Scaling properties of seismic energy and fracture energy

Satoshi Ide[1]

[1] Dept. EPS, Univ. of Tokyo

During fault motion of an earthquake, released potential energy is divided into frictional work, fracture energy, and seismic energy that propagates to far-field. Although only seismic energy is measurable from the records of seismic waves at one station, it is also possible to estimate fracture surface energy from the detailed source model as a result of seismic wave inversion. In this case, we can discuss not only total fracture energy loss but also its spatial distribution. This paper discuss about scaling properties of seismic energy and fracture energy based on recent study.

Seismic energy is estimated by integration of velocity seismograms or spectra. There are many studies of seismic energy estimation for earthquakes of various size and also furious discussion about scaling property of the ratio of seismic energy and seismic moment. As Ide and Beroza (2001) and Ide et al. (2003) showed, there are various kinds of artifacts in the previous measurements. For example, crustal attenuation parameter Q and site amplification generally have frequency dependence, and it leads artificial size dependence when we assume a constant Q and no site amplification, which are widely used. So far, we should conclude that we do not have enough evidence that denies a constant seismic energy/moment relation for earthquakes for over 17 orders of seismic moment, from Mw -4 to Mw 7. However, it is also true that this relation contradicts with estimated values of fracture surface energy of rocks measured in laboratory, 10-10^4 J/m^2, and averaged stress drop of large earthquakes, 1-10 MPa. This suggests that fracture energy is small and/or stress drop is large for small events.

It is known that fracture energy scales with characteristic length of surface in laboratory rock experiments (Ohnaka and Matsuura, 2002). For the 1995 Kobe earthquake, fracture surface energy is on the order of 10^6 J/m^2 (Ide, 2003), which is higher than values in rock experiments by orders. Fracture energy of 10^7 J/m^2 is necessary for the 1992 Landers earthquake, too (Olsen et al., 1997). Hence, these facts support the size dependence of fracture energy for wide range. The reason of this dependence is probably the scale difference of complexities that brake during slippage. Since the characteristic size need not be large at the initial stage of rupture, fracture energy may be small at first and increase during rupture process. Self-similar crack growth is consistent with a linear increase of fracture energy (Kostrov, 1964) and such growth can explain observed seismic waves to some extent. Such increase of fracture energy should be taken into account for the study of earthquake dynamics.