Three-dimensional textural characteristics of symplectite from the Horoman peridotite, Hokkaido, Japan

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Three-dimensional textural characteirstics of symplectite from the Horoman peridotite, Hokkaido, Japan

Tomoaki MORISHITA and Shoji ARAI

Department of Earth Sciences, Faculty of Science, Kanazawa University, Kakuma, Kanazawa 920－1192, Japan

Abstract: Symplectite of possibly garnet origin is characteristic of the Horoman peridotite, Hokkaido, northern Japan. To know three-dimensional shapes and distributions of minerals in a symplectite, successive back scattered electron (BSE) images of symplectites consisting of orthopyroxene, clinopyroxene and spinel from a spinel peridotite sample were taken on the polished surface using SEM. We obtained 21 and 18 BSE images for two symplectites and 21 BSE images for an aggregate of small symplectites. Symplectite clinopyroxene shows branch structure and would be connected to clinopyroxene in a fine-grained mineral aggregate around the symplectite. Symplectite spinel has rod-like shapes with branch structures, and the thickness of spinel rod is almost the same in a symplectite. Almost all spinel grains would be located at the grain boundaries between orthopyroxene and clinopyroxene. Distribution of spinel and clinopyroxene is closely related to each other, possibly suggesting that spinel was nucleated from Al-rich pyroxenes.

Introduction

Occurrence of a symplectite, an intergrowth of irregular fine-grained minerals, is one of features of the Horoman peridotite, Hokkaido. The symplectite from the Horoman peridotite has been interpreted to be of pyrope-rich garnet origin (e.g., Kushiro & Yoder,1966; Takahashi & Arai, 1989; Ozawa & Takahashi, 1995; Obata et al., 1997; Morishita & Arai, 1997). It is very important to know the formation processes of the symplectite because the symplectite is possibly evidence for the derivation of the Horoman complex from the garnet peridotite stability filed (Kushiro & Yoder, 1966; Takahashi & Arai, 1989; Ozawa & Takahashi, 1995; Takazawa et al.,1996). Obata et al. (1997) examined the symplectite texture by means of digital image analysis according to Morishita & Obata (1995). Morishita

(1998) simulated the symplectite texture using a simple mathematical model of pattern generation. Their observations are, however, based on textures in two-dimensional planes as suggested in their papers. Recently, the three-dimensional analysis of natural rock textures has been done by many workers (e.g., Kondo, 1996 ; Denison & Carlson, 1997 ; Denison et al., 1997 ; Kondo et al., 1998). Morishita (submitted) also presented a preliminary result on three-dimensional shapes and distributions of minerals in a symplectite using successive two-dimensional images of symplectites in one spinel lherzolite sample. The aim of this paper is to provide all successive two-dimensional images data.

Geological background

Geological outline

The Horoman Peridotite Complex is located at the southern end of the Main Zone of the Hidaka metamorphic belt, which belongs to the Hidaka belt (e.g., Komatsu et al, 1982 ; Niida, 1984) (Fig.1). The Horoman complex is 8 x 10 km in plan and is more than 3 km in thickness (e.g., Igi, 1953 ; Komatsu & Nochi, 1966 ; Niida, 1984 ; Sawaguchi, 1999).

The complex consists of various kinds of layered peridotites with small amounts of mafic rocks (e.g., Igi, 1953 ; Komatsu & Nochi, 1966 ; Niida, 1984 ; Obata & Nagahara, 1987 ; Frey et al., 1991 ; Takahashi, 1991 ; Shiotani & Niida, 1997 ; Takazawa et al., 1999). On the

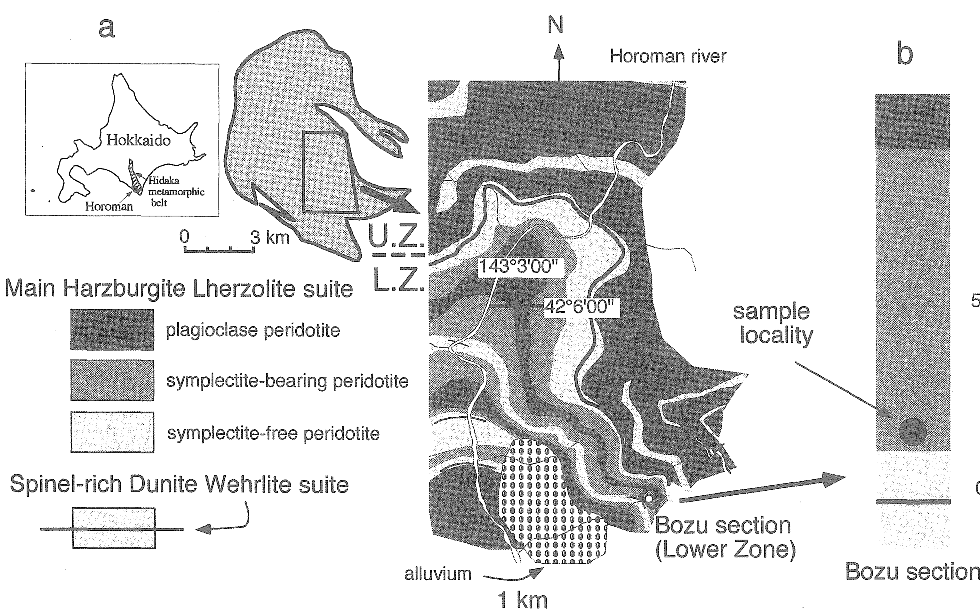

Fig. 1. Lithological map of the southeastern part of the Horoman Peridotite Complex (a) and columnar section of the Bozu section (b) showing the locality of the studied sample. The Banded Dunite-Harzburgite suite is omitted for simplicity. The U.Z. and L.Z. are the Upper and Lower Zones, respectively.

basis of petrography and mineralogy, the Horoman peridotites are divided into three suites (Takahashi, 1991). The first is the Main Harzburgite-Lherzolite suite (MHL), which has typical residual characteristics resulting from various degrees of magma extraction (Obata & Nagahara, 1987 ; Frey et al., 1991 ; Takahashi, 1991, 1997 ; Takazawa et al., 2000 ; Yoshida & Takahashi, 1997 ; Yoshikawa & Nakamura., 2000). The second is the Spinel-rich Dunite-Wehrlite suite (SDW), which is cumulate from a magma (Takahashi, 1991, 1997 ; Yoshida & Takahashi, 1997). The third is the Banded Dunite-Harzburgite suite, which is also cumulate from magma such as high-Mg andesite (Takahashi, 1991).

Komatsu & Nochi (1966) and Niida (1984) divided the complex into two zones, the Upper and Lower Zones. The Upper Zone is characterized by abundance of mafic layers and by sharp lithological boundaries. On the other hand, the Lower Zone is characterized by gradational lithological boundaries.

Symplectite

The symplectite in the Horoman complex has been divided into two types based on mineral assemblages irrespective of modes of occurrence ; spinel-type consisting of orthopyroxene, clinopyroxene and spinel and plagioclase-type consisting of plagioclase, olivine, spinel and minor amount of orthopyroxene (Niida, 1984 ; Takahashi & Arai, 1989 ; Morishita & Arai, 1997). Spinel- and plagioclase-type symplectits rarely occur together in single thin sections (Takahashi & Arai, 1989). Two modes of occurrences of symplectite have been reported (Takahashi & Arai, 1989 ; Morishita et al., 1995 ; Ozawa & Takahashi, 1995 ; Morishita & Arai, 1997). One is embedded in a lenticular fine-grained mineral aggregate (fine-grained aggregate). The constituent minerals of the fine-grained aggregate are the same as those of the included symplectite (spinel-type and plagioclase-type fine-grained aggregates). The other is included in pyroxene porphyroclast. The symplectite of this occurrence is only spinel-type one and is not associated with the fine-grained aggregate. Morishita & Arai (1997) summarized the occurrences of symplectite-bearing rocks and divided them into three types based on the petrography ; clinopyroxene-rich lherzolite of the MHL suite, pyroxenite in the MHL suite and pyroxenite in the SDW suite.

The studied sample was taken from a spinel lherzolite of the MHL suite in the Lower Zone (Fig. 1). The studied sample of spinel lherzolite shows a porphyroclastic texture. The Fo content of olivine and the Cr/(Cr+Al) atomic ratio of discrete spinel were measured by SEM-EDAX system at Kanazawa University and are 90.3 and 0.14, respectively.

