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Discontinuously Zoned Garnet in Sambagawa Schist from Central Shikoku, Japan

By

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with 7 Text-figures

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Abstract: The garnets in the Sambagawa siliceous pelitic schist from Tomisato, Central Shikoku, Japan, which have been described in this paper, belong to the type of reverse-zoned garnet. From zoning profiles for MnO and FeO and electron beam scanning images, individual garnet grains appear to be divided into four zones, core, intermediate zone, mantle and reverse zone in the rim. And the chemical composition changes discontinuously by about 9% for MnO between the outer part of the core (=ca. 32% for MnO) and the inner part of the intermediate zone and by about 7.2–16.5% for MnO between the outer part of the intermediate zone (=ca. 19.5–10.1% for MnO) and the inner part of the mantle. The garnets in the present specimen, therefore, will be newly designated as discontinuously zoned garnet.

Contents

I. Introduction

It has been clarified by some authors (e.g. Banno, 1965; Banno and Kurata, 1972; Higashino, 1975; Itaya, 1978) that garnets in the Sambagawa schists of Central Shikoku, Japan, show commonly zonation of chemical composition, in which the MnO content decreases from their central part to their rim, though it is frequently minimum near the rim as reverse-zoned garnet. Such zonation of chemical composition in garnets in the Sambagawa schists of Central Shikoku appears to contain also its discontinuous variation. It appears to be common, though not for all of them. This paper describes garnets of this type, discontinuously zoned garnets, in siliceous pelitic schist, which was collected from an outcrop in the biotite zone [=Zone C of Kurata and Banno (1974) (cf. Higashino *et al.*, 1977)] of the River Saruta of Tomisato, Central Shikoku, Japan, clarifying nature of discontinuous variation of chemical composition.

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II. Description and Discussion of Zoning Pattern of Chemical Composition

The siliceous pelitic schist in which the chemical zonation of garnets is examined in this paper is strongly folded, showing development of axial plane schistosity (S_2) and lineation (L_2) which both are defined by preferred dimensional orientation of its constituent minerals. L_2 is parallel to the fold axis and oriented in a direction of North-South (cf. Hara *et al.*, 1980). The main constituent minerals are quartz, plagioclase (porphyroblast) biotite, muscovite, chlorite, garnet and graphite. Though many of garnet grains in the schist show euhedral-like shape, they are commonly elongated to some extent in a direction parallel to S_2.

On the thin sections parallel to L_2 and normal to S_2 has been analysed zoning pattern of chemical composition for 50 garnet grains by a three-channel JEOL X-ray microprobe analyser (JXA-5A) (EPMA) with the beam diameter of 2–3 μm, 3 sec time constant and driving speeds of specimen in 10 μm, 20 μm and 50 μm/min. As measured along the line running through the position of the maximum value of MnO content and parallel to S_2, two end types and their intermediate types of zoning profiles for MnO in garnets have been found. Fig. 1 illustrates the two end types, Type I and Type II, and one of the intermediate types. They all are of reverse-zoned garnet.

The zoning pattern of Type I would be explained from profile for MnO shown in Fig. 1–a: The six zones can be divided in individual profiles as shown in Fig. 2, core, sharp zone I, intermediate zone, sharp zone II, mantle and reverse zone. The core is a zone with small volume, which is commonly placed near the center of grain and in which the MnO content is larger than ca. 32%. The sharp zone I is a zone just outside the core, which corresponds to the span on profiles for MnO from ca. 32% to ca. 23% and within which the profiles for MnO are shown as straight, though, strictly speaking, nearly straight, lines. The average gradient for individual "straight" profile lines has been measured. It is between 88.6° and 86°, as measured on profiles for which the MnO content has been measured by the beam diameter of 2–3 μm, 3 sec time constant and driving speed of 50 μm/min. and the change of 1% of MnO content is given by 7.37 mm (Fig. 3). The intermediate zone is a zone just outside the sharp zone I, in which the MnO content decreases from ca. 23% to a value between 19.5% and 10.1% showing growth of garnet in large volume (e.g. Fig. 1). The sharp zone II is a zone just outside the intermediate zone, which is placed at the span of profiles for MnO from a value between 19.5% and 10.1% to a value between 5.3% and 1.7% and within which the profiles for MnO are shown as straight, though, strictly speaking, nearly straight, lines with average gradient between 88.6° and 85° (Fig. 3). The gradient appears to increase with increase of the width of the span. The pattern of variation of the MnO content in the sharp zone II is similar to that in the sharp zone I. The mantle is a zone just outside the sharp zone II in which the MnO content decreases from a value between 5.3% and 1.7% to the minimum value showing growth of granet in large volume (Fig. 1). The reverse zone is placed just outside the mantle and at the outermost part of grain. The MnO content in the zone increases by a few per cent from the minimum value in the edge of the mantle, showing that the garnets in question belong to the type of reverse-zoned garnet. The zoning pattern for FeO is the opposite to that for MnO (Fig. 1), showing clearly the six zones described above.

