Probable Maximum Earthquake Magnitudes for the Cascadia Subduction

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Abstract

The concept of maximum earthquake magnitude (mx) is widely used in seismic hazard and risk analysis. However, absolute mx lacks a precise definition and cannot be determined from a finite earthquake history. The surprising magnitudes of the 2004 Sumatra and the 2011 Tohoku earthquakes showed that most methods for estimating mx underestimate the true maximum if it exists. Thus, we introduced the alternate concept of mp(T), probable maximum magnitude within a time interval T. The mp(T) can be solved using theoretical magnitude-frequency distributions such as Tapered Gutenberg-Richter (TGR) distribution. The two TGR parameters, β-value (which equals 2/3 b-value in the GR distribution) and corner magnitude (mc), can be obtained by applying maximum likelihood method to earthquake catalogs with additional constraint from tectonic moment rate. Here, we integrate the paleoseismic data in the Cascadia subduction zone to estimate mp. The Cascadia subduction zone has been seismically quiescent since at least 1900. Fortunately, turbidite studies have unearthed a 10,000 year record of great earthquakes along the subduction zone. We thoroughly investigate the earthquake magnitude-frequency distribution of the region by combining instrumental and paleoseismic data, and using the tectonic moment rate information. To use the paleoseismic data, we first

estimate event magnitudes, which we achieve by using the time interval between events, rupture extent of the events, and turbidite thickness. We estimate three sets of TGR parameters: for the first two sets, we consider a geographically large Cascadia region that includes the subduction zone, and the Explorer, Juan de Fuca, and Gorda plates; for the third set, we consider a narrow geographic region straddling the subduction zone. In the first set, the β-value is derived using the GCMT catalog. In the second and third sets, the β-value is derived using both the GCMT and paleoseismic data. Next, we calculate the corresponding mc values for different β-values. For magnitude larger than 8.5, the turbidite data are consistent with all three TGR models. For smaller magnitudes, the TGR models predict a higher rate than the paleoseismic data show. The discrepancy can be attributed to uncertainties in the paleoseismic magnitudes, the potential incompleteness of the paleoseismic record for smaller events, or temporal variations of the seismicity. Nevertheless, our results show that for this zone, earthquake of m 8.8±0.2 are expected over a 500-year period, m 9.0±0.2 are expected over a 1000-year period, and m 9.3±0.2 are expected over a 10,000-year period.

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