Sample preparation and procedure to obtain successive images of symplectite

Three plates of about 2 mm in thickness on the XZ plane (cutting vertical to the foliation plane (XZ plane) and perpendicular to the lineation (the direction of X axis) of the peridotite ; Fig. 2) were made from one sample. Polished surfaces were observed under the microscope by reflected light. We recognized one symplectite on two of the three plates and

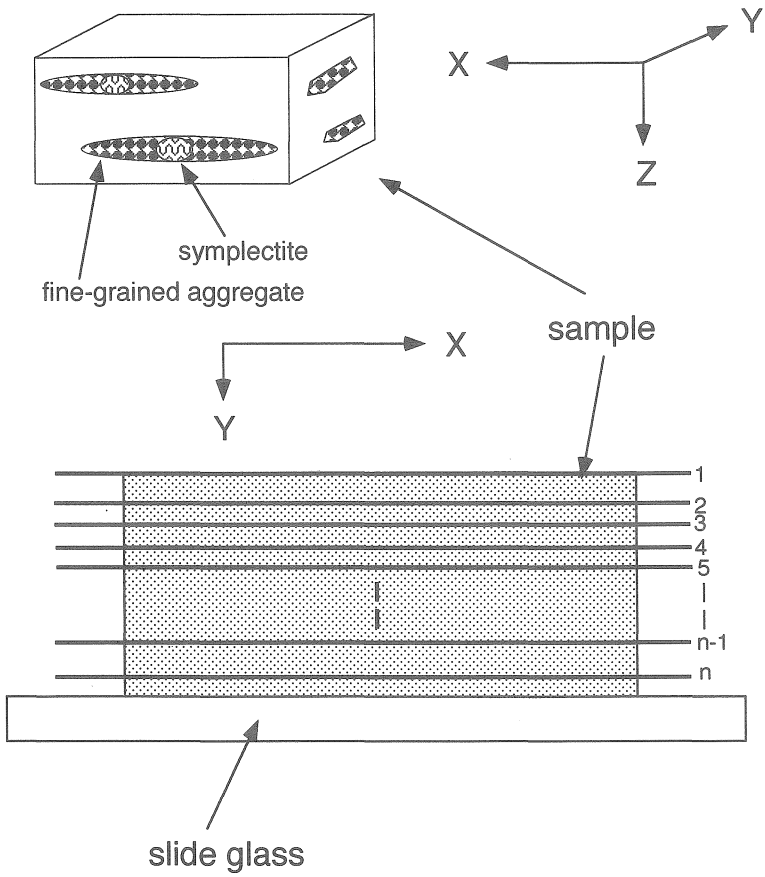

Fig. 2. Sample preparation for image processing. XZ plane indicates the plane cut vertically to the foliation and perpendicular to the lineation (the direction of X axis). The sample was successively scraped off from 1 to n to the direction of Y axis.

an aggregate of small symplectite on the other.

Back scattered electron image (BSE) was taken on the polished surface using SEM at Kanazawa University. The surface which was once taken by SEM was abraded to the direction of Y axis (ranging from 10 to 60 μm) and polished again (Fig. 2). New surface obtained in this manner was used for the next SEM micrograph. The interval to the Y axis between old and new surfaces was measured by a slide clipper (ERNST LEITZ GMBH WETZLAR). We repeated this procedure 21 times for two plates and 18 times for the third plate.

Some BSE images were converted to digital images by a digital image scanner (150-400 dpi ; SHARP JX-250). Outlines of minerals are traced by hand using a pen tablet (WACOM Art Pad II) on the digital image with carefully referring to the original pictures at the same time. This procedure was performed on Macintosh computer (Power Mac 7600/132 or iMac 266) using the PhotoshopTM ver.4.0 J software (cf. Nishimoto, 1996).

Result and Discussion

We obtained 21 and 18 BSE images for two symplectites (Plate I and III, respectively) and 21 BSE images for an aggregate of small symplectites (Plate II). Three-dimensional textural characteristics of symplectite minerals can be observed from these images and give us much information about formation of the symplectite texture. Results are as follows. (1) Although symplectite clinopyroxene grains are recognized as individual grains in a two-dimensional section, they are mostly connected to each other in other sections (Fig. 3). This means that some clinopyroxene grains show branch structure in symplectite (Fig. 6a). (2) Symplectite clinopyroxene would be sometimes connected to clinopyroxene in the fine-grained mineral aggregate around the symplectite (Figs. 3 & 6a, Plate III). Furthermore, orthopyroxene is optically continuous from symplectite to the host whenever the symplectite occurs as an inclusion of orthopyroxene porphyroclast. These mean that symplectite pyroxenes would grow from the outer side inwards sharing the crystal axis with pre-existing pyroxenes in the fine-grained aggregate or porphyroclast. In a garnet-bearing peridotite, orthopyroxene in a corona around garnet sometimes grows

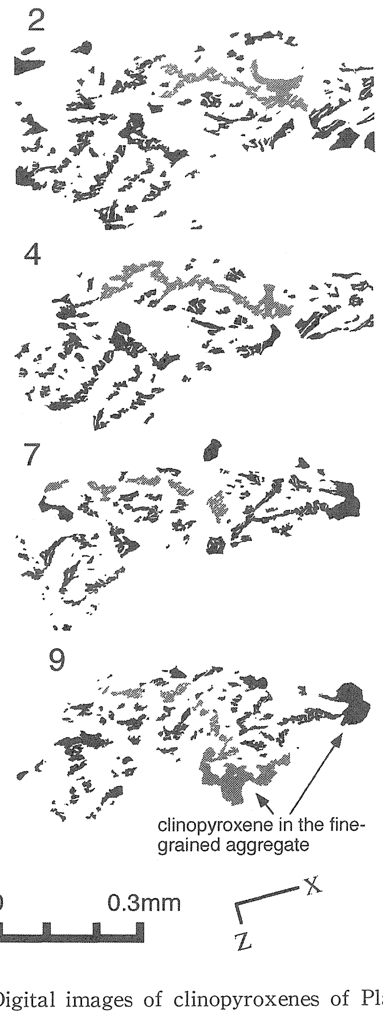

Fig. 3. Digital images of clinopyroxenes of Plate I. Note that the gray grain of section 1 (Plate I) is split to several independent grains in section 7. In the section 9, one of gray grains is in contact with pyroxene grains of the fine-grained mineral aggregate.

