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Probing Mechanical Properties of Rock with InSAR

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Interferometric Synthetic Aperture Radar (InSAR) observations from satellites have revolutionized our crustal deformation measurement capabilities with its high spatial resolution, global coverage, and low cost. The high spatial resolution (typically 5-20 m) allows us to map many small-scale surface deformation phenomena in great detail. These include surface faulting, fissuring, fault creep, and other strain localization phenomena. Another advantage of the small-scale deformation mapping is that it can provide information about mechanical properties of near-surface rocks.

Several studies have already been published on using InSAR to probe material properties of rock. Strain localizations at fault zones have been observed in co-seismic deformation fields near to large earthquakes and interpreted as expressions of weak fault zone materials that are a factor of two more compliant than the surrounding unbroken rock [Fialko et al., 2002]. Peltzer et al. [1999] argued that asymmetries in coseismic deformation patterns observed by InSAR showed evidence for non-linear elasticity, i.e. that the elastic moduli of shallow crustal material are different for compression and extension, due to small-scale cracks in the medium. This interpretation was later disputed by Funning et al. [2007], who provided an alternative explanation for observed deformation pattern based on along-strike variations in fault geometry and slip. In addition, observations and modeling of poro-elastic rebound after earthquakes have provided information about the difference in undrained and drained Poisson's ratio values of the near-surface rocks [Peltzer et al., 1996; Jónsson et al., 2003].

More recently we have used InSAR observations to put bounds on the tensional bulk strength of surface rocks. A dyke intrusion that took place in western Saudi Arabia in 2009 caused many moderate-sized earthquakes and extensive surface faulting. InSAR data of the area show that large-scale (40 km x 40 km) east-west extension of over 1 m took place as well as broad uplift amounting to over 40 cm. The center of the uplifted area was transected by northwest-trending graben subsidence of over 50 cm, bounded by a single fault to the southwest showing up to $\sim$1 m of normal faulting and by multiple smaller faults and tensional cracks (joints) to the northeast. We compare the mapped tensional strain with the occurrence of observed joints to estimate the tensional strain needed to form a new joint. We find areas that exhibit extensional strain of up to 0.05-0.08 millistrain but are still free of surface joints. Assuming rigidity of 10 GPa for the surface rocks in the area, the results indicate that the tensional bulk strength of the rock is close to 1-2 MPa, a value that is $\sim$10% of the strength that typically is estimated from small cm-scale intact rock samples of similar rock types in the laboratory.

Citations:
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