

Microstructural dynamics of central uplifts: Reidite offset by zircon twins at the Woodleigh impact structure, Australia

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Huber and Kovaleva (2019) take issue with three aspects of our recent model for shock deformation of zircon: (1) temperature constraints, (2) pressure estimates based on reidite, and (3) conditions of twin formation. We appreciate the opportunity to respond, as Huber and Kovaleva raise interesting points, but they also conflate some misunderstandings of these topics that require clarification.

(1) Temperature constraints. Pressure-temperature (*P-T*) diagrams have long been used for representing shock deformation, and our hypothetical *P-T* path (Cox et al., 2018) necessarily passes through reidite stability, but is largely insensitive to *T* evolution. Peak *T* is limited due to the absence of melt (as originally noted). At grain scale, reidite-bearing zircon has been shown to recrystallize to granular neoblasts when incorporated in melt (Cavosie et al., 2018); the absence of such grains in our sample supports a sub-solidus *P-T* path. The claim by Huber and Kovaleva that “a more appropriate temperature path” would encounter reidite at 200 °C (versus ~325 °C in our model) has no bearing on the sub-solidus evolution of zircon microstructures.

(2) Pressure estimates. Reidite has been calibrated to form at ≥30 GPa in shock recovery experiments (see review in Erickson et al., 2017); however, Huber and Kovaleva question our use of this value. They cite shocked sandstone showing localized *P* excursions due to porosity (Kowitz et al., 2016), and claim reidite in the Woodleigh zircon formed at 15 GPa along cracks due to localized *P* amplification. The reidite-bearing sample is gneissic granitoid, with no visible porosity or fractures, whereas the sandstone of Kowitz et al. (2016) has 25%–30% porosity. Images in our Data Repository (GSA Data Repository 2018372) show reidite in various habits, including lamellae (e.g., Fig. 1); many unassociated with preexisting fractures. The argument of Huber and Kovaleva thus represents a misapplication of the results of Kowitz et al. (2016), which are not relevant for coherent, low-porosity, crystalline rock. The high abundance of reidite (found in 75% of grains analyzed) with various habits all reinforce our initial pressure estimate of ≥30 GPa, which agrees with prior work (see Cox et al., 2018).

Moreover, if fractures facilitated reidite formation at 15 GPa, reidite should be common in impactites, given that zircon is often fractured, and many impact structures preserve bedrock shocked to >15 GPa. Occurrences of reidite, however, remain rare.

(3) Conditions of twin formation. We agree with Huber and Kovaleva, in that formation conditions of {112} lamellar twins in zircon are poorly understood, given they have not been produced in a shock recovery experiment. The conditions of ~20 GPa cited by us are based on empirical studies (e.g., Moser et al., 2011), and also their presence in a 20 GPa static diamond anvil experiment on zircon powder (Morozova et al., 2018). More broadly, Huber and Kovaleva seemingly agree with us in envisioning twins forming during pressure release caused by the rarefaction wave (which is indeed not a shock wave), a process that results in formation of a central uplift. The association of twins with central uplifts, discussed by us, focused on complex impact structures, and did not exclude their occurrence at simple craters, which, as Huber and Kovaleva note, we have documented previously (Cavosie et al., 2016).

All models contain uncertainty. Our model may not be the final treatment, but it does represent the current state-of-the-art approach for correlating grain-scale microscopic features to large-scale macroscopic processes in order to explain irreversible shock damage that occurs during violent impact events that invert Earth’s crust in seconds.

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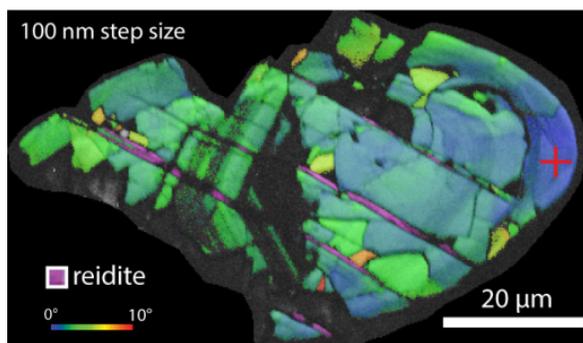


Figure 1. Orientation map (texture component) showing lamellar reidite in shocked zircon from the Woodleigh-1 core.