# Extensional stress conditions determined from the orientations of Middle Miocene dikes in the Kumano area

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We deny the established theory about the compressional stress in the SW Japan arc in the Middle Miocene after 15 Ma that terminated the Japan Sea opening. The orientations of dikes with such ages in the Kumano area, southern Kii Peninsula, are considered to evidence the compression (e.g., Tsunakawa, 1986; Yamamoto, 1991). A few tens of dikes in the area were considered to make a NNW trending parallel dike swarm, and the E-W trending folds of the strata that hosted the dikes were thought of as the evidence for the compression during the dike intrusion. However, it is uncertain when the formation was folded. In addition, previous researchers assumed that dikes were formed more or less perpendicular to the axis of maximum horizontal compression. This is not always true: Overpressured magma can intrude into fractures with various orientations. Consequently, the arguments about the timing of folding and the stress condition for the dike intrusion has been circular.

In the Kumano area, we observed 14 felsic dikes in the Early to early Middle Miocene Kumano Group and 151 mafic dikes in the early Middle Miocene Shionomisaki Igneous Complex. The uppermost part of the group interfingers with the basal part of the complex. The orientations of the dikes were inverted by fitting mixed Bingham distributions (Yamaji and Sato, 2011) to reveal the stress regime during their intrusions. The method determines three principal stress axes, stress ratio and non-dimensional magma pressure only from dike orientations. The method can determine one or a few stresses from non-parallel dikes.

As a result, the normal faulting stress regime with the ENE-WSW trending $\sigma_3$-axis and a stress ratio of 0.14 was determined from the felsic dikes. The magma pressure was relatively low. The mafic ones had various trends, but those with NW trends were dominant. The normal faulting stress regime with NE-SW trending $\sigma_3$-axis and a stress ratio of 0.50 was determined from the mafic dikes. The magma pressure was relatively high. We obtained the zircon fission-track ages of 14.5 ±1.4 Ma and 13.9 ±1.4 Ma from two felsic dikes. The microfossil and fission-track ages (Ikebe et al., 1975; Hoshi et al., 2003) indicate that both types of dikes intruded from 14.5 to ~13 Ma. Therefore, the area was affected by NE-SW to ENE-WSW extensional stress after 15 Ma. The folding probably postdated the magmatism.

Keywords: fission-track age, tectonic stress, forearc magmatism

 