Crustal strain across a deeply exhumed continental fault
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Strike-slip faults commonly arise in transpressional environments—the Denali fault is a
salient modern-day example—and are associated with large earthquakes. Geodetic data
can be used to assess the relative components of shortening and strike-slip shear of
modern transpressional faults. However, understanding the crustal strain
accommodated by such faults, which arise from long-term plate tectonic forces,
requires study of fault zones exhumed from mid- to lower-crustal levels. The 130-km-
long Proto-Kern Canyon fault (PKCF) in the southern Sierra Nevada, CA, is one such fault
that accommodated ~15 km of dextral displacement in response to obliquely directed
forces imparted during Farallon plate subduction. The PKCF traverses exposure levels of
~25 km, allowing investigation of structures and microstructures that provide
constraints on the distribution of stress and strain from ductile through brittle
conditions, including the transition zone. A regional geobarometric database of >200
locations through the batholith constrains the paleodepths of PKCF exposures. The fault
is ~2 km wide in most places—typical of mid-crustal shear zones—and across its width,
different rock types including marble, phyllite, quartzite, granodiorite, and amphibolite
are variably deformed. Thus, the PKCF provides a natural laboratory to investigate
crustal strain as a function of temperature, depth, and composition.

Samples from the study analyzed thus far crystallized at depths of 11–13 km and
temperatures of 700–725 °C. The Titanium-in-quartz thermometer (TitaniQ of Wark and
Watson, 2006) yields recrystallized quartz temperatures of ~480 °C for four igneous and
quartzite mylonite samples. The oldest deformed plutonic rocks within the shear zone
are 104 Ma, and the youngest igneous member was deformed as it was emplaced ca. 85
Ma. From the younger intrusion, two-feldspar thermometry on plagioclase with
stretched orthoclase overgrowths yields T = 480 ± 22 °C, and TitaniQ on recrystallized
quartz yields T = 461 °C ± 22 °C. Such uniform recrystallization temperatures in
intrusions spaced by up to 20 Ma indicated that temperature equilibrated fairly quickly
across the shear zone while it was active.

Deformation temperatures help refine our ability to determine strain rate along the
PKCF. Quartz piezometry-derived stresses for several samples are 50–95 MPa;
incorporating the TitaniQ-derived deformation temperature of 480 °C places natural
strain rates at 10^{15}–10^{13} s^{-1}. Compositional studies were paired with EBSD-derived
crystallographic preferred orientation (CPO) data for rocks of all compositions from the
shear zone. Quartz CPO is absent in micaceous quartzite that forms the western
boundary of the shear zone, indicating mica dictates the strength (or weakness) of mid-
crustal shear zones. In contrast, the shear zone’s eastern boundary displays
progressively diminishing quartz CPO of igneous mylonites, suggesting that when
temperature is high, it plays the greater role in imparting weakness through multi-mineralic rocks. This exhumed fault zone points to enhanced crustal weakness along a long-lived structure.