

RUTILE NANOSTRUCTURE AS AN INDICATOR OF SHOCK AND THERMAL HISTORY OF CHONDRITES.

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Introduction: Rutile, next to brookite and anatase, is one of the TiO₂ polymorphs. It is widely used in terrestrial metamorphic geology in the reconstruction of pressure-temperature-time evolution of rocks in which it occurs; in geochemistry; heavy minerals analyses and recently in U-Pb geochronology [1]. Rutile is also widespread, yet it is an accessory mineral that is present in all groups of meteorites [2]. It may be an important indicator of thermal and shock metamorphic events that the meteorites experienced on their parent bodies. Meteoritic rutile has however not been extensively studied so far and its response to processes operating in meteoritic parent bodies is not well understood. This study explores potential usefulness of rutile in concluding the thermal and shock histories of equilibrated ordinary chondrites.

Samples and methods: We analysed rutile grains from the Pultusk H chondrite. The grains occur in chondritic material of petrologic type 6 and are associated to ilmenite and kamacite [3]. Trace elemental composition of rutile grains (Si, Al, Ti, Zr, V, Cr, Fe, Nb) was measured by a Cameca SX-100 Electron Microprobe with an accelerating voltage 15 keV and beam current of 180 nA. Applied analytical conditions allowed for the detection of Zr at the level of 35 ppm and Nb with 390 ppm. The Zr content measured was plugged into the Zr-in-rutile thermometer [4] to generate rutile crystallization temperature value. Selected grains were further studied by FIB-TEM by utilizing TEM Tecnai F20x-twin with a field emission gun electron source at the GeoForschungsZentrum in Potsdam. TEM analyses were performed at 200 kV.

Results and discussion: Rutile occurs associated to ilmenite as either thin lamellae or anhedral grains less than 20 µm in diameter. Nanostructure of both distinguished rutile types differ significantly with each other. Lamellae of rutile reveal exsolution features and intergrowths similar to eutectic patterns (Fig. 1A). They were clearly formed by exsolution from ilmenite. The temperature of rutile crystallization as determined by Zr-in-rutile thermometer [4] is in the range 460-530°C. Such low closure temperature suggests the chondritic rock was slowly cooled down in static conditions and further not reprocessed.

In contrast, the anhedral-type rutile grains reveal many defects, which are shock indicators e.g., extension and contraction features or shock lamellae (Fig. 1B, C). Zr-in-rutile thermometry exhibits that the temperatures much above 700 °C were operating, suggesting the original features were disturbed by shock process. Nanostructural analysis and diffraction patterns show that anhedral rutile was recrystallized after the shock event (Fig. 1D).

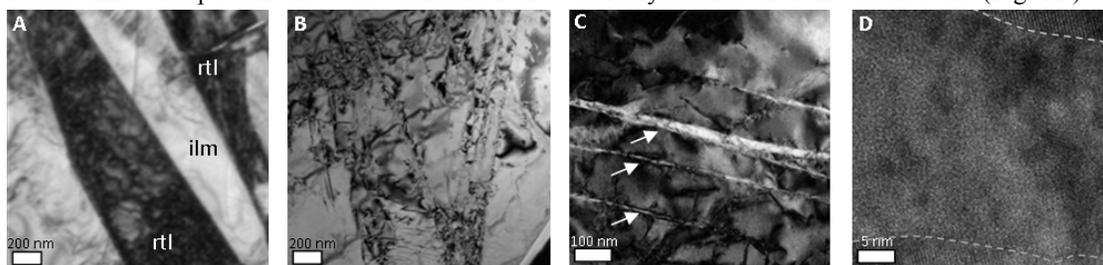


Fig. 1. Transmission electron micrographs of rutile (A-C: BF images, D: HR-TEM image). A) Lamellar rutile with eutectic intergrowth of exsolved phases. B) Shock features from contraction and post-shock cooling common in anhedral rutile. C) Post-shock recrystallized anhedral rutile grain with shock bands (arrows). D) Shock-molten and recrystallized anhedral rutile grain (amorphous material marked by dashed lines).

Interestingly, no diffraction contrasts are detected in analysed rutile grains. This indicates good stoichiometry of rutile and is a striking disparity to terrestrial rutiles [5]. Common departure of terrestrial rutile from the ideal stoichiometry is attributed to the association of water. As such, the observations on chondritic rutiles are consistent with rather dry metamorphic conditions on the chondritic parent bodies.

References: [1] Meinhold G. (2010) *Earth-Science Reviews* 102:1-28, [2] Buseck P.R. and Keil K. (1966) *American Mineralogist* 51: 1506-1515, [3] Krzesinska A.M. (2016) *Geological Quarterly* 60: 211-224, [4] Watson E.B. et al. (2006) *Contribution Mineralogy Petrology* 151: 413-433, [5] Casey W.H. et al. (1988) *Geochimica Cosmochimica Acta* 52: 1545-1556.