

A Frequency-Dependent Q Model Based Upon Transient Rheological Properties of Heterogeneous Materials

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Seismic attenuation at low frequency has previously been modeled using two approaches: (1) Examination of all possible microstructural dislocation mechanisms that involve irreversible thermodynamics [Minster and Anderson 1961, *P. Trans. R. S. Lond. A*, 299]; (2) Parameterized superposition of one-dimensional analogue springs and dashpots, usually consisting of a three-parameter standard linear solid arrangement [Liu et al. 1976, *G.J.R.A.S.*, 47]. The first approach is appealing in that a strong connection is made between micromechanical dissipation and short-term creep that can be studied in the laboratory. The second approach has the advantage of providing a robust 'fit' to actual seismic observations, but has little intrinsic physical content. Here we present an entirely new approach that is based upon composite theory of viscoelastic materials. The model consists of viscoelastic inclusions embedded in a viscoelastic matrix. The model has the unique advantage that it can be constrained by seismic observations of lateral Earth structure. At the heart of this rheological approach is construction of a generalized self-consistent scheme (GSCS). A two-dimensional constitutive equation is derived that contains a very natural transient creep behavior. The stress evolution of a two-phase media in a pure-shear creep test is discussed in detail. All of the effective properties of this composite rheology are controlled by a single set of isotropic elastic constants, κ' and μ' , two viscosities, η and η' (for matrix and particulate phases, respectively) and the volume concentration, c , of heterogeneities. The relevant dimensionless parameters are $\nu \equiv \kappa'/\mu'$, c and $R \equiv \eta'/\eta$. For $R \ll 1$ the predicted $Q(m)$ diagram consists of a single low frequency peak and a single higher frequency valley. All interpretations of mantle tomographic imaging imply lateral temperature contrasts of $O(1(K))^\circ C$ or greater. High temperature creep mechanisms imply orders of magnitude in lateral viscosity variation. Superposition of N phases of varying dimensionless viscosities $R_1, R_2, \dots, R_i, \dots, R_N$ and concentrations is discussed.

1. 1993 Spring Meeting
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5. (a) None
(b) 5144 Wave atten.
8160 Rheology of the
lithosph. and mantle
6. 0
7. 0%
8. Charge to Document Rev.
1,0, 0005359125 37481
M.S. 111-12.0, JPL.
Pasadena, CA 91109
9. C
10. None
11. No