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1 The strength of the San Andreas fault: a contrarian view

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Stress measurements in boreholes deeper than 1 km have universally shown that shear stresses in continental crust increase with depth at a rate defined by a friction coefficient of about 0.6 with lithostatic overburden and hydrostatic pore pressure. Yet for over 30 years it has been argued, based on the lack of a localized heat flow anomaly, that the San Andreas fault is much weaker than that, with a friction coefficient, $\mu \leq 0.2$. Observations that the maximum principal stress σ(max)g in some places in northern and central California is nearly perpendicular to the fault have been used to argue that it is even lower, $\mu \leq 0.1$. This conclusion has been widely accepted by scientists who study California seismotectonics, even though there has been no acceptable mechanism proposed as to how such a low strength could occur: hence the term San Andreas heatflow paradox. Nevertheless, the idea that faults can have extraordinarily low friction coefficients has begun to be applied to other tectonic situations.

A critical review of the literature reveals that observations of stress magnitudes or orientations either contradict or are inconclusive regarding the low strength hypothesis. Stress measurements in the Cajon Pass borehole, specifically designed to test the low stress hypothesis, demonstrated that the strength of a minor strike-slip fault adjacent to the borehole was normal (μ = 0.6), but did not provide any information regarding the strength of the SAF. Stress directions inverted from earthquake focal mechanism show that everywhere in southern California σ(max) rotates to smaller angles (30-60˚)

within 20 km of the San Andreas fault. The sense of this rotation is opposite to that expected from the low-strength hypothesis and indicates that the shear stress on the SAF comparable in magnitude to all other horizontal stresses in the system. The observation of active thrust faults subparallel with the SAF in central and northern California can be interpreted in terms of strain partitioning of an obliquely compressed plate boundary without a requirement that the SAF be weak.

The weak SAF hypothesis then rests entirely on the heat flow argument. Although there is no narrow heat flow anomaly that would be expected by a conduction model, there is a broad and large heat flow anomaly associated with the SAF. This anomaly disappears as the Mendicino triple junction is approach, where the SAF has zero age and displacement, suggesting that its origin is in frictional work done on the fault. The alternative is the Lachenbruch and Sass (1980) slab window model, in which requires temperatures of $\sim 1100^\circ$ C at 20 km depth at Cape Mendicino. Recent seismic profiling in this area, specifically designed to look for this, found no sign of it. Modeling of the effect on heatflow measurements by topographically driven groundwater flow shows that a conductive anomaly will be spread out to produce an irregular, broad anomaly such as the one observed. There remain only 4-5 heatflow measurements in the Mojave region that could be sensibly used to argue for a low strength SAF (Saffer et al. 2003)., and they may be questioned on several grounds. The widespread belief that the heatflow data proves that the SAF is weak is misplaced.