000,000 tetrahedral elements. The size of the elements is set 5 km around the slip region and gradually larger close to the boundaries. Fault slip can be modeled by giving constraint equation of displacement discontinuity. Slip region is taken on the upper surface of the Philippine sea plate shallower than the depth of 80 km along the Nankai trough and the Ryukyu trench. This region is divided into 216 subfaults where unit slip responses are calculated to obtain slip distribution by the inversion analysis using the crustal deformation data. Since the interseismic deformation includes the effect of the concurrent viscous relaxation in the asthenosphere, we used response after complete relaxation. As the crustal deformation data, we used data of 453 stations west of 138E and south of 36.5N from the F3 solutions of daily coordinates by GSI of Japan. From these time series, we took 10 years before the 2011 Tohoku-oki earthquake.

We obtained slip distribution that shows 4-8 cm/year slip-rate deficit along the Nankai trough and ˜4 cm/year slip-rate excess. While the slip-rate deficit along the Nankai trough is almost similar to the one obtained the previous studies, the slip-rate excess along the Ryukyu trench is strongly consistent with the slab rollback at the Ryukyu trench that leads to the backarc spreading of the Okinawa trough. The slip-rate excess along the Ryukyu trench is found necessary to explain the anti-clockwise motion on the Kyushu island as well as the slip-rate deficit along the Nankai trough. Using the slip distribution, we can

also calculate crustal stress field. Calculated stress field around the hypocenter of the Kumamoto earthquake is consistent with its focal mechanism.

We are also revising the source fault model published by the Headquarters for Earthquake Research Promotion. In this presentation, we apply the stress fields to the source fault model and calculate the Coulomb stress to show the relation with seismic activities.

Keywords: Southwest Japan arc, Ryukyu arc, Crustal deformation, Finite element method, Viscoelasticity, Coulomb stress