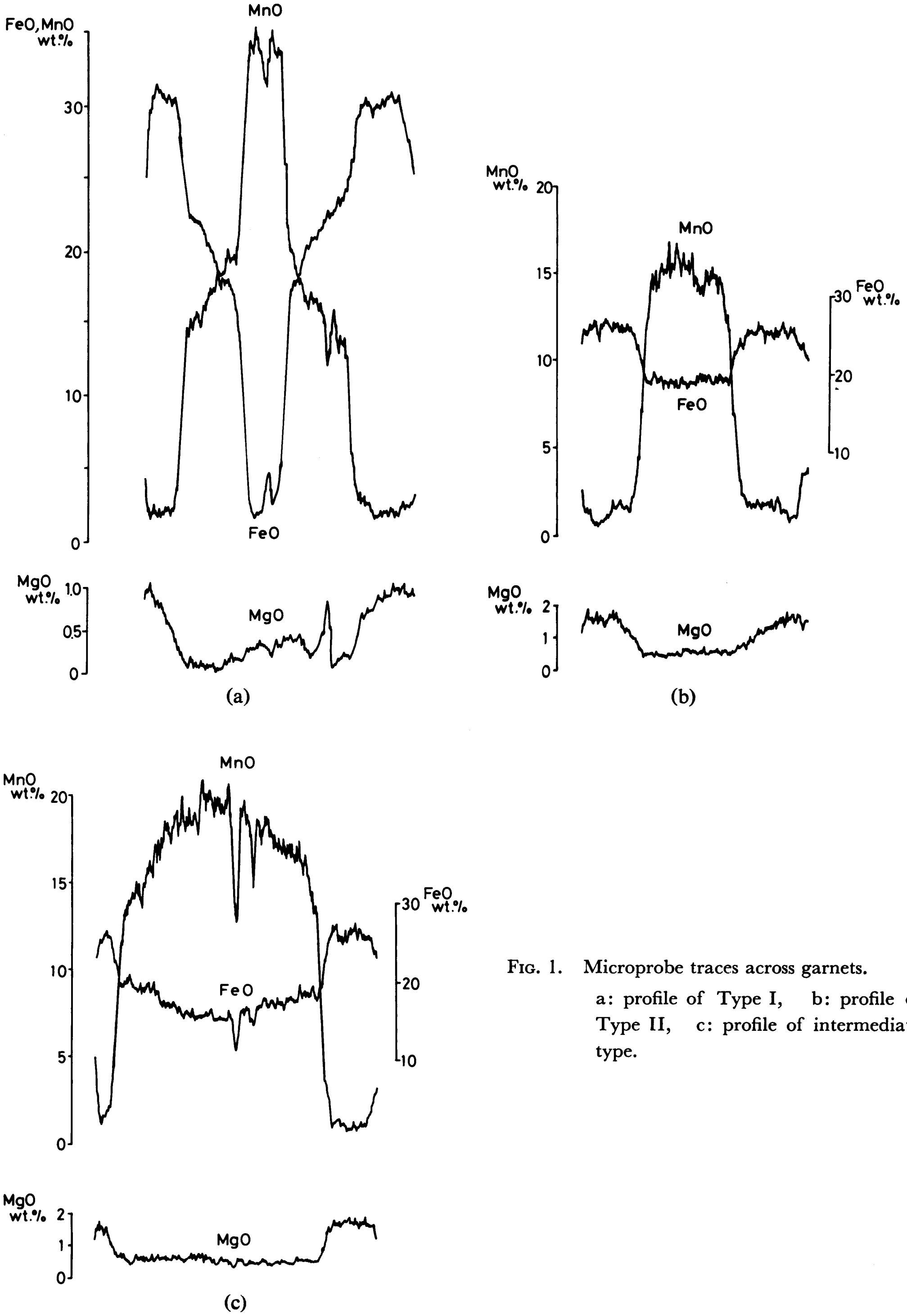

FIG. 1. Microprobe traces across garnets.
a: profile of Type I, b: profile of Type II, c: profile of intermediate type.

