

Note on rock-forming minerals in the Joetsu district, Niigata Prefecture, Japan. (12) Magnesio-arfvedsonite from the Omi district.

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ABSTRACT

Magnesio-arfvedsonite forms interstitial crystal, and aggregate of subhedral and euhedral green crystals in the melanocratic part of albitite rock in serpentinite, Kinzan valley, Omi, Niigata Prefecture, Japan. It coexisted with albite, pectolite and strontio-orthojoaquinite. Magnesio-riebeckite occurs as green, needle-shaped crystals of aggregate in garnet chlorite schist xenolith in serpentinite. Garnet is partially replaced by riebeckite and magnesio-riebeckite. magnesio-riebeckite coexists with muscovite, chlorite, plagioclase, K-feldspar and quartz. Pleochroism of magnesio-arfvedsonite is strong : X=greenish blue and Z=violet or greenish yellow.

Magnesio-arfvedsonite has the formula $(K_{0.33}Na_{0.64})_{0.97}(Na_{1.89}Ca_{0.11}Fe^{2+}_{1.22}Mg_{3.06}Fe^{3+}_{0.48}Cr_{0.02}Ti_{0.21}Al_{0.02})_7(Al_{0.01}Si_{7.99})_8O_{22}(OH)_2$. Unit-cell dimensions of magnesio-arfvedsonite are $a=9.386(12) \text{ \AA}$, $b=18.034(15) \text{ \AA}$, $c=5.305(6) \text{ \AA}$, $\beta=103.08(12)^\circ$ and $v=916.6(1.6) \text{ \AA}^3$.

KEY WORDS

Alkali-amphibole, Arfvedsonite, Eckermannite, Glaucophane, Magnesio-arfvedsonite, Magnesio-riebeckite, Omi, Richterite, Riebeckite

Introduction

Chihara(1978)reported that amphibole in ohmilite and strontio-orthojoaquinite (nunakawaite)bearing albitite is magnesio-riebeckite. He (1987) described eckermannite from Hiraiwa, Itoigawa and richterite-tremolite solid solution from Kinzan-dani, Omi, Niigata Prefecture. Sakai and Akai (1994) reported that alkali amphibole in the same albitite ($7 \times 7 \times 7 \text{ m}$) within serpentinite body on the bank of the Omi river is magnesio-arfvedsonite. However, we did not find the chemical composition and the physical properties of alkali amphibole in their literatures. Therefore, I give the chemical composition and the description on the occurrence and the physical properties of alkali-amphibole. On the basis of these data, we classify alkali amphibole according Leake's nomenclature (1968).