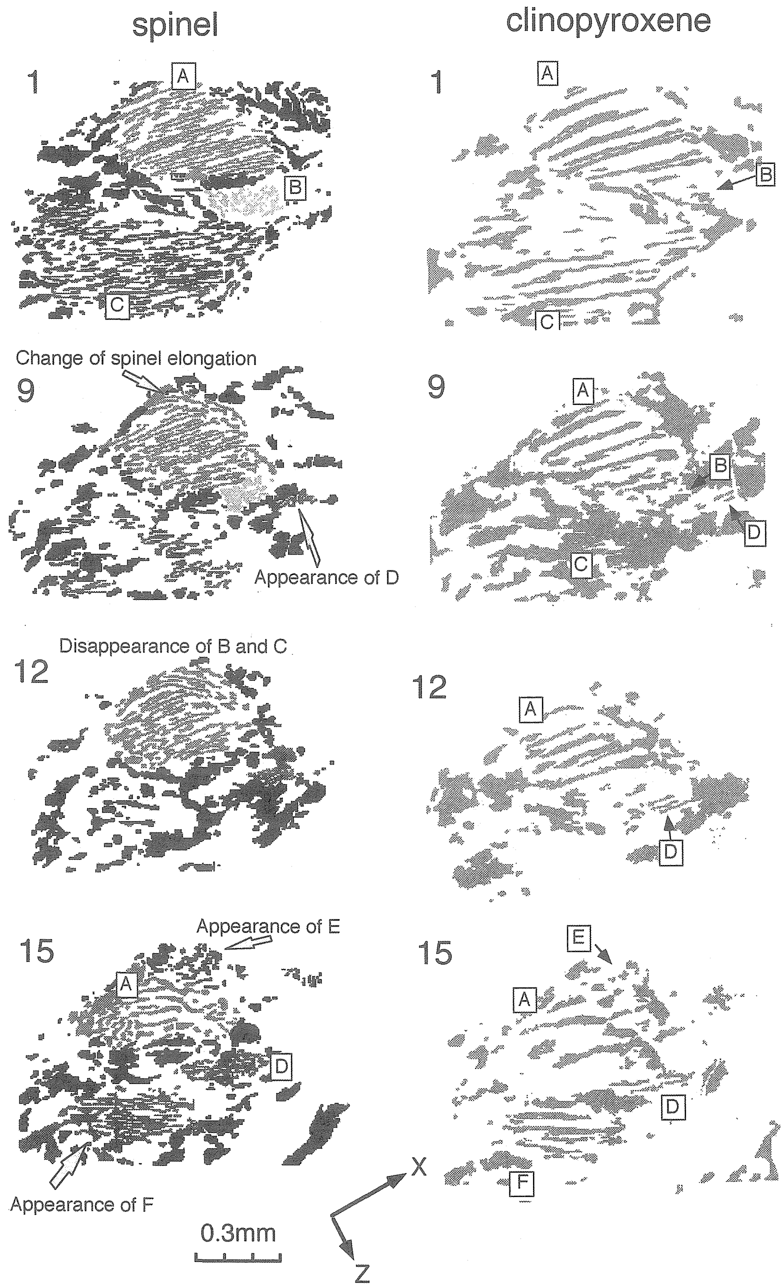

Fig. 4. Digital images of spinels and clinopyroxenes of some symplectites, A (+E?), B, C and D+F of Plate II. Each symplectite characterized by a direction of spinel elongation is distinguished by difference in gray scale. In the section 9, the direction of a part of spinel grains of A would be changed near the boundary with E (section 9 of Plate II), that is other part in the same symplectite or other symplectite. Note that distribution of spinel is closely related to that of clinopyroxene.

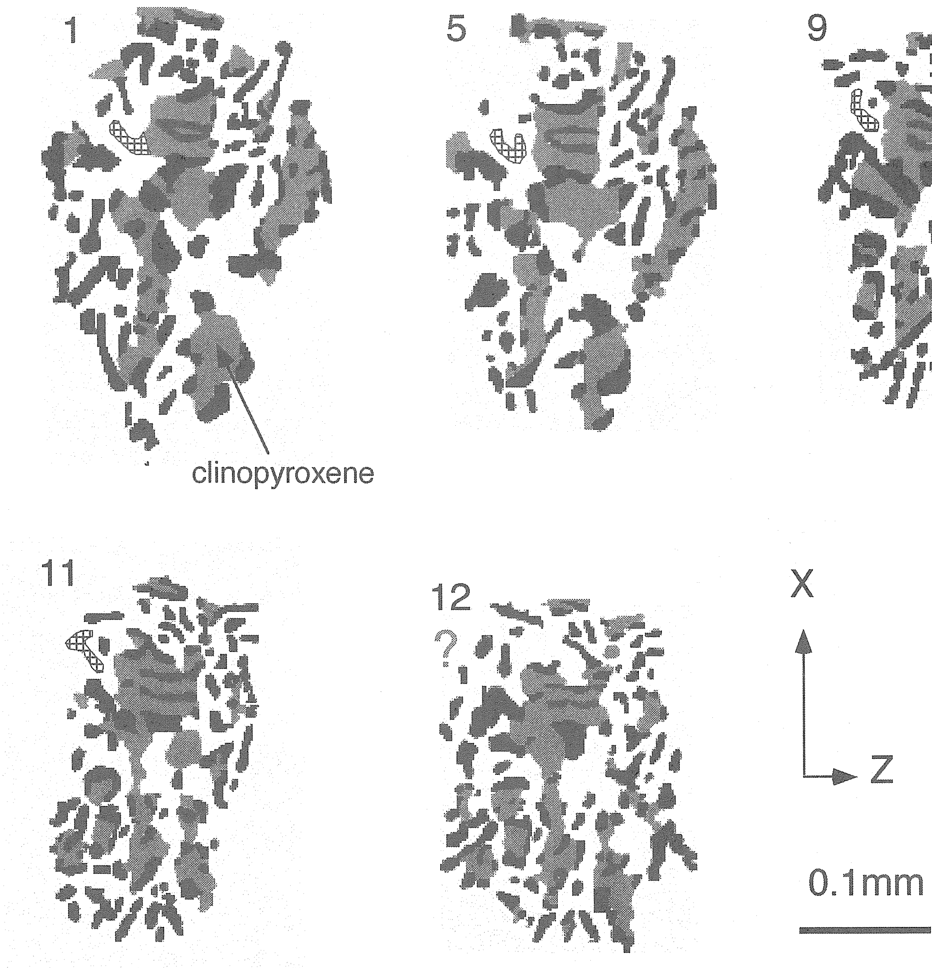

Fig. 5. Digital images of both clinopyroxenes (gray) and spinels (black) associated with orthopyroxene (white) in a part of symplectite of Plate III (area enclosed by dotted white line). Note the successive change of light gray and crosshatched grains from section 1 downward. In the section 1, the crosshatched grain is in contact with grain boundary between clinopyroxene and orthopyroxene and the light gray grain shows a ring-like shape. The crosshatched grain is totally enclosed by orthopyroxene from the section 5 forward. The light-gray grain shows rod-like shapes from the section 9 forward.

in optical continuity with the primary orthopyroxene (Reid & Dawson, 1972). (3) Spinel grains show rod-like, spherical and rope-like shapes in two-dimensional sections and also sometimes show branch structure in three dimensions (Figs. 4 & 5 ; Plates I to III). (4) The width of elongated spinel is almost the same in all sections of each symplectite (Plates I to III). (5) Symplectite spinel grains are totally enclosed by orthopyroxene in some two-dimensional sections and are sometimes located at grain boundaries between orthopyroxene and clinopyroxene in others (Figs. 5 & 6b). (6) Direction of the spinel elongation is not

