Geophysical Research Abstracts
Vol. 13, EGU2011-7559, 2011
EGU General Assembly 2011

Microstructural TEM-investigations on shock-metamorphic chert from the Jebel Waqf as Suwwan impact structure, Jordan

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The so-called "Jebel Waqf as Suwwan" structure (Arabic for "Mountain of steeply inclined chert") located in the Hamada desert of Northeast Jordan, close to the Saudi Arabian border (centered at N 31°03', E 36°48'), has been recently reconsidered as the first complex impact structure in the Middle East [1]. These inferences are based on its morphology showing a ∼5.5 km wide near-circular uplifted crater rim and a prominent central uplift, the occurrence of shatter cones as macroscopic shock evidence [2], and planar deformation features (PDFs) observed optically in quartz grains from the Cretaceous "Kurnub sandstone" [1] and shocked chert from the central uplift [3]. The eroded impact structure is emplaced in a nearly horizontal sequence of upper Cretaceous to Paleogene sandstones, limestones, marls, and cherts [1,4]. A Miocene-Pliocene impact age has been suggested [5].

In order to decipher the true nature of PDF-like features in quartz grains from formerly re-crystallised chalcedony-quartzine-veinlets in shocked chert from the central uplift, several conspicuous grains were drilled out from seven thin sections taken from the study of [3], mounted on TEM grids, thinned to electron transparency by ion thinning, and subsequently examined by transmission electron microscopy (TEM).

Our investigations clearly revealed the existence of amorphous PDF lamellae running parallel crystallographic $\{10\bar{1}1\}$ and $\{10\bar{1}3\}$ planes of quartz. The borders of both types of PDFs are usually scalloped by tiny dislocation loops, which also appeared sporadically in some of the adjacent quartz grains. We suggest that these dislocations nucleated around tiny impact-induced exsolution of bubbles during slight post-impact deformation. Whereas PDFs along $\{10\bar{1}3\}$ are usually 20-50 nm wide, decorated by ∼60 nm large bubbles, and running straight through the crystal, PDFs along $\{10\bar{1}1\}$ are not decorated by large bubbles and are appreciably shorter, sometimes only ~ 0.5 μm long and then offset by ~ 20 nm. Some of $\{10\bar{1}1\}$ PDFs are partially re-crystallised and, therefore, only visible by their adjoining bands of dislocations.

However, only a few of the observed quartz grains do show amorphous PDF lamellae. More frequently, narrow Brazil twins of about 10 nm width are observed in the (0001) basal plane of quartz, sometimes decorated by large bubbles. Brazil twins in the basal plane of quartz can be generated by shock-induced shear deformation at high differential stresses and are considered as a shock indicator for the lower shock pressure regime [2]. Non-shock related deformation features of these quartz grains are relatively rare, only a few individual dislocations have been observed and are usually re-equilibrated to small-angle grain boundaries.

It is remarkable, however, that beside quartz crystals showing clear shock metamorphic evidence, such as basal Brazil twins or amorphous PDFs, there are still many quartz crystals, which do not exhibit any deformation features at all. We therefore, suggest that the formation of shock metamorphic features in these quartz grains strongly depends on their crystallographic orientation with respect to the shock wave and the orientation to adjacent cryptocrystalline silica varieties of fibrous chalcedony and quartzine, which might deform more softly during shock deformation than larger quartz crystals.

The presence of many Brazil twin PDFs in the basal plane and PDFs along $\{10\bar{1}1\}$ and $\{10\bar{1}3\}$ lattice planes of quartz, however, provides additional TEM evidence that the Jebel Waqf as Suwwan structure is of impact origin and suggests that the rocks of the central uplift have been deformed by low to intermediate shock pressures exceeding 10 GPa.

References:

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