Cataclasite formation in the Chicxulub impact crater gleaned from 2D image analysis of the IODP-ICDP Expedition 364 drill core

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IODP International Ocean Discovery Program

icdp

ECORD European Consortium for Ocean Research Drilling

IODP Expedition 364 – Chicxulub K-Pg Impact Crater

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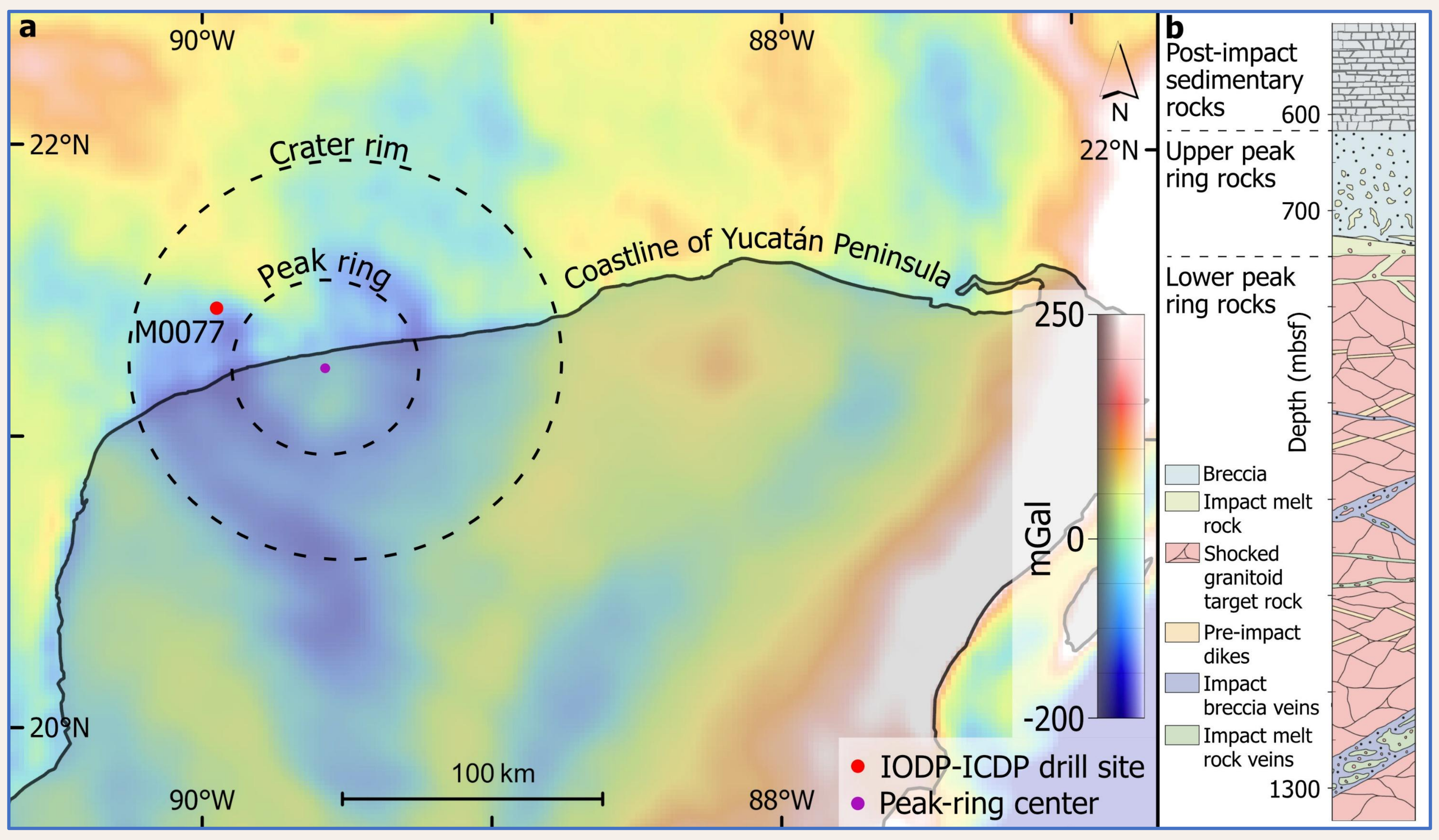


Fig. 1: (a) Location of the Chicxulub crater and the IODP-ICDP Expedition 364 drill site superposed on the gravity anomaly map based on Sandwell et al. (2014) (b) Schematic stratigraphy of the drilled lithologies, modified from Morgan et al. (2016). The depth is indicated in meters below sea floor (mbsf)

