Abstract

Recently, seismologists have discovered that some earthquakes are very slow with almost no energy radiated, while others excite strong and damaging seismic waves with extremely high rupture speed, sometimes believed to be super-shear (faster than shear-wave speed of the surrounding rock body). This variation reflects the difference in rupture physics dominating different tectonic environments. As a result it has become very important to understand what causes the dramatic variation of rupture speed, and rupture behavior. We have embarked on this problem by constructing laboratory models of earthquakes and by using high-speed imaging of photo-elastic rupture patterns. We have defined a series of experiments to determine the behavior of rupture under spontaneous loading similar to that of crustal earthquakes. With these experiments we have demonstrated that under reasonable loading conditions similar to those for natural earthquakes, super-shear rupture propagation can occur. In such cases we have studied the conditions leading to transition of a sub-Rayleigh rupture to supershear and have related the rupture growth length needed for transition to system parameters. The experiments and analysis has resulted in a better understanding of transition behavior encountered during natural earthquake events such as the 2001 Kunlun earthquake in Tibet. This is probably the first experimental demonstration of super-shear rupture propagation under spontaneous loading. (Xia, Rosakis and Kanamori, *Science*, 2004)

Motivated by such experiments we have also extended the work to observations of spontaneously nucleated events occurring, on frictionally held, bi-material interfaces. Previously, it was generally thought that if there is a velocity contrast the rupture preferentially grows toward the direction of sliding in the lower-speed side of the fault. In contrast to this, we have found that this is not necessarily the case; the rupture can propagate in both directions. In one direction, rupture always propagates at the Generalized Rayleigh wave speed (it is sub-shear) whereas in the opposite direction it may either be sub-shear or may transition to super-shear. This behavior could explain why the rupture in the recent Parkfield earthquake propagated to southeast whereas it propagated northwest in the previous two Parkfield earthquakes. It can also be used to explain field observations during the 1999 Izmit earthquake in Turkey. We hope that these results will help seismologists understand the basic physics of earthquakes and contribute to a better understanding of the vast diversity of earthquake characteristics. (Xia, Rosakis, Kanamori and Rice, *Science*, 2005)