RUPTURE PROCESSES DURING LABOPRATORY EARTHQUAKES

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Since the pioneering work of Brace and Byerlee (1966), the mechanism of stick-slip has been considered as a good analog to earthquake rupture propagation. Here, we report macroscopic stick-slip events in Westerly granite rock samples deformed under controlled upper crustal stress conditions in the laboratory. Experiments were conducted under triaxial loading using a high frequency acoustic monitoring array to record both particles acceleration during macroscopic stick-slip events and background microseismicity. For the first time, we also record the stress drop dynamically.

Prior to stick-slip instabilities, we observe a systematic exponential acceleration of precursory slip, but foreshocks are only observed when the normal stress becomes greater than ~ 50 *MPa*. This threshold corresponds to the normal stress above which the nucleation length becomes comparable to the size of typical fault asperities. Even in these conditions, most of precursory slip remains aseismic, but the total cumulative moment of the foreshock sequence also increases exponentially up to failure and the fault surface seem to evolve like a cascading asperity model. This exponential growth implies that the nucleation phase has a characteristic time, i.e. that both the foreshock sequence duration and precursory moment release scales with the size of the main asperity.

During the mainshock, we show that the dynamic stress drop, measured locally close to the fault plane, is almost total in the breakdown zone. The fault recovers strength within a few tens of microseconds. We demonstrate that the frictional behavior of stick-slip follows a slip-weakening law, well explained by flash heating theory, in agreement with our post-mortem microstructural analysis. Relationships between initial state of stress, rupture velocity, and stress drop demonstrate that supershear rupture is systematic at large normal stress. In these conditions, the ratio between fracture and radiated energies suggest that the rupture becomes more dispersive, meaning that the fracture energy eventually scales with both slip and stress drop. This result seems in agreement with linear elastic fracture mechanics theory and, possibly, with seismological observations.

References

[1] Brace, W. F., & Byerlee, J. D. (1966). *Stick-slip as a mechanism for earthquakes*. Science, *153*, 990-992.