American Mineralogist, Volume 98, pages 53–65, 2013

Correlating planar microstructures in shocked zircon from the Vredefort Dome at multiple scales: Crystallographic modeling, external and internal imaging, and EBSD structural analysis

TIMMONS M. ERICKSON,[1,*] AARON J. CAVOSIE,[1] DESMOND E. MOSER,[2] IVAN R. BARKER,[2] AND HENRI A. RADOVAN[3]

[1]Department of Geology, University of Puerto Rico Mayagüez, P.O. Box 9000, Mayagüez, Puerto Rico, 00681-9000, U.S.A.
[2]Department of Earth Sciences, Western University, London, Ontario N6A 5B7, Canada
[3]Department of Physics, University of Puerto Rico Mayagüez, P.O. Box 9000, Mayagüez, Puerto Rico, 00681-9000, U.S.A.

ABSTRACT

Microstructural and geochronological analysis of shocked zircon has greatly advanced understanding the formation and evolution of impact structures. However, fundamental aspects of shock-produced planar microstructures in zircon remain poorly known, such as their deformation mechanisms, crystallographic orientations, and how planar microstructures visible at the grain scale by scanning electron microscopy correlate to microstructures visible at sub-micrometer scales by transmission electron microscopy and electron backscatter diffraction (EBSD). To unify observations of planar microstructures in zircon made at different scales into a consistent framework, we integrate the results of: (1) three-dimensional crystallographic modeling of planar microstructure orientations, with (2) 360° external prism backscattered electron imaging at the grain scale, and (3) polished section cathodoluminescence and EBSD analysis at the sub-micrometer scale for a suite of detrital shocked zircons eroded from the Vredefort Dome in South Africa. Our combined approach resulted in the documentation of seven planar microstructure orientations that can be correlated from grain to sub-micrometer scales of observation: (010), (100), (112), $(1\bar{1}2)$, $(\bar{1}12)$, $(\bar{1}\bar{1}2)$, and (011). All orientations of planar microstructures exhibit minor variations in style, however all are considered to be fractures; no amorphous $ZrSiO_4$ lamellae were identified. We therefore favor the usage of "planar fracture" (PF) over "planar deformation feature" (PDF) for describing the observed planar microstructures in zircon based broadly on the nomenclature developed for shocked quartz. Some {112} PFs visible at the grain scale contain impact microtwins detectable by EBSD, and are the first report of polysynthetic twinning in zircon. The microtwins consist of parallel sets of thin lamellae of zircon oriented 65° about <110> and occur in multiple crosscutting {112} orientations within single grains. Curviplanar fractures and injected melt are additional impact-related microstructures associated with PF formation. Crosscutting relations of shock microstructures reveal the following chronology: (1) Early development of **c**-axis parallel PFs in (010) and (100) orientations; (2) the development of up to four {112} PFs, including some with microtwins; (3) the development of curviplanar fractures and the injection of impact derived melt; (4) the development of (011) PFs associated with compressional deformation; and (5) grain-scale non-discrete crystal plastic deformation. Experimental constraints for the onset of PFs, together with the absence of reidite, suggest formation conditions from 20 to 40 GPa for all of the planar microstructures described here.

Keywords: Shock metamorphism, zircon, Vredefort Dome, planar fractures