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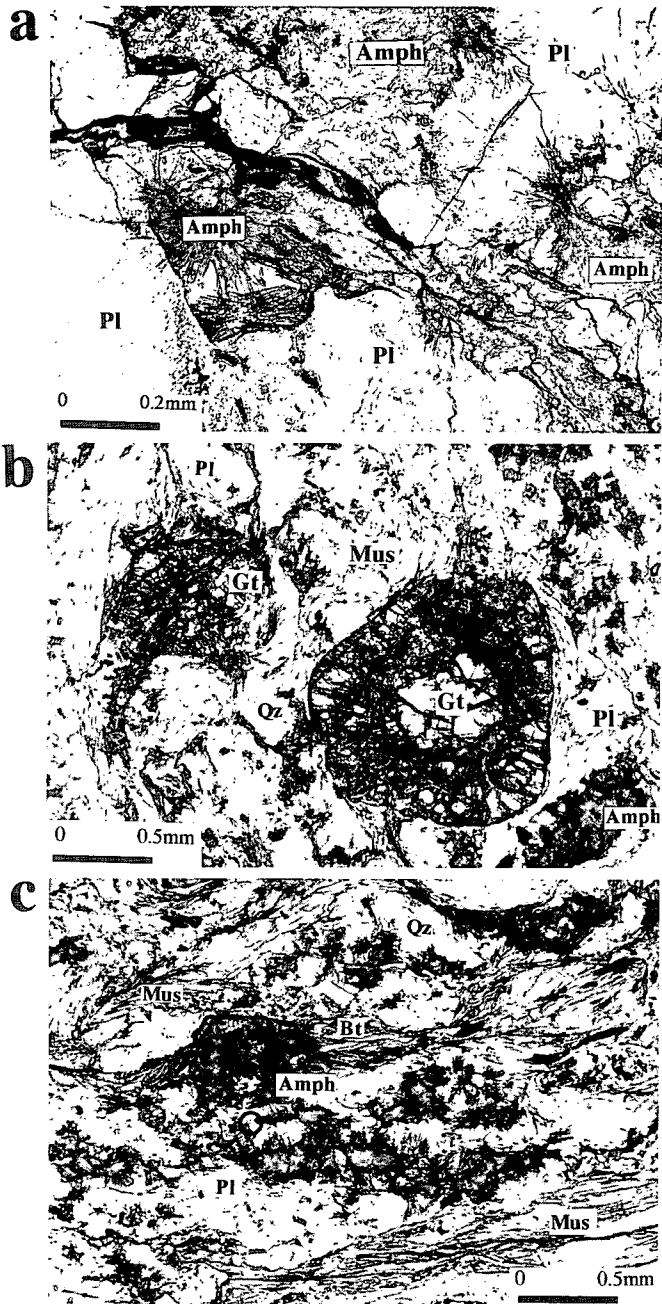


Figure 1. Photomicrograph of alkali amphibole.

a : Mg-arfvedsonite in albite b : garnet is replaced by riebeckite in garnet schist. c : Irregularly shaped aggregate of magnesio-riebeckite-riebeckite solid solution in garnet schist. abbreviation : Amph : amphibole, Bt : biotite, Gt : garnet, Mus : muscovite, Pl : plagioclase, Qz : quartz,

Occurrence

Alkali amphibole occurs in the leucosphenite bearing albitite ($1 \times 1 \times 0.5\text{m}^3$) reported by Oba (1996), and the small xenolith of garnet schist (6 cm in the length) enclaved in serpentinite. The leucosphenite bearing albitite is located on the lower part of the river for a distance of about 20m from the ohmilite and riebeckite bearing albitite reported by Chihara et al. (1978).

Fig. 1a shows the photomicrographs of alkali amphibole bearing albitite. Irregularly shaped fibrous aggregate of alkali amphibole forms in coarse albite. Alkali amphibole sometimes occurs as radiating crystal (Fig. 1a). Pleochroism of alkali amphibole is strong: X=greenish blue and Z=violet or greenish yellow. Fig. 1b shows that deformed garnet is replaced by alkali amphibole. In other part, irregular shaped aggregate of alkali amphibole coexists with muscovite, albite, K-feldspar and biotite (Fig. 1c). Pleochroism of the amphibole is strong: X=greenish blue and Z=greenish yellow.

Mineralogical data and discussion

Chemical composition: Electron microprobe analyses of the amphibole was performed using JEOL 8060 superprob at Niigata University.

