Lower limit of seismogenic zone beneath Japan based on hyopocenter catalog determined with 3D seismic velocity structure

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Abstract

Japanese Islands are marked by ongoing crustal deformation and seismic activity owing to the subduction of the oceanic plates; Pacific (PAC) and Philippine Sea plates. Earthquakes within the overlying plate are significant sources of seismic hazards as well as megathrust earthquakes. The lower limit of the seismogenic zone (D90) is important to estimate the maximum size of the earthquake in the overlying plates. The values of D90 in overlying plate mainly controlled by thermal regime and rheology, the obtained result of D90 values in overlying plate demonstrates that the values are mainly controlled by thermal regime and rheology, which was created by tectonic events since 20 Ma.

Data and Methodology

We relocated 561,611 events from October 2000 to December 2017 within 129.2-146.3E, 30-46N, and 0-100 km depth with 3D seismic velocity structure (Matsubara et al., 2019). We selected events with depths of 0-25 km to be considered as those related to the active faults. We investigated the index D90 as the lower limits of the seismogenic layer defined as the depth above which 90 % of the whole crustal events occurred from the surface.

Results

The main feature of our results is almost similar to the previous works (e.g. Omuralieva et al., 2012). The pattern of D90 in most areas is concordant with heat flow values (Matsumoto, 2007; Yano et al., 2020), namely the area of shallow D90 corresponds to the area of high heat flow. The area of active volcanoes is marked by shallow D90, commonly shallower than 8 km. D90 is shallower in the backarc rather than forearc.

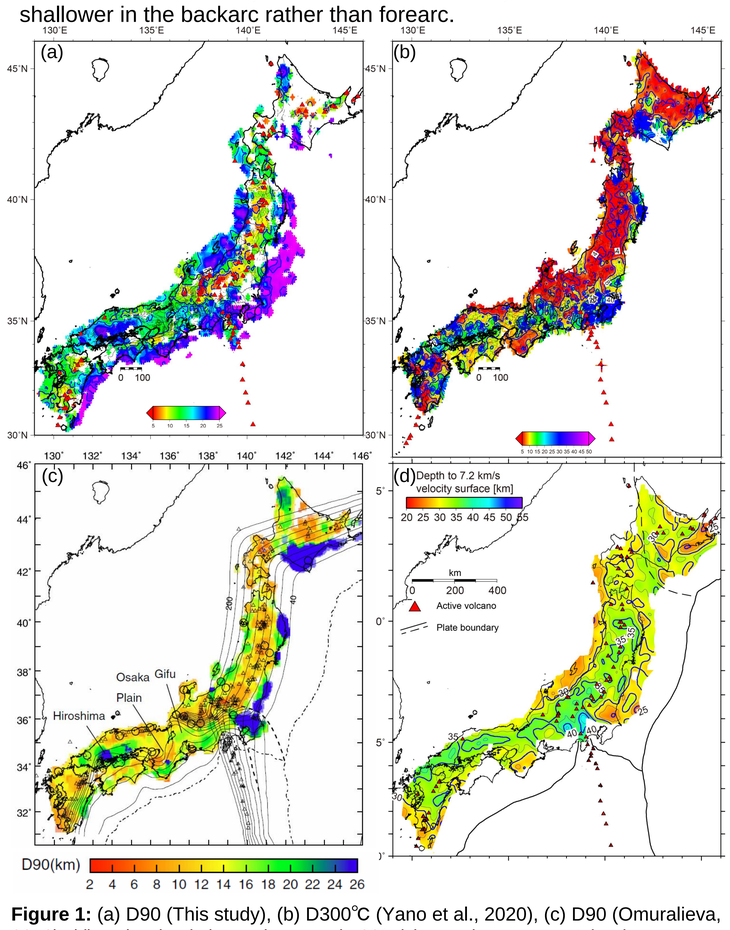


Figure 1: (a) D90 (This study), (b) D300℃ (Yano et al., 2020), (c) D90 (Omuralieva, 2012), (d) Moho depth (Matsubara et al., 2017) beneath Japanese Islands.

Due to the subduction of thick and cold PAC plate, deep D90 zones are well developed along the forearc side of Kuril, NE Japan and Izu-Bonin arcs. D90 is commonly 15 km, except for some tectonic zones. The arc-arc collision zones, such as Hidaka, central Hokkaido, and Izu, central Japan, show deep D90 and thick Moho (Matsubara et al., 2017).

