Mixed-Mode Seismic Slip and Aseismic Creep on a Highly Active Low-Angle Normal Fault System in Papua New Guinea

James Biemiller¹, Laura Wallace¹,², and Luc Lavier¹

¹University of Texas, Jackson School of Geosciences, Institute for Geophysics, United States of America (james.biemiller@utexas.edu)
²GNS Science, Lower Hutt, New Zealand

Whether low-angle normal faults (LANFs; dip < 30°) slip in large earthquakes or creep aseismically is a longstanding problem in fault mechanics. Although abundant in the geologic record, active examples of these enigmatic 'misoriented' structures are rare and extension rates across them are typically less than a few mm/yr. As such, geodetic and seismological observations of LANFs are sparse and can be difficult to interpret in terms of earthquake cycles. With a long-term slip rate of ~1 cm/yr, the Mai’iu fault in Papua New Guinea may be the world’s most active LANF and thus offers an outstanding natural laboratory to evaluate seismic vs. aseismic behavior of LANFs. Here, we use new results from a campaign GPS network to determine the degree of locking vs. aseismic creep on the Mai’iu fault and evaluate these results in the context of geological evidence for mixed seismic and aseismic slip in exhumed Mai’iu fault rocks.

We derive velocities from GPS measurements with 3-4 km station spacing above the shallowest portions of the fault, which dips 21-25° at the surface. Dislocation modeling of these velocities is consistent with 6-8 mm/yr of horizontal extension, corresponding to ~1 cm/yr dip-slip rates on a 27-35°-dipping fault. Strain rates and vertical derivatives of horizontal stress rates derived from these velocities confirm localized extension across the fault. We compare and evaluate two interseismic locking models that fit the data best: one in which the fault deforms by shallow near-surface creep updip of a deeper zone of increased interseismic coupling which soles into a steadily creeping shear zone at depth, and one in which the fault creeps steadily downdip of a shallowly locked patch. These results combined with field and microstructural evidence from the exhumed fault rocks suggest that the fault slips by a mixture of brittle frictional (seismic slip, fracturing, and cataclastic creep) and viscous (stress-driven dissolution-precipitation creep, or pressure solution) processes. Using depth-constrained mechanical properties and stress conditions inferred from exhumed fault rocks, we model the time-dependent competition between frictional slip and viscous creep to assess where and how elastic strain accumulates along the Mai’iu fault, and whether the fault is capable of hosting or nucleating earthquakes.