Structural evolution of the southern Sea of Japan and implications for Cenozoic plate interaction around Japan

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The Japanese arc is located in a highly seismically active region, with earthquake and tsunami hazard surrounding the island. Following the tsunami disaster due to the 2001 off-Tohoku M9 earthquake, the Japanese government initiated an extensive evaluation of the tsunami hazard along both the Pacific and Sea of Japan coastline. Since historical records of tsunamis along the western margin of Japan are limited, hazard assessment is based on structural analyses of on- and offshore data. To get a better understanding of potential tsunami source-faults, here we investigate the structural evolution of the Tsushima Strait, southern Sea of Japan.

The southern margin of the Sea of Japan is part of a structurally complex basin that has formed as a result of multiple tectonic events during the last 25 Ma including back-arc rifting and rotation, post-rift inversion and thrusting, and strike-slip deformation. The region is previously studied extensively, however, as most of the studies were limited to one margin of the rift basin (Korean Peninsula, East China Sea, or SW Japan), conflicting hypotheses of its structural evolution have been forwarded. These contradicting understandings have direct implications for the larger scale interaction between the Eurasian, and Pacific and Philippine Sea plates driving these tectonic events.

In this study we investigate the Tsushima Strait, which is located between the Korean Peninsula and southwest Japan, providing a direct view of the rifted basin and its southwestern margin. This region has only been investigated by several previous studies using an offshore commercial 2D seimic dataset from the 70’s and 80’s, including eight wells. Since the results of those studies do not directly align with recent findings in this region, here we re-evaluate the evolution of the Tsushima Strait using the same dataset, in addition to detailed gravity data and recently obtained (2013) 2D seismic profiles. We observe large basement blocks and igneous bodies, and inverted and cross-cut rift-related (half) grabens filled with syn-kinematic deposits. We observe clear stratal terminations that imply a direct transition from an extensional to compressional stress regime. The seismic interpretations are tested using gravity modelling and simple structural restoration.

We argue that the structures in the Tsushima Strait represent a complex history of multiple tectonic events. The subduction of the Pacific and Philippine Sea Plate under the Eurasian plate let to the initial opening of the Sea of Japan by back-arc rifting from 25 Ma. Based on recent previous work, rapid fan-shaped opening of the southern Sea of Japan and Tsushima Strait with clock-wise rotation of the SW Japanese Island arc occurred between 17.9 –15.9 Ma, filling the region with >5400 m thick shallow to deep marine syn-rift sediments. We propose that the pivot-point of this rotation is located southwest of Tsushima Island and migrated along the Tsushima-Goto dextral strike-slip fault during rifting. Contrary to previous studies that suggest a tectonically inactive post-rift period spanning from 15 –8 Ma, we argue that rifting was terminated by a compressional stress regime due to the collision of the Izu-Bonin-Mariana arc system to east Japan at 15 Ma. The northward movement of the young Shikoku Basin within the Philippine Sea Plate caused resistance along the Nankai trough due to its high thermal buoyancy, leading

to compression from 15 Ma. During this shortening event, rift inversion and reverse faults developed in the Tsushima Strait including movement reversal of the Tsushima-Goto fault to sinistral strike-slip. Subsequently, sub-horizontal Pliocene sediments covering the compressional structures mark the subduction of the Shikoku Basin from 5 –1 Ma. Lastly, reactivation of reverse faults to strike-slip is assumed to reflect the change in stress regime at 1 Ma due to a northwesterly shift of the Philippine Sea Plate and opening of the Okinawa Trough.

Keywords: Tsushima Strait, Inverted back-arc rift, Seismic interpretation, Tsunami hazard, Structural evolution

