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Variability of Great Earthquakes in the World's Subduction Zones Revealed from Paleoseismology

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Paleoseismological studies conducted since the 2004 Indian Ocean tsunami revealed that a giant earthquake similar to the Sumatra-Andaman earthquake (M 9.1) occurred several hundred years ago. Studies of tsunami deposits made in Sumatra Island (Monecke et al., 2008), Thai coast (Jankaew et al., 2008), Andaman Island (Malik et al., 2011) and Indian Coast (Rajendran et al., 2011) show evidence of past tsunamis. Coseismic coastal uplifts were inferred from marine terraces in Myanmar (Aung et al., 2008) or microatolls in Andaman Island (Kayanne et al., in preparation) and Sumatra Island (Sieh et al., 2009). Evidence of past coseismic subsidence was found in southern Andaman Island (Malik et al., 2011).

These paleoseismological studies also indicate variability of past earthquakes. The date of penultimate earthquake was estimated at around AD 1300 to 1450 in Thailand, AD 1290-1400 in Sumatra, but much later, post AD 1600 in Andaman Island. These variable dates may indicate that the last earthquake was not exactly the same type as the 2004 Sumatra-Andaman earthquake.

Such variability in size of past earthquakes or supercycle of earthquake recurrence (Sieh et al., 2008) was also found in subduction zones around the Pacific Ocean (Satake and Atwater, 2008). In Kuril subduction zone, unusually large earthquakes occurred with approximately 500 years but variable intervals (Nanayama et al., 2003; Sawai et al., 2009), with the last earthquake in the 17th century. Historical tsunami heights or coastal changes from the large recurrent earthquakes along Nankai trough also show variability. In southern Chile, the 1960 earthquake was much larger than the previously recorded earthquakes in historical literature in 1837 and 1737, and similar to the 1575 earthquake (Cisernas et al., 2005). In Cascadia subduction zone of North America, giant earthquakes similar to the 1700 earthquake seems to have occurred at approximately 500 years interval, but the detailed studies show that recurrence interval and size of past earthquakes also seem to be variable (Atwater et al., 2005).

Variable recurrence patterns, revealed from paleoseismological data for much longer time range than historical records, indicate a difficulty in long-term forecast for future earthquakes. While most long-term forecasts of next earthquakes and its size assume recurrence of characteristic earthquakes, they may need to consider the variability observed in other subduction zones. This is more important in a few subduction zones, such as the Kuril subduction zone off Hokkaido or the Sunda subduction zone off Sumatra, because they might have entered in an active period of great earthquakes.

Keywords: Subduction zones, earthquake, tsunami, paleoseismology, recurrence, long-term forecast