Harvard University, Solid Earth Physics Seminar
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4th Floor Faculty Lounge, Hoffman Laboratory, 20 Oxford St.

Rock Damage, Earthquakes and Faults

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We review observational and theoretical results on seismic radiation and brittle rock damage in two complementary problems. (i) Rapid damage generation by sources with sufficiently high amplitude and subsequent gradual healing. (ii) Effects of brittle rock damage within the source volume on the seismic radiation to the bulk.

(i) Analysis of seismic data recorded near the North Anatolian fault shows clear regional reduction of seismic velocities in the top 100-500 meters during the time of the 1999 Mw7.1 Duzce earthquake [1]. Spectral ratios of seismograms recorded at fault-zone and off-fault sites show changes of spectral curves right after the Duzce earthquake consistent with a reduction of the *S*-wave velocity at the fault-zone site of 20-50% [2]. The co-seismic changes are followed by logarithmic recovery that is very pronounced in the first day and continues with appreciable amplitude in the subsequent 3 months. Similar results are found around other rupture zones [3]. The observations are compatible with laboratory experiments with granular materials and rocks [4], and they can be simulated with a nonlinear continuum damage rheology [5]. Since the damage generation is resisted by normal stress, and healing is enhanced by it, the evolution of rock damage over many earthquake cycles produces a flower-type fault zone structure, with significant shallow damage that decreases in amplitude and width with depth [6]. This is consistent with detailed analysis of fault zone trapped waves and other characteristics of rock damage [7].

(ii) A seismic representation theorem that includes, in addition to the standard moment term, a damage-related term (stemming from co-seismic changes of elastic moduli) indicates that the damage-related radiation is associated with products of the changes of elastic moduli and the total elastic strain components in the source region [8]. Decreasing elastic moduli in the source region (as produced generally by brittle deformation of low-porosity rocks and explosions) increase the radiation to the bulk, while increasing moduli (which may be produced during the formation of compaction bands in porous rocks) decrease the radiation. Order of magnitude estimates suggest that the damage-related contribution to the seismic radiation, which is neglected in standard calculations, can have appreciable amplitude that may in some cases be comparable to or larger than the moment contribution. A decomposition analysis shows that the damage-related source term has an isotropic component that can be larger than its double couple component.

References

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