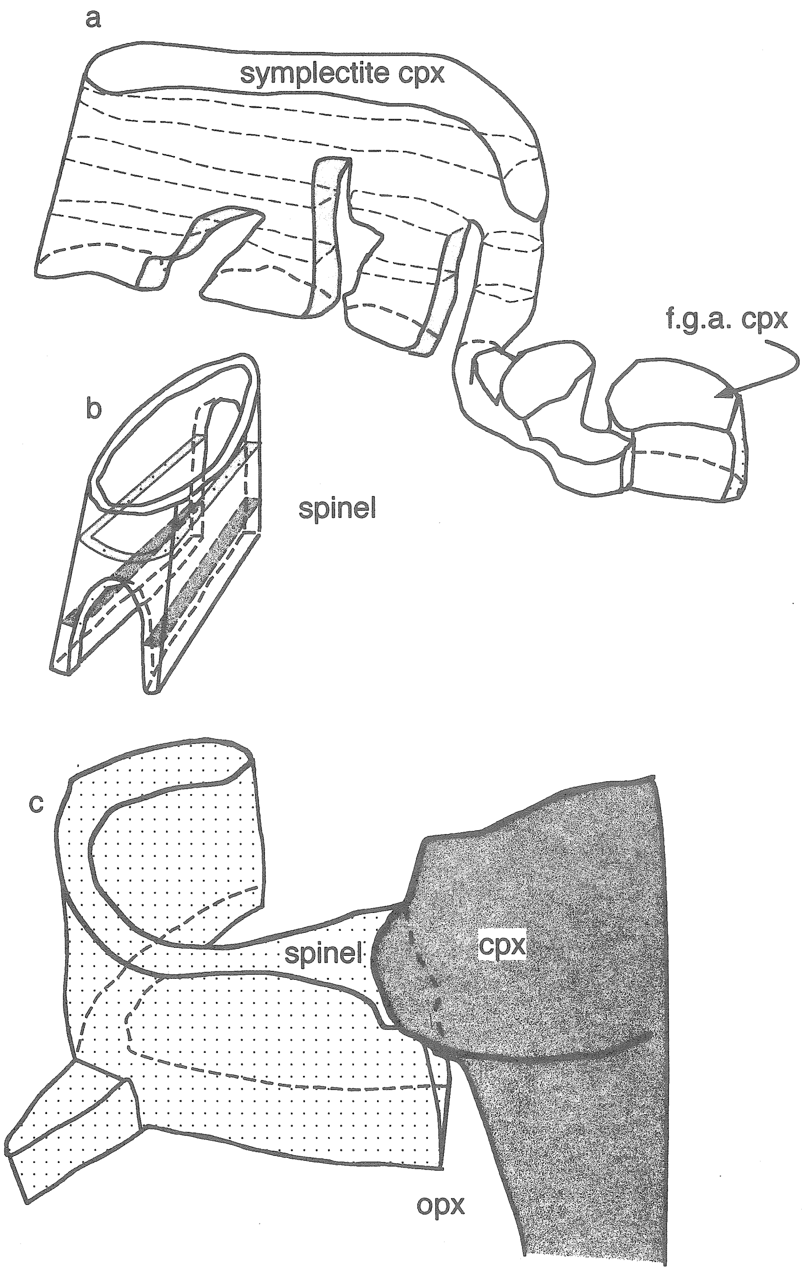

Fig. 6. Schematic three-dimensional images of symplectite minerals. (a) Symplectite clinopyroxene (gray grain of Fig. 3) shows branch structure and is connected to clinopyroxene in a fine-grained mineral aggregate around the symplectite. (b) Symplectite spinel (light gray grain of Fig. 5) shows rod-and rope-like shapes with branch structures. (c) Relationship between symplectite clinopyroxene and spinel grains (crosshatched grain of Fig. 5). Abbreviations : spl, spinel ; cpx, clinopyroxene ; opx, orthopyroxene ; f.g.a., fine-grained aggregate.

concordant with the foliation plane of peridotite. Direction of spinel elongation is sometimes curved at the junction with other part (or symplectite) characterized by different direction of spinel elongation (9 of Fig. 4 and Plate II). (7) Distribution of symplectite clinopyroxene is closely related to that of symplectite spinel (Fig. 4). Observations of (5) and (7) suggest that spinel grains preferentially nucleated on grain boundaries between orthopyroxene and clinopyroxene after the formation of pyroxene domain as suggested by Obata et al. (1997).

Table. 1. Intervals of thickness.

Plate I		Plate II		Plate III	
	μm		μm		μm
1	—	1	—	1	—
2	—	2	10	2	10
3	10	3	20	3	10
4	20	4	10	4	20
5	20	5	30	5	60
6	40	6	10	6	60
7	20	7	20	7	20
8	10	8	20	8	20
9	30	9	20	9	20
10	10	10	20	10	20
11	10	11	10	11	20
12	20	12	20	12	20
13	20	13	20	13	20
14	20	14	30	14	30
15	10	15	30	15	20
16	10	16	20	16	20
17	20	17	20	17	20
18		18	30	18	30
		19	30	19	20
		20	20	20	20
		21		21	
total	250		390		450

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*in Japanese with English abstract, **in Japanese

Plate I. Eighteen BSE images of symplectite. In the section 9, one of gray grains is in contact with pyroxene grains of the fine-grained mineral aggregate. See Fig. 3. Abbreviations : spl, spinel ; cpx, clinopyroxene ; f.g.a., fine-grained aggregate.

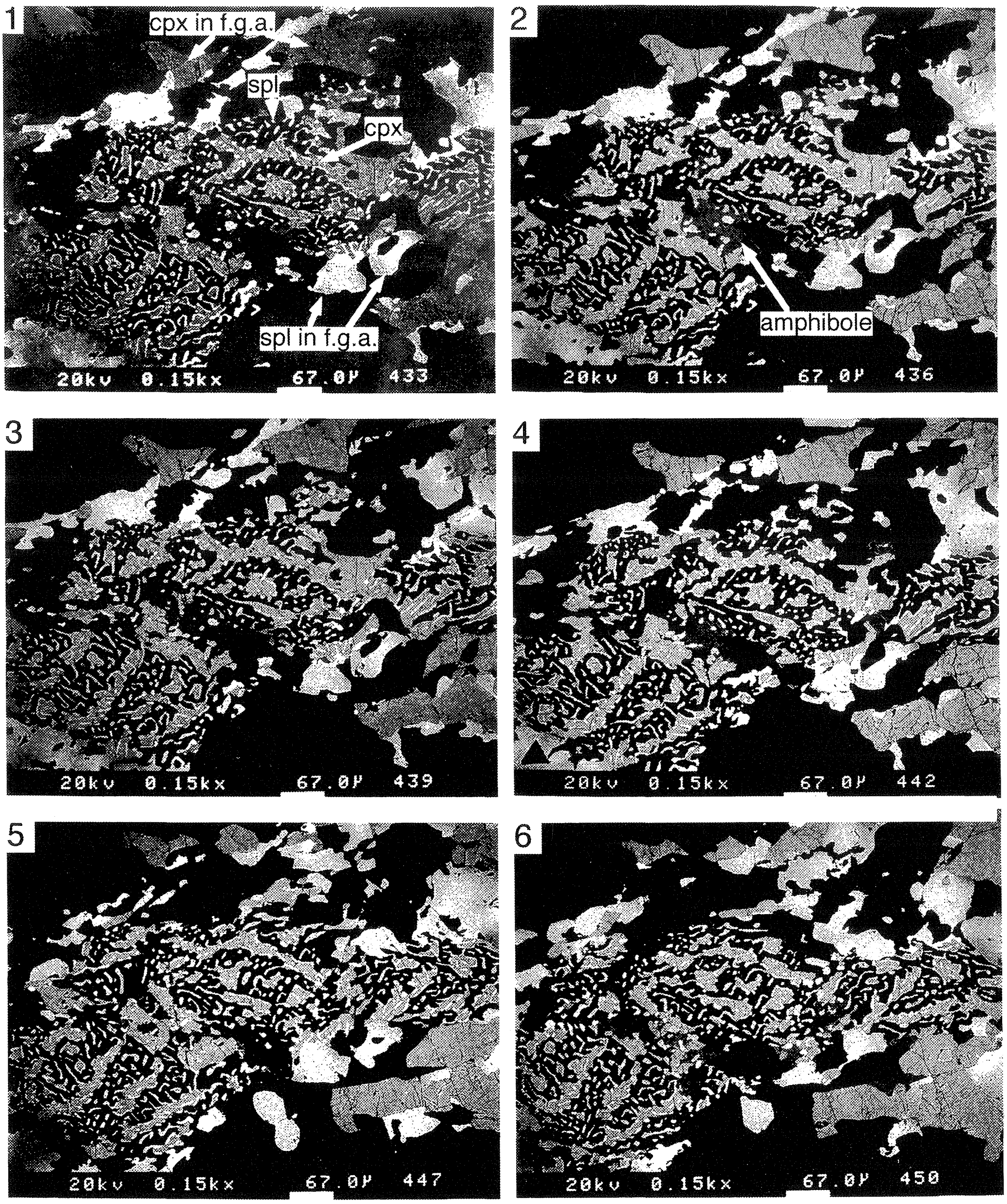
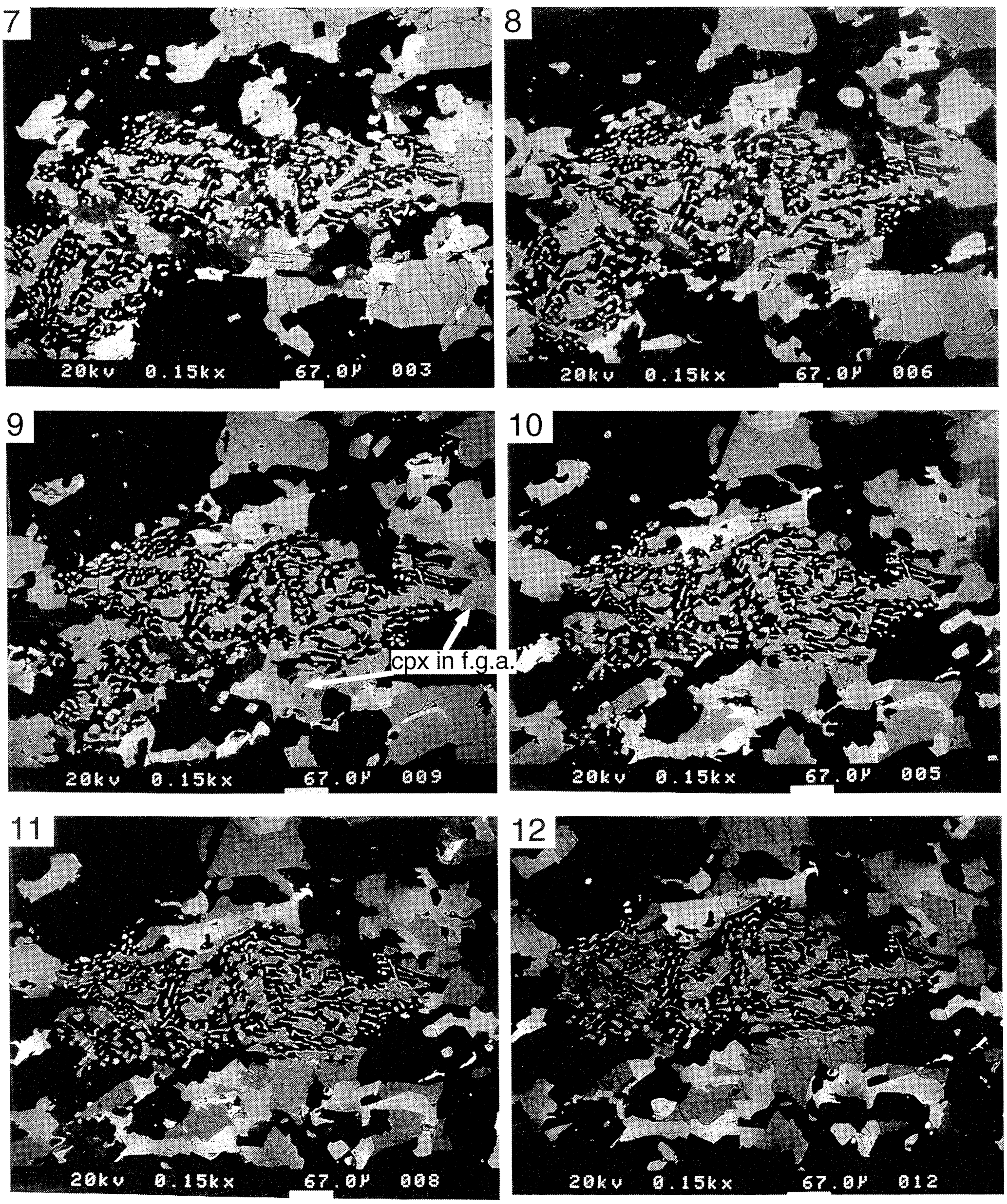


