MECHANICAL BRAZIL TWINS AND $\{10\bar{1}1\}$ PDFs IN QUARTZ: INDICATORS OF LOW-PRESSURE SHOCK METAMORPHISM

Agnese Fazio[1], Kilian Pollok[1], and Falko Langenhorst[1,2], [1]Analytical Mineralogy of Nano- and Microstructures, Institute of Geosciences, Friedrich Schiller University Jena, Germany (Agnese.Fazio@uni-jena.de; Kilian.Pollok@uni-jena.de; Falko.Langenhorst@uni-jena.de) [2]Hawai'i Institute of Geophysics and Planetology, School of Ocean and Earth Science and Technology, University of Hawai'i at Manoa, USA.

Introduction: The largest volume of rocks involved in a meteorite impact is shocked at pressures below 15–20 GPa [1], thus the recognition of eroded and ancient or small and young impact craters might be facilitated and based on the identification of low-shock-pressure indicators. However, the shock signature of rock-forming minerals in the low-pressure regime and in particular below 10 GPa is still unclear. In order to inspect the low-pressure response of quartz, shock recovery experiments on sandstone and quartzite were performed between 5 GPa and 17.5 GPa in the framework of the MEMIN research program [2,3]. In this work, we present new results of the transmission electron microscopic (TEM) investigation of these samples.

Samples and Methods: Nine electron transparent samples were prepared via Ar ion milling from Seeberger sandstone shocked at 5, 7.5, 10, and 12.5 GPa and Taunus quartzite shocked at 7.5, 10, 12.5, and 17.5 GPa. A FEI Tecnai G^2 FEG microscope operating at 200 kV was used to acquire bright- and dark-field images, as well as selected area electron diffraction patterns. Due to the high beam sensitivity of quartz, images were taken at low magnification with a broad beam minimizing the electron dose of the samples. Changes in the microstructures were not observed, even after several TEM sessions.

Results and Discussion: Despite the difference in porosity, quartzite (<0.5 vol%) and sandstone (12-19 vol.%) show the same types of shock features; however, they differ in their relative abundances. Quartz from both rock types displays planar defect microstructures at all pressures, lowering the so far reported shock pressure range of their formation to 5 GPa for sandstone and 7.5 GPa for quartzite [2,3].

Two thirds of these planar defect microstructures consist of sets of lamellae parallel to the basal plane (0001) and to the rhombohedral planes $\{10\bar{1}1\}$. Subordinately, sets of lamellae parallel to other rhombohedral planes and glassy veins were recognized.

At pressures below 10 GPa (sandstone) and 12.5 GPa (quartzite), the (0001) lamellae are very thin and straight and extend across entire quartz grains. If inclined to the beam, they show the typical fringe patterns and partial dislocations known for mechanical Brazil twins [4,5]. The formation of mechanical Brazil twins requires that a high shear stress (~2 GPa) prevailed on the quartz basal plane at moderate temperatures (500–700°C) and pressures > 4 GPa [4]. Thus, the formation of mechanical Brazil twins illustrates that at the low-pressure regime the shear stress plays a significant role in quartz deformation.

It was observed for the first time that Brazil twins incur a process of amorphization. The amorphization starts apparently at the cores of partial dislocations in samples shocked at 5 GPa (sandstone) and 7.5 GPa (quartzite), similarly to the early partial melting phenomenon observed in pyroxenes [6]. The process proceeds at higher pressure with a complete amorphization of the Brazil twin boundaries. Contrary to the original Brazil twins, the now amorphous lamellae can then become optically detectable. Thus, we suggest that the basal lamellae optically identified by universal stage measurements are not classical PDFs, but rather amorphized mechanical Brazil twins.

PDF lamellae parallel to the rhombohedral planes are amorphous, as well. Due to their orientation and nature, they are interpreted as classical planar deformation features (PDFs). In the spatial context of glassy veins, it is common to find $\{10\bar{1}1\}$ PDFs with a feather-like appearance, as described by [7]. These features have the same orientation and nature of PDFs, thus they may not be regarded as an extra type of planar microstructures.

The glassy veins represent quenched silica melt that partly crystallized as stishovite [8]. In addition to our previous study [8], stishovite was also detected in the sandstone shocked at 5 GPa and in the quartzite samples shocked at 12.5 and 17.5 GPa.

Conclusions: This works established that the mechanical Brazil twins and $\{10\bar{1}1\}$ PDFs at the nanoscale are the typical indicators of the low-pressure shock regime. Hence, it highlights the importance of nanoscale observations in absence of optically visible shock criteria.

References: [1] Melosh H.J., *Impact Cratering: A Geologic Process*. 1989, New York: Oxford University Press. [2] Kowitz A., et al. (2013) *Meteoritics & Planetary Science* 48:99-114. [3] Kowitz A., et al. (2016) *Meteoritics & Planetary Science* 51:1741-1761. [4] McLaren A.C., et al. (1967) *Physica Status Solidi* 19:631-644. [5] Goltrant O., et al. (1991) *Earth and Planetary Science Letters* 106:103-115. [6] Doukhan N., et al. (1993) *American Mineralogist* 78:1246-1256. [7] Poelchau M.H. and Kenkmann T. (2011) *Journal of Geophysical Research* 116:B02201. [8] Mansfeld U., et al. (2017) *Meteoritics & Planetary Science* 52:1449-1464.