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Garnets in a Biotite Schist from Southwestern Part of Mikawa Plateau, Central Japan

By

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with 1 Table, 6 Text-figures and 2 Plates

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Abstract: The garnets in the analysed biotite schist consist of two types, euhedral garnets showing equiaxial euhedral shape and anhedral garnets showing ellipsoidal shape whose longest axes are oriented parallel to the schistosity. The euhedral garnets have inclusion-rich radial zones separated by inclusion-poor sectors (or sectors of clear garnet) which are oriented along the rational crystallographic directions, while the ellipsoidal garnets have homogeneously distributed inclusions which are oriented parallel to the schistosity in their matrix. The euhedral garnets are rarely included in the ellipsoidal garnets, suggesting that the latter postdates the former. Antipathetic relation in zonal variation between MnO and FeO are found in the garnets of both types. In the euhedral garnets normal zoning and reverse zoning develop in the cores and outermost margins respectively, while in the ellipsoidal garnets zonal variation (reverse zoning) developes only in the outermost margins. It has been assumed that, during the phase of appearance of the ellipsoidal garnets, their nucleation and growth occurred independently upon the pre-existing euhedral garnets and the overgrowth of the latter hardly occurred and that the appearance of the ellipsoidal garnets began during the phase of growth of the parts of euhedral garnets at which (=near the rim) MnO is minimum.

Contents

I. Introduction

The succession of metamorphic phases in regional metamorphic belt can be understood on the basis of analysis of microtextures of metamorphic minerals employing deformation-structures as time-markers in dating their appearance. Seo and Hara (1980) have discussed by this technique the progress of metamorphism of biotite schists in Southwestern part of Mikawa Plateau, Central Japan, which is placed in the andalusite zone of the Ryoke metamorphic belt. And they have clarified that the biotite schists sufferred deformations in three phases and metamorphisms of two different types: the metamorphism of the one type in which muscovite did not appear occurred under static condition during the intermediate phase between the deformation of the first phase and that of the second phase, and the metamorphism of the other type in which muscovite appeared occurred during the deformation of the third phase. In this paper the authors describe microtexture and zonal variation of chemical composition of garnets in a biotite schist collected from an outcrop (Miyazaki) in the andalusite zone of Southwestern part of Mikawa Plateau and discuss pattern of growth of the garnets through the processes of the metamorphisms of two types.

II. ANALYSIS OF MICROTEXTURE AND CHEMICAL ZONING OF GARNETS

The biotite schist, in which garnets are described in this paper, consists mainly of biotite, muscovite, quartz, plagioclase, garnet and opaque mineral. Three groups of biotite flakes (A-biotite, B-biotite and C-biotite), which have been described in the biotite schists of the andalusite zone of this district by SEO and HARA (1980) as is of different generation from each other, are also found in the biotite schist.

The biotite schist is macroscopically characterized by distinct schistosity (S) in a single set and by a weak lineation (L). The schistosity S is quite even but not folded within the analysed specimen. The microtextural characteristics of the biotite schist is identical with that of the biotite schists described by SEO and HARA (1980). And, from microtexture of biotite flakes, it can be pointed out that the development of the schistosity in the former is essentially the same as that of the latter. The schistosity development in those biotite schists is re-explained in Table 1.

TABLE 1. DEFORMATION HISTORY OF BIOTITE SCHISTS OF SOUTHWESTERN PART OF MIKAWA PLATEAU, CENTRAL JAPAN (SEO & HARA, 1980)

Phase	Event
1st	Deformation related to formation of the schistosity of the first phase (=initial S_1) which is recognized as S_1 in A-biotite flakes at present.
2nd	Appearance of A-biotite flakes (=inclusion-rich cores) under static condition=mimetic recrystallization of A-biotite flakes on initial S_1.
3rd (S-deformation)	Intracrystalline slip deformation of A-biotite flakes under compression parallel to initial S_1, associating formation of small recrystallized biotite flakes (C-biotite flakes) in them.
4th (P-deformation)	Deformation related to formation of the schistosity of the second phase (=S)=formation of elongate platelets of A-biotite dimensionally preferentially oriented parallel to S, which is related to its pressure solution under compression normal to S but not to its intracrystalline slip deformation, associating formation of inclusion-free mantles, and appearance of B-biotite and muscovite flakes showing preferred lattice and dimensional orientation parallel to S.