Plate I. (continued)



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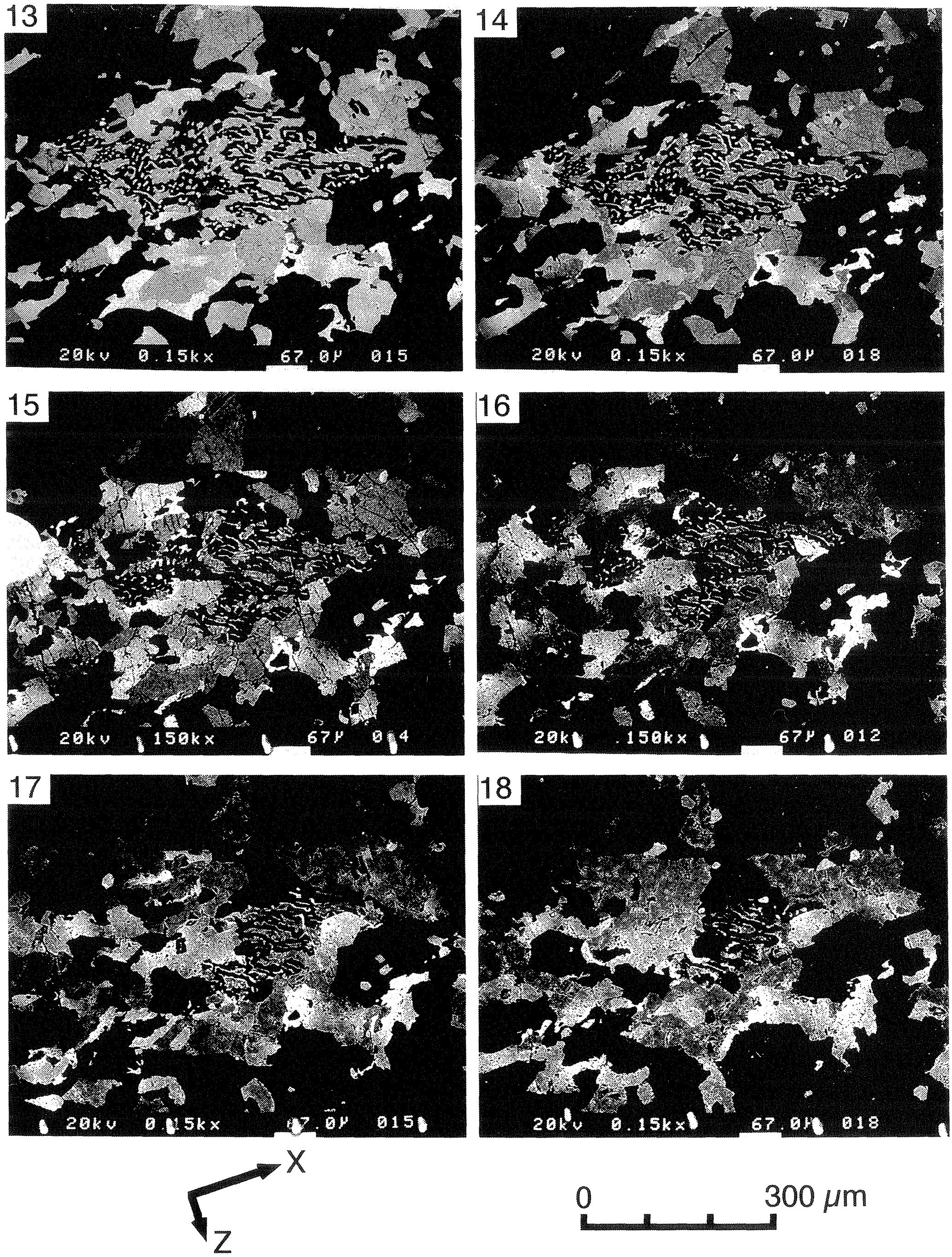

Plate II. Twenty-one BSE images of an aggregate of small symplectites. Small symplectites (A to F) are characterized by a direction of spinel elongation. In the section 9, the direction of a part of spinel grains of A would be changed near the boundary with E, that is other part in the same symplectite or other symplectite. See Fig. 4. Abbreviations are the same as Plate I.