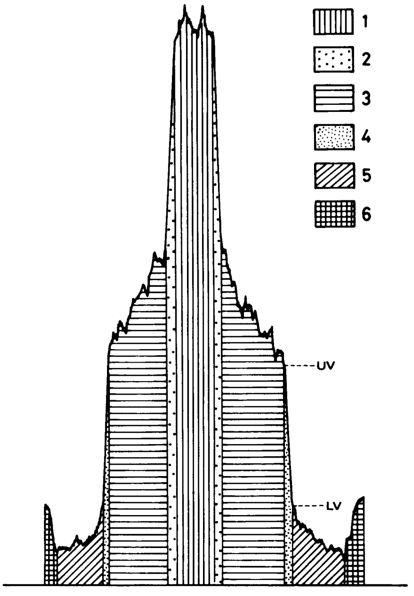

FIG. 2. Schematic diagram showing six zones on profile for MnO.

1: core, 2: sharp zone I, 3: intermediate zone, 4: sharp sone II, 5: mantle, 6: reverse zone. UV: upper end-point of "straight" profile line of sharp zone II, LV: lower end-point of "straight" profile line of sharp zone II.

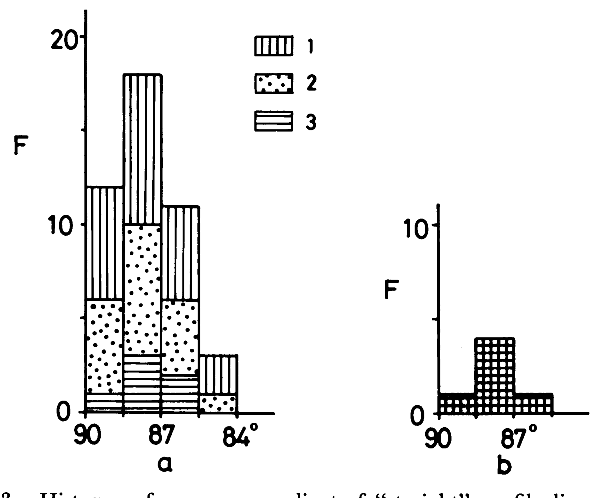

FIG. 3. Histogram for average gradient of "straight" profile line of sharp zone.

a: data for sharp zone II, 1: data from profile of Type II, 2: data from profile of intermediate type, 3: data from profile of Type I.

b: data for sharp zone I.

The zoning pattern of Type II would be explained as to be identical with a part of the profile of Type I, as is obvious in Fig. 1–b. The sharp zone II, mantle and reverse zone are clearly observed on the profiles of Type II. The uppermost horizon of the profiles of Type II, which is commonly shown by the MnO content less than 16%, appears to correspond only to the lower horizon of the intermediate zone of the profiles of Type I. While the profiles of the intermediate type are defined by remarkable development of the intermediate zone as, for example, shown in Fig. 1–c.

Fig. 4 illustrates the profiles for MnO and FeO obtained along four different parallel

