Analogue modelling of the structural evolution of the Neogene Northern Fossa Magna basin as an intra-arc basin

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This study aimed to simulate the development of the Northern Fossa Magna (NFM) basin and to give more insights to understand the geometry of the active faults systems transecting this area. The NFM intra-arc basin was developed during the Neogene period at the final stage of the Sea of Japan. It is bounded westward by the Itoigawa-Shizuoka Tectonic Line (ISTL) from the Pre-Neogene basement rocks. In order to analyze the development process of the Northern Fossa Magna basin, we conducted a series of analogue experiments. This technique is a powerful method for studying the development of the tectonic structures at various scales. Sandbox experiments carried out in this work allowed us to visualize the development of the geological structures in a scaled model from the opening of the basin, through the filling up and finally the closure of the basin with the accompanied uplift during the tectonic inversion. Three experiments were performed with respect to the scaling model conventions, with some model limitations. According to calculated thicknesses of the strata based on surface geology and referring to results of sandbox models, the subsidence rate was greater in the Miocene period, and relatively during Pliocene. Experiments results suggest that this thickness variation of the strata from the east to the west is to be related to growth normal faults, which were developed successfully in all experiments. These growth normal faults explain well, what we consider to be lack of certain members in the stratigraphical column as well as for the thickness variation of the Neogene strata, which characterize this part of the NFM. Field survey also shows evidence of contemporaneous activity; such as small graben structures with the related synsedimentary normal faults embedded in between horizontal layers. This suggests that the NFM basin has been largely controlled by major normal faults related to the master detachment fault–we named pre-ISTL–during Miocene and Pliocene, which was observed in sandbox experiments. Concerning the basin geometry, results from the experiments at the term of the extension phase, show a basin width of 31 km in average, and the maximum thickness of the sediments accumulated in this fosse is 9 km in average. This analogue model result integrated with other data (well-log data and seismic reflection profile) suggest that the depth of the Neogene strata that have been accumulated is a relatively short time (10 Ma) is about ca. 8.5 to 9 km. Understanding the geological process that created the NFM basin and the geometry of the fault system surrounding this basin is of great importance. Two faults in the study area are considered among the major active faults in central Japan; the Itoigawa-Shizuoka Tectonic Line active fault system and The Western Nagano Basin Fault. During the compression of the sandbox, a popup structure of the NFM was developed in all experiments directed at initial stage of the tectonic inversion by reactivation of preexistent normal faults. At a later stage of the compression, new reverse faults were developed out of the basin. Displacement observed along these new faults accommodated part of the compressive stress. A latest thrusting fault dipping 35 degree occurred at about 7 km depth down east and propagates upward toward the west and emerged at similar location of the ISTL. During the compression, a large amount of the stress seems to confine at a depth of 4.5 to 7 cm in the scaled model, which is equivalent to 9-14 km in the natural prototype beneath the center of the basin. This match well the depth of the historical seismic activity known in this region (10-14 km).