1. Introduction

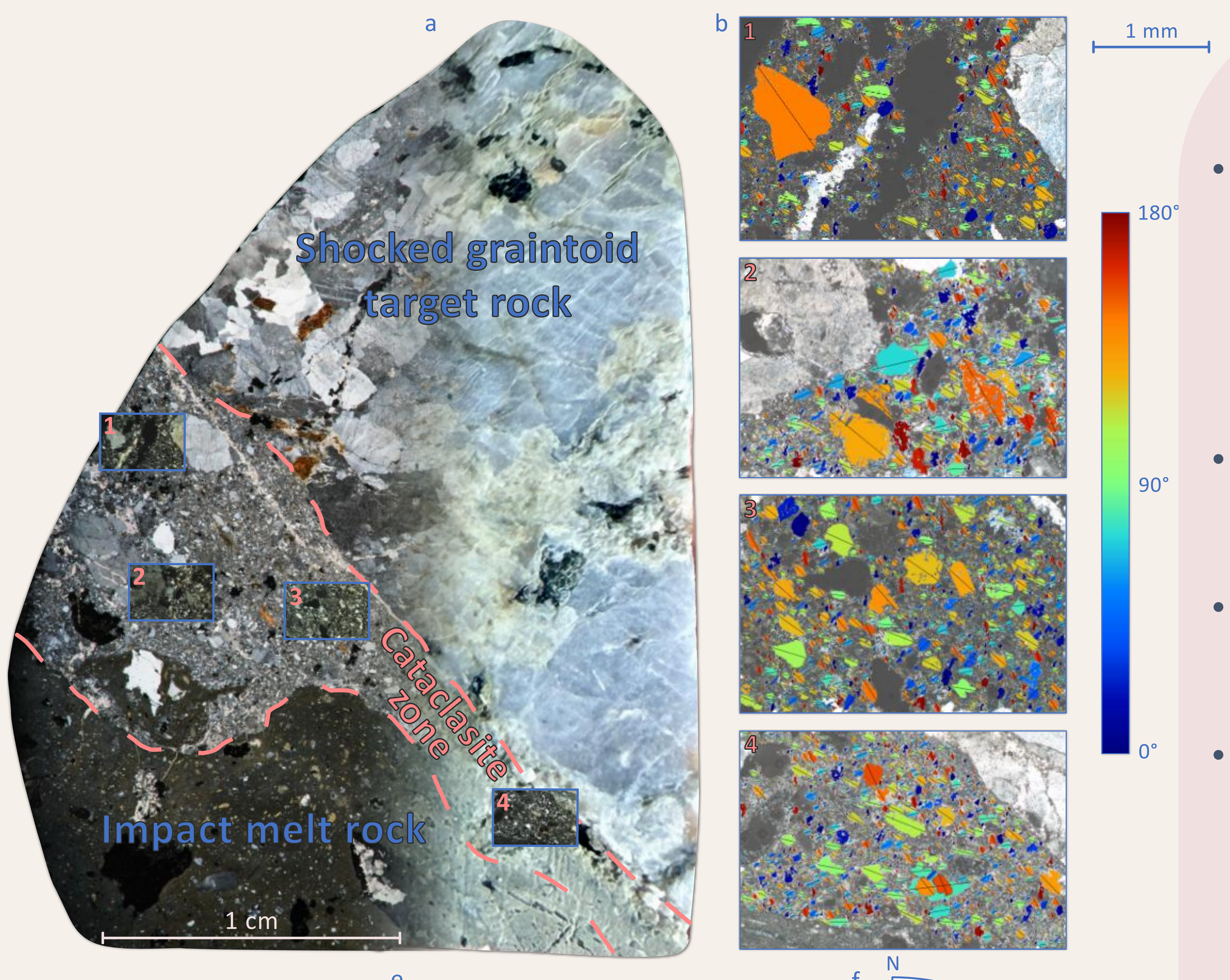
- The **Chicxulub crater**, located on the Yucatán Peninsula in Mexico, was formed by the impact of a ≈ **10-km Ø meteorite** on Earth **66 Ma ago**[1]
- The impact left behind a complex **crater** with a **peak ring** that was successively covered by post-impact sedimentary rocks (Fig. 1b)[1,2]
- The lower peak ring rocks are primarily heavily fractured and faulted **granitoid target rocks** that pervasively exhibit **cataclasite zones**, as observed in the **IODP-ICDP Expedition 364 drill core M0077** (Fig. 1)[2]
- **Cataclasites** are a category of shearing-induced fault rocks. They develop in the brittle realm, leading to the formation of mostly angular grains within a fine-grained matrix
- The formation of these zones during cratering is attributed to the **transition from acoustic fluidization to localized shear faulting**[3]
- Quantifying the **orientation of fragments** in cataclasite zones provides geological evidence for the **formation mechanism** of these fault rocks, crucial for our **understanding of the progressive cratering and deformation mechanisms**

2. Research questions

- To what extent does cataclasis result from **acoustic pressure fluctuations**, leading to pure crushing of target rock (i.e., random fragment orientation), and comminution of rocks caused by **zone-parallel shearing** (i.e., a pronounced shape-preferred fragment orientation)?
- At what stage of cratering did **acoustic fluidization cease**? Was the transition **immediate or gradual**?