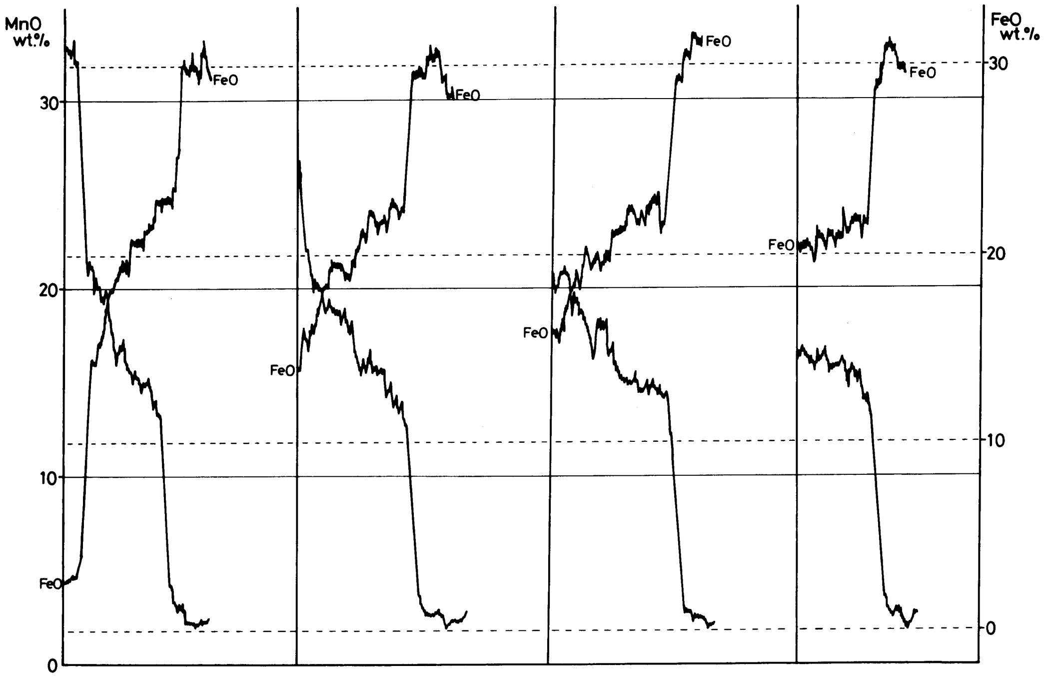

FIG. 4. Microprobe traces along four lines through a single grain.

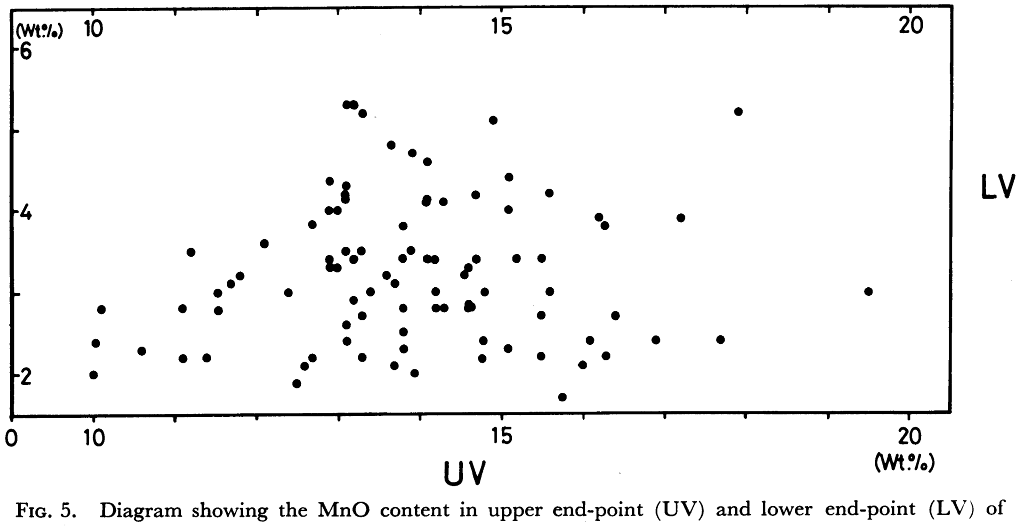

FIG. 5. Diagram showing the MnO content in upper end-point (UV) and lower end-point (LV) of "straight" profile line of sharp zone II for 50 grains.

lines cutting across a garnet grain showing the zoning pattern of Type I. Among the profiles are found the two end types and their intermediate types of zoning pattern. The profile along the line cutting across a point near the center of the grain is of Type I, while that from its margin is of Type II. The profiles of the intermediate type have been obtained from the part of the grain between the line for the Type I and that for the Type II.

