[Invited] Active and passive seismic investigations in the Ryukyu Trench and the Okinawa Trough: A review of 7-year achievements by JAMSTEC

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The Ryukyu subduction zone in southwestern Japan hosts a variety of slow earthquakes and thus is an ideal study field to understand the physical controls on slip behaviors along the plate boundary. The Okinawa Trough, an active back-arc basin behind the Ryukyu arc, also provides a superb site for studying the lithospheric evolution associated with the continental rifting process. However, the background structure of this trench-arc-backarc system and physical properties of faults accommodating the plate subduction and back-arc rifting have been poorly documented. To better understand the seismogenic, volcanic and tectonic processes around the Ryukyu arc, JAMSTEC have been conducting intensive seismic investigations since 2013 as part of “Research Project for compound disaster mitigation on the great earthquakes and tsunamis around the Nankai Trough region”. This project consists of across-arc active-source seismic surveys, including multichannel seismic reflection profiling and refraction studies using ocean bottom seismographs, and passive onshore/offshore seismic observations. In this presentation, we will give a brief review of our achievements over the last seven years.

In the southern Ryukyu Trench off Ishigaki Island where a large tsunami earthquake occurred in 1771 (Nakamura, 2009), we found evidence for thin low-velocity zones along the plate interface at 5-22 km depths and interpreted them to be caused by high fluid pressure (Arai et al., 2016). This fluid-rich plate boundary hosts low-frequency earthquakes at 15-18 km depths and suggests that a strongly-coupled zone, which is typical at these depths in other subduction zones, may be missing. The passive seismic observations also confirmed that the low-frequency earthquakes are located close to but do not overlap regular earthquakes (Yamamoto et al., 2018). This spatial pattern of seismicity suggests that the frictional properties along the plate boundary may vary not only in the dip direction but also along the strike.

On the back-arc side of the southern Ryukyu arc, we revealed symmetrical rift system across the rift axis (Yaeyama Rift) characterized by dense inward-dipping normal faults in the back-arc basin (Arai et al., 2017a). The rift structure accompanies narrow axial intrusions resulted from passive upwelling of magma which drive hydrothermal venting at the seafloor and seismic swarms at the shallow crustal depths.

In the northern Ryukyu Trench off Amami-Oshima Island where the Amami Plateau collides with the overriding plate, we found that the subducting plate is vertically displaced and forms obvious normal-fault steps of over 1 km at the plate interface (Arai et al., 2017b). This slab-intersecting faults are located at the downdip of the subducting seamount and are active as evidenced by large normal-fault earthquakes in 1995. These findings suggest that internal heterogeneities of the slab, especially significant buoyancy acting on the thick oceanic plateau, can produce sufficient differential stress leading to high-angle normal-fault earthquakes within the slab. We also found a number of slab seismicity in the forearc region east off Tanegashima Island and suggest that, same as the southern Ryukyu Trench, there is a clear spatial separation between regular earthquakes and slow earthquakes (Yamamoto et al., 2020).

In contrast to the southern Okinawa Trough, the overall faulting style in the northern Okinawa Trough is significantly asymmetric and rapidly transitions from normal faults to strike-slip faults (Arai et al., 2018). We also detected evidence for active magmatic intrusions around the volcanic front, suggesting that the volcanism in the northern Ryukyu arc is robustly supported by magmatic supply from the subducting slab. The overall rift system in the Okinawa Trough are thought to be controlled by the along-trough variation in extension rate as well as the strength and thermal structure of the plate.