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Three-dimensional numerical modeling of temperature and dehydration fields associated with subduction of the Philippine Sea plate, southwest Japan

Shoichi Yoshioka (1), Yingfeng Ji (2), and Takumi Matsumoto (3)

(1) Kobe University, Kobe, Japan (yoshioka@port.kobe-u.ac.jp), (2) Kobe University, Kobe, Japan (31911431@qq.com), (3) National Research Institute for Earth Science and Disaster Prevention, Tsukuba, Japan (mtakumi@bosai.go.jp)

We investigated temperature and mantle flow distributions associated with subduction of the Philippine Sea (PHS) plate beneath southwest Japan, by constructing a three-dimensional parallelpiped model incorporating a past clockwise rotation, the bathymetry of the Philippine Sea plate, and distribution of the subducting velocity within its slab. The geometry of the subducting plate was inferred from contemporary seismic studies, and was used as a slab guide integrated with historical plate rotation into the 3D simulation. Using the model, we estimated a realistic and high-resolution temperature field on the subduction plate interface, constrained by a large data set of heat flow, and attempted to clarify its relationship with occurrences of megathrust earthquakes, long-term slow slip events (L-SSEs), and non-volcanic low frequency earthquakes (LFEs). Results showed that the oblique subduction coupled with the 3-D geometry of subducting slab was a key factor affecting the interplate and intraplate temperature distributions, leading to a cold anomaly in the plate interface beneath western Shikoku, the Bungo Channel, and the Kii Peninsula. Temperatures in the slab core in these regions at a depth near continental Moho were nearly 200°C lower than that in eastern Shikoku, indicating a high thermal lateral heterogeneity within the subducting PHS plate. The geothermal control of the LFEs beneath western Shikoku was estimated to be within a range from 400 to 700°C, and the interplate temperature for the L-SSEs with a slip larger than 15 cm beneath the Bungo Channel was estimated to be approximately 350∼500°C. A large horizontal temperature gradient of approximately 2.5∼°C/km was present where the LFEs occurred repeatedly. The steep temperature change was likely to be related to the metamorphic phase transformation of hydrous minerals from lawsonite or blueschist to amphibolite within the MORB of the subducting PHS plate.