The cross-section of a garnet grain observed on a thin section is not to run always through its core from which it began to grow. As examined on many grains in a thin section, therefore, many patterns of chemical zonation should be found. In the present specimen, however, the sharp zone II, mantle and reverse zone have clearly been observed in all of the examined grains, showing the constancy of the average gradient of the "straight" profile line for the sharp zone II (Fig. 2). This is a quite peculiar evidence. As compared the above-described patterns of chemical zonation with those previously described by some authors (e.g. BANNO, 1965; BANNO and KURATA, 1972; ITAYA, 1978), the former is clearly distinguished from the latter by the development of the sharp zone I and sharp zone II.

Fig. 5 illustrates the MnO content on both end-points [UV and LV (Fig. 3)] of the "straight" profile line in the sharp zone II for 50 garnet grains. The MnO content at the upper end-point (UV) is larger than 10% and that at the lower end-point (LV) smaller than 5.4%. The width (UV-LV) for individual "straight" profile lines, as measured by the difference in MnO content between their end-points, is larger than 7.1% and smaller than 16.6%. Figs. 6 and 7 illustrates that, even within individual grains, UV, LV and UV-LV vary in large amount from place to place.

Plate 4–a and b is electron beam scanning images (compositional images) of garnet grains of Figs. 6 and 7 respectively. Some bands are observed in the grains. Three bands of them are selectively drawn in Figs. 6 and 7. For convenience's sake, the three bands are respectively called, toward the rim, A-band, B-band and C-band. The boundaries between those bands are quite sharp and shown as a line on Plate 4–a and b. Figs. 6 and 7 illustrate the relationship between those three bands and the profiles for MnO. From profiles for MnO in those figures, it can be safely said that the C-band corresponds to both mantle and reverse zone, while the B-band and A-band belong to the intermediate zone, and that the sharp boundary between the C-band and the B-band corresponds to the

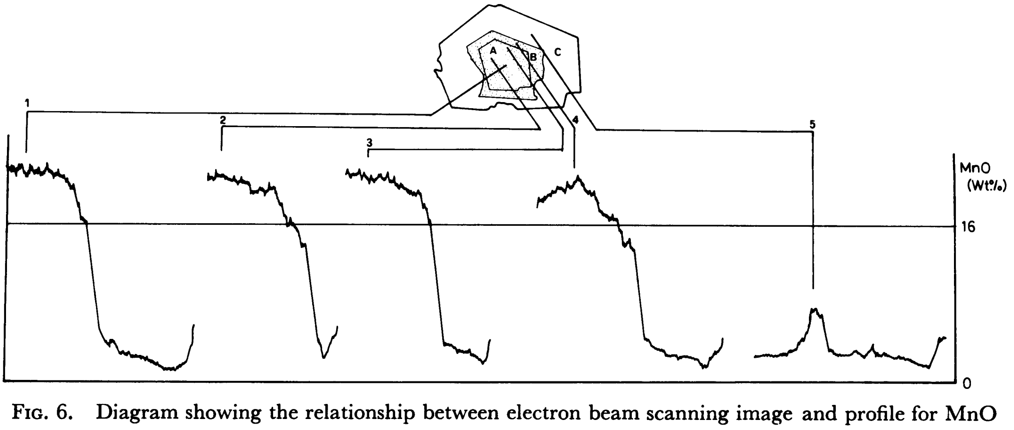

FIG. 6. Diagram showing the relationship between electron beam scanning image and profile for MnO for the grain of Plate 1–a.