The end members of alkali-amphibole according of Leake's nomenclature (1968) are as follows: glaucophane: $\text{Na}_2\text{Mg}_3\text{Al}_2\text{Si}_8\text{O}_{22}(\text{OH})_2$, ferro-glaucophane: $\text{Na}_2\text{Fe}^{2+}_3\text{Si}_8\text{O}_{22}(\text{OH})_2$, magnesio-riebeckite: $\text{Na}_2\text{Mg}_3\text{Fe}^{3+}_2\text{Si}_8\text{O}_{22}(\text{OH})_2$, riebeckite: $\text{Na}_2\text{Fe}^{2+}_3\text{Fe}^{3+}_2\text{Si}_8\text{O}_{22}(\text{OH})_2$, magnesio-arfvedsonite: $\text{NaNa}_2\text{Mg}_4\text{Fe}^{3+}\text{Si}_8\text{O}_{22}(\text{OH})_2$, arfvedsonite: $\text{NaNa}_2\text{Fe}^{2+}_4\text{Fe}^{3+}\text{Si}_8\text{O}_{22}(\text{OH})_2$, eckermannite: $\text{NaNa}_2\text{Mg}_4\text{AlSi}_8\text{O}_{22}(\text{OH})_2$, ferro-eckermannite: $\text{NaNa}_2\text{Fe}^{2+}_4\text{AlSi}_8\text{O}_{22}(\text{OH})_2$, magnesio-richterite: $\text{NaNaCaMg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$, richterite: $\text{NaNaCaFe}^{2+}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$. The selected analyses are given in Table 1 together with their structural formulae. Fe^{3+} contents are calculated using the RECOMP (Spear and Kimball, 1984). 1, 3, 4 and 5 formulae are estimated by assuming $T+M_1+M_2+M_3=13$. The formulae of Amph 1 and Amph 5 in Table 1 are $(\text{K}_{0.33}\text{Na}_{0.64})_{0.97}(\text{Na}_{1.89}\text{Ca}_{0.11}\text{Fe}^{2+}_{1.22}\text{Mg}_{3.06}\text{Fe}^{3+}_{0.48}\text{Cr}_{0.02}\text{Ti}_{0.21}\text{Al}_{0.02})_7(\text{Al}_{0.01}\text{Si}_{7.99})_8\text{O}_{22}(\text{OH})_2$, and $(\text{K}_{0.10}\text{Na}_{0.28})_{0.38}(\text{Na}_{1.63}\text{Ca}_{0.37}\text{Fe}^{2+}_{1.73}\text{Mg}_{1.77}\text{Fe}^{3+}_{1.41}\text{Mn}_{0.06}\text{Ti}_{0.03})_7(\text{Fe}^{3+}_{0.19}\text{Al}_{0.02}\text{Si}_{7.79})_8\text{O}_{22}(\text{OH})_2$.

Fig. 2 shows that amphiboles in garnet schist are plotted on the join riebeckite-richterite. On the other hand, amphiboles in albitite were plotted on arfvedsonite-rich side of the join riebeckite-arfvedsonite. Amphiboles with Na and K contents in A site > 0.5 are plotted in Fig. 3a. Amphiboles in leucosphenite bearing albitite are plotted in magnesio-arfvedsonite field, and in garnet schist are plotted on arfvedsonite. They are not eckermannite because of low Al content. If we recalculate the unit formula on the basis of total iron = Fe^{3+} (Amph 2 in Table 1), the cation sum in A site is 0.559 (2 in Table 1). This value above 0.5 suggested that alkali amphibole is magnesio-arfvedsonite. Fig. 3b

Table 1. Chemical compositions of alkali amphiboles from Omi.

