FEATHER FEATURES IN SHOCKED QUARTZ AS A TOOL TO CONSTRAIN DEFORMATION IN IMPACT CRATERS: A CASE STUDY OF CHICXULUB'S PEAK RING M. Ebert[1], M. H. Poelchau[1], T. Kenkmann[1], Ritu Sah[1] [1]University of Freiburg, Geology, Freiburg, Germany (matthias.ebert@geologie.uni-freiburg.de)

Introduction: In order to unravel the complex formational process of peak rings we need to understand the heterogeneous deformation mechanisms that have occurred during large meteorite impacts. The recent drilling into Chicxulub's peak ring (IODP-ICDP Expedition 364, 2016) provides a unique view into the deformation styles of a peak ring [1]. The sampled core reveals the occurrence of shock-related feather features (FFs) within ~580 m of granitic basement rocks [2,3]. These microstructures consist of a planar fracture (PF) and a set of lamellae that emanate in one direction from the PF. The PFs are interpreted as early stage shock features. Shearing of these PFs is connected to the formation of FF lamellae (FFL) which are interpreted to form in the late stages of shock deformation during pressure release [4]. The orientation of the FFL is suggested to be controlled by the orientation of the principal axis of stress σ_1 within the shock wave, which indicates the propagation direction of the shock front [4]. Based on this FF-model, we have determined local σ_1 orientations in order to see if a consistent or interrelated orientation occurs throughout the Chicxulub peak ring core. This approach aims at identifying a deformation path and stress history within the peak ring, which is essential for reconstructing the overall crater formation process. This unique drill core thus allows a better quantification of FF formation conditions, and documents their usefulness as a stress orientation indicator.

Methods: 39 polished thin sections from various depths within the granitic section of the drill core were systematically searched for FFs. The orientation (azimuth and dip) of each PF and the corresponding FFL relative to the thin section reference frame were determined with a universal stage microscope. We defined the orientation of σ_1 as the linear that i) lies within the surface plane of the FFL and ii) is oriented 90° to the intersection line of the FFL and PF planes. Dip and azimuth of σ_1 were calculated from FF measurements using stereonet software (Stereo32®). σ_1 orientations were then reoriented to geographic north using rotational corrections from [5].

Results: In individual thin sections, the majority of the FF lamellae emanate from the PFs in the same direction. Less than 10% of FFs point to the opposite direction of the main orientation. Subordinately, 1 to 2 additional FF orientations beside the main one also occur. The FFL are straight to slightly bent, their lengths range between 10 and 50 µm and the space between individual lamellae also varies between ~2 and 10 µm. Preliminary SEM analysis shows that FFL are tensile micro-fractures opened up to 1 µm in width.

σ_1 values were determined for each of the 39 thin sections (Fig. 1 and 2). The number of FFs on which the orientation is based varies from sample to sample (1 to 11 FFs). We have found a twofold pattern of σ_1 orientations with increasing depth of the drill core: (i) Between ~750 and ~1200 mbsf the inclination angle of σ_1 increases, from relatively shallow ~10° to steep ~80° (Fig. 1).

The azimuth values in this part of the Chicxulub drill core are particularly striking, as they dip in WNW direction and are thus strongly confined to a radially outwards oriented trend relative to the crater center. In the stereoplot, they show a clear girdle with WNW-ESE strike (Fig. 2.) Occasionally, samples occur where the azimuth of σ_1 points in the opposite direction (ESE). The granitic rocks were intruded by pre-impact mafic and felsic igneous dikes, the opposite azimuth values (e.g. at 855 mbsf) may be caused by reflections of the shock wave at those lithology changes. (ii) Below 1200 mbsf no general correlation of the σ_1 could be observed. σ_1 orientations only show a similar trend in a few cases where the distance between the samples was < 10 m (e.g., at 1325 mbsf).

Discussion: Numerical modeling shows that this part of Chicxulub's peak ring was at a depth of ~7.5 to ~10 km at the time of impact and that the shockwave propagated sub-horizontally through the granitoid target rock [6]. Therefore, σ_1 orientations and the corresponding FFL should also have initially been sub-horizontal. During initial crater collapse in the modification phase, the granites were faulted inwards from the transient crater rim and incorporated into the central uplift [6]. During this process, the granites must have been rotated from their original position, possibly by more than 90°. In the late stages of crater modification, the granites within the central uplift were displaced outwards to form the peak ring [6]. The final rotation of these granites is estimated at ~90° from numerical models [7], suggesting that FFL and σ_1 orientations should be sub-vertical.

Our σ_1 data indicate that the granite between 750 and 1200 mbsf behaved as a semi-coherent block that underwent an internal rotation or folding. The rotation axis is in NNO-SSW direction, i.e., concentric to the crater center (Fig. 2). Figure 1 shows discrete structural units from [8], which are based on macroscopic mapping of deformational characteristics within the drill core.

