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LABORATORY EXPERIMENTS ON ROCK FRICTION FOCUSED ON UNDERSTANDING EARTHQUAKE MECHANICS

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TECHNICAL ABSTRACT

We have investigated frictional resistance in laboratory experiments at intermediate velocities, with applications to dynamic earthquake slip. We observe dramatic to extreme frictional weakening for displacements from tens of millimeters to ~10 m and slip rates from 0.1 mm/s to 3.2 mm/s. Over most of the investigated velocity range the weakening is by about a factor of two. The weakening is seen in quartzite, feldspar-rock, and granite. The magnitude of the weakening is similar for quartzite over the normal stress range from 16 to 112 MPa. In contrast, weakening in granite does not occur at 28 MPa, but does at 112 MPa. The mechanism for this reduction in strength is not clear, although it appears to be in some way due to elevated temperatures caused by shear heating. Our calculations of the maximum average temperature attained on the sliding surface and of the local ‘flash’ temperatures at asperity contacts suggest that the temperature is much too low to be explained by melting. However, at higher slip speeds than we can currently attain melting would be expected, and probably cause a further reduction in shear resistance. Supporting this idea, in one experiment on granite at 112 MPa our Teflon sliding jackets broke down and some fluorine entered the fault surface, apparently fluxing melting well below the normal melting temperature. This experiment showed the lowest coefficient of friction, a drop to 0.14 from the normal values of about 0.7. The substantial weakening we observe at 2.5 orders of magnitude lower slip rates than those typical for earthquakes suggest melting should be common during earthquake slip and dynamic stress drops should be substantial, resulting in strong ground motions.

NON-TECHNICAL ABSTRACT

We have measured the frictional resistance of rock and find that if slip is fast enough, but still considerably slower than natural earthquake slip, heat produced by friction can be enough to weaken the fault by about a factor of two. The reason for this is not clear, but the temperatures resulting from the frictional heating are too low to have produced melting. In one case where melting apparently occurred for another reason, the friction became very much lower. This suggests that faster slip during earthquakes should generate enough heat to cause melting, and that this melting could cause the resistance to be low during seismic slip. This low resistance could cause unexpectedly strong shaking of the ground and potentially more severe damage than currently expected.