| | 1 | 2 | 3 | 4 | 5 |
|--|--------|--------|--------|--------|--------|
| SiO ₂ | 55.52 | | 52.75 | 53.07 | 53.77 |
| TiO ₂ | 1.90 | | 0.44 | 0.26 | 0.31 |
| Al ₂ O ₃ | 0.14 | | 0.09 | 0.12 | 0.17 |
| Cr ₂ O ₃ | 0.19 | | 0.02 | tr. | 0.04 |
| FeO | 14.09 | | 24.53 | 27.12 | 24.61 |
| MnO | 0.01 | | 0.38 | 0.48 | 0.46 |
| MgO | 14.27 | | 8.32 | 8.10 | 8.50 |
| CaO | 0.74 | | 3.35 | 2.36 | 5.37 |
| Na ₂ O | 9.06 | | 6.50 | 6.70 | 5.21 |
| K ₂ O | 1.79 | | 0.64 | 0.52 | 0.62 |
| Total | 97.71 | | 97.02 | 98.73 | 99.05 |
| Si | 7.991 | 7.784 | 7.933 | 7.970 | 7.955 |
| Al ^{IV} | 0.009 | 0.023 | 0.016 | 0.021 | 0.030 |
| Fe ³⁺ | | 0.192 | 0.051 | 0.189 | 0.016 |
| Al ^{VI} | 0.015 | | | | |
| Ti | 0.206 | 0.200 | 0.050 | 0.029 | 0.034 |
| Cr | 0.022 | 2.021 | 0.002 | 0 | 0.005 |
| Fe ³⁺ | 0.476 | 1.460 | 0.867 | 1.407 | 0.657 |
| Mg | 3.061 | 2.982 | 1.865 | 1.772 | 1.874 |
| Fe ²⁺ | 1.220 | 0 | 2.168 | 1.733 | 2.371 |
| Mn | 0.001 | 0.001 | 0.048 | 0.060 | 0.058 |
| M ₁ -M ₃ | 5.000 | 4.664 | 5.000 | 5.000 | 5.000 |
| Ca | 0.114 | 0.111 | 0.540 | 0.371 | 0.851 |
| Na | 1.886 | 2.225 | 1.460 | 1.629 | 1.149 |
| M ₄ | 2.000 | 2.236 | 2.000 | 2.000 | 2.000 |
| Na | 0.642 | 0.238 | 0.435 | 0.278 | 0.346 |
| K | 0.329 | 0.320 | 0.123 | 0.097 | 0.117 |
| Total | 15.971 | 15.559 | 15.558 | 15.375 | 15.463 |
| Fe ²⁺ /Fe ²⁺ +Mg | 0.285 | 0 | 0.538 | 0.495 | 0.559 |
| Fe ³⁺ /Fe ²⁺ +Fe ³⁺ | 0.281 | 1 | 0.297 | 0.479 | 0.221 |
| Fe ³⁺ /Al+Fe ³⁺ | 0.967 | 0.986 | 0.983 | 0.987 | 0.957 |

1 : Magnesio-arfvedsonite, 3 : riebeckite, 4 : magnesio-riebeckite, 5 : ferro-barroisite

Table 2. The chemical compositions of bulk rocks.

| | 1 | 2 |
|--------------------------------|-------|-------|
| SiO ₂ | 63.33 | 62.86 |
| TiO ₂ | 0.13 | 0.46 |
| Al ₂ O ₃ | 13.10 | 15.38 |
| Fe ₂ O ₃ | 0.75 | 3.87 |
| MnO | 0.02 | 0.08 |
| MgO | 1.47 | 4.01 |
| CaO | 8.39 | 1.11 |
| Na ₂ O | 11.30 | 10.99 |
| K ₂ O | 0.16 | 0.42 |
| P ₂ O ₅ | 0.02 | 0.01 |
| Total | 98.67 | 99.19 |

| | ppm | |
|----|-----|------|
| Ba | 77 | 1900 |
| Co | 9 | 26 |
| Cr | 79 | 110 |
| Cu | 18 | |
| Nb | 6 | 7 |
| Ni | 68 | 91 |
| Rb | 1 | 2 |
| Sr | 824 | 2100 |
| V | 1 | |
| Y | 20 | |
| Zn | 9 | |
| Zr | 125 | 120 |

1. Melanocratic albitite from Omi, Niigata Prefecture: this study
2. Melanocratic albitite from Omi, Niigata Prefecture: Sakai and Akai (1994)

