Supershear Mach-Waves Expose the Fault Breakdown Slip

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During an earthquake, changes in stresses on the fault and within the surrounding material occur as the fault slips and radiates seismic waves. The radiated energy strongly depends on the way fault tractions evolve close to the rupture front, where most of dissipative mechanisms concentrate. Thus, any constraints obtained from observations on how tractions drop as the fault slips are crucial for understanding the rupture process and the generation of reliable physics-based model predictions. One of the most important parameters controlling the strength drop is the breakdown slip, Dc, which is defined as the slip required by the shear traction to progress from its peak value to its residual value during rupture propagation. Mikumo et al. (2003) showed that it is possible to estimate Dc as the slip at the time of the peak slip rate for rupture propagation with subshear speeds. Fukuyama and Mikumo (2007) later attempted to extend this method off the fault to extract information about Dc as the displacement at the time of the peak particle velocity from strong-motion records due to ruptures propagating at subshear speeds. However, a reasonably accurate estimate of Dc in this rupture regime is only possible within a case-dependent narrow zone adjacent to the fault. The length of this zone, Rc, is comparable to the length of the fault cohesive zone where the breakdown process takes place during rupture, and approximately equal to 80% of the wavelength associated with the breakdown frequency (Cruz-Atienza et al., 2009). When the rupture propagates with supershear speeds, on the other hand, this energy is carried much farther away from the fault by Mach waves, in particular Rayleigh Mach-waves when rupture reaches the Earths surface. Here, we present a new approach to estimate Dc from strong-motion records containing Mach-waves (Cruz-Atienza and Olsen, 2010). First, we show that the method by Mikumo et al. is valid for supershear rupture propagation. This method is then used to estimate Dc via an asymptotic approximation of the slip and slip-rate time histories from Mach-waves recordings. Using spontaneous rupture simulations we demonstrate that, for a visco-elastic half-space model, Dc can be estimated with an accuracy of 40% from Mach-waves that have propagated a distance of at least 3 km from the fault. The method is applied to estimate Dc for the 2002 Mw7.9 Denali, Alaska, earthquake (1.5 m) and for the 1999 Mw7.6 Izmit, Turkey, earthquake (1.7 m).

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