The garnets in the biotite schist contain minerals of other species as inclusions and are porphyroblastic. They can be divided into two types with reference to their shape, euhedral garnets and ellipsoidal garnets (Plates 2 and 3). Fig. 1 illustrates degree of elongation [=length of the longest axis (A)/length of its normal (B)] for the granets of both

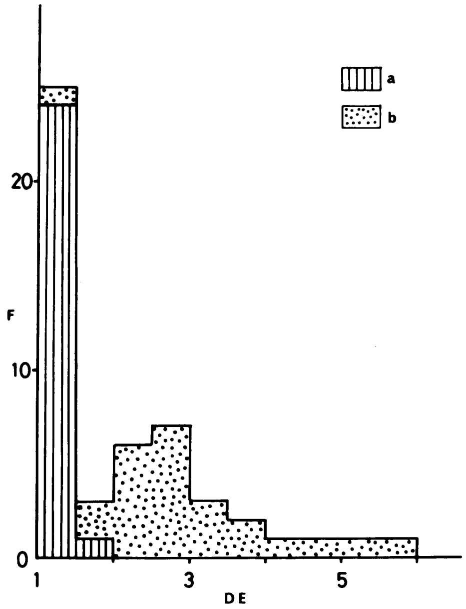

Fig. 1. Diagram showing the degree of elongation (DE) of the garnets.

a: data for the euhedral garnets.
b: data for the ellipsoidal granets.
F: Frequency is given by number of grain.

types as measured on thin section normal to L. The euhedral garnets show euhedral shape and are approximately equiaxial with the elongation degree of 1.13 in average value, while the ellipsoidal garnets are strongly elongated with the elongation degree between 1.4 and 5.9 (2.9 in average value). The ellipsoidal garnets show lens-like shape but are not euhedral. And they are preferentially oriented with their longest axes parallel to S. The dimensional fabric of the ellipsoidal garnets is consistent in pattern with that of biotite flakes (A-biotite and B-biotite) (Seo and Hara, 1980). The grain boundaries of the ellipsoidal garnets are serrated, unlike the case of the euhedral garnets which can commonly be drawn as sharp straight boundaries, (Plates 2 and 3). Fig. 2 and 3 illustrates size distribution of the garnets of both types in which the size is given as $\sqrt{AB}$: The ellipsoidal garnets are much larger in average size than the euhedral garnets.

The garnets of both types can be also distinguished from each other with reference to orientation pattern of inclusion minerals (Plates 2 and 3). In the ellipsoidal garnets inclusion minerals are uniformly distributed and show preferred dimensional orientation defining a single schistosity (S_I) (Plate 3). The schistosity S_I is commonly oriented parallel to S. While inclusion minerals in the euhedral garnets distribute heterogeneously, forming inclusion-rich radial zones separated by inclusion-poor sectors (or sectors of clear garnet), (Plate 2). The inclusion-rich radial zones are converging towards the center of grain. The directions of the radial zones coincide with those of the crystallographic edges of the euhedral garnets, showing that they are parallel to the rational crystallographic directions. Such the orientation pattern of inclusions in the euhedral garnets is identical with that in garnets described by Harker (1950) and Rast and Sturt (1957).

The ellipsoidal garnets contain rarely some euhedral garnets as inclusions, as shown in Fig. 4 and Plate 3–e. It is therefore clear that the former postdates the latter. For garnets described by Rast and Sturt (1957), inclusion-bearing radial zones develop in

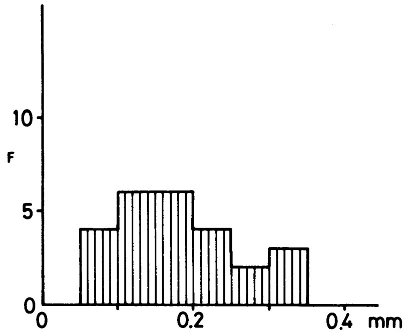

FIG. 2. Diagram showing the size distribution of the euhedral garnets.

F: Frequency is given by number of grain.

