Methods Summary

We conducted 28 experiments to investigate the phenomenon of secondary tensile microcrack formation by dynamic shear rupture along an interface (the model fault surface) with friction (due to the applied uniaxial load) and cohesion (due to the glued interface). Ruptures were induced along a precut interface in Homalite samples by exploding a nickel-cadmium wire embedded across the interface (Fig. 1A). Rupture interfaces were sawcut through initially intact square samples. Epoxy resin (Loctite 330 adhesive) was applied uniformly to one surface; Loctite 7387 activator was applied to the other surface; and the two surfaces were held together while curing to force excess resin out of the interface. The bond was cured for five hours at room temperature and the procedure produced a layer 20-50 µm in thickness between the two Homalite surfaces. To constrain the static coefficient of friction, $f$, and the cohesive shear strength, $\tau_o$, of the bond we conducted static strength tests on 14 Homalite samples with glued interfaces at angles ranging from 30° to 80° using an Instron electromechanical testing machine. The samples were subjected to uniaxial loads (Fig. 1B) through a spherically seated platen moving at a steady downward displacement rate of 0.25 mm/s. The stress path during loading and stress drop at failure was recorded using a 100 kN load cell. The load at failure, $P_{\text{crit}}$, was used to calculate the resultant critical normal, $\sigma_n$, and shear tractions $\tau$ on the interface. The experimental strength envelope has a slope $f = 0.32 \pm 0.15$ and y-intercept $\tau_o = 11.3 \pm 1.5$ MPa, where the errors are one standard deviation of the residuals (Fig. 2C).

During the dynamic experiments, the samples were compressed under an axial stress $P$ applied at an angle $\alpha$ to the normal to the interface (Fig. 1B). Test values of $\alpha$ were 60°, and 70° and 80°, and $P$ varied between 30 and 38 MPa (corresponding to a range between ~85% and 98% of the limiting stress $P_{\text{crit}}$). Note that in these experimental configurations, the cohesive strength of the interface far exceeds the frictional strength. While this experimental ratio of cohesive to frictional strength may not represent the expected ratio for faults in the earth, the large cohesive strength is necessary in order to produce stress concentrations larger than the
tensile strength of the Homalite ($\sigma_T \approx 35$ MPa) which is much greater than typical tensile strength of rocks ($\sigma_T < 10$ MPa).

Using digital photographs of the photoelastic fringes, we were able to track the propagating rupture tip from the nucleation site (i.e. from the exploding wire) out to distances of 110mm. The distance to the rupture tip from the nucleation site was measured in sequential photographs. Velocities were then calculated at each measurement distance from a sixth order polynomial fit to the distance-time data.

Because the rupture velocity is less than the Rayleigh wave speed, elastodynamic waves travel away from the nucleation site faster than the speed of the rupture: near the edges of the sample interaction with reflected waves tend to slow the rupture down. In order to maximize the length of rupture free of such boundary effects, the nucleation site was shifted several centimeters upward to the left from the center of the sample (Fig. 1B). In most cases the velocity decreased as the rupture approached the edge of the sample (Fig. DR1), and this is interpreted as a boundary effect due to reflected waves from the sample edges. Therefore we restricted our analyses to data from the first 100 mm of rupture growth.

Supplementary Figure Captions

**Fig. DR1:** Shear rupture velocity, $v_{II}$, and microcrack angle, $\theta$, versus distance of rupture tip from the nucleation site for experiments with (left column) $P = 32$ MPa and $\alpha = 60^\circ$. and (right column) with $P = 38$ MPa and $\alpha = 70^\circ$.

**Fig. DR2:** Opening microcrack rupture velocity, $v_O$, versus distance of the shear rupture tip from the nucleation site for experiments with $P = 32$ MPa and $\alpha = 60^\circ$.

**Movie DR1:** Rupture sequence of experiment 60I, with $P = 32$ MPa and $\alpha = 60^\circ$. Time after rupture nucleation of each frame is shown in the lower left hand corner. At 55 $\mu$s after rupture nucleation, microcracks can be seen forming faintly below the rupture. By 65 $\mu$s, a clear triangular front of circular shadow spots has formed, showing the front of the developing
tensile crack damage zone. In the last frame, at 110 µs, a trail of tensile microcracks extends across most of the sample, left in the wake of the growing rupture.

\[ P = 32 \text{MPa}, \alpha = 60^\circ \]

\[ P = 38 \text{MPa}, \alpha = 70^\circ \]

Fig. DR1
Fig. DR2