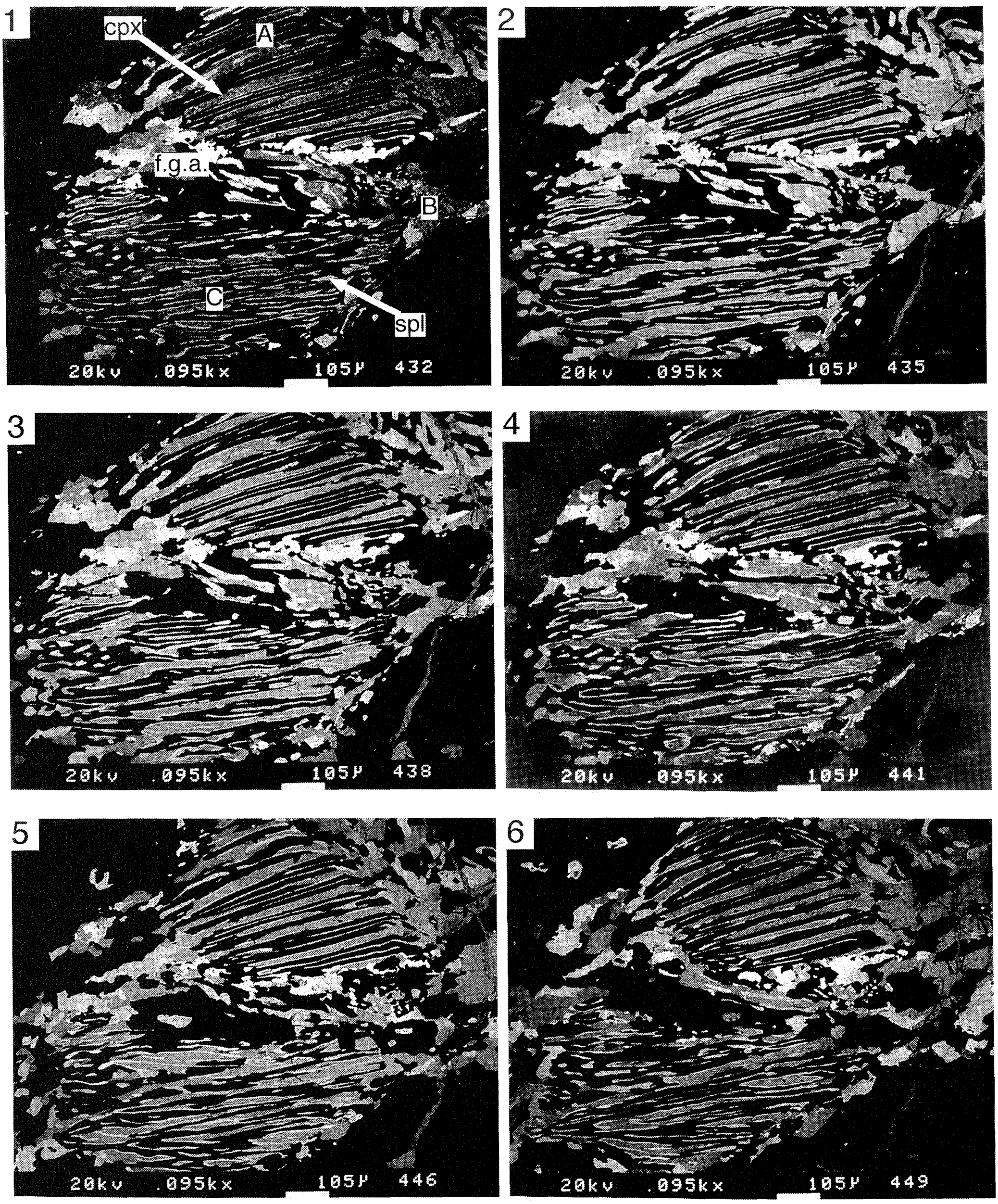

Plate II. (continued)

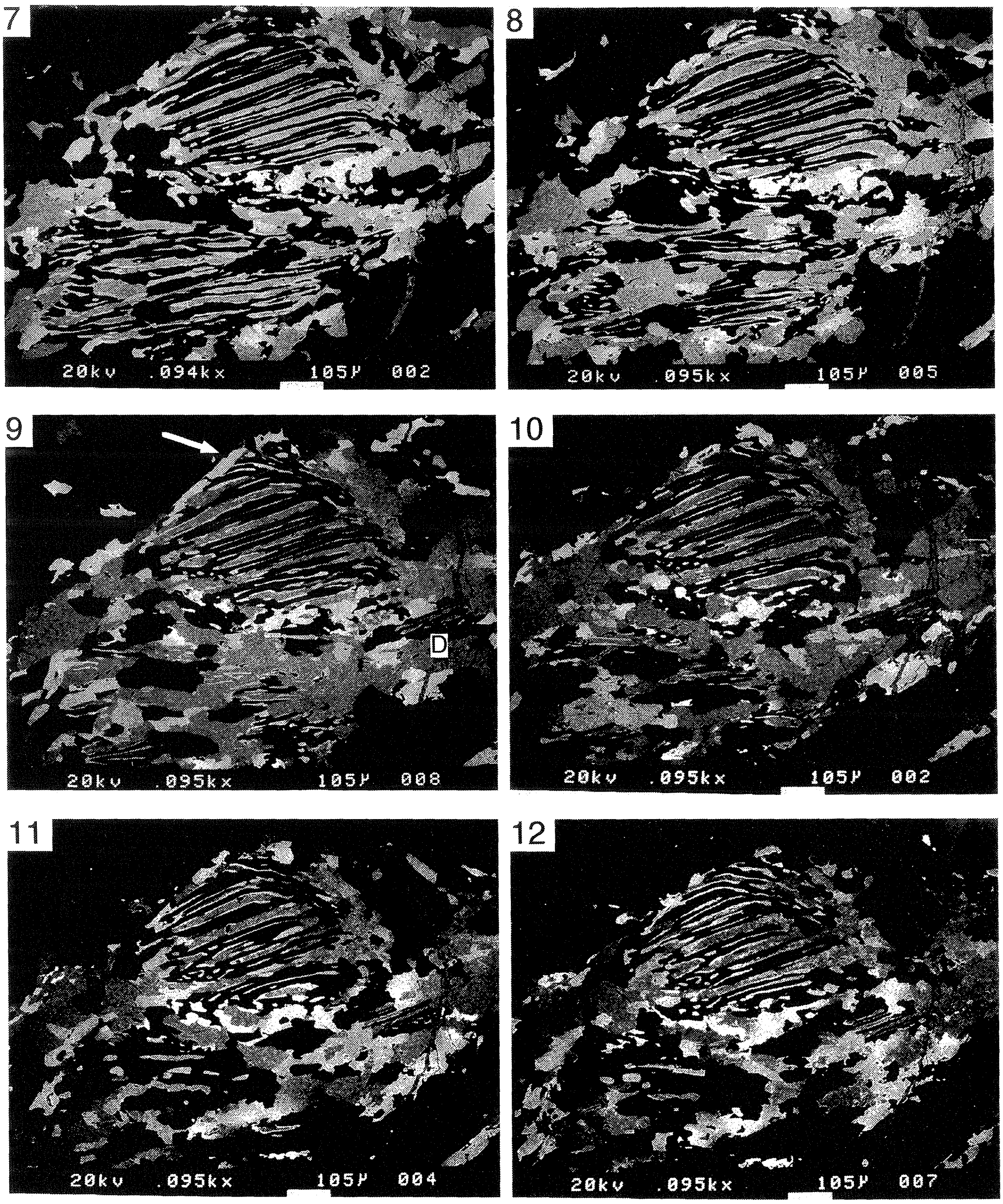

Plate II. (continued)

