

Axinite-(Mg) from Kashio, Nagano Prefecture, Japan

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Abstract Axinite from Kashio, Nagano Prefecture is composed of axinite-(Fe) and axinite-(Mg). The specimen was collected as a small bolder at Kashio-river bed. Although the origin of the bolder is not distinct, it may be derived from greenstone of Sanbagawa terrain. Axinite is pale lilac color and is in association with white band mainly composed of albite and minor calcite and datolite. Axinite-(Mg) mole is in the range of approximately 58% to 23%. An electron microprobe analysis for the most Mg-rich area corresponding to axinite-(Mg) component gave SiO₂ 43.29, Al₂O₃ 18.23, FeO (as total Fe) 4.92, MnO 0.26, MgO 4.22, CaO 20.78, B₂O₃ 6.45, total 98.15 wt.%. The empirical formula excluding H₂O is: Ca_{2.04}(Mg_{0.58}Fe_{0.38}²⁺Mn_{0.02})_{Σ0.98}Al_{1.98}B_{1.02}Si_{3.98}O_{15.5} on the basis of O=15.5. The B contents of the present axinite vary 1.1 to 0.63 *apfu* and insufficient B is filled with Si in BO₄-tetrahedron.

Key words: axinite-(Mg), axinite-(Fe), Kashio

Introduction

Axinite-(Mg), Ca₂MgAl₂BSi₄O₁₅(OH), was described by Jobbins *et al.* (1975) from alluvium including gem stones of Tanzania. The original mineral name was magnesioaxinite, but it was re-named to axinite-(Mg) according to the guideline of the Commission on New Minerals, Nomenclature and Classification of IMA (Burke, 2008). Excluding Tanzania the localities of axinite-(Mg) are known from Australia, Austria, Russia, Slovakia, Sweden and USA (Dunn *et al.*, 1980; Anthony *et al.*, 1995; Mineral Data, 2011). They occur in skarn, hydrothermal and alpine vein rocks.

During the study on minerals from the area along Kashio river, Kashio Village, Nagano Prefecture, Japan, we have found axinite-(Mg) in axinite-albite rock.

The present paper deals with the first occurrence of axinite-(Mg) in Japan and brief discussion on the chemical composition, especially on the relationship of B and Si contents in the present axinite.

Occurrence

We collected the studied specimen as a small bolder at Kashio-river bed where various rocks belonging to Sanbagawa, Chichibu and Shimanto terrains are observed. The bolder is composed of pale lilac and pale greenish white band-like parts, and is in association with fragment of greenstone or green schist (Fig. 1). The former is aggregates of axinite and the latter is aggregates of albite with minor calcite and datolite. Although the origin of the bolder is not distinct, a few bolder including axinite are sometimes collected in this area. We think that they may be derived from greenstone body of the Sanbagawa metamorphic terrain. Axinite occurs as anhedral crystals less than 1 mm length. Under the microscope the axinite is colorless and shows heterogeneous extinction in crossed polars (Fig. 2).

X-ray Crystallography

The bulk powder X-ray diffraction patterns of Kashio axinite were obtained by using a Gandolfi camera, 114.6 mm in diameter, employing Ni-fil-

tered Cu-K α radiation. Compared with those of axinite-(Mg) from Tanzania (Jobbins *et al.*, 1975) and axinite-(Fe) from France (Milton *et*



Fig. 1. Axinite (pale lilac) in association with albite, calcite and datolite (pale greenish white), and greenstone or green schist (pale to dark green). Specimen is approximately 10 \times 11 cm.

al., 1953), the patterns of the present axinite are close to those of axinite-(Fe) which includes FeO 6.02, MnO 2.99, and MgO 2.41 wt.% (Table 1).

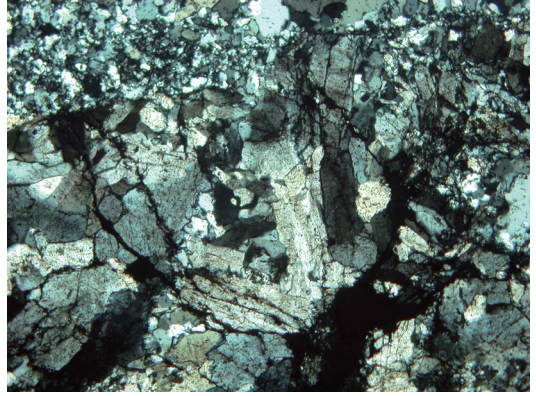


Fig. 2. Photomicrograph of the thin section of axinite. Crossed polars. Field view: approximately 1.2 \times 0.9 mm.

