Location and depth of the 1855 Ansei Edo earthquake inferred from seismic intensity characteristic

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The 1855 Ansei Edo earthquake (hereafter, the 1855 earthquake) occurred on 2nd day of 10th month in 2nd year of Ansei era (November 11th, 1855 on the Gregorian calendar) and caused severe damage in and around Edo City, former Tokyo Metropolis. While detail seismic intensity distribution from this earthquake has been studied (Usami, 1994, private publication; Nakamura and Matsu’ura, 2011, Historical Earthquakes), the earthquake epicenter and depth has been controversial; whether it was a shallow crustal earthquake or a deep one (down to 100 km depth). One of the reasons for this ambiguity is a non-circular shape of isoseismals resulting from a heterogeneous attenuation (Qs) structure (Nakanishi and Horie, 1980, JPE; Nakamura et al., 2007, Historical Earthquakes) due to a complex plate configuration; the Philippine Sea Plate (PHS) and Pacific Plate (PAC) subduct from the south and east, respectively, beneath Tokyo. However, from recent studies, it is unlikely that the 1855 earthquake was a shallow crustal earthquake, according to S-P times estimated from historical literature (Nakamura et al., 2003) and our previous study (Nakamura et al., 2014, 2015) which showed that the felt area can be explained by intermediate-depth earthquakes.

In this study, we re-examined the characteristics of the seismic intensity distribution for the 1855 earthquake by comparing with the seismic intensity distribution of recent earthquakes observed by the Japan Meteorological Agency (JMA), as well as with those calculated using a 3-D attenuation Qs model. We concluded that the 1855 earthquake was either an intra-plate earthquake within PHS at depth of around 50 km or an inter-plate earthquake between PHS and continental plate (depth around 30 km).

The seismic intensity distributions for both the 1855 earthquake and recent inter-plate earthquakes between PHS/PAC (depth 60-80 km) show common characteristics that seismic intensities in the western Tokyo are smaller than those in eastern and southern Tokyo, which we call “the property of constriction” (Nakamura et al., 2007, Historical Earthquakes). However, the seismic intensity along the cross section are quite different (Figure 1(a)); the 1855 intensity has a peak near central Tokyo, while those from an inter-plate (PHS/PAC) earthquake are smaller at central Tokyo than at central Kanagawa Prefecture (southwest of Tokyo Metropolis). This result implies that the 1855 earthquake was not an inter-plate earthquake between PHS/PAC.

We then calculated seismic intensity distribution by using a 3-D attenuation Qs structure (a block size of 0.1 deg*0.1 deg*5 km) estimated by using the K-NET and KiK-net records during 1996-2016.7. Figure 3 is a example of seismic intensity distribution calculated for an intra-plate earthquake assuming at a depth of 50 km. The seismic intensity distributions of earthquakes within the PHS slab at depths of 40-60 km have the property of “constriction”. Even if the epicenter is shallower than 60-80 km, the property of “constriction” is created, and the seismic intensities near central Tokyo become larger as the hypocentral depth becomes shallower. These support that the earthquake source was within or on the upper boundary of PHS slab.

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Keywords: 1855 Ansei Edo earthquake, Abnormal seismic intensity distribution, Hypocentral depth, Attenuation structure

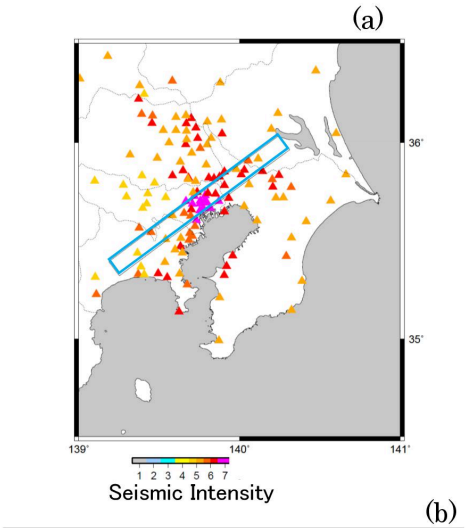

Fig.1 Ansei Edo earthquake
Usami(1994) The Japan Electric Association

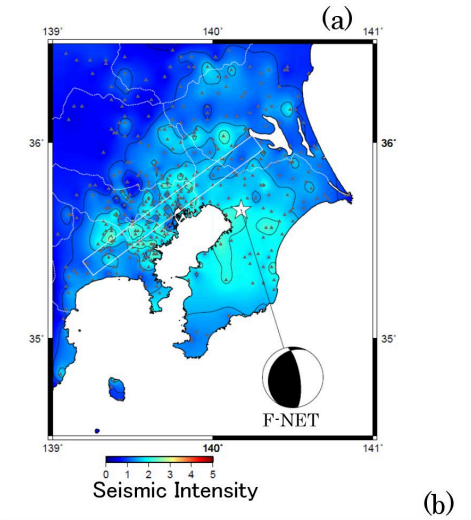

Fig2 PHS/PAC plate boundary
JMA data

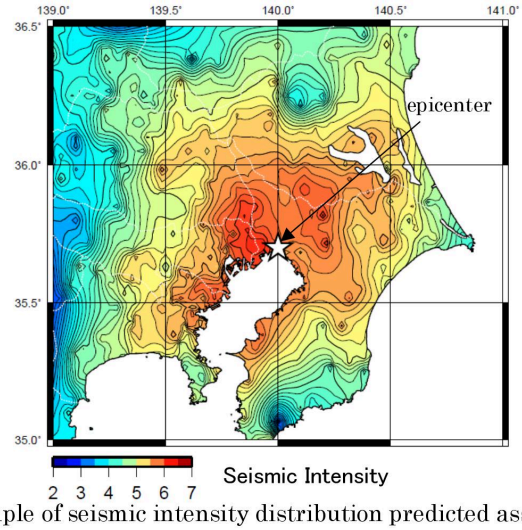

Fig.3 An example of seismic intensity distribution predicted assuming 50 km depth