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Fault Structure, Frictional Properties and the Spectrum of Fault Slip Behaviour

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In the last ten years, high-resolution GPS and seismological data have revealed that tectonic faults exhibit complex, multi-mode slip behavior including earthquakes, creep events, slow and silent earthquakes, low-frequency events and post-earthquake afterslip. The physical processes responsible for this range of behavior and the mechanisms that dictate fault slip rate or rupture propagation velocity are poorly understood. One avenue for improving knowledge of these mechanisms involves coupling direct observations of ancient faults exhumed at the Earth's surface with laboratory experiments on the frictional properties of the fault rocks. Here we show that fault zone structure has an important influence on mixed-mode fault slip behaviour. Our field studies depict a complex fault zone structure where foliated horizons surround meter- to decameter-sized lenses of competent material. The foliated rocks are composed of weak mineral phases, possess low frictional strength, and exhibit inherently stable, velocity-strengthening frictional behavior. On the contrary the competent lenses are made of strong minerals, possess high frictional strength, and exhibit potentially unstable, velocity-weakening frictional behavior. Tectonic loading of this heterogeneous fault zone may initially result in fault creep along the weak and frictionally stable foliated horizons. With continued slip, stable sliding and fault creep may increase stress within the strong and potentially unstable lenses leading to nucleation of seismic rupture. Our studies provide field constraints and a mechanical explanation for complex, mixed-mode fault slip behavior ranging from repeating earthquakes to creep events.