Table 1. Powder X-ray diffraction data for axinite-(Mg) from Tanzania (Jobbins *et al.*, 1975), axinite-(Mg) from Kashio, and axinite-(Fe) from France (Milton *et al.*, 1953).

| Axinite-(Mg) | | | | Axinite-(Fe) | | Axinite-(Mg) | | | | Axinite-(Fe) | |
|-------------------|-----|-------------------|-----|-------------------|-----|-------------------|-----|-------------------|-----|-------------------|-----|
| Tanzania | | Kashio | | France | | Tanzania | | Kashio | | France | |
| $d_{\text{obs.}}$ | I | $d_{\text{obs.}}$ | I | $d_{\text{obs.}}$ | I | $d_{\text{obs.}}$ | I | $d_{\text{obs.}}$ | I | $d_{\text{obs.}}$ | I |
| 8.95 | 15 | | | | | 2.753 | 5b | 2.76 | 10 | 2.760 | 40 |
| 6.29 | 25 | 6.31 | 25 | 6.3 | 70 | 2.633 | 5 | 2.65 | 8b | 2.667 | 40 |
| | | | | 5.87 | 5 | | | | | 2.643 | 40b |
| | | | | 5.15 | 5 | | | | | 2.575 | 50 |
| 4.96 | 4 | 4.98 | 5 | 4.99 | 10 | 2.556 | 25 | 2.56 | 20 | 2.564 | 60 |
| 4.76 | 8 | 4.79 | 5 | 4.80 | 20 | | | | | 2.526 | 30 |
| 4.51 | 2 | 4.54 | 8 | 4.53 | 30 | | | | | 2.489 | 20 |
| 3.97 | 10 | 3.99 | 6 | 3.99 | 20 | | | | | 2.474 | 20 |
| | | | | 3.80 | 30 | 2.429 | 18 | 2.44 | 15 | 2.444 | 50 |
| 3.66 | 5 | 3.68 | 8 | 3.68 | 60 | 2.415 | 18 | 2.42 | 15 | 2.424 | 50 |
| 3.44 | 65 | 3.46 | 70 | 3.46 | 80 | | | | | 2.396 | 10 |
| | | | | 3.42 | 5 | 2.352 | 8 | 2.36 | 10 | 2.363 | 50 |
| | | | | 3.39 | 5 | 2.305 | 1 | 2.32 | 3 | 2.318 | 5 |
| 3.27 | 20 | 3.29 | 20 | 3.28 | 60 | | | | | 2.292 | 10 |
| | | | | 3.23 | 5 | | | | | 2.271 | 30 |
| | | | | 3.19 | 5 | 2.252 | 1 | | | 2.250 | 30 |
| 3.14 | 65 | 3.16 | 65 | 3.16 | 90 | | | | | 2.226 | 10 |
| 3.07 | 8 | 3.08 | 12 | 3.08 | 40b | | | 2.20 | 5 | 2.206 | 30 |
| | | 3.02 | 25 | 3.02 | 50 | 2.176 | 30 | 2.19 | 10b | 2.190 | 60 |
| 2.985 | 20b | 3.00 | 23 | 2.998 | 60 | | | | | 2.179 | 20 |
| | | 2.97 | 20 | 2.968 | 50 | 2.150 | 30 | 2.16 | 30 | 2.163 | 70 |
| | | 2.93 | 6 | 2.931 | 30 | 2.121 | 4 | 2.13 | 5 | 2.134 | 30b |
| 2.877 | 20 | 2.89 | 35 | 2.874 | 30 | 2.048 | 14 | 2.06 | 8 | 2.060 | 50 |
| | | 2.84 | 12 | 2.839 | 40 | 2.028 | 14 | 2.04 | 12 | 2.040 | 50 |
| 2.796 | 100 | 2.81 | 100 | 2.812 | 100 | | | | | | |
| | | | | 2.792 | 40 | | | | | | |

