INTRODUCTION

Studies of morphology and roughness properties of fault surfaces at laboratory and outcrop scale have shed light on brittle faulting processes ranging from nucleation and abrasion of asperities during slip to stress field variations that control nucleation and propagation of seismic rupture (e.g. Brown & Scholz 1985; Power & Tullis 1988; Schmittbuhl et al. 1993; Aimtrano O. and Schmittbuhl, J. 2002; Renard et al. 2006; Savy et al. 2007; Candela et al. 2009; Candela et al. 2013). The outcrop scale is crucial to understanding the roughness of microfractures from microscopic to outcrop and the fact that frictional properties of fault gouge is not very well understood.

We have studied a gouge sample from the actively creeping southwestern deforming zone (SDZ) in the San Andreas Fault Observatory at Depth (SAFOD). This, nearly cohesionless, phyllosilicate-rich foliated gouge bears clear evidence of pervasive frictional sliding at grain scale. We ask whether the roughness properties of the sliding surfaces in the gouge are comparable to outcrop-scale fault surfaces studied by others, and how these properties might relate to the size distribution of the gouge particles.

THE GOUZE SAMPLE

The studied sample was extracted from the SAFOD phase 3 lateral drill core section G28 at a measured depth (MD) of 3197.2m, corresponding to 3192.17m MD in the SAFOD Main Hole, where active creep was deforming the borehole casing at the time of drilling (Zoback et al. 2010).

Above: Repository shots showing location of the sample within the split G28 core section. At core scale, the anastomosing gouge has a granular-flaky texture and highly reflective slickenside surfaces with occasional round lithic fragments and serpentine phyllophorystals (S). The material is easily disturbed by touch. On the right: The EOX spectrometer indicates that the gouge is mainly composed of illite-smectite and Mg-rich-smectite clays.

Below: in thin sections, the gouge shows lozenge-shaped fabric defined by microliths separated along sliding surfaces. We define as first order (S1) the surfaces that cut across the fabric and as the second order (S2), the surfaces that bound the microliths. We consider S1 and S2 as grain-scale shear fracture surfaces.

Below: the SEM image of section through an S1 surface. Note trace of micron-scale roughness amplitude. A phyllosilicate-rich ultracataclasite band (same composition as gouge) appears more prominently on the lower side of the surface forming the underlying surface with higher relief. Inset reference image shows fracture density near the slip surface.

Below: Typical morphology of S1 (on the right) and S2 sliding surfaces characterized by fine slip striations.

Below: The DEM shows the gouge surface at a higher resolution. The S1 surfaces are defined by a series of closely spaced parallel striations, while the S2 surfaces show a more striated and less ordered surface.

Above left: Typical subset DEM of the sliding surfaces acquired using a high resolution white light interferometry microscope. Scaling property of the roughness was estimated by averaging the computed power spectral density along thousands of profiles perpendicular and parallel to sliding orientations derived from the DEM data matrix.

Above right: Plots showing roughness properties parallel and perpendicular to sliding orientations in the S1 and S2 sliding surfaces in the SAFOD gouge. Maximum length scales of transition from isotropic to anisotropic surface roughness are indicated by circles on the plots.

ANALYSIS & CONCLUSIONS

For all studied surfaces there is a crossover length scale from isotropic roughness (H0.5: surface having same roughness perpendicular and parallel to slip) to anisotropic roughness (H1.5). In the anisotropic regime the Hurst exponent values of 0.6 and 0.8 are similar to those found for a number of outcrop-scale fault plane surfaces measured by Candela et al. (2009, 2012), suggesting correlation of some underlying physical properties and mechanisms over a wide range of scales. The onset of the isotropic regime for the smoother surfaces (S2 surfaces in general) occurs at smaller length scales. This result is consistent with other measurements performed on several fault surfaces in various geological settings. Candela et al. 2012 (see Poster T13-E2660) argued that the onset of isotropic roughness is linked to the particle size distribution of the gouge layer that lines the slip surface; The onset of isotropy occurs at smaller length scales for more evolved particle size distributions. The role of particle size in roughness is further supported by the P(>8μm) of the crossover length scales in this study, which may reflect different degrees of slip-related comminution along the S1 and S2 surfaces.

Depending on the stress field orientation, the isotropic aspect of the surfaces in this study may reflect a preferential resurfacing by pressure solution that tends eliminate roughness anisotropy. This speculation is particularly attractive since it implies that deformation of the creeping fault gouge might be taking place via a dual frictional-ice mass transfer mechanism. Hadiizadeh et al (2012) suggested that deformation of the San Andreas fault gouge in G28 core section may be characterized as a frictional granular flow assisted by stress-driven pressure solution.

REFERENCES

Armitrano D. and Schmittbuhl J. (2002). Fracture roughness and gouge distribution of a granite shear band, JGR 107, 2375.

