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STUDY OF THE PREFERENTIAL ORIENTATION DISTRIBUTION OF SHOCK-INDUCED PLANAR MICROSTRUCTURES IN QUARTZ AND FELDSPAR.

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Introduction: The distribution of the orientations of shock-induced planar microstructures in feldspar and quartz, such as planar fractures (PFs), planar deformation features (PDFs; e.g., [1,2]), and possibly microtwins (e.g., [3-5]), has never been considered to our knowledge at the sample scale, because such a distribution of orientations is considered to be random. Indeed, even the intensity of shock effects has a large variability within a sample, due to the local shock wave scattering, caused by the different shock impedance between mineral phases, between crystals of the same mineral but with different crystallographic orientations, or due to pre-existing heterogeneities in the rock. However, the frequency of such microstructures, for example the frequency of specific crystallographic orientations of PDFs in quartz, measured on a statistically meaningful number of grains, provides information on the shock intensity (e.g., [2]) and has allowed studies on shock attenuation (e.g., [6]). Recently, it was proposed to use the shear sense indication along PFs in quartz, as inferred from the orientation of feather features (FFs), in samples from the IODP-ICDP Chicxulub Expedition 364 drill core [7] to constrain the original orientation of granitic target blocks in the peak ring, by relating the supposed orientation of the maximum compression axis with the center of the crater [8], after having unsuccessfully tried in the past with PDFs in quartz [9].

In this work, we focus on the orientation of planar microstructures in shocked feldspar and quartz, in the hypothesis that they preferentially develop along directions that are favorably oriented with respect to the local shock waves, disregarding their mechanism of formation (maximum compression, shock relaxation, or shear). We have measured the orientation of such microstructures with the Universal-stage (U-stage) with respect to a selected local reference system. In shatter cone samples, the used reference is the striated surface, and in "oriented" IODP-ICPD Chicxulub Expedition 364 drill core samples, the reference is the core axis. Comparing the results from the shatter cone samples with those from the Chicxulub drill core, we discuss the possibility to infer information on the original orientation of the blocks in the peak ring of the Chicxulub impact structure.

Samples and methods: Shatter cone samples used in this study were: CHA09-12-01 from the Charlevoix impact structure, Canada, recording no pre-impact tectonic deformation (e.g., [10;11]), WMM-102A-64C1 from the Manicouagan impact structure, Canada, recording weak pre-impact deformation (e.g., [12;13]), and VN3 from the Keurusselkä impact structure, Finland, which is strongly foliated (e.g., [14]). Thin sections were cut roughly normal to the striated surface and the striation direction. The samples were selected with different stages of tectonic deformation to exclude a potential influence of pre-impact crystallographic preferential orientation of the investigated phases in the orientation of the shock microstructures. The samples from the Chicxulub drill core [7] are 132R1_54-57 (838.76 m below sea floor, mbsf), 164R2_47-52 (919.52 mbsf), 188R2_11-13.5 (986.19 mbsf), 212R1_129-131.5 (1056.01 mbsf), and 224R1_61-63.5 (1091.39 mbsf). Thin sections were cut both normal and parallel to the core axis. Petrographic thin sections were investigated with the U-stage, and data were plotted with the program Stereo32.

Results: In the shatter cone samples, a strong preferential orientation of the shock-induced planar microstructures in quartz and feldspar is obvious, disregarding the abundance of such microstructures or the nature of the mineral they are contained in. This preferential orientation defines a maximum in the pole figures with an angle of ca. 30° with respect to the striated surface of the shatter cones and is independent from the eventual presence of foliation (Fig. 1). In the Chicxulub drill core samples, a preferred orientation is not obvious in the investigated samples and does not seem to be strongly correlated with the orientation of the considered thin section (normal or parallel to the core axis). However, it seems that the pole figures obtained from thin sections cut parallel to the core axis are similar to those obtained for the shatter cones, defining a maximum in orientation frequency. The pole figures obtained from thin sections cut normal to the core axis commonly show either no maximum or two or more maxima, implying a more random orientation distribution of the shock planar microstructures in this case.

