Temporal clustering, energy-state proxy, and recurrence of Holocene paleoearthquakes in the region of the 2004 Sumatra-Andaman earthquake

Earthquakes and tsunamis are some of the most deadly natural disasters, with the 26 December 2004 Sumatra-Andaman earthquake and tsunami responsible for the deaths of nearly a quarter of a million people. Knowledge about the earthquake cycle, through many cycles, is fundamental to understanding both the societal risk and the nature of the seismogenic process. Recurrence of great earthquakes (7 ka, years before present, BP, 1950) is estimated based on turbidite stratigraphy (representing earthquake events) correlated between 49 deep sea sediment cores in the region of the 2004 rupture. We apply criteria developed in Cascadia, Japan, and in Sumatra thus far to discriminate such events from those triggered by other mechanisms by testing the turbidite stratigraphy for synchronous triggering of turbidity currents between sedimentologically isolated basin core sites and deeper trench sites using radiocarbon, multiple proxies, and ash stratigraphy.

Nineteen turbidites are interpreted to have been triggered during strong ground shaking from earthquakes over the past ~7,000 years. The youngest turbidite is most likely the result of the 2004 earthquake. Calibrated probability density function peak ages for events 4 – 13 are 560±60, 710±80, 1100±110, 1420±80, 1480±60, 2210±80, 2580±60, 3580±90, 4400±80, 4760±60 years BP and events 15 – 19 are 5040±120, 5320±110, 5660±100, 6430±90, and 7000±70 years BP. The turbidite record is also compatible with the developing onshore record of paleoearthquakes in Aceh, Thailand, Sumatra, forearc Islands (Simeulue, Siberut, Sipora, and the Pagai Islands), and the Andaman Islands, but the terrestrial record is less complete. The recurrence interval (RI) estimate for earthquakes in the 2004 rupture region for the last 7 ka is 390±70 years. The recurrence pattern appears to include significant clustering through the Holocene, with three apparent clusters, and two gaps of 700-1000 years.

We know that each earthquake cycle does not perfectly reflect plate convergence and seismic energy loss. Faults may gain or lose energy in longer cycles as implied for Chile and Sumatra (Cisternas et al., 2005; Sieh et al, 2008). Timing of earthquakes is combined with turbidite mass to develop a proxy for the relative energy state of the subduction zone.

We present preliminary results from our energy state proxy analysis. Like the comparison of moment rates to plate convergence, we evaluate long term energy cycling using plate convergence rate as a measure of strain accumulation and deposition of turbidite mass as a proxy for energy dissipation. Turbidite mass is related to convergence rate and paleoearthquake timing to estimate the relative energy state. The plate coupling ratio is not known, so we use a value of one. The energy state is also assumed to have zero net gain so we do not bias the interpretation to believe the energy state is increasing or decreasing over time. We do not know the transfer function between mass and seismic moment, so this is currently relict to being a relative scale. What we do find is that the subduction zone has variable behavior. What is apparent is that some events appear to release less while others appear to release more energy than available from plate convergence (slip deficit). Those that are larger may have borrowed stored energy from previous cycles.

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