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Microstructural investigation of a locally mirror-like surface collected at 4 km depth in a Pomeranian shale sample

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The presence of shiny sliding surfaces, or mirror surfaces, is sometimes thought to have been caused by slip at seismic velocities. Many fault mirrors reported so far are described to occur in carbonate-rich rocks. Here we present microstructural data on a mirror-like slip surface in the Pomeranian shale, recovered from approximately 4 km depth. The accommodated sliding of this fault is probably small, not more than one or two centimeter. The Pomeranian shale is a dark-grey to black shale, composed of 40-60% illite plus mica, 1-10% organic matter, 10% chlorite, and 10 % carbonates plus minor amounts of K-feldspar, plagioclase and kaolinite. In this sample, the surface is optically smooth with striations and some patches that reflect light. Observations using a Hitachi TM3000 (table-top) SEM show that the striations are omnipresent, though more prominent in the carbonate patches (determined using EDS analysis). The smooth surface is locally covered by granular material with a grain size up to 10 μm. This is shown to consist of a mixture of elements and thus likely locally derived fault gouge. The clay-rich parts of the smooth surface are equidimensional grains, with sub-micron grain sizes, whereas in the unperturbed part of the shale core the individual clay platelets are easy to distinguish, with lengths up to 10 μm. The striated calcite-rich patches appear as single grains with sizes up to several millimeters, though they occasionally are smeared out in a direction parallel to the striations.

We have analyzed surface roughness at magnifications of 2.5x to 100x using a standard White Light Interferometer, parallel and perpendicular to slip. At low magnifications, 2.5x and 5x, Hurst exponents were anomalously low, around 0.1 to 0.2, interpreted to be related to a lack of sufficient resolution to pick up the striations. At higher magnification the Hurst exponent is 0.34 to 0.43 parallel to the striation, and 0.44 to 0.61 perpendicular to the striation. This relatively low Hurst exponent suggests that this surface has not experienced high strains, even though it locally exhibits mirror-like properties. As such, this data supports the notion that the formation of shiny surfaces is related to grain size reduction, but does not necessarily indicate major slip events. Additionally, the more strongly visible striation in the carbonate-rich parts indicates that some mineralogies are more prone to the formation of striations than others. A full interpretation of this sample is of course complicated by its small size, but these data suggest that when examining fault mirrors and the presence of striations spatial difference in mineralogy need to be taken into account.