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Silica gel in a fault slip surface: Field evidence for palaeo-earthquakes?

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ABSTRACT

High-velocity friction experiments have shown an almost complete loss of strength associated with silica gel formation on slip surfaces. The identification of frictional silica gel products in palaeo-seismic faults is, however, problematic, because there are multiple natural sources of silica gel and recrystallization of gel to quartz complicates preservation. The importance of gel formation on natural faults is therefore unknown. Here, we report a structurally distinct and semi-continuous, 0.5–10 mm thick layer of microcrystalline quartz along a major carbonate-hosted fault, the Olive fault, in the Naukluft Nappe Complex, Namibia. The quartz layer is distinguished by flow banding-like textures and unusual cathodoluminescence characteristics. The layer consists of ~2–20 μm hexagonal quartz crystals, which include distinct, crystalline, pore-bearing micro-to nano-spheres, separated by pore geometries indicative of volumetric contraction, and with grain boundaries enriched in aluminium. We interpret these features to indicate that the quartz crystals formed from recrystallization and dehydration of a silica gel. Because it is found in a carbonate-hosted fault and crosscuts lithological layering, the silica source is not from comminution of local wall rocks. Rather, the gel likely formed from reshear of a quartz-coated fault surface, or incremental shear slip associated with precipitation of silica driven by co-seismic pressure drops. This example of fault-related silica gel may have formed by a different mechanism than the gels produced in high-velocity friction experiments, but once formed, may have comparable rheological effects.

1. Introduction

Recognizing evidence for past earthquake slip in the rock record is problematic. Other than the presence of pseudotachylyte, which is extremely rare compared to the frequency of earthquakes (Sibson and Toy, 2006; Kirkpatrick et al., 2009; Di Toro et al., 2009; Kirkpatrick and Rowe, 2013), there has been no universally accepted direct field evidence for past seismic slip along faults (Cowan, 1999). Other slip-weakening processes that may record evidence of palaeo-earthquakes have been suggested, such as fluidization of gouge, coseismic carbonate dissociation, and clay breakdown (Otsuki et al., 2003; Rowe et al., 2012; Ujiie and Tanaka, 2013). However, the prevalence of these mechanisms during natural fault slip is not well documented and the evidence can be ambiguous. The formation of hydrous silica gel on slip surfaces has been observed in rock-friction experiments, concurrent with slip-weakening, indicating that silica gel, or its products after diagenesis, may be an alternative indicator of palaeo-earthquakes within the rock record (Goldsby and Tullis, 2002; Di Toro et al., 2004; Hayashi and Tsutsumi, 2010; Di Toro et al., 2011). Recently, a field example of solidified and recrystallized silica gel has been identified in the Corona Heights fault, in San Francisco, California (Kirkpatrick et al., 2013). This study highlighted fault microstructures associated with possible silica gel lubrication, and provides evidence that silica gel may be created in natural fault systems as well as in experiments.

In the experiments, rapid slip weakening was recorded coincident with the formation of the silica gel. The formation of the silica gel was attributed to the presence of moisture, and the slip weakening effect to the thixotropic behaviour of the gel (Goldsby and Tullis, 2002; Di Toro et al., 2004; Hayashi and Tsutsumi, 2010; Niemeijer et al., 2012). However, the few experiments that have been conducted have produced silica gel at a variety of slip rates

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