Anomalous depth distribution of deep low-frequency earthquakes at the northeast Tokai district

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Deep low-frequency earthquakes are distributed in a belt-like form along the isodepth contour of 30 km depth of the upper plate boundary of the Philippine Sea slab as pointed out by Obara [2002]. Hirose et al. [2007] confirmed this features on the basis of precisely determined geometry of the Philippine Sea slab, but further revealed that at the northeastern Tokai district deep low-frequency earthquakes are distributed away from the isodepth contour of 30 km depth of the plate boundary and lie on the isodepth contour of 40 km depth. Shelly et al. [2006] and Ide et al. [2007] analyzed mechanism of deep low-frequency earthquakes and insisted that deep low-frequency earthquakes are generated by shear slip on the plate interface. If they occur on the plate boundary even in the Tokai district, it is expected that their depths become deeper toward the northeastern Tokai. It is known that many deep low-frequency earthquakes occur during continuous deep low-frequency tremors [Shelly et al., 2007] and tend to occur in succession in the Tokai district [Kobayashi et al., 2006], which makes it difficult to pick P and/or S phases accurately. As a result, the depth distribution of deep low-frequency earthquakes is scattered in the depth range of 20-50 km.

To constrain and precisely estimate the depth of deep low-frequency earthquakes, we selected 69 deep low-frequency earthquakes from 1582 events in the JMA catalogue that occurred from November 1, 2002 to December 31, 2006 in the Tokai district. The selection is based on the following criteria; (1) P-wave arrival times are picked at more than 3 stations, (2) total number of P- and S-wave arrival times picked are 10 or more, and (3) the magnitude is greater than 0.0. We checked waveforms of the 69 events and re-picked P- and S-wave arrival times. In the picking procedure, we noticed several wrong phase pickings resulting from the continuous occurrence of low-frequency earthquakes. Some of events with wrong phase pickings were located at a depth of ~45 km in the JMA catalogue with travel-time residuals of more than 1 sec. We excluded those wrong pickings and unclear phases and picked only clear phases in each seismogram, which yields 53 deep low-frequency earthquakes recorded by 10 or more stations. Then, the 53 events were relocated with one-dimensional JMA2001 seismic velocity model [Ueno et al., 2002]. After that, they were relocated with the three-dimensional velocity structure estimated by Hirose et al. (2007), by applying DD location algorithm [Waldhauser and Ellsworth, 2000], together with ordinary earthquakes that occurred within the slab and in the overriding plate.

As a result, deep low-frequency earthquakes were clustered and located at depths of ~30 km in the southwestern part and at depths of 35-40 km in the northeastern part, indicating a gradual deepening of deep low-frequency earthquakes from southwest to northeast. Distribution of deep low-frequency earthquakes agrees with almost the plate boundary estimated by Hirose et al. (2007). This result supports the idea that deep low-frequency earthquakes occur on the plate boundary [Shelly et al. (2006), Ide et al. (2007)]. It is very important for considering the extent of the source area of the anticipated Tokai earthquake that the depth of deep low-frequency earthquakes becomes locally deep to about 40 km at the northeastern Tokai district.