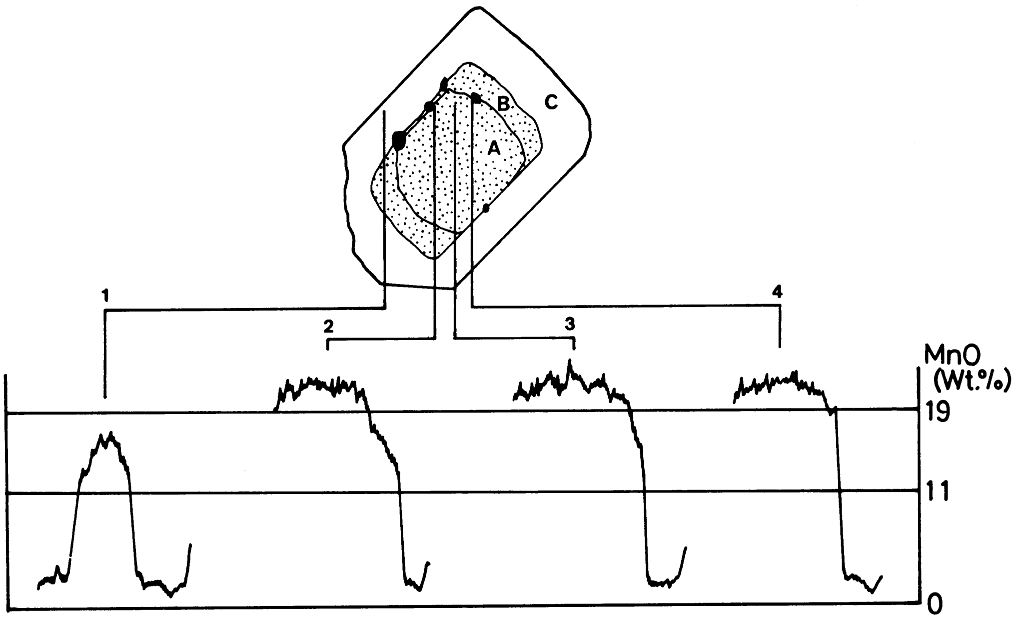

Fig. 7. Diagram showing the relationship between electron beam scanning image and profile for MnO for the grain of Plate 1–b.

sharp zone II. The development of B-band is not always uniform through grain but varies in width from place to place. UV is larger in a position, in which the C-band contacts with the inner part of the B-band, than in that in which the C-band contacts with the outer part of the B-band. Where the B-band disappears and the C-band contacts directly with the A-band, UV shows the highest value. It is therefore clear that in the sharp zone II (and also sharp zone I) the variation of MnO content (and other chemical composition) is discontinuous. The chemically discontinuous boundaries (=sharp zone II and sharp zone I) appear to be frequently non-planar surface and crystallographically irrational surface as is obvious in Plate 4. Thus, it would be said that the garnets in question do not appear to have continuously grown from core to mantle but their growth appear to have discontinuously occurred. Namely, the sharp zones I and II may correspond to the stages when the growth of garnets hardly occurred and their resorption partially occurred. (Hara et al., 1981)

As mentioned in the preceding page, the garnets in the present specimen are commonly elongated parallel to S_2. The reverse zones and outer part of the mantles are not always developed, as measured along the line normal to the grain elongation and running through the center of grain. The disappearance of the reverse zones and outer part of the mantles in a direction normal to S_2 appear to be related to pressure solution of the garnets during the development of S_2 (Hara et al., 1983).

