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Planar microstructures in zircon from paleo-seismic zones

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Abstract

Pseudotachylytes resulted from frictional melts associated with ultramylonites in high-grade metapelitic rocks from the Ivrea-Verbano zone in the Southern Alps (Northern Italy) were studied with focus on the deformation microstructures in zircon. The aims were to investigate the characteristics of zircon deformation in seismic zones, and to recognize specific microstructures generated in zircon during earthquakes, which could be useful for mineral dating of paleo-seismic events; helps to understand how seismic energy is released at depth and interacts with metamorphic processes.

The interior of polished zircon grains ranging from 30 to 150 μm in length were investigated with optical microscope and scanning electron microscope (SEM) techniques, including secondary electron (SE), backscattered electron (BSE), forward scattered electron (FSE), cathodoluminescence (CL) imaging, and crystallographic orientation mapping by electron backscatter diffraction analysis (EBSD). Grains were studied in situ and as separated fractions embedded in epoxy disks. Among different cataclastic and crystal-plastic deformation microstructures in zircon we identified characteristic planar deformation bands (PDBs), planar fractures (PFs), and curviplanar fractures (CFs).

Planar deformation bands in zircon are crystallographically controlled planar lattice volumes with misorientation from the host grain, which varies from 0.4° to 2.7°. PDBs are usually parallel to {100} crystallographic planes, have width from 0.3 to 1 μm and average spacing of 5 μm in 2D sections. Planar deformation bands appear as contrast lamellae in orientation contrast images and in EBSD maps, and in rare cases can be observed with the optical microscope. PDBs form in specifically oriented grains due to high differential stresses, high temperatures, and high strain rates generated in seismically active environment and/or due to shearing in the vicinity of frictional melts. Discovered structures represent a result of crystal-plastic deformation of zircon grains with operating dislocations having <100>{010} glide system and <001> misorientation axis, therefore, they can be classified as a new type 4 lattice distortion pattern, according to the existing classification for zircon (Piazolo et al. 2012; Kovaleva et al. 2014).

We have demonstrated that formation of planar fractures in zircon takes place not only during impacts, but also in seismically active zones. We observe at least two cases of formation of PFs with {100} orientation: (1) as a result of evolution of PDBs and (2) as micro-cleavage.

This study demonstrates that planar microstructures in terrestrial zircon do not exclusively form during impact events, but also as a result of seismic events at depth due to unusually high differential stress, strain rate, and temperature. According to the new findings, PDBs in zircon from the deep-crust are supposed to represent newly recognized evidence of seismicity.

Keywords: Electron backscatter diffraction (EBSD), zircon, shear zone, pseudotachylytes, planar deformation bands, planar fractures, crystal-plastic deformation