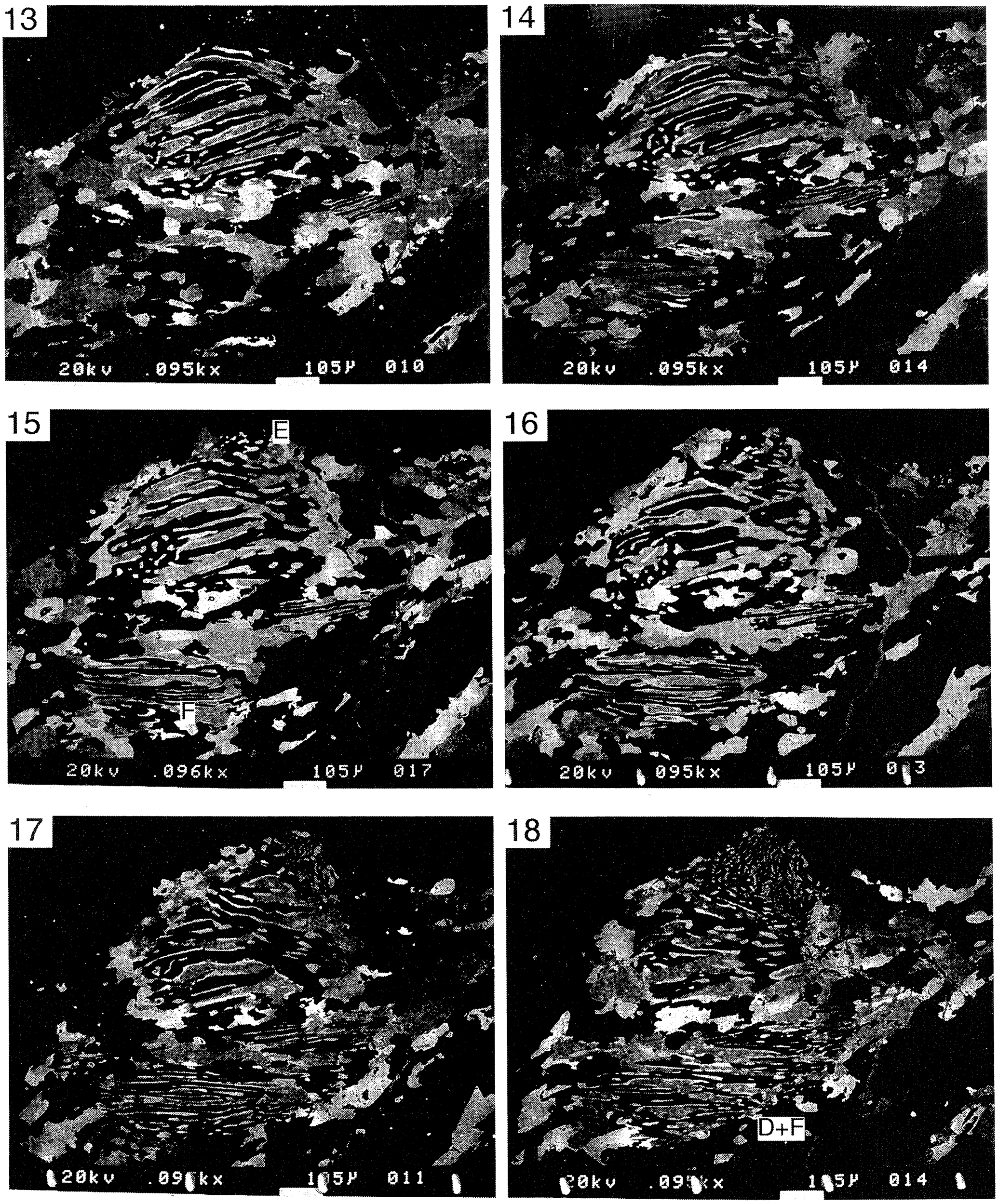

Plate II. (continued)

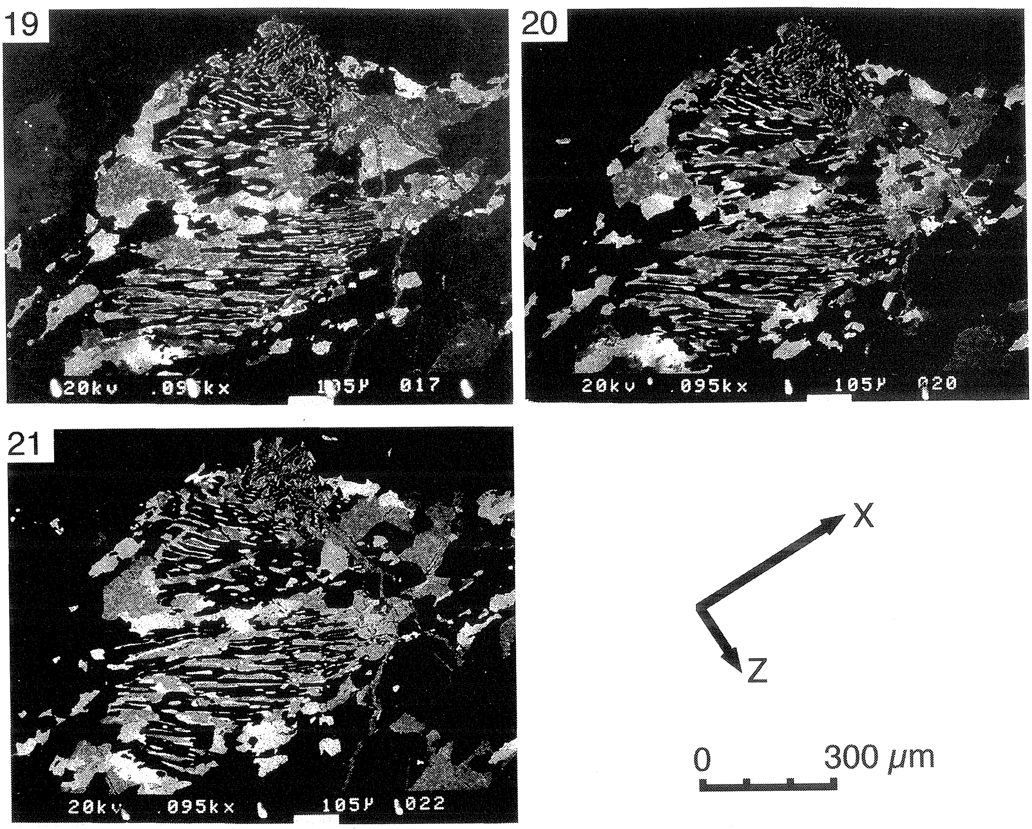

Plate III. Twenty-one BSE images of symplectite. Area encircled by dotted white line in the section 1 (central right) is shown on Fig. 5. In the section 17, one of gray grains is in contact with pyroxene grains of the fine-grained mineral aggregate. See Fig. 5. Abbreviations are the same as Plate I.

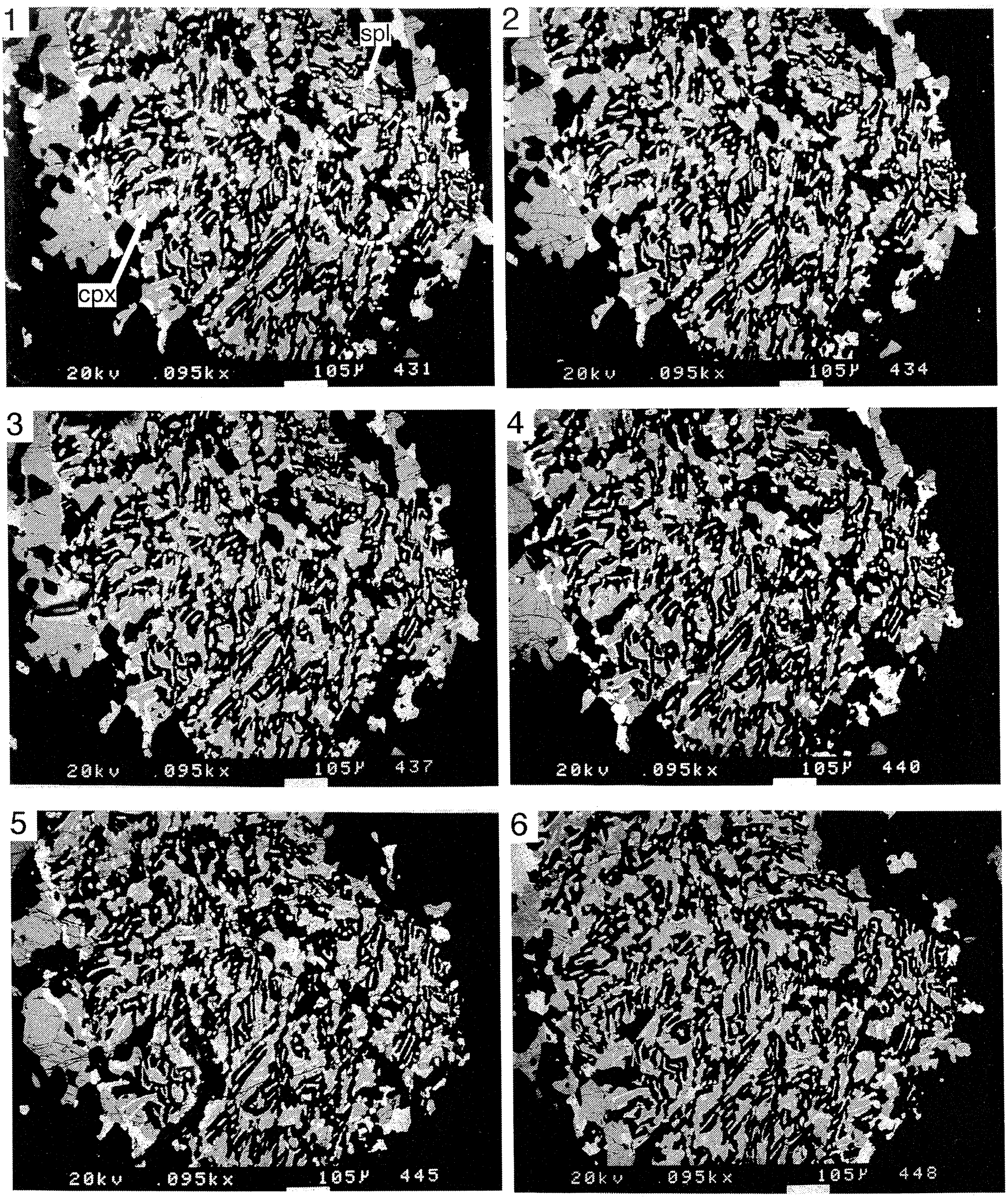

Plate III. (continued)

