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A physics-based model for seismic velocity changes induced by dynamic strain

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Seismic velocity changes in response to static stress changes can be explained by closing and opening of soft porosity at crack edges and around weak contacts. Additionally, dynamic strain changes during the passage of large amplitude seismic waves usually cause the seismic velocity to drop. This leads to the common observation of a co-seismic velocity reduction in fault areas but also at significant distance from the fault. What causes the velocity to drop during a symmetric strain oscillation and to stay at a lower level even when the perturbation has terminated without leaving a permanent deformation? Which processes cause the recovery of the velocity in the post-seismic period?
To answer these questions we assume that the processes which lead to field observations of co-seismically decreasing velocities in seismology are similar to the processes involved in nonlinear mesoscopic elasticity in acoustic laboratory experiments. A similar assumption underlies the study of acoustic emissions as an analog of seismicity. Based on this assumption we construct a model for the observations of a particular set of laboratory experiments called Dynamic AcoustoElastic Testing (DAET).
Our mathematical model explains the nonlinear behavior by the two counteracting processes of healing and damage. Healing constantly takes place and increases the stiffness of the material. Damage decreases the stiffness proportional to the absolute value of strain rate. With a range of healing processes differing in their characteristic time our model explains the DEAT observations of both fast and slow dynamics.
The physical interpretation of this mathematical model is that damage is related to internal shear deformation that occurs in a heterogeneous materials even with a longitudinal excitation. The shear motion damages connections across weak contacts and healing is a physical-chemical process that re-establishes the connections. This process is supported by observations in friction experiments that demonstrate the increase of friction when a contact is at rest (frictional aging). These processes include capillary bridges, mineral fibers, and chemical bonds.
For seismology this means that the observation of dynamically induced velocity changes is related to changes of the internal structure of the material that are likely to influence a variety of other physical properties of the material such as the strength, hydraulic conductivity, and electrical conductivity.