SHOCKED QUARTZ GRAINS IN GRANITOIDS FROM THE CHICXULUB IMPACT STRUCTURE PEAK-RING IODP-ICDP EXPEDITION 364 DRILL CORE: CHARACTERIZATION AND SHOCK PRESSURE ESTIMATIONS

Feignon, Jean-Guillaume; Ferrière, Ludovic; Koeberl, Christian

Published in:
Large Meteorite Impacts VI 2019 (LPI Contrib No. 2136)

Publication date:
2019

Document Version:
Final published version

SHOCKED QUARTZ GRAINS IN GRANITOIDS FROM THE CHICXULUB IMPACT STRUCTURE PEAK-RING IODP-ICDP EXPEDITION 364 DRILL CORE: CHARACTERIZATION AND SHOCK PRESSURE ESTIMATIONS. J-G. Feignon[1], L. Ferrière[2], and C. Koeberl[1,2], [1]Department of Lithospheric Research, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria (jean-guillaume.feignon@univie.ac.at), [2]Natural History Museum, Burgring 7, A-1010 Vienna, Austria.

Introduction: The peak-ring of the ~200-km diameter Chicxulub impact structure (Mexico) was drilled in 2016 during the International Ocean Discovery Program (IODP) and International Continental Scientific Drilling Program (ICDP) supported Expedition 364. The impactite sample suite recovered provides a unique opportunity to better understand peak-ring formation mechanisms, the nature and composition of the rocks it is made of, and also to characterize shock effects with depth [e.g., 1].

A continuous core (M0077A) was recovered between 505.7 and 1334.7 mbsf (meters below sea floor). It was divided in three main lithological units: (1) a "post-impact" sedimentary rocks section (from 505.7 to 617.3 mbsf), (2) a "upper peak-ring" section (from 617.3 to 747.0 mbsf) made of ~105 m of melt-bearing polymict impact breccia (suevite) overlaying ~25 m of impact melt rocks, and (3) a "lower peak-ring" section (from 747.0 to 1334.7 mbsf) consisting of granitoid (coarse-grained leucogranite with aplite and pegmatite dikes) intruded by several pre-impact sub-volcanic dikes and intercalations of millimeter to decameter suevite and impact melt rocks [1].

Here we report on the main results of a detailed investigation of shocked quartz grains in granites from the "lower peak-ring". The characterization of the shock features in quartz was followed by an estimation of the average shock pressure recorded by each sample.

Material and Methods: Forty polished thin sections were prepared for a selected number of granite samples (taken as regularly as possible between 747.0 and 1334.7 mbsf). They were investigated for shock metamorphic features in quartz and other minerals using optical microscopy and scanning electron microscopy (SEM). Planar deformation feature (PDFs) orientations were further investigated using the Universal stage (U-stage) microscope for nine thin sections ranging from 752.5 to 1311.1 mbsf. These thin sections were selected due to their high abundance in individual quartz grains (at least 15 or 20) in order to provide reasonable statistics. The indexing of the PDFs orientations was performed using WIP software [2] as well as manually [3]. Shock pressure estimates were done following the method described in [4].

Results: Quartz grains are relatively abundant in the granite from the "lower peak-ring" section, representing 25 to 35 vol. % of the mineral phases. Orthoclase (25-40 vol. %) and plagioclase (25-35 vol. %) and, to a lesser extent, biotite generally chloritized (1-5 vol. %) are the other main minerals. Quartz grain size varies from 0.5 to 4 cm, with also submillimeter-sized grains in cataclasite (microbrecciated) veins cross-cutting some granite samples.

In rare cases, shock effects in quartz grains can be seen with the naked eye, in the form of macroscopically visible planar fractures (PFs). In the investigated thin sections, nearly all observed quartz grains are shocked (only one apparently unshocked quartz grain was seen during our survey), including PFs with (or without) feather features (FFs) and decorated PDFs (up to 6 sets of PDFs as seen under the U-stage) (Fig. 1). In addition, a number of quartz grains show strong undulose extinction and rarely even kinkbands. As seen under the optical microscope and further documented under the SEM, PFs can be filled with calcite and PDFs are decorated with tiny vugs or fluid inclusions (Fig. 2).

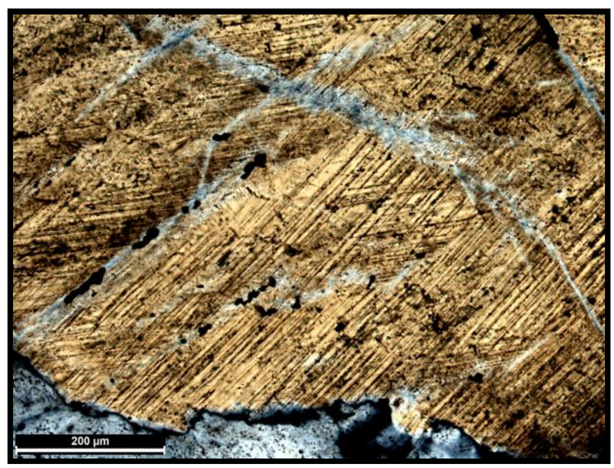

Fig. 1 Microphotograph (cross-polarized light) of a quartz grain with two sets of PFs with FFs and three sets of strongly decorated PDFs. Granite sample 201R1_70-74 (1022.2 mbsf).

The U-stage was used to characterize the crystallographic orientation of both PFs and PDFs in quartz. In total, 808 sets of PDFs were measured in 302 quartz grains, resulting in an average of ~2.7 PDFs sets per grain.

