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Thermal Runaway during Intermediate-Depth Earthquake Rupture

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Intermediate-depth earthquakes occur at depths of 50 to 300 km in subducting lithosphere. Despite their ubiquity in earthquake catalogs, their physical mechanism remains unclear because ambient temperatures and pressures are expected to lead to ductile, rather than brittle deformation. There are two leading explanations for the physical mechanism that enables these earthquakes. In the first, high pore pressure from metamorphic dehydration reactions in the subducting slab reduces the effective normal stress sufficiently to enable frictional failure. In the second, slow deformation generates heat, which leads to weakening, further deformation, and a self-localizing thermal shear runaway. We use the nest of intermediate-depth earthquakes under Bucaramanga, Colombia as recorded by the digital RSNC (Red Sísmica Nacional de Colombia) regional seismic network to explore these two possibilities. We observe a combination of high stress drop and low radiation efficiency for Mw 4-5 earthquakes in the Bucaramanga Nest that points to the importance of thermal effects. If we assume a cm-scale fault-zone width, this combination implies a temperature increase of 600-1,000ºC during earthquake failure, which suggests that substantial shear heating, and possibly partial melting, occurs during intermediate-depth earthquake failure. Our observations support thermal shear runaway as the mechanism for intermediate-depth earthquakes. This mechanism could help explain differences in their behavior, such as the paucity of aftershocks, compared to shallow earthquakes. Although we have inferred these mechanisms for intermediate depth earthquakes, it's likely that they would apply for rapid deformation on the deep extensions of fault zones as well - particularly during large earthquakes, such as the 2012 Mw 8.6 strike-slip event off Sumatra, which is inferred to have ruptured well into the oceanic mantle.