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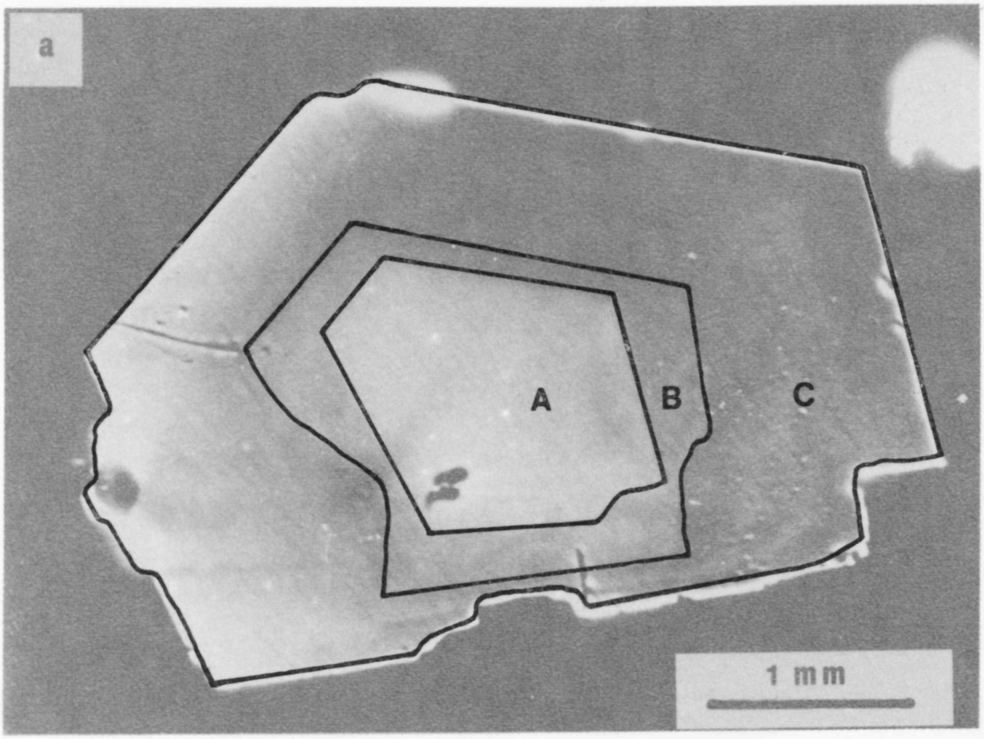
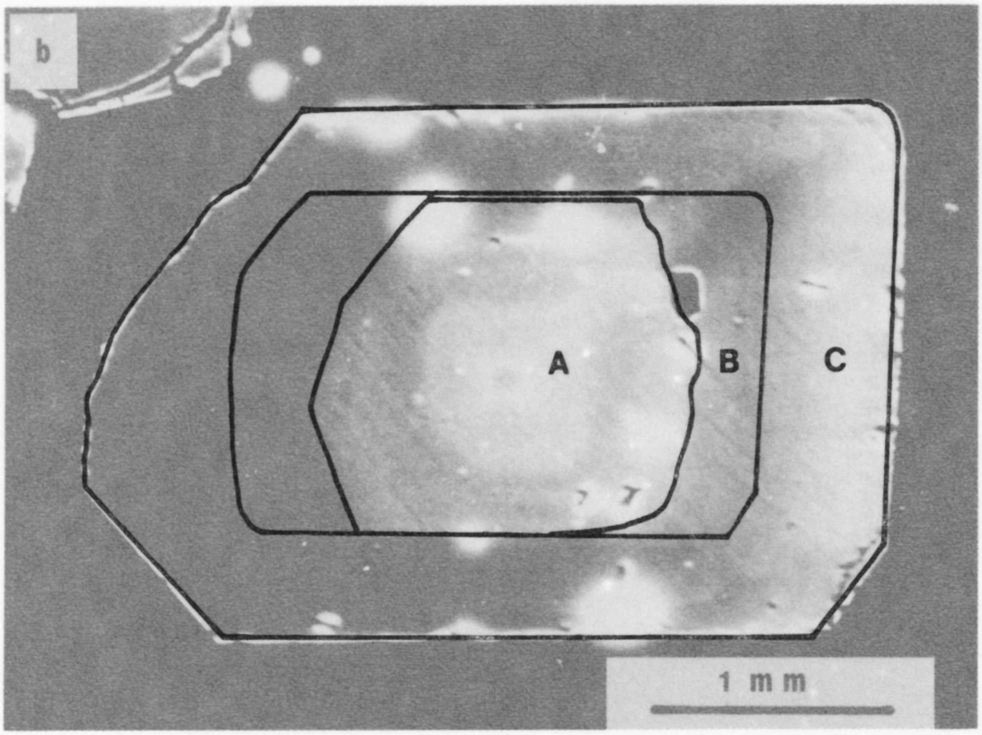
EXPLANATION OF PLATE 4

a: Electron beam scanning image of a garnet.
b: Electron beam scanning image of a garnet.