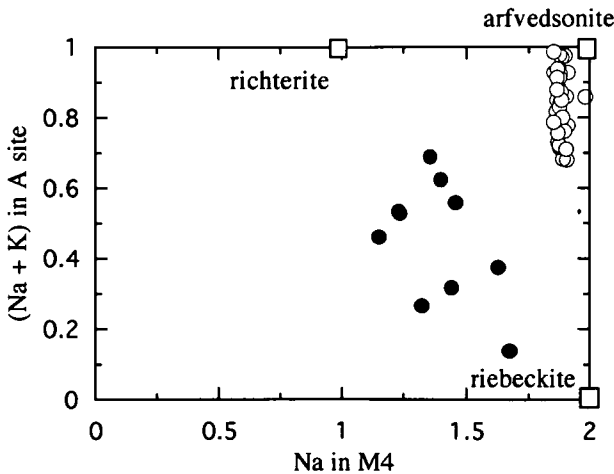
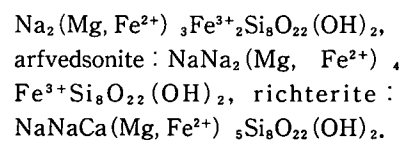


Figure 2. (Na+K) in M4 site versus (Na+K) in A site diagram.

The end members of alkali-amphibole are follows as ; riebeckite :



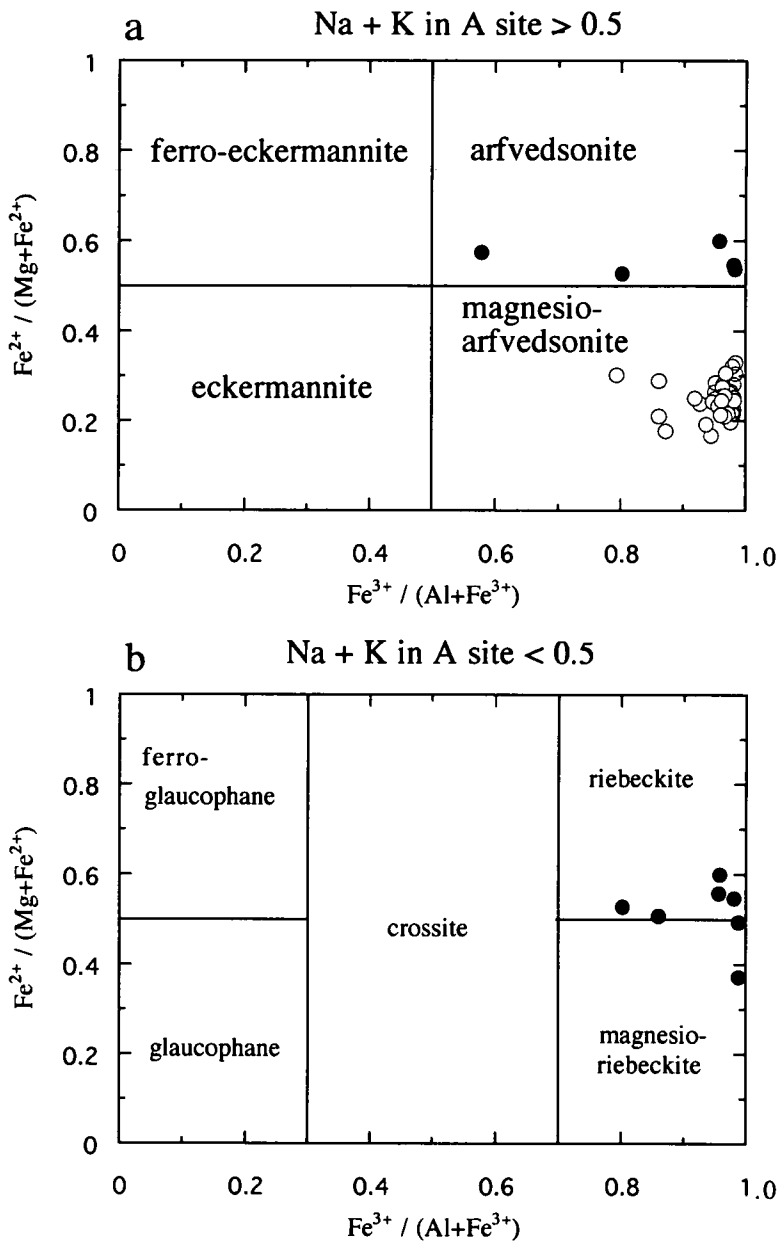


Figure 3. Classification of alkali amphiboles, which Na in M 4 site > 1.34. a : (Na + K) in A site > 0.5, b : (Na + K) in A site < 0.5