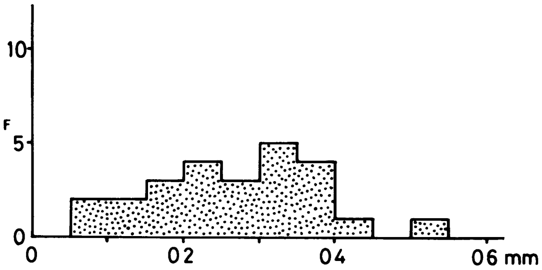

FIG. 3. Diagram showing the size distribution of the ellipsoidal garnets.

F: Frequency is given by number of grain.

their inner parts, while their outer parts have homogeneously distributed inclusions which show an S-shaped trend. For the present specimen, however, the euhedral garnets with inclusion-rich radial zones are not always associated with outer parts having homogeneously distributed inclusions. But the ellipsoidal garnets which contain rarely some euhedral garnets as inclusions have homogeneously distributed inclusions which form the schistosity S_i parallel to S. During the phase of appearance of the ellipsoidal garnets, namely, their nucleation and growth appear to have occurred independently upon the pre-existing euhedral garnets and the overgrowth of the latter appears to have hardly occurred. This point would be also examined on the basis of analysis of zonal variation of chemical elements in the garnets of both types.

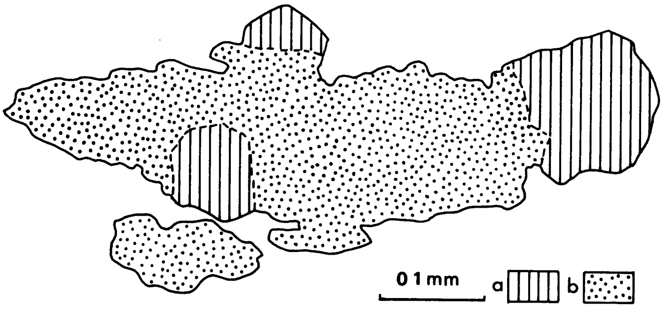

FIG. 4. Schematic sketch of an ellipsoidal garnet including euhedral garnets (which is shown in Plate 3–e).

a: euhedral garnet.

b: ellipsoidal garnet.

Microprobe traces for the euhedral garnets and ellipsoidal garnets (which do not contain euhedral garnets as inclusions) are respectively illustrated by Figs. 5 and 6. Antipathetic relation in zonal variation between MnO and FeO can be clearly described for the garnets of both types. In the euhedral garnets (Fig. 5), MnO is maximum at the core and rim of grain and minimum near the rim. The zonal variation of MnO (and other elements) is rather smooth, though the pattern of reverse zoning near-at the rim (=the outermost margin) is sharp. While, in the ellipsoidal garnets (Fig. 6), MnO is approximately constant throughout the whole part of grain except for the rim at which MnO is maximum. The pattern of reverse zoning at the outermost margin is sharp and comparable with that for the euhedral garnets. The normal zoning which develops at the cores of the euhedral garnets is not seen in the ellipsoidal granets. As mentioned in the preceding page, the euhedral garnets are rarely included in the ellipsoidal garnets (Fig. 4 and Plate 3–e), showing that the latter postdates the former. Thus, it may be assumed that the ellipsoidal garnets were nucleated and grown during the phase of growth of the parts of euhedral garnets at which MnO is minimum. The reverse zoning at the outermost margins of the garnets of both types would be identical with that of the garnets in the Ryoke metamorphic rocks described by ONO (1976, 77). ONO said that the reverse zoning may be formed during cooling period of the metamorphic belt.

