3-D thermal modeling of generation mechanisms for short-term slow slip events and low-frequency earthquakes along the Ryukyu trench

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Interplate seismicity, such as short-term slow slip events (S-SSEs) and low-frequency earthquakes (LFEs), has been identified in the Ryukyu Trench, southwest Japan. As one of the specific characteristics of these events, the depths where S-SSEs take place at the plate interface beneath Okinawa Island are approximately 10 km shallower than those beneath the Yaeyama Islands. In this study, we constructed a three-dimensional parallelepiped thermal convection model associated with subduction of the Philippine Sea (PHS) plate beneath the Amurian (AM) plate at the Ryukyu subduction zone. We applied the subduction history of the PHS plate in the model region, referring to the plate rotation model and the trench motion model. Then, we performed a time-dependent numerical simulation for the last 15 Myr to elucidate the relationships among the calculated thermal structure, dehydration from the subducting plate, and interplate seismic events. To constrain the calculated thermal structure, we used observed heat flow data. As a result, the interplate temperatures where S-SSEs occur are estimated to range from 350℃ to 450℃ beneath both Okinawa Island and the Yaeyama Islands, although the latter are approximately 50-100℃ higher than the former. This temperature range corresponds well with that of the transition zone from unstable sliding to stable sliding. On the other hand, LFEs occur in a temperature range of 300 to 400℃ beneath both Okinawa Island and the Yaeyama Islands in our model, which is roughly within the temperature range of the transition zone, although it is approximately 50℃ lower than that in the region where S-SSEs occur. Using phase diagrams for hydrous minerals of the oceanic crust and the slab mantle, we estimated the water content distribution and dehydration gradient per unit distance in the subduction direction of the PHS plate. Near the S-SSE fault planes, a dehydration gradient of 0.05 wt%/km is identified beneath Okinawa Island associated with the phase transformation from blueschist to lawsonite blueschist within hydrous minerals of the oceanic crust. In contrast, dehydration gradients of 0.13 wt%/km and 0.12 wt%/km are identified beneath the Yaeyama Islands associated with the phase transformation from lawsonite blueschist to amphibole eclogite within the oceanic crust and from brucite to antigorite within the slab mantle, respectively. Further, there are no specific dehydration gradients in the LFE occurrence region beneath both Okinawa Island and the Yaeyama Islands in our model, although there is a possibility that dehydration fluid materials in the S-SSE occurrence region are transported to the LFE occurrence region, considering the migration feature of LFEs and the synchronicity of activity between S-SSEs and LFEs. Therefore, we conclude that both the interplate temperature and dehydration gradient play key roles in the occurrences of S-SSEs and LFEs and that the larger dehydration gradient beneath Yaeyama Island than beneath Okinawa Island is the main reason for the depth difference in S-SSEs.