a
A
B
C
1 mm


b
A
B
C
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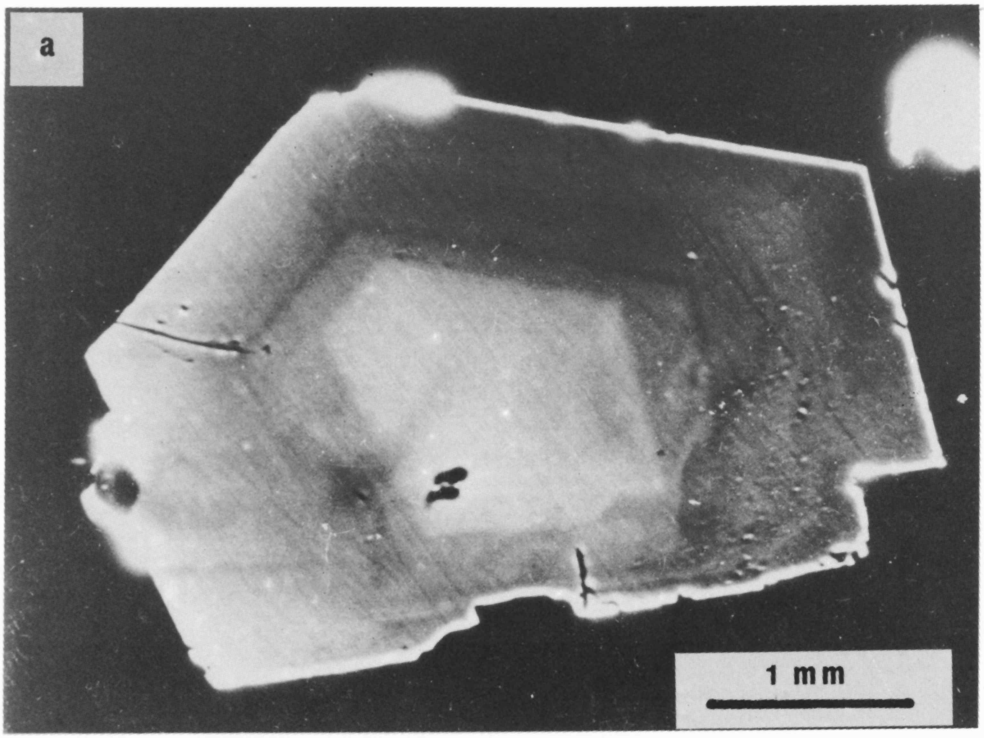
a
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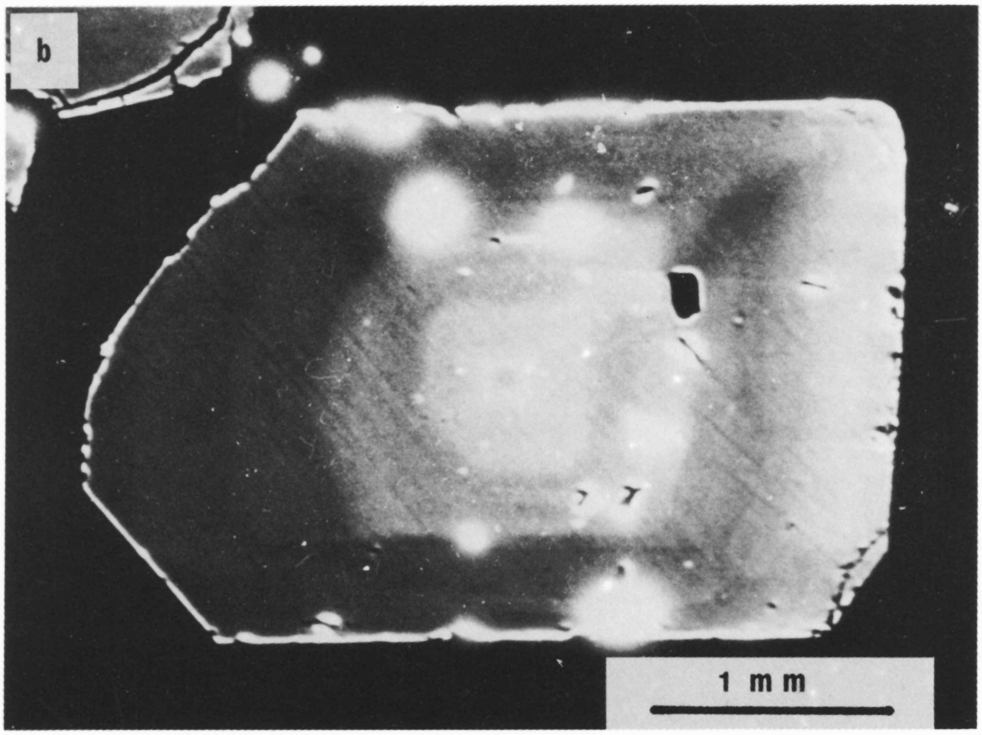
b
1 mm