We could not find a trend for σ_1 in samples below ~1200 mbsf. In this region, the peak ring shows extreme deformation that is characterized by a wide range of structures, including brittle shear faults, mm- to cm-thick zones of cataclasis, striated shear planes and dm-thick zones of foliated and crenulated mineral fabrics. The combination of all these deformation processes may induce to a large number of small-scale rotational movements in the peak ring units, which is reflected by the chaotic σ_1 orientations. This lower part of the peak ring core is interpreted as the main outward thrust zone active during imbrication of the peak ring [6].

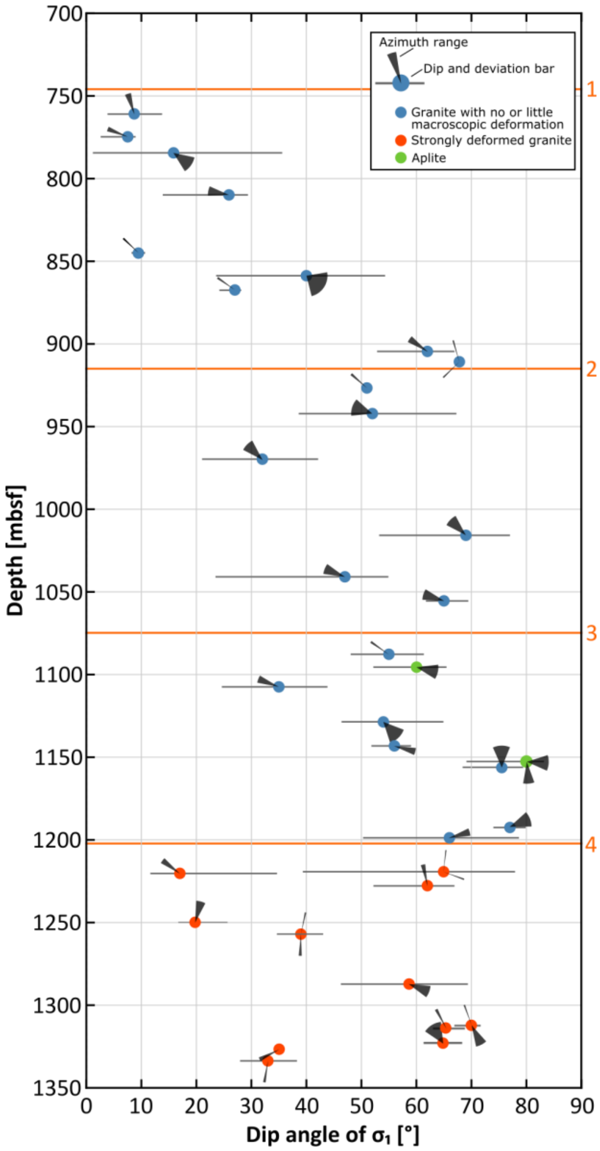

Fig. 1. Tadpole plot showing dip versus depth of σ_1 values measured in 39 thin sections of shocked granitic rocks from Chicxulub's peak ring. 0° indicates horizontal orientation. The black wedges indicate the range of the azimuth values (between 0°-360°) in the respective thin section, while thin black lines indicate the range of dips. Orange horizontal lines labelled 1-4 mark discrete structural units of deformation characteristics from [8].

Conclusion: The present study could clearly show that (i) the orientation of the FFs towards Chicxulub's crater center emphasizes the connection between shock wave propagation and FF formation, (ii) the orientations of FFs can be used to trace small-scale to large-scale movements of the target rock which occur during crater formation and (iii) our method allows the identification of coherent rock units in drill cores of impact craters.

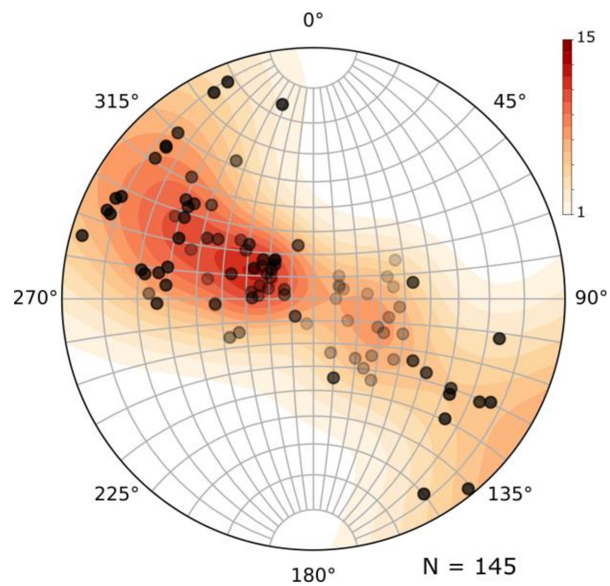

Fig. 2. σ_1 orientation density map for samples between 750 and 1200 mbsf. Data form a girdle oriented radially to the crater center. Deeper values are shown in lighter colors.

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