

## Broadband Earthquake Science Broadband Earthquake Science

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A huge earthquake can significantly change the atmosphere of our society. Although a practical scheme for predicting future earthquakes has been one of the most desired research products in earth science, it yet remains totally unrealized. Rather, increasing knowledge on the rupture process of earthquakes reveals how and why the deterministic prediction of earthquake is difficult. While each dynamic rupture process obeys deterministic physical laws, the nonlinearity in these laws and the complexity of hosting fault systems limit our predictability. Thus, rupture apparently behaves like a stochastic process, which is only probabilistically predictable.

In one extreme view, an earthquake is a randomly growing rupture process starting from a tiny nucleus. The growth is scale independent and the final size of each event is almost unpredictable by observing the initial stage. However, this view is not always correct. Sometimes, high regularity is observed in size and timing for a group of earthquakes, such as well-known repeating earthquakes in the Tohoku-Oki region. Such regularity cannot be ruled out by randomness and must be related to the characteristic structure in seismic regions. Therefore, the quantitative understanding of structural heterogeneity is an important task for probabilistic forecasts of seismic activity.

Structural heterogeneity in seismic region has been considered using a locked region, which is often loosely defined as "asperity", in the sliding background. The background was considered as an unobservable imaginary system, like a steadily slipping plate interface. However, this perspective has been changed by recent discoveries of "slow earthquakes" in many places worldwide. The background is probably the place where spatially and temporally variable slow deformations occur. Unlike ordinary earthquakes finishing in several hundred seconds at most, slow earthquakes continue for hours, days, and even several months. Slow earthquakes controls stress loading in seismogenic region and may precede very large earthquakes. There is some evidence for the effects of atmosphere and ocean on seismic activity, probably through slow earthquakes, which are susceptible to small stress change. To understand slow earthquakes and their effects on fast earthquakes, we need very broadband observations and modeling of tectonic system.

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