Miocene intra-arc rifting in SW Japan: Tectonostratigraphy of the Hokutan Group and the paleostresses analyses of dike orientations

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Abstract

Geologic history of an ocean basin is usually recognized from magnetic anomaly patterns in the basin, but the complicated pattern in the Japan Sea backarc basin hindered the understanding of the mode and timing of the basin formation. So, onshore geology around the basin has been useful for the understanding, and has made researchers to believe that a few drastic events occurred at ~15 Ma. That is, rapid paleomagnetic rotations in the NE and SW Japan arcs at around 15 Ma were found in the mid 1980s, and were attributed to the opening of the backarc basin. Many grabens filled with Early to Middle Miocene strata were found in NE Japan, and several ones in SW Japan, indicating intra-arc rifting associated with the Japan Sea formation. The tectonostratigraphy of the strata suggests the termination of the extensional deformation at ~15 Ma. In addition, Middle Miocene forearc magmatism began simultaneously with the marine regression and with the change in the stress field from extensional to compressional in SW Japan at ~15 Ma. Consequently, it is thought that intra-arc rifting in the drifting Japan arcs and the Japan Sea formation ceased at that time. However, it was found recently that the rotations in SW Japan came to an end at ~16 Ma. In addition, the paleostress analyses of dike orientations to have contributed in the 1980s to this classical view about the Japan Sea formation could not determine stress regimes. Consequently, the regimes were inferred based on the senses of contemporaneous map-scale faults. However, faulting was inactive after 15 Ma, giving rise to the uncertainty about the Middle Miocene stress regime of SW Japan.

The purpose of this thesis is to challenge this classical view about the Early to Middle Miocene tectonics of SW Japan, especially about the simultaneous tectonic events at ~15 Ma. To this end, the author studied, first, the tectonostratigraphy of the Hokutan Group—an Early to Middle Miocene thick succession in San'in region at the southern margin of

the Japan Sea. Andesitic dikes in this area were used in the mid 1980s to argue the change from extensional to compressional stress condition at ~15 Ma. Second, the author applied the latest stress inversion techniques to the orientation data that he obtained from dikes in the Tajima, Suo-Oshima and Kumano areas. Those areas represent the backarc, axial and near-trench regions in the SW Japan arc, respectively.

As a result, syndepositional, map-scale, extensional tectonic features, i.e., a graben and a monocline at the extension of a normal fault, were found in the Hokutan Group. The fossil and radiometric ages of the strata constrained the activity from ~21 to 16.5 Ma. The upper part of the group younger than 16.5 Ma was not involved in the map-scale deformations. That is, map-scale extensional deformation was abandoned at that time in the Tajima area. Contrary to the classical view, this sedimentary basin did not uplifted simultaneously, but subsided to make the accommodation until 14–15 Ma for the accumulation of the upper part with a thickness of ~500 m. Some researchers attribute the Early Miocene paleomagnetic rotations in SW Japan to bookshelf-type block rotations.

There are Early Miocene grabens in SW Japan. They are filled with strata as thick as 10^2 m: The maximum thickness at ~1 km is documented from the Kabuto graben, central Kinki region. The thicknesses are smaller than those of contemporaneous grabens in NE Japan by an order of magnitude, suggesting that the extensional deformations in SW Japan was much smaller than those in NE Japan. Early Miocene intra-arc deformations were so small to allow paleomagnetists to argue the coherent rotation of the SW Japan arc.

Although previous researchers argued the change in stress at ~15 Ma from NNW-SSE extension to NNW-SEE compression based on the orientations of some 60 dikes in the Tajima area, the 716 orientations that the author collected from dikes and sills in this area did not support the change. The U-Pb and fission-track dating of this study indicated that the magmatism begun at ~21 Ma and ceased at ~13 Ma. The stress inversion by means of mixed Bingham distribution revealed for NE-SW extension from the 716 data irrespective to the stratigraphic horizon of their host rocks. Since the stress ratio was very small, the intrusion occurred under a nearly vertical compression before and after the termination of map-scale extensional deformation at ~16.5 Ma in the Tajima area.

The dike orientations in the Suo-Oshima and Kumano areas were inverted using the

same technique. The magmatism in the former area is known to be about 12 to 15 m.y. old. Twenty-nine rhyolite and sixty-five andesitic dikes yielded a normal-faulting stress regime with NW-SE extension, and twenty-six dacite ones showed similar extensional stresses. The Suo-Oshima area exists in the axial zone of the SW Japan arc where Early Miocene grabens are found in the Kuma area to the south of Suo-Oshima and in central Kinki region. Tectonostratigraphy indicates that the graben formation was terminated before the magmatism. Accordingly, the extensional stress remained after the termination of the intra-arc rifting that is represented by the grabens in the axial zone of the SW Japan arc similar to the tectonic history of the Tajima area.

It has been known that there are N-S to NNW-SSE trending Middle Miocene dikes in the Kumano area. Previous researchers regarded the dike intrusion under arc-perpendicular compression, because early Middle Miocene formation is folded in the area with E-W fold axes. Unfortunately, the crosscutting relationship between folds and dikes is not clear, but they thought that the folding was simultaneous with the dike intrusion. The author obtained 151 data from mafic dikes and 14 ones from granite porphyry dikes in the Kumano area. The radiometric and fossil data indicate that both types of the dikes are about 15 to 14 m.y. old, consistent with the fission-track ages of the granite porphyry obtained in this study. As a result, the mafic and granite porphyry dikes showed normal faulting stress regimes with NE-SW and ENE-WSW trending σ_3-axes, respectively. Therefore, the magmatism occurred under a more or less arc-parallel extension in this area probably before the folding.