Structural evolution of the Tsushima Strait, Southern Sea of Japan, and its role in active faulting

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The Japanese island arc is situated in a highly active tectonic area, with earthquakes and tsunami hazard on both the Pacific and Sea of Japan coasts. Following the tsunami disaster produced by the 2001 off-Tohoku earthquake (M9), the Japanese government started an intense evaluation of tsunami hazard spanning the both coastlines. Due to the lack of historical records of tsunamis along the western margin of Japan, hazard assessment is based on structural analyses of on- and offshore data. Here, we investigate the structural evolution of the Tsushima Strait, southern margin of the Sea of Japan, to get better constraints on the structural geometry of this region and develop a present-day tsunami source-fault model.

The Tsushima Strait is a structurally complex area that formed as the result of several regional tectonic events during the last 25 Ma that include back arc rifting and rotation, post-rift compression, weak thrusting, and strike-slip deformation. Previous work in this area is mainly based on onshore sedimentological, biostratigraphic, and paleomagnetic analyses, either on Kyushu and SW Honshu, or Tsushima Island, and only few studies include offshore subsurface data. However, the evolution of this region is not yet well understood, as conflicting hypotheses have been forwarded due to the limited resolution of the data available and methods applied.

In this study we use an extensive offshore subsurface dataset spanning ~625 km along SW Japan and ~150 km offshore in the Tsushima Strait. The data includes 2D seismic reflection profiles with a spacing between 2 –20 km imaging up to 7000 metres depth and 8 wells including detailed completion logs. We observe large basement blocks and igneous bodies, as well as rift-related grabens and half-grabens filled with syn-rift deposits, of which some are inverted. On several locations, these structures are cross-cut by strike-parallel reverse faults, or orthogonally trending flower structures. The observations are interpreted to be the result of a complicated geometrical development of the Tsushima Strait, related to the structural evolution of the Japan island arc and the Sea of Japan.

We argue that multiple, small, basins formed parallel to the Japan arc, during back arc rifting as a result of the subduction of the Pacific and Philippine Sea plates along the east coast of Japan initiating the opening of the sea of Japan (25 –14 Ma). Based on previous palaeomagnetic studies, clock-wise rotation of the SW Japan arc with its pivot point located in the SW of the Tsushima Strait occurred at the end of the rifting phase (17.9 –15.9 Ma), filling the basins with shallow to deep marine syn-rift sediments. From 14 –5 Ma, the marginal rift zone was then exposed to a compressional stress, resulting reverse faults and selective inversion in the Tsushima Strait. We link this shortening phase to the collision of the Izu-Bonin-Mariana arc system onto the Japan along its eastern side and the northward movement of the young Shikoku Basin within the Philippine Sea Plate. Previous work suggests that the high thermal buoyancy of the Shikoku Basin caused resistance along the Nankai trough leading to shortening. Subsequently, we propose that the sub-horizontal Pliocene sediments that cover the compressional structures mark the subduction of the Shikoku basin (5 –1 Ma). Lastly, the reactivation of reverse faults to strike-slip is assumed to represent another major change in stress regime at 1 Ma, as a result of a

northwesterly shift of the Philippine Sea plate and the opening of the Okinawa trough. The present-day active source-faults are defined in at least two different groups: 1) NW-trending, near vertical strike-slip faults, and 2) NNE- to ENE-trending steep (~70°) faults. The former group of active strike-slip faults are interpreted as the result of the current rotated stress field around Kyushu, and the latter to reactivation of the earlier Palaeogene and Neogene structures.

Keywords: Tsushima Strait, Structural evolution, Tsunami source-fault model, Crustal deformation, Sea of Japan, Seismic reflection data