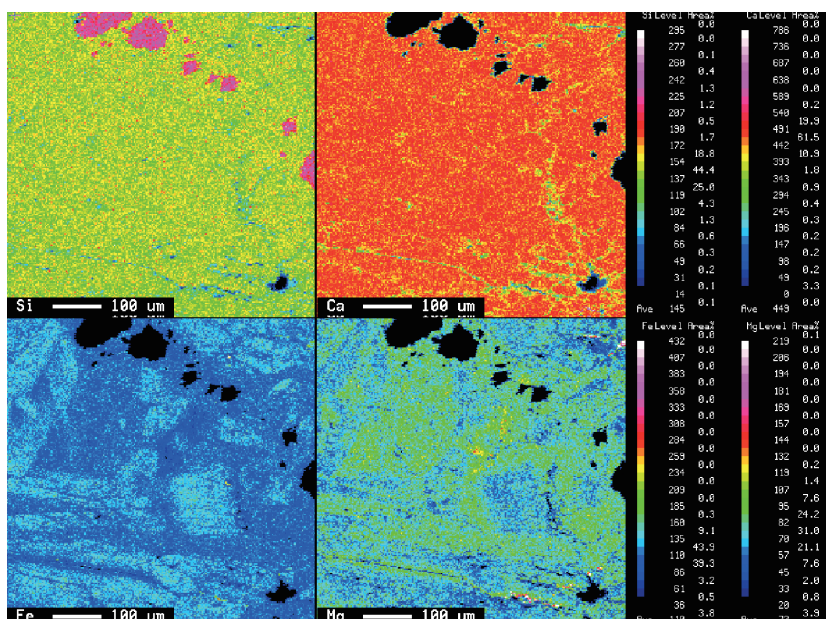


Fig. 3. Mapping of Ca–Fe–Mg–Si contents of axinite. High-Mg areas (green to yellow) correspond to axinite-(Mg).

Table 2. Representative chemical compositions of axinite-(Mg).

| | 1 | 2 | 3 | 4 | 5 |
|--------------------------------|-------|-------|-------|-------|-------|
| SiO ₂ | 44.93 | 44.64 | 42.91 | 43.29 | 44.81 |
| Al ₂ O ₃ | 18.17 | 18.21 | 18.31 | 18.23 | 17.96 |
| CaO | 20.75 | 20.88 | 20.42 | 20.78 | 20.55 |
| MgO | 3.82 | 4.13 | 3.93 | 4.22 | 3.82 |
| FeO | 5.34 | 5.79 | 5.33 | 4.92 | 5.75 |
| MnO | 0.27 | 0.10 | 0.23 | 0.26 | 0.23 |
| B ₂ O ₃ | 4.78 | 4.90 | 6.65 | 6.45 | 4.98 |
| Total | 98.06 | 98.65 | 97.78 | 98.15 | 98.10 |

atomic value calculated on the basis of O=15.5

| | | | | | |
|----|------|------|------|------|------|
| Si | 4.17 | 4.13 | 3.96 | 3.98 | 4.16 |
| Al | 1.99 | 1.98 | 1.99 | 1.98 | 1.96 |
| Ca | 2.06 | 2.07 | 2.02 | 2.05 | 2.04 |
| Mg | 0.53 | 0.57 | 0.54 | 0.58 | 0.53 |
| Fe | 0.41 | 0.45 | 0.41 | 0.38 | 0.45 |
| Mn | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 |
| B | 0.77 | 0.78 | 1.06 | 1.02 | 0.80 |

Chemical Composition

The chemical analyses of the present axinite were carried out using a WDS (JEOL 8800) (15 kV, 20 nA, 2 μm beam diameter). The present axinite is chemically inhomogeneous (Fig. 3) and the

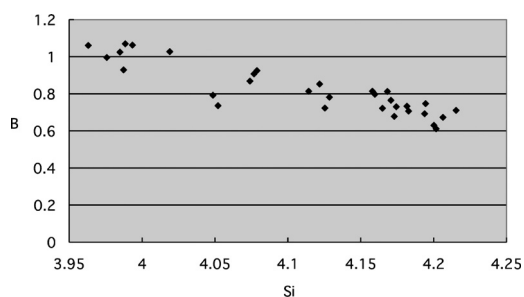


Fig. 4. B vs. Si diagram in axinite.

