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Forecast of large earthquaks: the use and limitation of the characteristic earthquake model

Koji Okumura[1]

[1] Dept. of Geography, Hiroshima Univ.

http://home.hiroshima-u.ac.jp/kojiok

Until middle 1990s the characteristic earthquake model has been a way to estimate the size of future earthquake on the basis of sporadic geologic data along the surface faults. The rapid development of long-term seismic hazard assessment and probabilistic ground-shaking forecasts pushed the model forward to the key of the future earthquakes. The characteristic earthquaek model simply hypothesizes a segment of a fualt would rupture as a whole with similar amount of slip to generate similar earthquakes repeatedly. The recognition of the segments are usually based on fault geometry and point-to-point geologic data. For the earthquakes that we know only from geologic records the model is the only way to tell the location and size of the future earthquakes. While the recurrence of historically or instrumentally observed earthquakes are expected without any proof or reason, characteristic earthquakes are always challenged with scepticism owing to the lack of detailed data. Without the model associated with the time-dependent nature of the large earthquakes there is no way to quantitatively forecast future earthquakes. Seismologists as well as geologists themselves are not confident on the validity of the model. The seismotectonic research in the past decade brought some favorable and some unfoavorable facts for the model. The most favorable was the finding of very regular slips repeated during several earthquake cycles on the Carrizo segment of the San Andreas fautl and on the 1944 segment of the North Anatolian fault. The latter result also indicates the slip is indifferent to the total length of rupture. Those results came from straight portions of a fault without complexities. The irregularity reported, for example on the Mojave segment of the San Andreas fault or in central Japan, seems to have derived from the complex tectonic setting of the big restraining bend or the networks of conjugate faults. Recent advancement of inversion techniques also revealed the distribution of slips on the fault plane precisely and the distribution at the surface is proportional to the slip at the depth. Some subduction earthquakes showed the same asperity generated a series of similar events. The unfavorable facts are the less-than-characteristic damaging earthquakes and large subduction events. The blind faulting under Kobe in 1995 is now considered as a less-than-characterisitc sub-event. We do know this kind of Mw = 6 class events tend to occur at the ends of a faults or sutructural discontinuities but do not know when and how they occur. The subduction interface off eastern Hokkaido raised two issues. One is the difference between 1952 and 2003 earthquakes. The portion of the interface called Off-Akkeshi segment did rupture in 1952 and did not in 2003. The segment may not rupture by itself but triggered by ruptures on adjacent segments. Or the portion is just a transitional zone between two master segments. The entire interface off eastern Hokkaido is supposed to have ruptured in 17th century A.D.. This tectonic paroxysm may indicate non-characterisitc behavior of the subduction interface. However, the paroxysm may repeat by itself. In the latter case, we need to assume hierarchical occurrence of characteristic earthquakes. We need to know the regularity and irregularity of the gigantic cascading event like 2004 Sumatra earthquake to understand the behavior of subduction interface in a very long term.