Asperity as an undividable unit of earthquake rupture

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Gutenberg-Richter (GR) power law is commonly found for magnitude-frequency distribution in regional seismicity and sometimes generated by numerical simulations. This is often taken as evidence for that earthquake occurrence is a critical phenomenon, where the magnitude of individual earthquake is unpredictable. On the other hand, the Characteristic Earthquake (CE) Model has been suggested mainly from geological/geomorphological observations including trench survey. CE Model claims that the CE, which breaks the entire fault segment, occurs more frequently than expected from the power-law distribution of smaller earthquakes of the region. This has profound implications on the possibility of earthquake prediction. If the extent of individual rupture on the subduction interface is mostly determined by stochastic factors, a great earthquake is thought to be a rupture that was accidentally not stopped halfway. In this case, occurrence of great earthquakes would be hard to predict. In contrast, if subduction seismicity is inactive during the interseismic period and the CE ruptures the entire segment more or less periodically, knowledge of the physical conditions would help to predict the occurrence of great earthquakes. An extreme possibility is that the asperity of great earthquake is an undividable unit of rupture, whose rupture propagation never stops halfway once a part of it starts rupturing. GR relation would not hold for seismicity of such an asperity. The present study investigates this issue for the rupture segment of great subduction earthquakes by investigating seismicity along the Nankai Trough, where repetition of great subduction earthquakes has been firmly established from historical documents and archeological and tsunami deposit studies.

The last Tonankai and the Nankai earthquakes occurred in 1944 and 1946, respectively, and the instrumental earthquake catalog by the JMA is available from January 1923. Magnitude-Time (M-T) diagram for these source regions indicates that few moderate to large earthquakes (M5+) occurred except for precursory activity, mainshock, and its aftershocks. The GR relationship does not hold even if the precursory activity and aftershocks are all included, suggesting that the rupture segment of a great earthquake does not show complicated behavior where ruptures of different sizes occur in probabilistic manners. Instead, the great earthquake asperity seems to behave essentially as a single coherent unit repeating simple seismic cycles. Such tendency would be even more clearly seen by constructing M-T diagram for interplate events only. We are now reanalyzing the source location and fault plane solutions of smaller events, trying to exclude as many intraplate events as possible. The spatial pattern of seismicity is almost independent of catalog interval and of the threshold magnitude. Except for precursory activity and aftershocks, there are very few earthquakes that may have ruptured a part of the faulting area of the great earthquake. The case study suggests that rupture of (strongly coupled) subduction interface within the asperity of its great earthquake is essentially binary: it either ruptures entirely or does not rupture at all. The idea that the spatial extent of rupture is stochastically determined does not seem to apply to this case.