

Seismicity patterns on different fault systems

Yehuda Ben-Zion
Department of Earth Sciences
University of Southern California,
Los Angeles, CA, 90089-0740

A large number of multi-disciplinary observations indicate that faults evolve toward structural simplicity at different scales. Fault zones appear to be formed as highly disordered structures associated with strain hardening rheology, creation of granularity and band-limited fractal structures at several hierarchies, and low mechanical efficiency. With increasing slip, this is replaced by strain weakening, localization, and evolution toward geometrical regularity and high mechanical efficiency. Such structural evolution is expected to manifest itself in accompanying evolution of earthquake population. The understanding of seismicity patterns on faults with different levels of geometric and strength disorder may be used to organize data in categories associated with different dynamic regimes. This can in turn reduce from the apparent complexity of seismicity data and enhance potentially informative signals.

We have studied properties of earthquake populations on different types of fault systems using numerical and analytical work involving the following three hierarchies of space-time scales: (1) Long deformation history on a smooth homogeneous fault. (2) Seismicity on individual fault systems with fixed strong heterogeneities. (3) Coupled evolution of regional earthquakes and faults. The results from all these frameworks indicate consistently the existence of three basic dynamic regimes. The first is associated with strong fault heterogeneities, power law frequency-size statistics of earthquakes, random or clustered temporal statistics of intermediate and large events, and phases of accelerated seismic release before large events. The second is associated with homogeneous or relatively regular faults, frequency-size statistics compatible with the characteristic earthquake distribution, and quasi-periodic temporal occurrence of large events without preceding phases of accelerated seismic release. For a range of parameters, there is a third regime in which the response switches spontaneously back and forth between the forgoing two modes of behavior.

The theoretical results are compatible with friction, fracture, and other data of rock mechanics experiments, and in-situ observations spanning wide ranges of space and time scales. The latter include fault trace maps and compiled earthquake statistics, high-resolution microseismicity patterns, and long paleoseismic records.