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Subduction related antigorite CPO patterns from forearc mantle in the Sanbagawa belt, southwest Japan

A. Nishii[a,*], S.R. Wallis[a], T. Mizukami[b], K. Michibayashi[c]

[a] Department of Earth and Planetary Sciences, Graduate School of Environmental Studies, Nagoya University, Nagoya 464-8601, Japan
[b] Department of Earth Science, Graduate School of Environmental Studies, Kanazawa University, Kanazawa 920-1192, Japan
[c] Institute of Geosciences, Shizuoka University, Ohya 836, Suruga-ku, Shizuoka 422-8529, Japan

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ABSTRACT

Antigorite (Atg) is stable throughout large parts of the wedge mantle of most subduction zones. Atg shows strong acoustic anisotropy and crystallographic preferred orientation (CPO) patterns of this mineral may contribute significantly to seismic anisotropy in convergent margins. Atg CPO patterns from the Higashi-Akaishi (HA) forearc mantle body of southwest Japan adds to the data set suggesting the most common Atg CPO pattern has a c-axis perpendicular to the foliation and a b-axis parallel to the stretching lineation. Statistical analysis using the eigenvector method of Atg CPO from two mutually perpendicular directions in the same sample (*YZ*-section and *XZ*-section) shows no significant differences implying sample preparation has no significant affect on the resulting Atg CPO. Reuss (uniform stress) averages of anisotropy for the Higashi-Akaishi samples are approximately treble the values for Voigt (uniform strain) averages. When comparing calculated anisotropy of hydrated mantle peridotite samples—such as the Higashi-Akaishi unit—with observed S-wave delay times in convergent margins, the appropriate averaging method needs to be considered.

1. Introduction

Thermal modeling and petrological studies suggest that antigorite (Atg) is stable throughout large parts of the wedge mantle of most subduction zones (e.g. Ulmer and Trommsdorff, 1995; Hyndman and Peacock, 2003; Wada et al., 2008). There is also observational evidence for the presence of this mineral in convergent margins, in particular close to the subduction boundary (e.g. Bostock et al., 2002; Blakely et al., 2005; Wada et al., 2008; Kawakatsu and Watada, 2007). Atg has an acoustic anisotropy much stronger than olivine (Ol) (Bezacier et al., 2010)—the major constituent mineral of the mantle wedge—and a number of recent studies have emphasized the possible importance of Atg crystallographic preferred orientations (CPO) in discussing seismic anisotropy in convergent margins (e.g. Katayama et al., 2009; Faccenda et al., 2008). However, only a few examples of natural Atg CPO patterns have been published (Bezacier et al., 2010; Hirauchi et al., 2010; Jung, 2011; Moortèle et al., 2010; Soda and Takagi, 2010). From the limited data available it seems there are two distinct types of Atg CPO. Both types have c-axes concentrated in a direction perpendicular to the foliation, but they differ in whether there is a concentration of a-axes or b-axes parallel to the mineral lineation. We refer to these two distinct types as A- and B-types, respectively. In this contribution we report a further example of a B-type Atg CPO from the Higashi-Akaishi (HA) garnet peridotite body of SW Japan. This body represents a sliver of forearc mantle (Mizukami and Wallis, 2005; Hattori et al., 2010) and the related Atg fabrics formed during subduction (Mizukami and Wallis, 2005). These Atg CPOs, therefore, are likely to be representative of CPO fabrics in the mantle wedge. In this contribution, we discuss the implications of our CPOs for wedge mantle seismic anisotropy. We also address an issue of whether any artifacts are introduced in the CPO due to disruption of the crystal lattice either by small-scale plastic deformation or brittle processes caused during sample preparation. Such disruption need only be on a scale of a few nm to influence the measured CPO. As far as we are aware there has been no systematic study of this issue. If such a problem exited for Atg it could also be a significant issue for other sheet silicates.

2. Geology of the Higashi-Akaishi body

The Higashi-Akaishi (HA) peridotite is part of the oceanic subduction type Sanbagawa metamorphic belt and is located in the Besshi region of central Shikoku, Japan (Fig. 1). The HA body is a sliver of mantle wedge exhumed from depths of 100 km or more

* Corresponding author.
E-mail address: nishii.aya@c.mbox.nagoya-u.ac.jp (A. Nishii). .

