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Dehydration breakdown of antigorite and the formation of b-type olivine CPO

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Observations of the seismic waves in the mantle wedge (MW) above many subduction zones display a fast seismic direction perpendicular to plate motion. This cause of this anisotropy is considered by many workers to be due to the existence of b-type olivine (Ol) CPO in the MW with [100] axes concentrated perpendicular to the flow direction parallel to plate motion.

Deformation experiments show that b-type CPO patterns can be formed as a result of dislocation creep under water-present high-stress conditions(1) and thermomechanical models have been used to suggest that conditions necessary to form b-type Ol CPO may be achieved close to subduction boundaries(2).

However, work on hydrated antigorite (Atg) bearing forearc mantle shows that the presence of Atg destroys any preexisting CPO and prevents strong Ol CPO from being developed(3). The reduction in CPO strength is thought to be due to slip concentrating in the weaker Atg layers with associated grain-boundary sliding occurring between Ol and Atg. This result suggests that b-type Ol CPO fabrics are unlikely to be developed close to subduction boundaries where Atg is expected to be stable.

Nevertheless, several examples of naturally occurring b-type Ol CPO have been reported. A review of published reports shows some of these were formed at relatively high temperatures and low stress, which is incompatible with the predictions from experimental work. Natural samples also lack evidence for c-slip, which is expected for the formation of b-type Ol CPO by dislocation creep.

These considerations show that the formation of naturally occurring b-type Ol CPO is not well understood.

Here we document b-type Ol CPO formed by the topotaxial growth of Ol on Atg from the Happo-One region of the Hida Marginal belt, Japan. Before dehydration and conversion to Ol, the Atg had a strong preexisting CPO due to deformation at relatively shallow levels under low temperatures and hydrated conditions. In the Happo-One region, non-deformed secondary Ol formed in veins as a result of the dehydration of foliated Atg, due to contact metamorphism(4).

The CPO of the vein Ol shows a strong b-Type fabric that is characterized by a c-axis concentration parallel to the stretching lineation and a b-axis concentration normal to the foliation. The CPO of the Atg bordering the vein shows a strong concentration of c-axes at a high angle to the foliation and a strong alignment of b-axes parallel to the lineation. Many recent studies have shown this type of Atg CPO is the most widespread in the forearc MW.

Two types of topotaxial growth relationships are known between Ol and Atg: in both cases [010]atg is parallel [001]ol but [010]ol may be parallel to either [100]atg (type 1) or [001]atg (type 2)(5). The observed relationships between the Ol and Atg CPO patterns in this study imply type 2 topotaxial relationships between the two minerals.

Atg-bearing mantle is predicted to be a widespread component of forearc mantle. As this material is dragged down by the traction of the downgoing slab, it will become deformed and foliated. When this foliated antigorite schist reaches sufficiently high T and P conditions, it will undergo dehydration. Our results show that when this dehydration occurs, the newly formed Ol is likely to have a b-type Ol CPO. This topotactic Ol CPO can form in the MW away from the coldest part immediately adjacent to the subduction boundary.

The CPO formation mechanism reported here can reconcile the differences between the laboratory and natural examples of b-type Ol CPO patterns and also explain why such b-type CPO is found associated with subduction zones.

References

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