Planar fractures are mainly oriented parallel to (0001) and $\{10\bar{1}1\}$. The PDFs are preferentially oriented parallel to $\{10\bar{1}3\}$ and $\{10\bar{1}4\}$ orientations (i.e., representing together 53 to 82 % of the total). Then, by decreasing abundances, PDF parallel to $\{10\bar{1}2\}$, $\{10\bar{1}1\}$, $\{11\bar{2}2\}$, $\{22\bar{4}1\}$, $\{31\bar{4}1\}$, and (0001) orientations occur (i.e., abundance between ~2 and 10 % on average). Other PDFs orientations are rare, representing less than 2 % of the total.

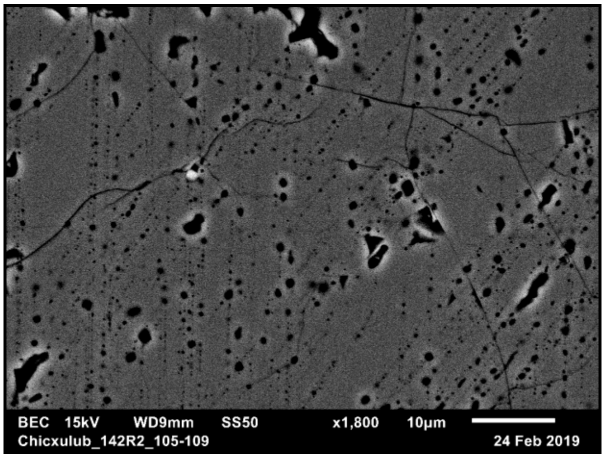

Fig. 2 Backscattered electron (BSE) image showing two strongly decorated sets of PDF in a quartz grain. Granite sample 142R2_105-109 (861.9 mbsf).

The average number of PDFs sets per grain seems to slightly decrease with increasing depth. The three deepest samples investigated so far have mainly shocked quartz grains with two sets of PDFs (representing ~32 to 49 % of the total), whereas the shallowest samples have a majority of quartz grains with three sets of PDFs (representing ~30 to 48 % of the total).

Discussion and Conclusions: Based on our U-Stage results we estimate that the granites from the "lower peak-ring" section have recorded shock pressures between ~15 and 18 GPa with a very slight shock attenuation with increasing depth (Fig. 3). Our pressure estimates are consistent with observations on zircon grains, as the absence of impact-induced microstructures in zircon grains indicates that the shock pressure was <20 GPa [5]. In general, the range of pressure estimates is very narrow, taking into account the errors associated with the measurements, however, interestingly, PDFs parallel to the $\{10\bar{1}2\}$ orientation (i.e., known to form at pressures of ~20 GPa [4]) are significantly more abundant in the upper section of the granite basement (representing between 6 and 14 %) than in the lower section (representing less than 3 %). This further supports the suggestion that the upper section of the granite basement experienced slightly higher shock pressures than the lower section.

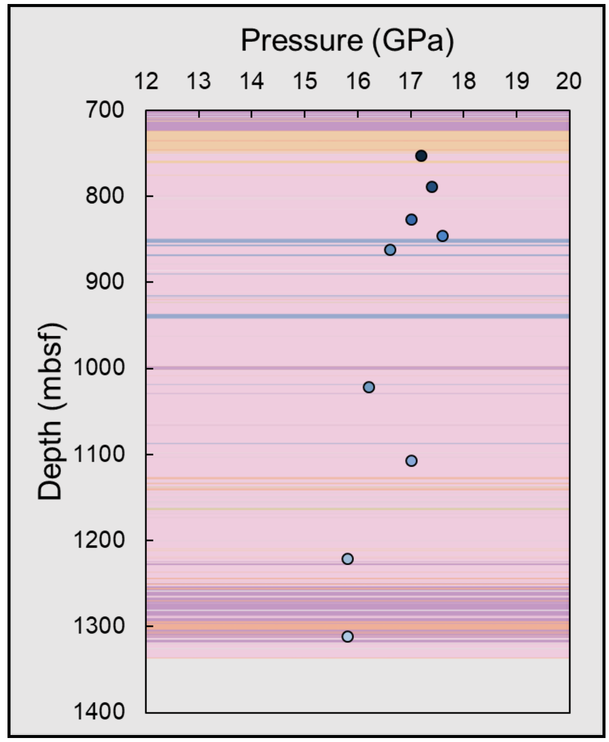

Fig. 3 Average shock pressure estimates versus depth in granites from the "lower peak-ring" section. The pressure range is narrow but a slight decrease with depth is apparent.

The average of 2.7 PDF sets per grain is significantly higher than in all previously investigated drill core and for most K–Pg boundary samples (e.g., [6] and references therein). However, comparisons between different sets of data are difficult as user experience can influence the results.

Acknowledgements: The Chicxulub drilling was funded by the IODP as Expedition 364 with co-funding from ICDP. The ECORD implemented Expedition 364, with contributions and logistical support from the Yucatán state government and Universidad Nacional Autónoma de México.

References: [1] Morgan J. V. et al. (2016) *Science, 354*, 878–882. [2] Losiak A. et al (2016) *MAPS, 51(4)*, 647–662. [3] Ferrière L. et al. (2009) *MAPS*, 44(6), 925–940. [4] Holm-Alwmark S. et al. (2018) *MAPS*, 53(1), 110–130. [5] Timms N. E. et al. (2019) *Contrib. Min. Pet., 174*, 38. [6] Nakado Y. et al. (2008) *MAPS, 43*, 745–760.