ELECTRON MICROSCOPICAL STUDY OF INDURATED QUARTZ GOUGES

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The frictional properties of sandstone depend, in part, on the nature of the quartz gouge between the sliding surfaces. Gouge consisting of crushed quartz grains forms between sliding surfaces of fractured sandstone. Generally gouge is an unindurated but compacted aggregate of particles whose median diameter is about 25 μm, an order of magnitude less than the initial diameter of the sandstone quartz grains. In recent experiments on the frictional properties of quartz gouge between sandstone a 40 μm layer of indurated gouge has been generated at 1.0-kb normal stress. The purpose of this investigation is to characterize this unusually fine-grained indurated gouge and to suggest its influence on the frictional properties of sandstone.

Transmission electron micrographs of the ultra thin-sectioned gouge reveal an aggregate of very poorly sorted particles (Fig. 1). The aggregate has a normal particle-size distribution which varies from 4.0 μm to less than 0.06 μm and a median particle size of 0.4 μm, as determined by a point count on a calibrated micrograph. The aggregate consists of relatively well rounded particles (Fig. 1) as well as larger conchoidally fractured angular particles (Fig. 2). Interstitial voids filled with embedding epoxy indicate that the indurated gouge is not completely compacted. Electron diffraction facilitates the identification of the gouge particles which are predominantly quartz, in association with some finer particles of clays and calcite from the cement of the initial sandstone. The larger particle (Fig. 1; arrow) which exhibits diffraction contrast internally is uncommon and has not been positively identified.

Conchoidal fractures on quartz particles suggest that brittle fracture is the primary deformation mechanism and that the indurated gouge is generated by mechanical abrasion. The angularity of 0.3-0.5 μm ground quartz shown by Cartwright[1] is striking when compared with rounded particles shown in Fig. 1. This difference in angularity is attributed primarily to the influence of a 1.0-kb normal pressure which promoted extensive mechanical wear of the quartz during the sliding friction experiment. The contrast in degree of rounding within the indurated gouge suggests that certain portions of the aggregate are subject to more mechanical wear than other portions and that abrasion is as effective a mechanism for rounding of submicron particles as for sand-sized grains.

An unresolved problem is that of identifying the mechanism of induration of these fine quartz particles. Handin[2] describes some fine-grained gouge which has been indurated with a glassy matrix. Accordingly, it has been suggested that the particles in Fig. 1 and 3 (arrows) with internal diffraction contrast may be glass shards. To date it has not been possible to separate these particles from other crystals in order to determine if these particles produce an electron diffraction pattern. Even when the gouge is disaggregated ultrasonically, other crystalline particles normally cling to the unusual particle preventing necessary isolation.

When the 40 μm thick layer of indurated gouge forms between a precut sample of sandstone and a 1200 μm thick layer of compacted but unindurated gouge, the measured kinetic coefficient of friction increases about 5%. The particle size of the indurated gouge is small relative to the asperities on the sliding surface of the sandstone. The irregular surface layer of the indurated gouge as shown by SEM and the upper portion of Fig. 1 probably conforms to irregularities on the sliding surface. Thus, the area of contact between the sliding surface and the indurated gouge is probably very high. Rabinowicz[3] observes that the shear force along surfaces of metals in contact increases as the area of actual contact increases. The same phenomenon is suggested as a cause of the increase in frictional force during experiments in which the indurated gouge forms.

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1. J. Cartwright, Mineral. Soc. Mono. 3, 301 (1971).
2. J. Handin, Rpt. ARPA Contract 14-08-001-12723, 1 p. 33 (1972).
3. E. Rabinowicz, Friction and Wear of Materials, Wiley, p. 36 (1965).

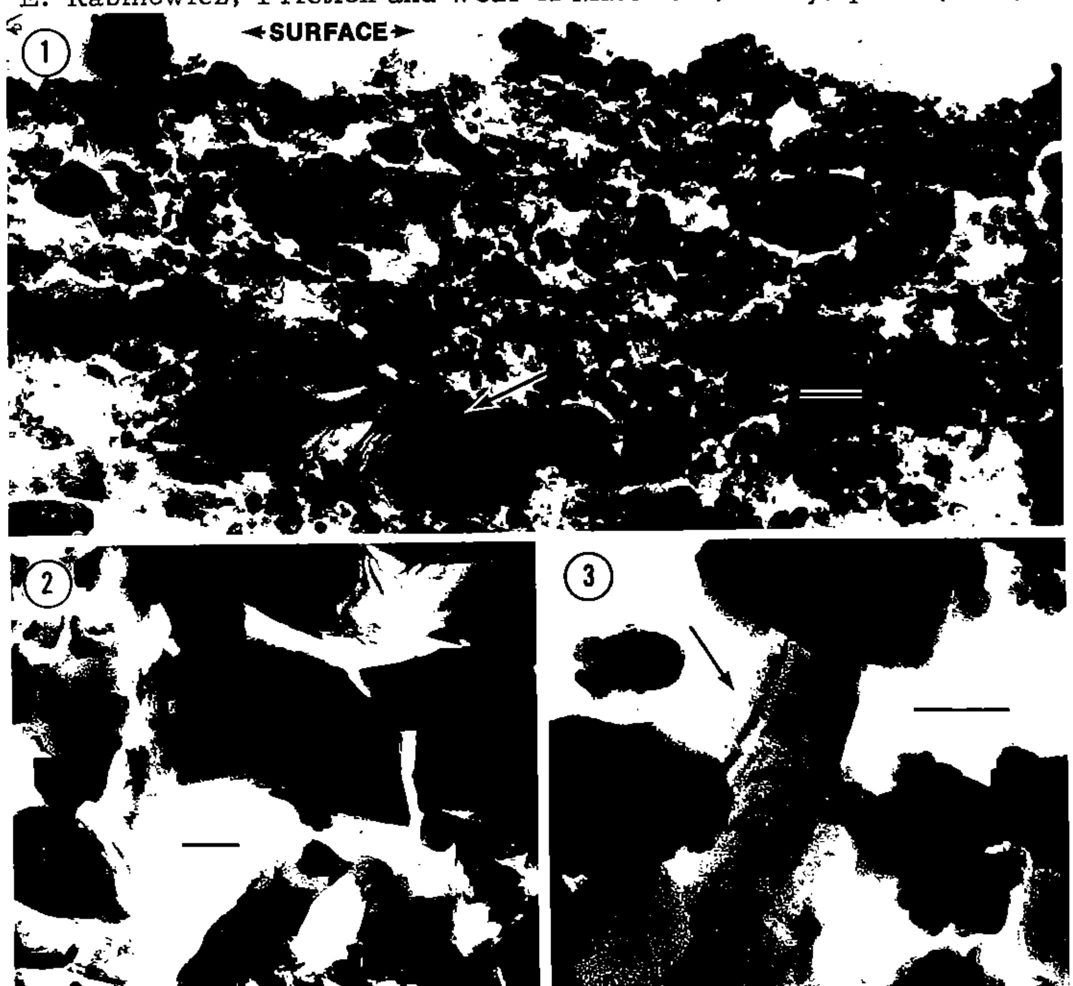

Fig. 1: Micrograph of an ultra-microtome cross section of the indurated gouge showing its irregular surface. Fig. 2: Micrograph of the portion of indurated gouge characterized by angular particles. Fig. 3: Micrograph of ultrasonically disaggregated and drop-mounted particles from the indurated gouge. (Scale bars indicate 1 μm; arrows point to unidentified particles exhibiting diffraction contrast internally.)