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How firm is *Terra Firma*: Extrapolating in time and space to estimate rock strength

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Understanding the physical mechanisms of rock deformation is a critical component in a wide range of geologic and engineering problems, including global geodynamics, plate tectonics, the orogeny of mountain belts, the mechanics of faulting, subsidence of sedimentary basins, well stability, basin engineering, tunneling, excavation, and waste isolation. For natural tectonic processes, estimating rock strength is particularly difficult because of the complex chemistry of the mineral and fluid phases, extreme temperatures and pressures, and the staggeringly large range of strain rates and spatial scales. Based on the results of laboratory experiments by many investigators, semi-quantitative bounds have been obtained for the strength of monomineralic aggregates of olivine, feldspar, quartz, carbonates, or halite, although the rigor of the bounds depend substantially on the particular deformation mechanism, mineral, and thermodynamic conditions. In many cases, the general hierarchy of brittle, semi-brittle, frictional, and creep mechanisms that results from the experimental data is in qualitative agreement with observations of field and micro- structures in naturally deformed rocks and with large-scale geophysical measurements. Important challenges remain, however, including detailed understanding of localization and stability of large-scale faults and shear zones; of the inter-relationship of fluids, fluid transport, and deformation, and of the evolution of creep strength, particularly in multi-phase aggregates. Given the observation that fluid phases may be present even to depths Č° 10 km, the deformation of porous, fluid-filled rocks may be important for many processes in the lithosphere. The possibility that fluids in these rocks may migrate, suggests that at least a portion of the deformation of the deep lithosphere may involve semi-brittle mechanisms. Similar mechanisms may operate in partially molten mantle rocks.