component of axinite-(Mg) varies 58 to 23% in mole ratio. The zoning domain of axinite-(Mg) and axinite-(Fe) has range 10 to 50 μm in width. The representative five analyses corresponding to axinite-(Mg) excluding H₂O are given in Table 2. The concentration of Mn in the present axinite is negligible small. The empirical formula of the most Mg-rich axinite in Table 2 is: Ca_{2.04}(Mg_{0.58}Fe_{0.38}Mn_{0.02})_{Σ0.98}Al_{1.98}B_{1.02}Si_{3.98}O_{15.5} on the basis of O=15.5. For comparison the chemical compositions between axinite-(Mg) from Tanzania and Kashio, and axinite-(Fe) from Kashio and Kuchisenmata (Shizuoka Prefecture, Japan) are indicated in Table 3. Kuchisenmata material

Table 3. Chemical compositions in comparison with axinite-(Mg) from Tanzania (Jobbins *et al.*, 1975) and Kashio, and axinite-(Fe) from Kashio and Kuchisenmata.

| | Axinite-(Mg) | | Axinite-(Fe) | | |
|--------------------------------|--------------|--------|--------------|--------------|-------|
| | Tanzania | Kashio | Kashio | Kuchisenmata | |
| SiO ₂ | 44.0 | 43.29 | 43.13 | 43.03 | 43.37 |
| TiO ₂ | 0.03 | 0 | 0 | 0 | 0 |
| Al ₂ O ₃ | 17.9 | 18.23 | 18.18 | 17.96 | 17.74 |
| V ₂ O ₃ | 0.13 | 0 | 0 | 0 | 0 |
| CaO | 21.7 | 20.78 | 20.25 | 20.48 | 20.50 |
| MgO | 6.9 | 4.22 | 2.58 | 2.47 | 1.77 |
| FeO | 0 | 4.92 | 7.22 | 7.87 | 8.37 |
| MnO | 0.4 | 0.26 | 0.33 | 0.51 | 0.71 |
| ZnO | 0.06 | 0 | 0 | 0 | 0 |
| K ₂ O | 0.01 | 0 | 0 | 0 | 0 |
| B ₂ O ₃ | n.d. | 6.45 | 6.70 | 5.23 | 5.95 |
| Total | 91.13 | 98.15 | 98.39 | 97.55 | 98.41 |

atomic value calculated on the basis of O=15.5

| | | | | | |
|----|------|------|------|------|------|
| Si | 4 | 3.98 | 3.99 | 4.07 | 4.06 |
| Al | 1.92 | 1.98 | 1.98 | 2.00 | 1.96 |
| Ca | 2.11 | 2.04 | 2.01 | 2.07 | 2.05 |
| Mg | 0.94 | 0.58 | 0.36 | 0.35 | 0.25 |
| Fe | 0 | 0.38 | 0.56 | 0.62 | 0.65 |
| Mn | 0.03 | 0.02 | 0.03 | 0.04 | 0.06 |
| B | | 1.02 | 1.07 | 0.85 | 0.96 |

Jobbins *et al.*, 1975

occurs in association with quartz and datolite found in greenstone body of Setogawa group, one of constituents of the Shimanto terrain.

In 30 analyses B content varies 1.1 to 0.63 *apfu*, and it is distinct that B is in inverse proportion to Si atom (Fig. 4).

Discussion

Axinite-(Mg) is still an uncommon mineral among axinite group minerals, axinite-(Fe), axinite-(Mn), axinite-(Mg), and tinzenite. But the occurrence of axinite-(Mg) may disappear behind axinite-(Fe) or other axinites in case of the present axinite-(Mg), for example. Although the bulk powder X-ray diffraction patterns of the present axinite are close to those of axinite-(Fe), the domain corresponding to axinite-(Mg) exists undoubtedly.

The relationship between B and Si contents (Fig. 4) indicates that insufficient B may be filled with Si atom in BO₄-tetrahedron.

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