The formation of garnets with inclusion-rich radial zones would generally be understood in RAST's (1975, p. 85–86) terms, "it seems reasonable to accept SEAGER's (1953) suggestion that such radial zones represent directions of rapid growth of the crystal. ......The skeltal crystal thus produced then grows through layers originating by slower growth but between the dendrites." RAST and STURT (1957, p. 215) explained also the growth of garnets with homogeneously distributed inclusions as follows, "in the outer zone, the more or less uniform distribution of inclusions implies that the velocity of growth was generally high enough to ensure the preservation of the inclusions. Since the inclusions in the outer zone show an S-shaped trend, the growth of the mineral must have proceeded under dynamic condition happening simultaneously with rotation of the garnet. Thus the dynamic factor of deformation increases the velocity of growth to such an extent that the purely crystallographic effects, seen in the inner zone of the mineral, are completely overshadowed." This explanation would be also valid for the appearance of the ellipsoidal garnets in the present specimen. Their ellipsoidal shape clearly indicates that their growth has proceeded under deformation condition. From their dimensional orientation and S_1 orientation, the deformation concerned would be regarded as flattening under the maximum compression normal to S without rotation. SEO and HARA (1980) have clarified that the biotite schists of the andalusite zone of this district sufferred deformations in three phases and main metamorphisms in two phases (see Table 1): The metamorphism of the earlier phase occurred under static condition during the intermediate phase between the deformation of the first phase and that of the second phase, and the metamorphism of the later phase occurred during the deformation of the third phase which occurred under the maximum compression normal to S without rotation. The deformation during the phase of appearance of the ellipsoidal garnets can be correlated with that of the third phase. As mentioned in the preceding page, the euhedral garnets predate the ellipsoidal garnets. It seems probable to assume that the shape of the euhedral garnets implies that their growth has proceeded under static condition, unlike the case of the ellipsoidal garnets, and therefore that the euhedral garnets appeared during the metamorphism of the earlier phase. When A-biotite flakes contain garnets as inclusions, the garnets are commonly equiaxial and approximately euhedral. A-biotite flakes appeared under static condition during the metamorphism of the earlier phase (SEO and HARA, 1980). The garnets in A-biotite flakes would be of the same generation

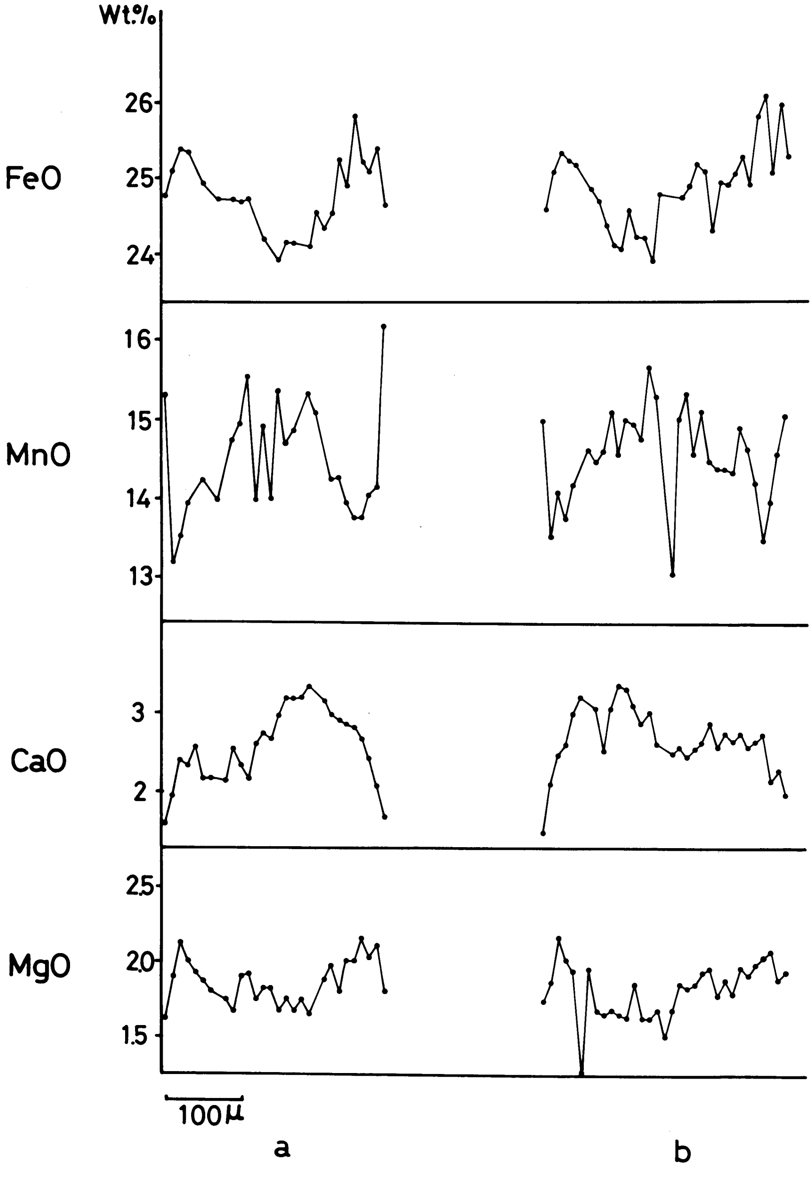

FIG. 5. Microprobe traces across an euhedral garnet.

a: profile parallel to S.

b: profile normal to S.

