Cenozoic evolution of the Tsushima Strait and the Fukue Basin, southern Sea of Japan: an interplay of tectonics, palaeo-environment, and volcanism

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The Japanese island arc is tectonically active with earthquake and tsunami hazard along both the Pacific and Sea of Japan coasts. Following the tsunami disaster from the 2001 Off-Tohoku (M9) earthquake, the Japanese government initiated an extensive evaluation of tsunami hazard around Japan. Since records of prior tsunamis along the southern Japan Sea margin are rare, we here investigate the geologic evolution of the SW Japan back-arc basin to identify and analyse potential tsunami source-faults.

Located between SW Japan and the Korean Peninsula, and connecting the Japan Sea and East China Sea, the Tsushima Strait and the Fukue Basin represent a structurally complex region that formed over the last ~25 Ma as a result of several tectonic phases: (i) back-arc rifting and rotation, (ii) post-rift compression, (iii) weak thrusting, and (iv) subsidence and strike-slip deformation. Syn-depositional volcanism and changes in regional palaeo-environment are known from previous studies surrounding this connecting region, but how these factors fit together in the regional tectonic framework is not well understood. In addition to analysing recent seismic reflection data and detailed gravity data, we here re-evaluate extensive seismic reflection profiles and well data of ten boreholes offshore the SW Japan arc. We observe large basement blocks and igneous bodies, and inverted and cross-cut half grabens filled with syn-kinematic deposits. Clear stratal terminations suggest multiple transitions in regional stress regime. The gravity data allow us to link the syn-depositional igneous bodies to previously-dated volcanism onshore. Additionally, planktonic and calcareous nanno-fossils from the well data provide control on absolute timing of different kinematic stages, while benthic foraminifers and pollen show changes in palaeo-water depth, coeval with local, relative palaeo-climate reversals, respectively.

From ~25 Ma pollen data show warming of the local climate in southern Japan Sea side of the Tsushima Strait, while on the East China Sea side in the Fukue Basin relative cooling is observed. This is related to initial rifting, opening up back-arc basin allowing relative warm water to flow through the Tsushima Strait into the Japan Sea warming the local climate, and relative cold water flowing back cooling the local environment in the Fukue Basin on the opposite side of the Tsushima Strait. Subsequently, negative flower structures and large half-grabens filled with over 5400 m of synrift sediments developed between ~18-16 Ma, containing benthic foraminifera suggesting a deepening marine environment. This is linked to the rapid, clock-wise rotation of SW Japan, which pivot point migrates along a dextral oblique normal fault west of Tsushima. At ~15 Ma rift structures are abruptly inverted or cross-cut by thrust faults and wedge thrusts, with microfossils and pollen on the Japan Sea side suggesting shallowing of the palaeo-waterdepth and cooling of the local climate, respectively. Contrary, in the Fukue Basin, the local climate shows relative warming. We suggest that during this compressional tectonic event a topographic sill developed in the Tsushima Strait that cut off water flow between the cooler Japan Sea and the subtropic East China Sea. From ~6 Ma, the local climate on the Japan Sea side warms again contemporarily with deepening of the marine palaeo-environment and deposition of sub-horizontal

Pliocene sediments, implying a weakening of the compressional stress and renewed water flow through the Tsushima Strait. These observations along with previously published data of the surrounding areas enable us to better understand the connection between the Cenozoic structural development of the SW Japan arc, and the related the palaeo-environment changes and volcanism. As a result, we are better able to identify potential tsunami-source faults along the southern Japan Sea margin based on our understanding of the structural evolution.

Keywords: Structural evolution, Tsushima Strait, Fukue Basin, Palaeo-environment, Back-arc rift basin, Inversion

