Microstructure and texture of enstatite-spinel-plagioclase symplectites: EBSD analyses of (ultra)fine-grained multi-phase aggregates

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Intimate intergrowths of (ultra)fine-grained orthopyroxene, spinel and plagioclase are common reaction-products of garnet-breakdown in olivine-poor (ultra)basic rocks as pyroxenites and granulites. In the past, information on their phase content and microstructure was hardly accessible due to the small grain size of the symplectite phases. High-resolution SEM and the EBSD method provide new opportunities to study the microstructure and texture at sufficiently high spatial resolution (Dégi et al. [1]; Obata [2]; Obata and Ozawa [3]).

Our current study aimed for yielding new information on the mechanisms of symplectite forming mineral reactions, symplectite-microstructure formation, related material transport and reaction induced lattice rotation.

We studied orthopyroxene-spinel-plagioclase intergrowths in peridotite xenoliths from the locality Zinst (Bavaria, Germany) by SEM and EBSD using a FEI™ Quanta 3D FEG instrument at the University of Vienna (Austria), equipped with a field emission electron source and an EDAX™ Digiview IV EBSD camera as well as an EDAX™ Apollo XV silicon drift detector for EDX-spectrometry. The OIM™ Data Collection and Analysis software packages have been used for EBSD data acquisition and processing.

Garnet breakdown in the studied samples occurred during multiple stages of the rock evolution. We concentrated on the latest, ultra-fine grained generation of symplectites, which form about 5 millimeter sized patches. Although the precursor phase has not been preserved, the integrated bulk composition of symplectite concurs with pyrop-rich garnet.

Based on the microstructure and the crystallographic preferred orientation of the symplectite phases three different types of orthopyroxene-spinel-plagioclase intergrowths have been identified:

Type A forms a 10-30 micrometer wide zone at the margin of the aggregate patches in immediate contact with an earlier coarse grained symplectite generation, consisting of fine- to medium grained lath shaped crystals with the same phase content (Figure 1 left). In Type A symplectite orthopyroxene and plagioclase form the matrix, whereas spinel is present as a few tens of nanometers wide rods or lamellae within orthopyroxene. All phases have a strong shape preferred orientation and a high aspect ratio, with the trace of the long axis in the section plane oriented perpendicular to the interface with the fine- to medium grained symplectite generation. At irregularities of this interface, the shape preferred orientation of the ultra-fine grained phases changed and microstructural domain boundaries initiated, which propagated into the interior of the precursor garnet during progressive garnet breakdown. EBSD data yielded a clear topotactic relationship of Opx(100)//Spl(111) and Opx(101)//Spl(110) as already reported by Obata and Ozawa [3]. Furthermore, the crystallographic orientation of orthopyroxene and spinel in Type A symplectite coincides with the orientation of the earlier fine- to medium-grained symplectite generation. Both the microtexture and -structure therefore indicate the nucleation of type A symplectite at the interface with the earlier symplectite generation and the propagation of the ultra fine-grained symplectite with a shape preferred orientation perpendicular to the reaction front towards the core of the precursor garnet grain.

Type B symplectite predominates and differs from Type A by a lower aspect ratio of the spinel grains (Figure 1, right). Straight grain boundary segments and triple junctions between all three symplectite phases were developed. Although the described topotaxy between orthopyroxene and spinel was observed in type B as well, the lattice orientations scatter widely and unsystematically around a rotation axis parallel to the growth direction. Furthermore, the crystal lattices are rotated gradually in growth direction. These crystallographic orientation changes are in some cases significantly larger than changes in the shape preferred orientation in 2D sections. Therefore we demand for a distinction between microstructural and crystallographic symplectite domains.

Type C symplectite represents an alteration product of type A and type B symplectite, supposedly related with fluid access along microfractures. Type C symplectite is characterised by an increase in plagioclase content and grain size and a change in the orthopyroxene composition. Contrasting with types A and B, spinel grains in type C have spherical grain shape and are not confined to inclusions in orthopyroxene, but also occur within plagioclase. As the shape preferred orientation characteristics of symplectite A and B were partly preserved within symplectite C, the latter is interpreted as a secondary symplectite generation, whereas type A and B supposedly represent primary breakdown products of precursor garnet.

EBSD analyses of the multi-phase aggregates were impeded by several challenges. Plagioclase behaved significantly weaker during the mechanical and chemical polishing procedure of sample preparation, thus producing significant topography. EBSD pattern of plagioclase therefore were rather weak and grain boundary domains were scarcely indexed. Furthermore, plagioclase analyses strongly deteriorated during the EBSD analysis runs, so that relatively large step sizes of 0.1 micrometer had to be chosen.

Despite of the analytical difficulties in EBSD investigation of heterogeneous phase aggregates with strongly differing mechanical behaviour during preparation, the new lattice orientation data yielded new information on the mechanism of symplectite growth from breakdown of a single precursor phase. We interpret the changes in crystallographic orientation along and across the microstructural symplectite domains as due to plastic deformation supposedly corresponding to the volume increase during the garnet breakdown reaction.

References

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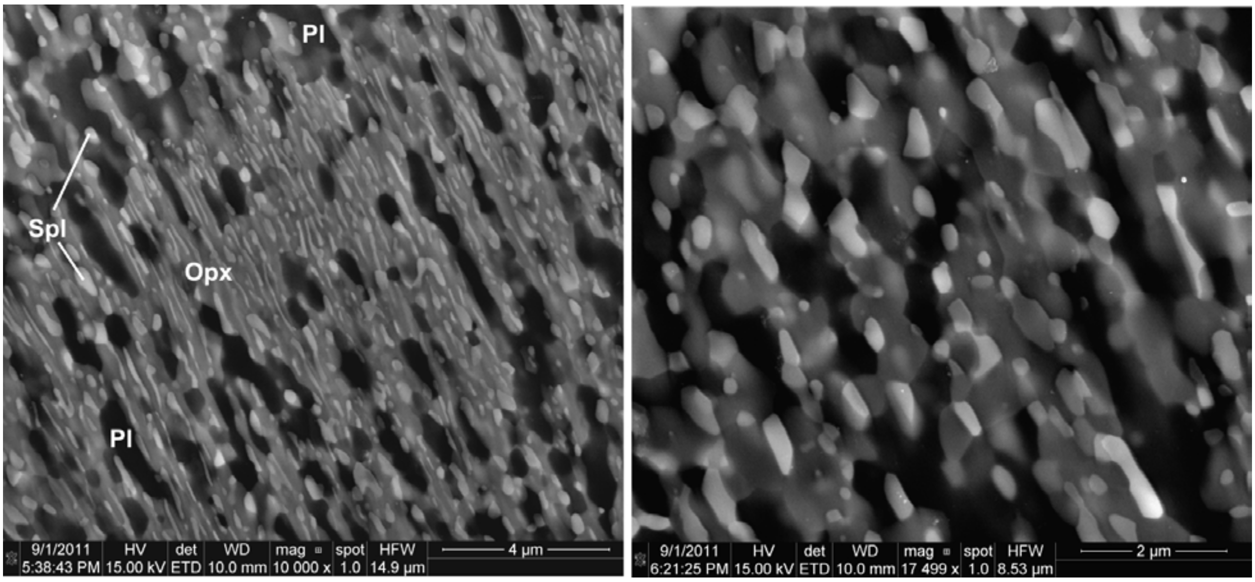

Figure 1. *Secondary electron images show characteristic microstructures of Type A (left) and Type B (right) symplectitic intergrowths of orthopyroxene (Opx), spinel (Spl) and plagioclase (Pl)*