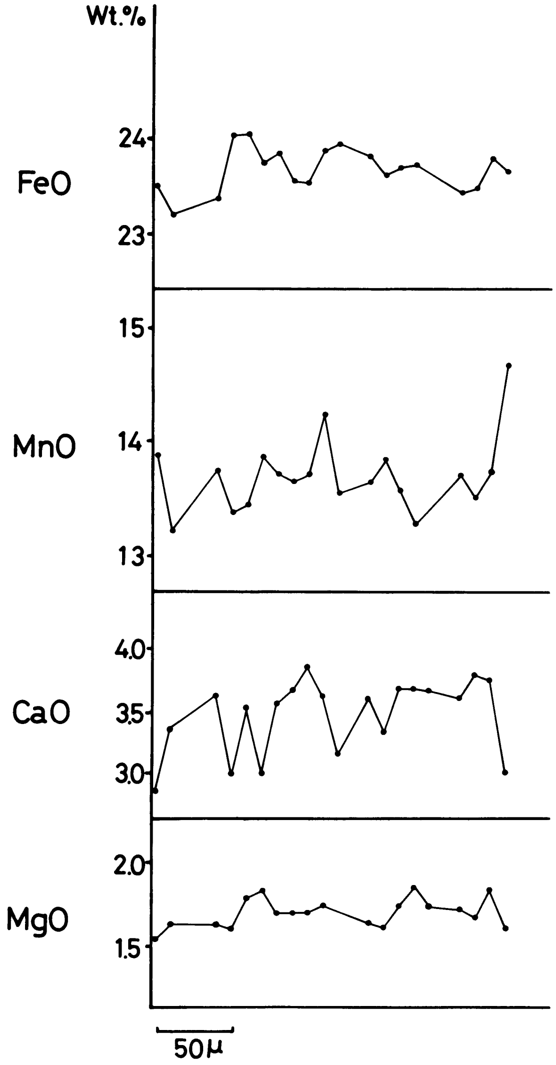

Fig. 6. Microprobe traces across an ellipsoidal garnet. The data is a profile parallel ot its longest axis.

as the euhedral garnets.

The euhedral garnets and ellipsoidal garnets appear to distribute approximately randomly within the specimen (thin section). However, detailed observation indicates that modal values of micas vary from place to place within a thin section and that the euhedral garnets tend to occur in mica-rich parts (about 54 per cent for micas) and the ellipsoidal garnets in mica-poor parts (about 23 per cent for micas). As seen in Plates 2 and 3, the euhedral garnets are commonly mainly surrounded by mica flakes (B-biotite and muscovite) which appeared during the metamorphism of the later phase (cf. Seo and Hara, 1980), while main constituent minerals surrounding the ellipsoidal garnets are quartz and plagioclase. Such a difference in environment between the euhedral garnets and the ellipsoidal garnets may be responsible for the phenomenon that, during the phase of appearance of the latter, the overgrowth of the former hardly occurred.

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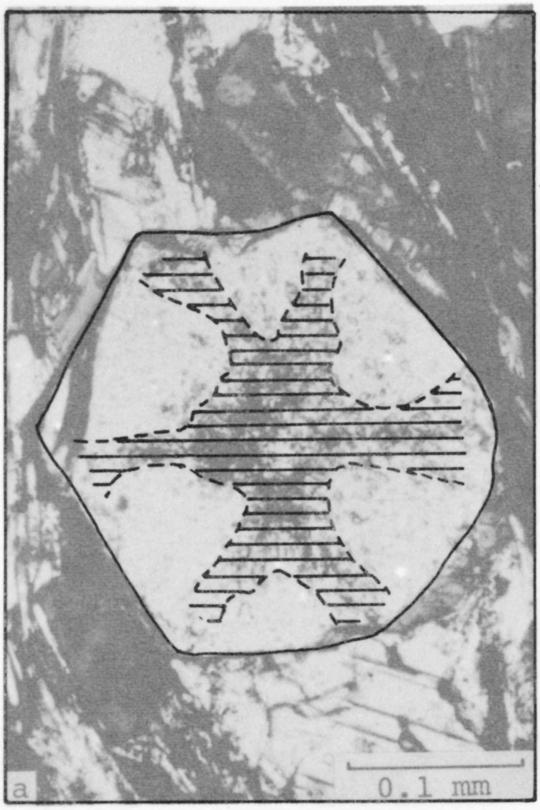
EXPLANATION OF PLATE 2

Photomicrographs of euhedral garnets in the biotite schist from Miyazaki, Mikawa Plateau, Central Japan.

