A CLOSER LOOK AT FEATHER FEATURES IN QUARTZ AS DIFFERENTIAL STRESS INDICATORS IN THE SHOCK WAVE.

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During the impact cratering process, a shock wave in generated by the impacting projectile that deforms the target rocks. While there is a large hydrostatic pressure component within these shock waves, differential stresses of up to 1-2 GPa can occur. In planar shock waves formed e.g., in experiments, it can be assumed that stress and strain are coaxial, leading to pure shear deformation. However, numerical modeling indicates that there is a non-coaxial component of strain leading to subsimple shear and vorticity [1]. The amount of these components varies based on the distance and depth relative to the point of impact, and can also increase within a sample as the shock wave passes through.

While the results of [1] show that the stress-strain relationship of the shock wave can be complex, it underlines the fact that differential stresses occur within the shock wave, and that shear-derived shock features should be formed. To test this general hypothesis, the orientations of microstructural deformation features were measured in a previous study in order to constrain the compressional axis of the shock wave [2]. These were i) conjugate systems of grain-scale micro-shear faults found in quartz, termed “feather features” (FFs), consisting of a shear plane and well-ordered subsidiary fractures to one side, ii) basal PDFs, i.e., Brazil twins that form through shearing along the basal plane in quartz, and iii) kinked biotites. These features were found in shocked granites of the peak ring of the Chicxulub impact crater in Yucatán, Mexico, which was drilled by IODP/ICDP Expedition 364 [3]. Results of this study show a general agreement of the compressional axes to within 30°, indicating the three microstructures formed under the same differential stress-strain regime within the shock wave.

Despite these results, some colleagues remain unconvinced that feather features are shear features, and that their orientations are related to the differential stresses in the shock wave. To improve the current knowledge of FFs, an initial study was performed on two sandstone samples from the Gosses Bluff structure, Australia. Thin sections were surveyed and FF displacements were measured. Of 228 feather features surveyed, 174 showed displacement of the grain boundary on either one or both sides of the grain. 76% thus confirm the sense of shear inferred by the orientation of subsidiary fractures relative to the shear plane. 75 FFs showed shearing along both grain boundaries, i.e., 33%. Only 2 FFs (0.9%) showed “reverse” displacement, and 2 showed two shear directions (“fish tails”). Displacement of grain boundaries by the FFs was typically between 10 and 30 µm, with values occasionally reaching 60-70 µm. (Grain sizes of the samples were ~500-1000 µm.)

The results of this preliminary study strongly support the shear-based nature of feather features. Furthermore, the planar shear planes of these two samples are oriented in well-defined conjugate sets, and the orientation of subsidiary fractures is strongly clustered as the angle bisector of the conjugate sets. These strong preferential orientations underline that a differential stress component must have been involved in their formation. The orientation of this differential stress component is certainly of importance on a scale of tens to hundreds of meters, as shown by [2], however, the relationship to the point of impact and the shock wave front may be more complex, as shown by [1].

Finally, cross-cutting relationships of feather features with other microstructures can be a useful tool to determine when microstructures form within the shock wave. Conglomeratic quartzite clasts were collected on a recent field trip to the Araguainha structure in Brazil. These clasts are remarkable in that they are “shattered”, i.e., they show conjugate shear sets on the hand specimen scale, with mm- to cm-scale displacements. Similar “shattered” clasts observed in the Nördlinger Ries have been suggested to form due to deformation in the shock wave ([4]). The clasts from Araguainha revealed a surprisingly high density of FFs in thin section. The FFs were crosscut by the larger shear faults, and in 2 of 4 clasts examined, the shear sense of FFs and large shear faults were in opposing directions. As FFs must form late in the shock wave, since they overprint PDFs [5], this raises the question if these “shattered” could have formed within the shock wave, or are a result of deformation in the excavation or modification stage.

Feather features thus remain an interesting and intriguing phenomenon, and have a high potential as a microstructural tool. More detailed studies of these features should lead to an improved understanding of deformation processes in the shock wave.

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