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Initial effective stress controls the nature of earthquakes

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Modern geophysics highlights that the slip behaviour response of faults is variable in space and time and can result in slow or fast ruptures. Despite geodetical, seismological, experimental and field observations, the origin of this variation of the rupture velocity in nature, as well as the physics behind it, is still debated. Here, we first discuss the scaling relationships existing for the different types of fault slip observed in nature and we highlight how they appear to stem from the same physical mechanism. Second, we reproduce at the scale of the laboratory the complete spectrum of rupture velocities observed in nature. Our results show that when the nucleation length is within the fault length, the rupture velocity can range from a few millimetres to kilometres per second, depending on the available energy at the onset of slip. Our results are analysed in the framework of linear elastic fracture mechanics and highlight that the nature of seismicity is governed mostly by the initial stress level along the faults. Our results reveal that faults presenting similar frictional properties can rupture at both slow and fast rupture velocities. This combined set of field and experimental observations bring a new explanation of the dominance of slow rupture fronts in the shallow part of the crust and in areas presenting large fluid pressure, where initial stresses are expected to remain relatively low during the seismic cycle.