EXPLANATION OF PLATE 3

Photomicrographs of ellipsoidal garnets in the biotite schist from Miyazaki, Mikawa Plateau, Central Japan.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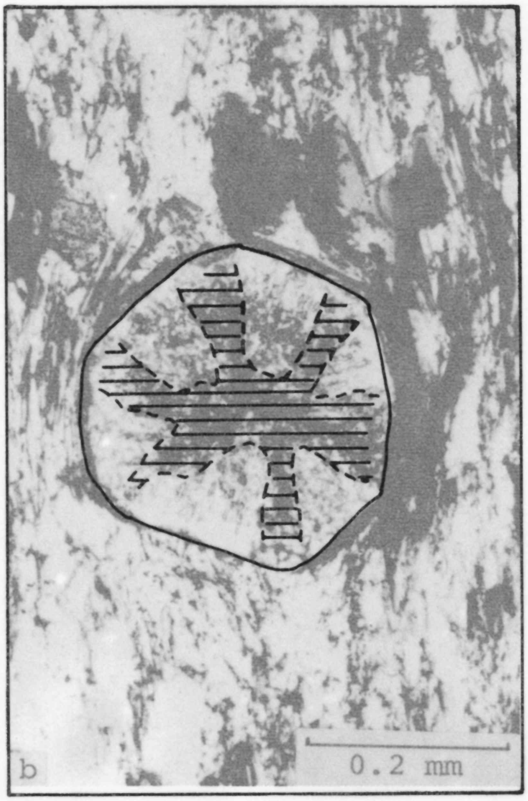
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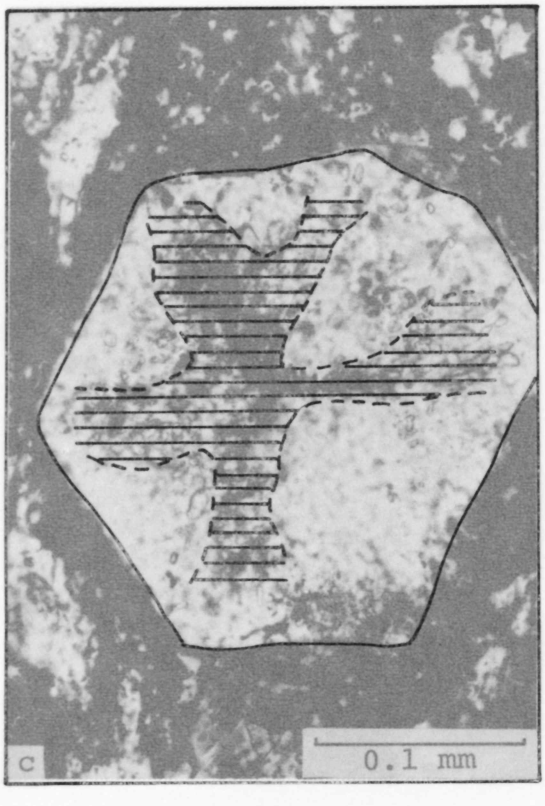