Discussion: The geometry of the U-stage limits the investigated volume for planar microstructures to the central area in stereographic projections, which means that the poles plot all along the margin of the pole figures. For this reason, thin sections cut in different orientations with respect to the reference system are needed for a full 3D characterization of the distribution of planar microstructure orientations. As the shatter cone samples were only available in the form of one set of thin sections, we cannot proceed to cut additional thin sections along other directions for testing the validity of our hypothesis.

The Chicxulub samples are also not ideal due to their coarse grain size (i.e., limiting the number of grains that can be measured per thin section) and the lack of control on the sample orientation. Although the orientation with respect to the drill core axis (dip) could be reconstruct, the azimuth orientation of the thin section cannot be constrained.

Even though the formation mechanism of shatter cones is still debated and different shatter cone orientations can be seen within a single sample, the striated surface offers a local reference system for shock propagation at the thin section scale. In the considered samples the preferred orientation distribution of planar microstructures in thin sections cut normal to the striated surface is incredibly consistent among the samples. A similar pole figure is obtained for thin sections cut sub-parallel to the drill core axis in the case of the Chicxulub samples. However, the unknowns at the local scale, in terms of shock wave scattering, and the uncertainty in the 3D orientation of the samples from the drill core cannot be ignored and prevent any straightforward extrapolation. Any attempt to constrain the original position of the granitic blocks in the target rock at the time of the impact based on the preferred orientation of such planar microstructures is, therefore, not possible.

Conclusions: Even though studies on the preferred orientation distribution of planar microstructures in shocked samples look promising to constrain the shock wave propagation direction, the extremely local shock wave scattering hampers the use of this technique at a larger scale than a thin section, especially in the absence of a proper reference.

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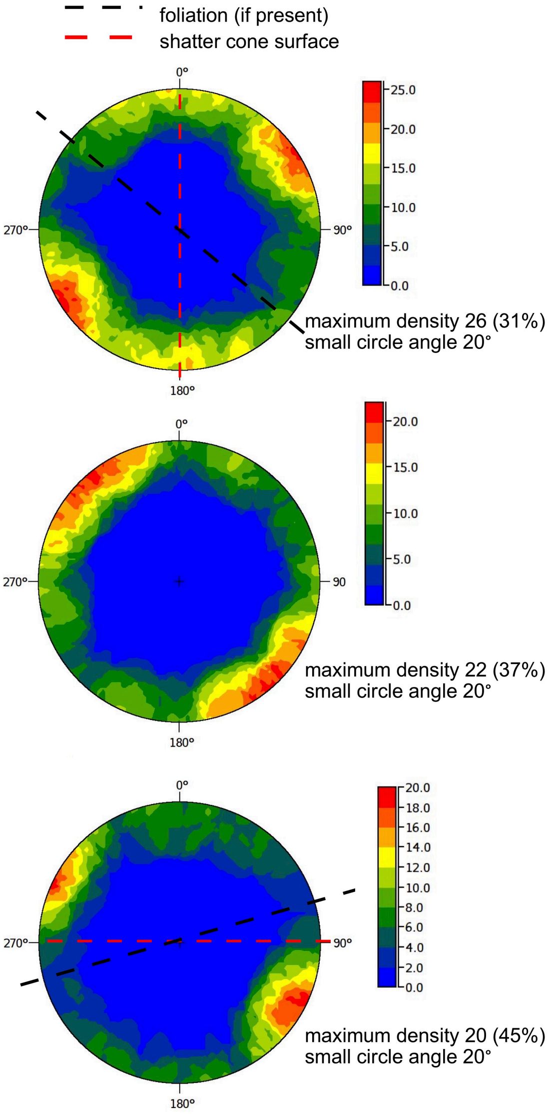

Fig. 1 *Pole figures of all planar microstructures measured in samples from shatter cones in several impact structures.*