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Slip-weakening distance in the presence of seismic melts

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It is now generally accepted that there exists no slip-weakening distance Dc as a constitutive parameter of earthquake faults. Instead, the apparent slip weakening is itself a dynamically determined, and rather unpredictable, outcome of the fracture process. Indeed, while some seismological studies based on seismic wave inversion indicate that the apparent Dc is of the order of 0.5-1.0 m, others suggest that Dc increases with earthquake size. Yet it is still quite convenient to define and use a slip weakening distance in earthquake models, (1) because of habit and (2) because it provides a direct and intuitive link to the breakdown energy dissipated during rupture.

In this contribution we explore the evolution of Dc in the presence of frictional melt wetting the sliding surface (the so-called pseudotachylyte once solidified), based on exhumed faults observations, high-velocity rock friction experiments and theoretical models.

Field work conducted on pseudotachylyte-bearing faults from the Outer Hebrides Thrust (Scotland) and the Gole Larghe strike slip (Italy) indicate Dc comprised between 0.15 and 0.4 m.

Experimental data from high-velocity rock friction experiments extrapolated to natural conditions suggest similar estimates for Dc.

Assuming an average friction tau and slip rate V, theoretical work on frictional melting yields the estimate

$$\text{Dc} = 8\ \text{k}\ [\text{rho}\ (\text{L} + \text{c}_p\ (\text{T}_m - \text{T}_{hr}))\ /\text{tau}]^{\ 2}\ /\ \text{V}$$

where k is thermal diffusivity, rho rock density, L latent heat, c_p heat capacity, T_m

melt temperature, T_{hr} host rock temperature. Thus theory predicts that Dc in the presence of melt decreases with increasing slip rate and shear stress; it is related to the thermal evolution of the fault (i.e., it is not a fixed constitutive parameter). However, estimates of Dc from exhumed faults lie within a small range (0.15- 0.4 m), suggesting production of frictional melt took place under similar physical conditions on the two observed faults.