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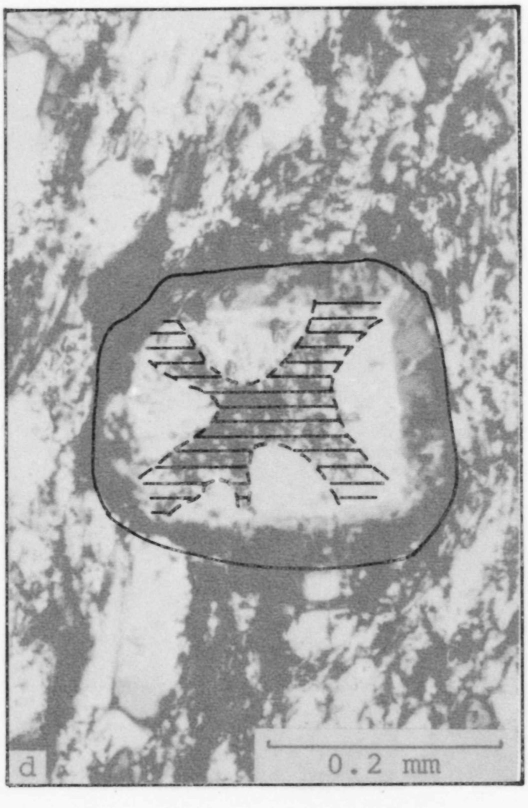
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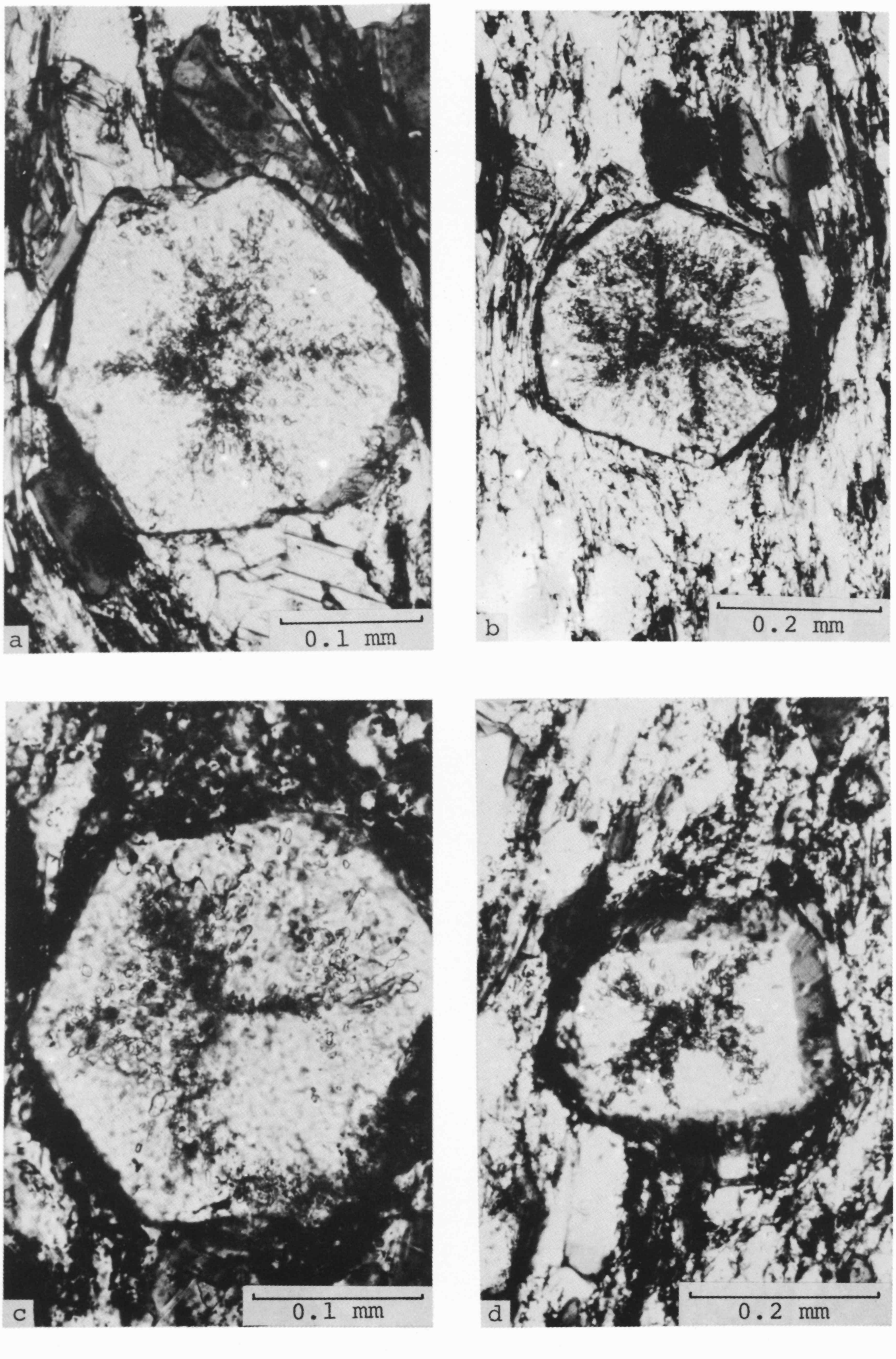
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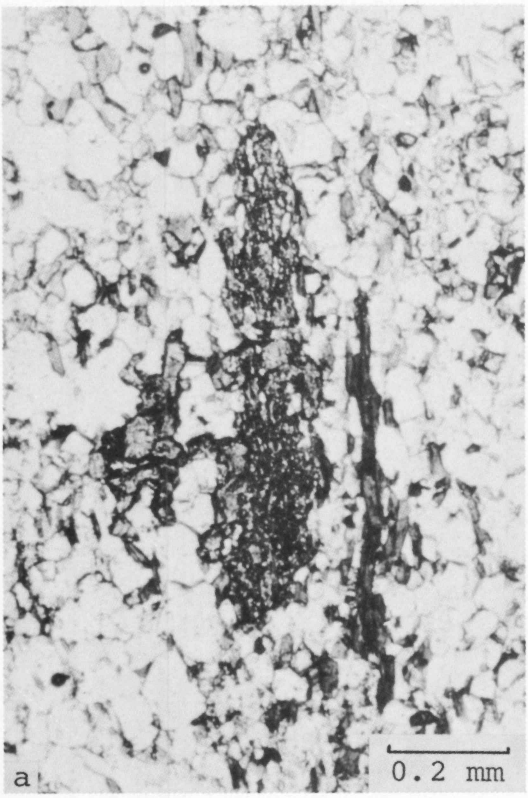
