Mechanism of large earthquakes along the southwestern Ryukyu subduction zone and the east coast of Taiwan

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The Philippine Sea Plate subducts along the southwestern Ryukyu Trench, while it collides to the east coast of Taiwan. Tectonics of this complex region is discussed based on our recent results from studies of tsunami deposits and seafloor crustal deformation observation.

1. Large tsunamis off the coast of Miyako and Ishigaki islands.

Results of our recent survey on Ishigaki reveal that large tsunamis occurred approximately with a recurrence interval of 600 years (Ando et al. 2017). We found fissures in the soil bed beneath the 1771 tsunami layer, which were certainly created during the strong ground motions of the 1771 earthquake. Usami (2010) estimated the seismic intensity of the scale of JMA as IV for Okinawa, 400km east of Ishigaki. Thus, the strength of ground shaking of the 1771 earthquake is to be equivalent to seismic intensity V or more. We infer that the 1771 event was not as anomalous as the 1896 Sanriku-oki earthquake, and was rather an ordinary thrust earthquake at the southern Ryukyu trench. Another huge tsunami occurred on the east of the 1771 source area. On Shimo-jima (Miyakojima city), the largest tsunami boulder (Obi-ishi) in Japan has been transported to the current site by another tsunami. This tsunami is estimated to have occurred between 11th century and 1771. These observations suggest that large earthquakes and tsunamis occurred repeatedly over at least 250 km long along the Ryukyu Trench. These earthquakes are considered to be reverse fault earthquakes at the plate boundary. Based on the model of the 1771 earthquake (Nakamura, 2009), the seismic coupling ratio of the upper and lower plates is estimated to be 20%.

2. Trench retreat and strain field

According to GPS observation, the Ryukyu arc retreats south to southeastward at a velocity of 4-6 cm/y. This migration is caused by the southward retreat of the Ryukyu subduction zone, which causes Sakishima islands stretched at a strain rate of +1–3x10^{-8}/y. Accordingly, in the Okinawa trough, the back-arc basin of the Ryukyu subduction zone, magma intrudes intermittently in a passive manner. In April 2013, magma intrusion occurred in the Okinawa trough, 50 km north of Yonaguni Island. Approximately 3 months after this event, magma intrusion possibly happened 100 km west of the site of 2013 which is revealed by a seafloor crustal deformation observation (Koumi et al., 2017). In the southeastern Ryukyu subduction zone, the trench retreats, while compressional strain is still accumulated near the trench associated with the subduction, and large earthquakes are generated with a recurrence interval of 600 y. It is notable that large earthquakes can occur recurrently even in a weakly coupled subduction zone.

3. Seafloor crustal deformation observation

A survey of seafloor crustal deformation started in 2014, 60 km south of Hateruma Island. Our recent results reveal that this seafloor site moved southward relative to Hateruma, suggesting this region stretched in the trench-normal direction. However, the reliability of the observational results is still low because of its short observation period (2 years). It is necessary to continue the observation at least three more years. At the same time, off the east coast of Taiwan, seafloor observation started in 2009 at three sites to verify the interplate-coupling ratio on the east coast of Taiwan. The recent results of the northernmost site (off Ilan), for the period of 2012 to 2016, show the velocity at 4 cm/y southing and 8 cm/y easting (Koumi et al., 2017). However, the observation point is too far from the trench to estimate a coupling ratio of the subduction zone. Further observation is really required at sites closer to the trench (off Hualien and Chenggong).

4. Summary

In order to elucidate the mechanism of the large earthquakes along the southwestern Ryukyu Trench, the continual observation of crustal deformation off Hateruma Island, and sites near the trench off the east coast of Taiwan.

Keywords: Ryukyu trench, Tsunami, Plate coupling rate, Recurrence interval, Large earthquake, Extensional strain field

