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Naturally constrained profiles of the strength of the lower crust near the brittle-ductile transition

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We present a method in which paleopiezometry using electron backscatter diffraction (EBSD), Ti-in-quartz thermobarometry (Titani-Q), and simple 2-D thermal modeling can be used to construct naturally constrained profiles of crustal strength in areas of exhumed mid-crustal rocks. As an example, we examine the footwall of the Sierra Alhamilla metamorphic core complex (SAMCC) in the Betic Cordillera of southern Spain. Rocks in the SAMCC were initially deformed during continental collision between the Alboran domain and Iberia. Rapid exhumation in the middle Miocene initially occurred by distributed ductile shear under high T/low stress conditions, evolved toward more localized ductile shear under lower T/higher stress conditions during cooling, and culminated in cataclasis and discrete brittle fracture as the rocks approached the brittle-ductile transition (BDT). The increasing localization and cooling during exhumation allowed earlier microstructures to be preserved, and rocks in the SAMCC therefore represent several 'points' in temperature-stress space (and by inference depth-stress space). In detail, the progressive localization of the SAMCC footwall is associated with several zones, including: 1) early, non-localized, high T fabrics; 2) kilometer-scale, anastomosing, ultramylonitic shear zones that cross-cut the non-localized fabrics; 3) folds and crenulation cleavages that overprint the ultramylonitic foliation near the detachment and cause a progressive swing in trend of the stretching lineation by ~ 30 degrees; and 4) finely laminated brittle-to-ductile shear zones beneath the detachment that may include transposed pseudotachylitic layers. Quartzites within each of these zones exhibit unique stress/temperature microstructures, to which we apply the experimental piezometer of Stipp and Tullis (2003, GRL, vol. 30, no. 21), and the Titani-Q thermobarometer of Thomas et al. (submitted manuscript). To relate the temperature measurements from each sample with depth, we use a finite-element code to solve the 2D heat-transfer equation for the pressure-temperature-time path of the footwall, using published cooling rates and standard material parameters. We compare the resulting crustal strength profile for the southern Betics to a similarly constructed profile for the Miocene Whipple mountains metamorphic core complex in eastern California.