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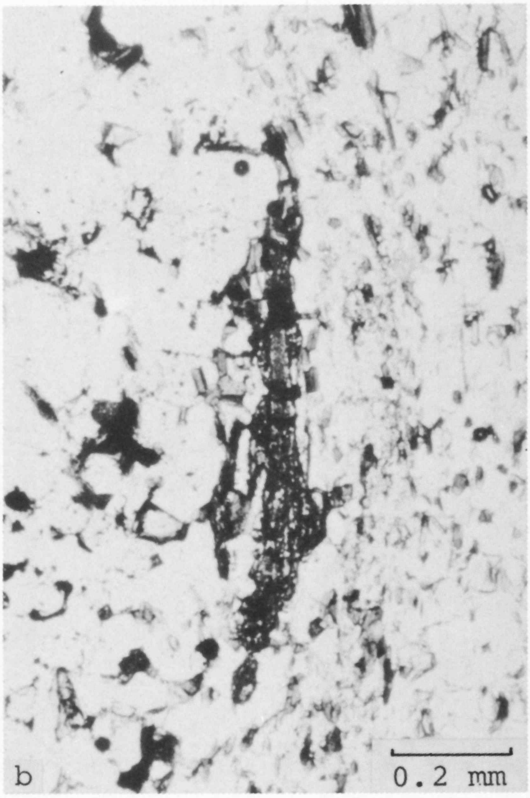
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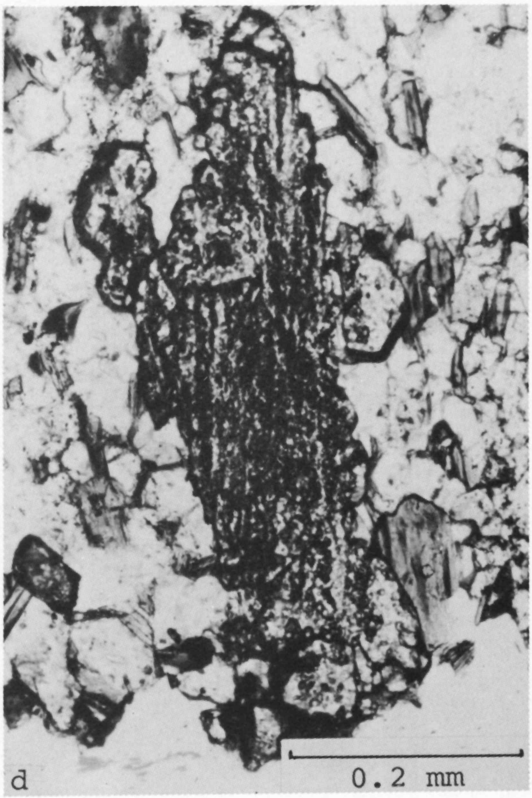
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