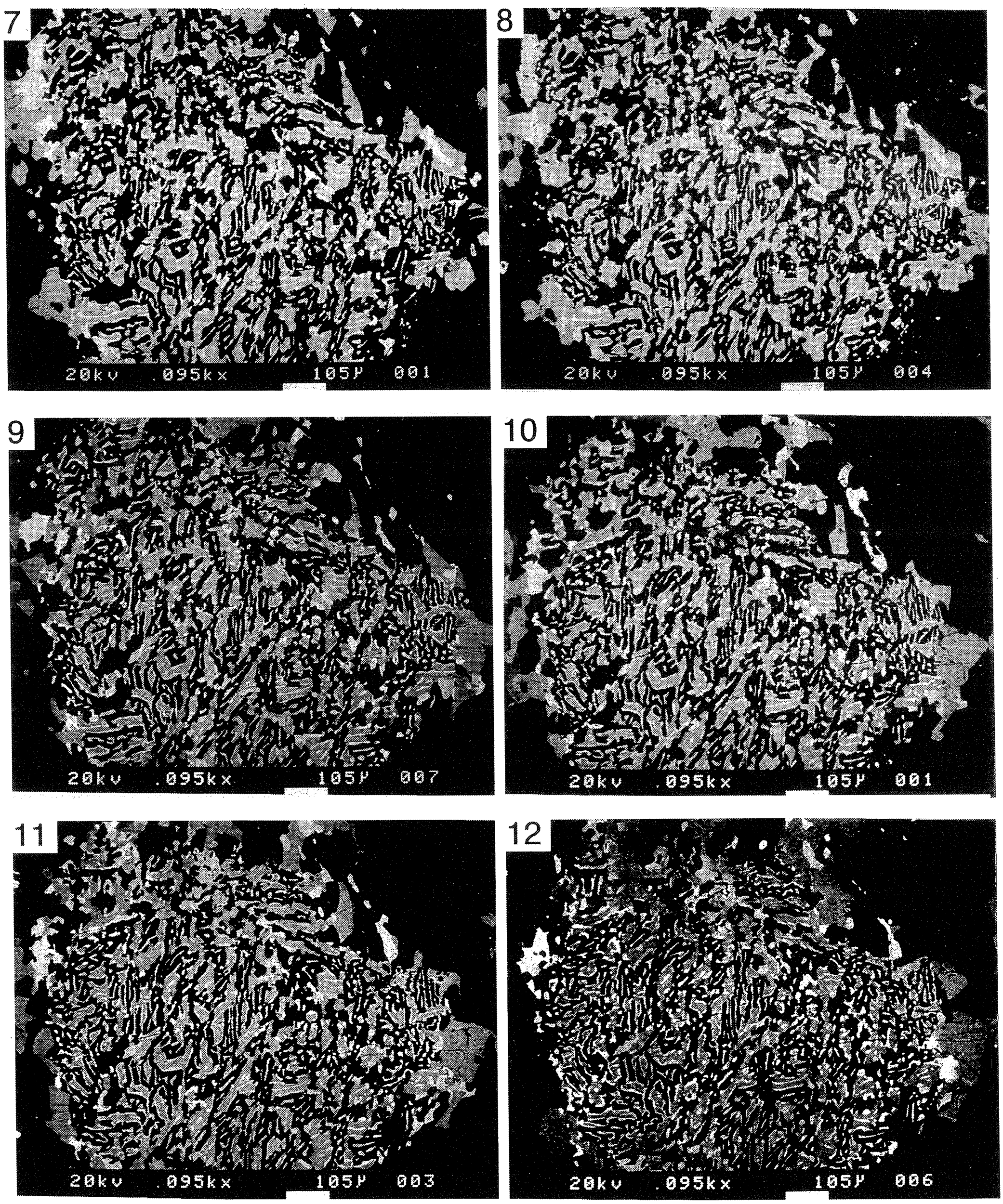

Plate III. (continued)

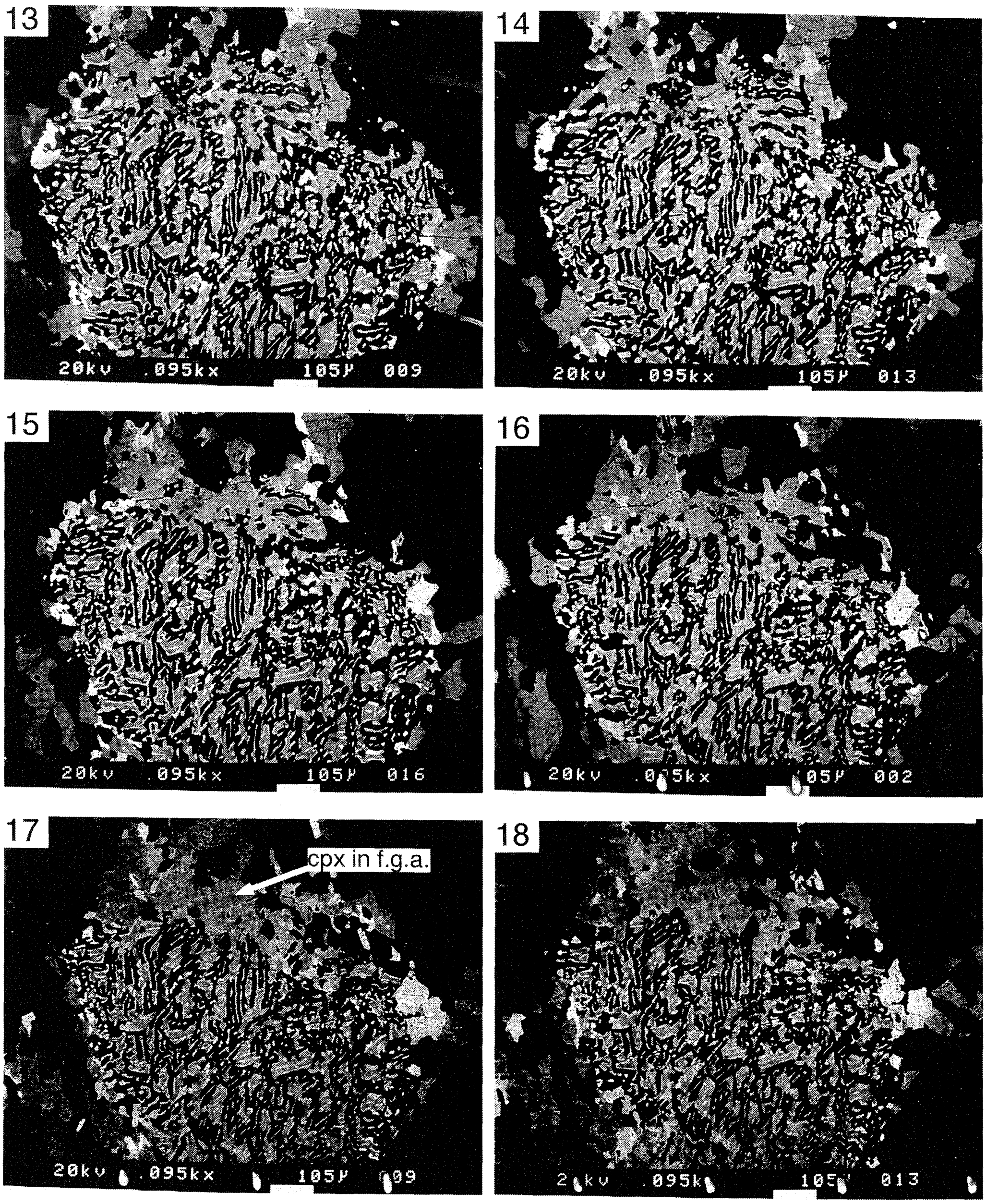

Plate III. (continued)