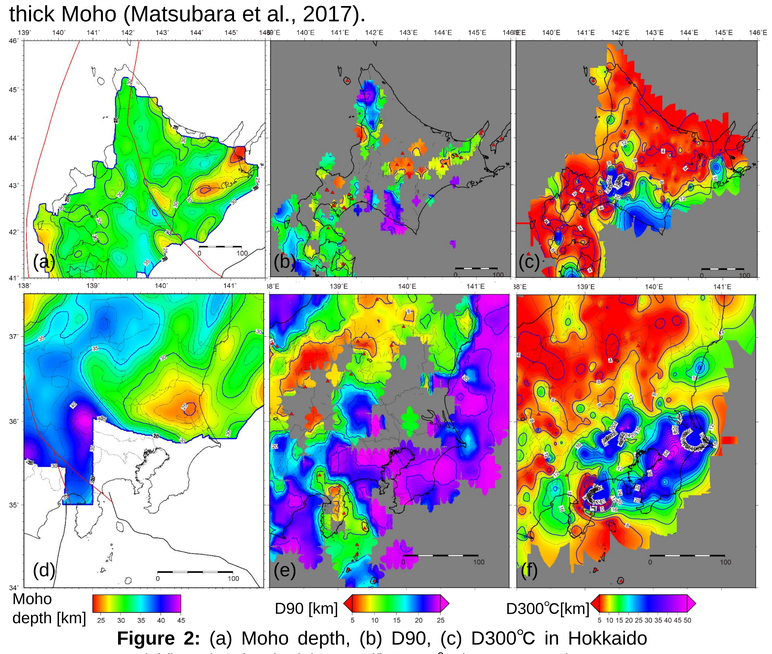
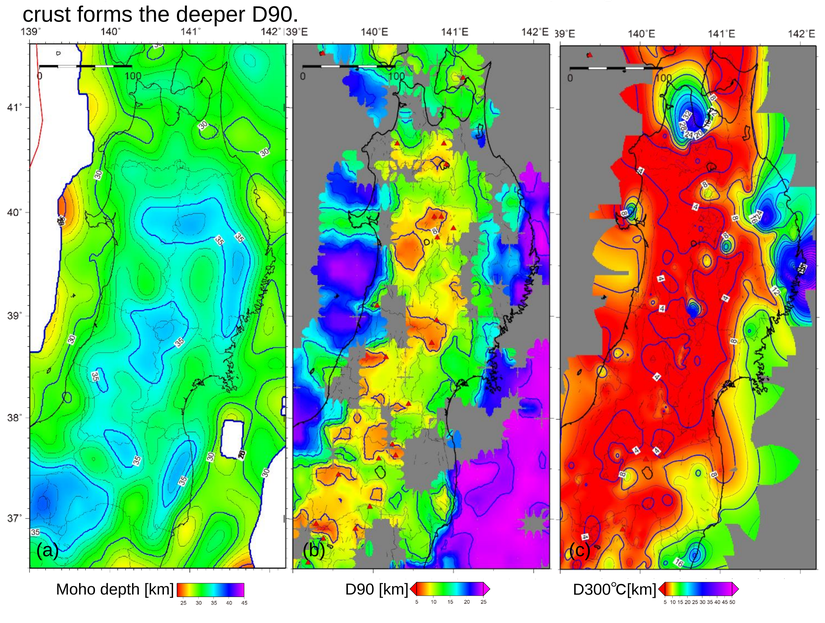


Figure 2: (a) Moho depth, (b) D90, (c) D300℃ in Hokkaido and (d) Moho depth, (e) D90, (f) D300℃ in Kanto region.

The backarc side of Northern Honshu, experienced backarc rifting associated with the opening of the Sea of Japan in the middle Miocene (Sato, 2014) and these areas demonstrate deep D90 exceeding over 20 km. In such failed rifts, the compositional difference as mafic rich rocks composing the middle to lower crust forms the deeper D90.



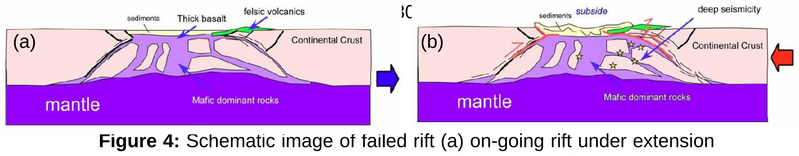


Figure 4: Schematic image of failed rift (a) on-going rift under extension and (b) after stopping under compression (Sato et al., 2014)

D90 beneath the SW Japan is approximately 15 km except beneath the volcanoes. D90 on the southern side of the Median Tectonic Line is 9-10 km. Along the Seto inland sea, forearc of SW Japan is marked by deep D90 values, concordant with the low heat flow zones.

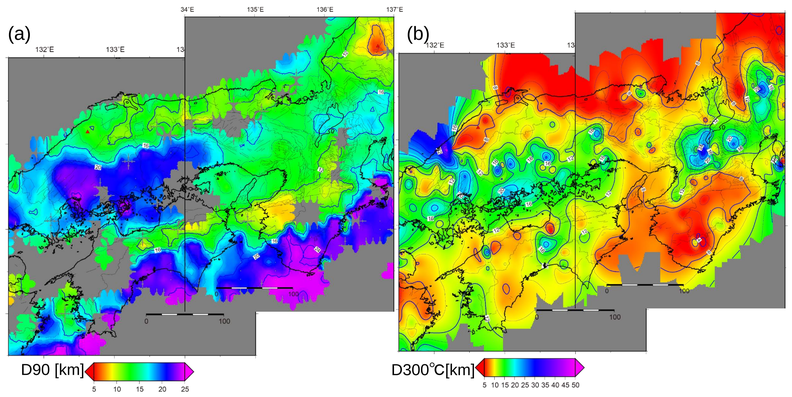


Figure 5: (a) D90 and (b) D300℃ in southwestern Japan.

The obtained result of D90 values in overlying plate demonstrates that the values are mainly controlled by thermal regime and rheology, which was created by tectonic events since 20 Ma.

Summary/Conclusion

Japanese Islands are marked by ongoing crustal deformation and seismic activity owing to the subduction of the oceanic PAC and PHS plates. Earthquakes within the overlying plate are significant sources of seismic hazards as well as megathrust earthquakes. The index D90 is important to estimate the maximum size of the earthquake in the overlying plates. We investigated D90 using the hypocenter catalog relocated with the 3D seismic velocity structure. The pattern of D90 in most areas is concordant with heat flow values (Matsumoto, 2007; Yano et al., 2020), namely the area of shallow D90 corresponds to the area of high heat flow. The area of active volcanoes is marked by shallow D90, commonly shallower than 8 km. D90 is shallower in the backarc rather than forearc. The values of D90 in overlying plate mainly controlled by thermal regime and rheology, the obtained result of D90 values in overlying plate demonstrates that the values are mainly controlled by thermal regime and rheology, which was created by tectonic events since 20 Ma.

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