SHOCK RELATED MICROFABRICS OF ILMENITE AND ASSOCIATED FE-BEARING PHASES

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Abstract: Shock related modifications on ilmenite ($FeTiO_3$) as a function of temperature, pressure, and oxygen fugacity remain poorly understood, although ilmenite is an important Fe-bearing mineral, commonly found in shocked basement rocks. Here, we present two case studies on ilmenite shock effects analyzed by modern microanalytical techniques, including the electron backscatter diffraction (EBSD), energy dispersive X-ray spectroscopy (EDS), and Raman spectroscopy from (1) shocked Archean gneisses from the Vredefort impact structure, South Africa, and (2) shocked gneiss clasts within suevites from the Ries impact structure, Germany.

(1) Ilmenite shocked at shock pressures <8 GPa (documented by planar factures and feather features in quartz) were studied in Archean gneisses lying ~20-30 km from the paleo impact center of the Vredefort impact structure. Coarse-grained (>100 µm) ilmenite contains exsolved magnetite and has lamellar mechanical $\{10\overline{1}1\}$ and (0001) twins indicative of dislocation-glide controlled deformation at non-isostatic stresses, both related to shock. Micrometer-sized magnetite and ilmenite veins emanate from their hosts that penetrate into shock-induced shear fractures in adjacent quartz and feldspar, indicating frictional heating and mobilization. Two types of µm-sized magnetite exsolutions from shocked ilmenite at relatively low shock pressures and non-isostatic stress conditions are documented. The first type can be characterized with lamellar shapes with a distinct orientation parallel $\{10\overline{1}1\}$ to the ilmenite host; the magnetite {110} planes parallel the $\{10\overline{1}0\}$ planes of the host ilmenite. The second exsolution type displays a spheroid shape with a random crystallographic orientation and occurs preferentially at grain boundaries and along the $\{10\overline{1}1\}$ twins, indicating heterogeneous nucleation at sites of increased disorder, facilitating diffusion.

(2) Coarse-grained ilmenite from target gneisses incorporated into suevite at the Ries impact structure experienced higher shock pressures and temperatures, as indicated by the associated presence of rhombohedral PDFs in quartz and glass fragments (Flädle). Ilmenite aggregates possess a foam structure characterized by grains with four to six smoothly curved grain boundaries and 120° angles at triple junctions and show a weak crystallographic preferred orientation governed by the crystallographic orientation of the host phase. This foam structure is suggested to represent the back-transformation to ilmenite from an original high-pressure phase, formed during shock loading (>16 GPa)[1]. This high-pressure phase is not preserved, as it is not stable at lower pressures. Instead, the high-temperature phases ferropseudobrookite ($Fe^{2+}Ti_2O_5$) and armalcolite [$(Fe^{2+},Mg)Ti_2O_5$] are present in some of the aggregates, commonly associated with increased porosity and rutile (TiO_2). Pseudorutile ($Fe^{3+}{}_2Ti_3O_9$) can occur at higher oxygen fugacities. Furthermore, titanite ($CaTi[O|SiO_4]$) can be formed within fractures and magnetite can be formed at the rim of the aggregates. The presence of ferropseudobrookite indicates the reaction of $2FeTiO_3 \rightarrow FeO + FeTi_2O_5$ at high temperature >1140°C in combination with a low oxygen fugacity[2,3]. Upon cooling, iron migration caused ferropseudobrookite to disintegrate, which resulted in the formation of a vermicular fabric of rutile and ilmenite: $FeTi_2O_5 \rightarrow FeTiO_3 + TiO_2$. Rapid cooling caused a shift in redox-conditions with the formation of euhedral µm-sized pure Fe magnetite from the iron-enriched rim of the aggregates and the local preservation of ferropseudobrookite. Silicate melt at the contact of the Fe-Ti-oxides provided magnesium to form armalcolite from ferropseudobrookite and calcium to form titanite within fractures.

The two case studies document that ilmenite from shocked basement rocks provides a high potential to record a broad range of different shock conditions by specific microstructures.

References:

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