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Long-term intact rock strength and critical in situ stresses in near-surface bedrock

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Near-surface in situ stresses in excess of gravitational or tectonic loading are frequently encountered in natural landscapes, although the question of their origin is rarely discussed in detail. These high near-surface stresses are common to both cratonic shield and alpine regions, and their relationship to landscape or landform development has been widely commented on, as they are often associated with the development of exfoliation or sheeting fractures. We suggest these high near-surface stresses originate from the elastic and thermoelastic response of bedrock to exhumation, and reflect a regional stress regime no longer in agreement with either Andersonian stress states or Byerlee's law, but instead limited by the long-term intact rock strength. Although sufficiently rapid extensional strain, or well-oriented Reverse faults are generally assumed to limit the development of such stresses, we suggest that in the absence of these factors, an upper limit to long-term in situ stresses may be defined by the onset of inelastic strain facilitated through micro-cracking, as the rock itself is not able to maintain further increases in differential stress.
Recent studies have made significant progress in understanding critical aspects of this system, in particular, the long-term behaviour of bedrock maintaining high differential stresses at shallow depths (100's of m) and the potential for micro-crack development in response to exhumation and thermoelastic relaxation. Our analysis of global in-situ stress measurements indicates good agreement between maximum differential stress magnitudes in compressional regimes and laboratory-derived threshold stresses required to initiate micro-cracking in intact rock. This correlation appears to hold for confining stresses up to 30 MPa (approximately 1 km depth) and indicates that the long-term cohesive component of rock strength may dominate the behaviour of high quality rock masses, and therefore define an upper-bound for in situ stresses in the near-surface.