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Specific combinations of planar deformation feature orientations in shocked quartz grains from the Bosumtwi impact crater as a signature of β-quartz

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Planar deformation features (PDFs) are sets of parallel planes of amorphous material, less than 2 μm thick and spaced 2-10 μm apart, which form in minerals due to shock metamorphism (e.g., Stöffler and Langenhorst, 1994). PDFs, generally multiple sets per grain, are predominantly developed along specific crystallographic orientations (see, e.g., Ferrière et al., 2009).

Alpha-quartz belongs to 32-point group symmetry, while β-quartz has a 622-point group symmetry. Because of this property, α- and β-quartz should have distinct combinations of PDF orientations; those present in α-quartz can exist also in β-quartz, but the combinations of PDF orientations characteristic in β-quartz cannot occur in α-quartz (Langenhorst and Deutsch 1994). For example, two {10-13} PDFs that are located 120° from each other in a quartz grain are characteristic to both α- and β-quartz, whereas combinations of PDFs that consist of two {10-13} PDFs located 60° from each other can form only in β-quartz.

Most PDFs in the investigated samples from the Bosumtwi crater (previously studied by Ferrière et al., 2009) are oriented parallel to {10-13} and {10-14} orientations. In some cases, even though the combinations of PDF orientations are characteristic for β-quartz, because of some limitations in the indexing of PDFs (see Ferrière et al., 2009), we cannot completely exclude their formation in α-quartz. However, we found a few specific combinations of PDF orientations that are unequivocally characteristic of β-quartz. For example, a grain was found with three sets of PDF oriented parallel to {10-12} and located 60° and 120° from the first feature. In order to form PDFs with this specific combination of PDF orientations, it is necessary for this quartz grain to have the symmetry characteristic for β-quartz. However, the investigated sample is derived from depths that are too shallow – from a depth of not more than 1-1.5 km, according to Ferrière et al. (2008) – for β-quartz to be stable.

Thus, we can envisage three scenarios: 1) Samples are derived from much greater depths (to be true this scenario requires to totally reconsider processes of transient cavity and central uplift formation); 2) Quartz is somehow transformed to its β form during the impact event, before or during the formation of PDFs – the physics of this possible transformation is not yet understood; 3) Our understanding of the crystallographic orientations of PDFs is incomplete.

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