3. Methods

1) Preparation of **thin sections** from drill core samples of cataclasite zones
2) **Photographing** ≥ 3 areas within each cataclasite zone at 5x magnification with an optical microscope
3) Semi-automated **2D image analysis** (in *SAGA*[5]):
   - Automatic identification of **fragment boundaries**
   - Generation of **polygon shapes** of individual fragments
   - Determination of various **geometric parameters**
4) **Quantification of fragment characteristics** of > 20 cataclasite zones from different core depths, and reorientation to match **geographical directions**



4. Results

- The > 20 investigated **cataclasite zones vary in characteristics** such as zone width, degree of comminution, fragment-to-matrix ratio, and transition to surrounding rocks (distinct vs. mingled or gradual)
- The **fragment size** varies between 0.01 µm and 808 µm, with a geometric mean of 15 µm
- Fragments generally exhibit weak **elongation**; stronger elongation is observed in medium-sized fragments (≈ 10^1 - 10^2 µm)
- The **D-value**, a measure for fragmentation intensity, ranges between 1.3 and 2.1, with a good fit (high R^2), and covering at least one order of magnitude in fragment size - these results are well within reported 2D D-values from other studies[6,7]
- The **orientation** of fragments is not random in any of the investigated cataclasite zones
- The significance of **shape-preferred orientations**, however, is mostly moderate, with higher values occurring in narrow cataclasite zones
- Geographically reoriented samples point to a shape-preferred orientation directed **radially with respect to the peak ring**

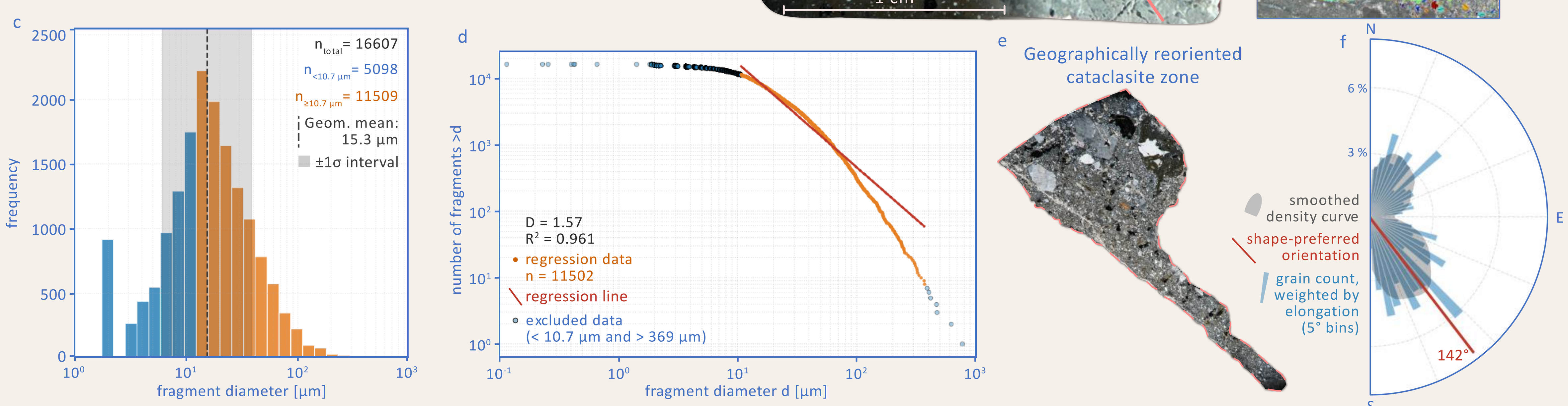


Fig. 2: (a) Merged cross-polarized thin section (left) and hand sample photograph (right) of a sample from the upper part of the lower peak ring rocks (754.7 mbsf). A cataclasite zone dissects the sample. Four out of 15 on this sample investigated areas are shown as cross-polarized microphotographs framed by blue rectangles, and can be seen in detail in b (b) Polygon shapes of fragments superposed on cross-polarized microphotographs. The polygons are colored according to their long axis orientation, which is furthermore delineated by black lines (c) Grain size distribution of the cataclasite zone (d) Log-log plot of the cumulative grain size distribution vs. fragment diameter for the calculation of the D-value (e) Cutout of the cataclasite zone from a reoriented to match the in-situ geographical direction (f) Rose diagram of the fragment orientations, adjusted to the in-situ geographical direction

5. Conclusions

- The observation of variably pronounced shape-preferred orientations in the impact target rocks suggests that **shearing played a significant role in cataclasite formation**
- These results imply that **zone-parallel shearing** may have triggered the reorientation of elliptical fragments formed by the comminution of rocks
- The variation in the intensity of shape-preferred orientation, as well as other parameters of the investigated cataclasite zones, indicates a **gradual fading of acoustic fluidization**
- **Acoustic fluidization** may have ceased prior to the consolidation of the cataclasite zones, meaning it **stopped at an earlier stage** than previously thought[3,8]

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