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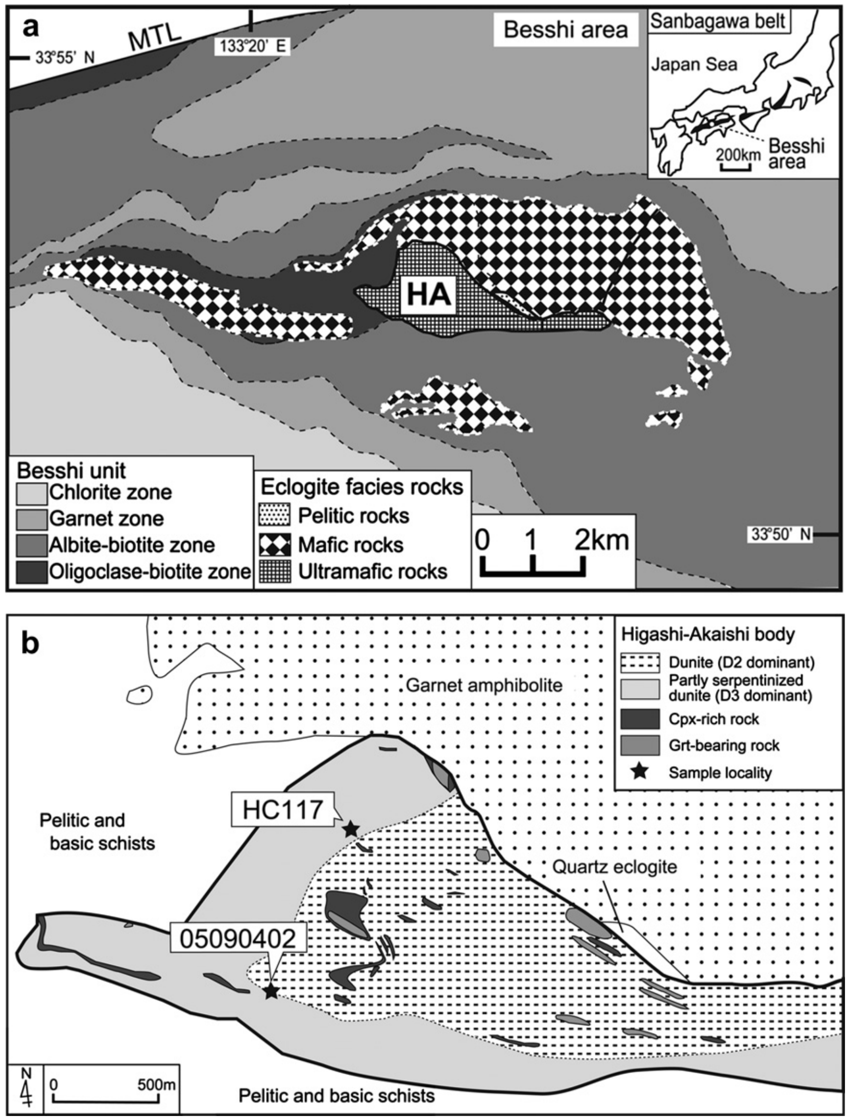

Fig. 1. (a) Geological map of the Besshi area modified after Aoya (2001). Only clearly identified eclogite facies areas are shown and the extent of similar grade rocks is likely to be considerably wider (e.g. Kouketsu and Enami, 2010). HA = Higashi-Akaishi peridotite body; MTL = Median Tectonic Line. (b) Geological map showing the distribution of areas preserving D2 and D3 fabrics and the sample localities.

(Enami et al., 2004; Mizukami and Wallis, 2005). A combination of microstructural and petrological studies allows four distinct deformation phases of high strain ductile deformation (D1–D4) to be identified within the body; the dominant deformation D2 occurred during subduction and the subsequent D3 and D4 stages are related to exhumation (Mizukami and Wallis, 2005). The tectonic significance of D1 is unclear. Antigorite (Atg) first formed during the later part of the D2 deformation. Therefore, we differentiate between the early Atg-free and later Atg-bearing stages and refer to these as D2a and D2b, respectively. A combination of garnet-orthopyroxene geothermobarometry with microstructural observations shows D2a was associated with increasing pressure with a peak in excess of 2.8 GPa and temperatures of 700–800 °C (Mizukami and Wallis, 2005). The increasing pressure shows that D2 formed during subduction. Atg that formed during the D2b stage is parallel to the D2a tectonic fabrics and shows syndeformational microstructures, which are interpreted as part of the same tectonic event as D2a (Wallis et al., in press). D2 took place in the presence of H_2O-rich fluids (Mizukami et al., 2004; Sumino et al., 2010). We suggest the formation of Atg occurred by the reaction of this H_2O with the olivine (Ol) as the temperature of the subduction zone cooled and pressure increased. The extra Si needed to form Atg may have been supplied by clinopyroxene (Cpx) which is present, generally in small quantities, throughout the HA body. The extra Si may also have been supplied by an external fluid. The petrological observations imply an anticlockwise P–T path, which can be interpreted as reflecting the conditions immediately after the onset of subduction (Mizukami and Wallis, 2005; Endo et al., 2009). The importance of these observations is that the Atg we report here formed at the lower parts of the mantle wedge. In other studies, many Atg schist samples either formed close to the surface or their formation conditions are poorly constrained. There is therefore some uncertainty about how well they reflect conditions deep in the wedge.

3. Sample description

The primary goals of this study are to investigate the type of CPO formed by Atg at depth within a subduction zone and to examine its implications for seismic anisotropy of wedge mantle. We studied