shows amphiboles with Na and K contents in A site < 0.5. Amphiboles in garnet schist were plotted near the boundary of riebeckite and magnesio-riebeckite. They have a considerable richterite molecule. Therefore, Amph 1 is magnesio-arfvedsonite. Amph 3 and 4 are riebeckite and magnesio-riebeckite, respectively. Amph 5 is ferro-barroisite

Table 3. X-ray powder data of arfvedsonite and riebeckite.

| | this study | | | Colvills & Gibbs (1965) | | Borg (1967) | | Kawahara (1963) | |
|-------------|-----------------------|-----------|------|----------------------------|------|-------------|------|--------------------|------|
| | Magnesio-arfvedsonite | | | riebeckite | | riebeckite | | arfvedsonite | |
| HKL | d Å (obs) | d Å (cal) | I/Io | d Å (obs) | I/Io | d Å (obs) | I/Io | d Å (obs) | I/Io |
| 110 | 8.507* | 8.461 | 30 | 8.429 | 100 | 8.40 | 100 | 8.51 | 70 |
| $\bar{1}11$ | 4.847* | 4.863 | 4 | 4.892 | 3 | 4.89 | 10 | 4.82 | 8 |
| 021 | 4.489* | 4.483 | 100 | 4.490 | 13 | 4.51 | 16 | | |
| 220 | 4.215* | 4.230 | 37 | 4.214 | 1 | | | 4.26 | 2 |
| 111 | | 4.063 | 34 | 4.050 | 2 | | | 4.04 | 14 |
| $\bar{1}31$ | 3.862* | 3.866 | 16 | 3.881 | 2 | 3.88 | 10 | 3.883 | 18 |
| 221 | | 3.650 | | 3.665 | 4 | 3.66 | 10 | | |
| 131 | 3.412* | 3.426 | 13 | 3.419 | 12 | 3.42 | 12 | 3.423 | 45 |
| 240 | 3.277* | 3.283 | 17 | 3.276 | 2 | 3.27 | 14 | 3.296 | 20 |
| 310 | 3.154* | 3.144 | 53 | 3.130 | 22 | 3.12 | 55 | 3.161 | 100 |
| 221 | | 2.993 | | 2.978 | 2 | 2.976 | 10 | 2.991 | 16 |
| 330 | 2.824* | 2.820 | 7 | 2.810 | 4 | 2.801 | 18 | 2.834 | 12 |
| 151 | 2.730* | 2.728 | 33 | 2.724 | 29 | 2.726 | 40 | 2.732 | 80 |
| 331 | 2.710 | 2.714 | 12 | 2.719 | 10 | 2.726 | 40 | 2.732 | 80 |
| 112 | | 2.621 | | 2.634 | 2 | | | 2.339 | 2 |
| $\bar{2}02$ | | 2.525 | 17 | 2.541 | 14 | 2.541 | 12 | 2.550 | 25 |
| 170 | 2.490* | 2.487 | 12 | 2.488 | 1 | | | | |
| $\bar{3}51$ | 2.327* | 2.325 | 15 | 2.239 | 8 | 2.324 | 12 | 2.345 | 25 |
| 171 | 2.292* | 2.294 | 21 | 2.298 | 1 | 2.191 | 4 | 2.276 | 20 |
| $\bar{3}12$ | | 2.258 | | 2.272 | 7 | | | | |
| 202 | | 2.085 | | 2.078 | 3 | 2.079 | 6 | 2.082 | 16 |
| 351 | | 2.042 | | 2.033 | 4 | 2.031 | 8 | 2.043 | 20 |
| 242 | 1.8900* | 1.892 | 3 | 1.8873 | 1 | 1.888 | 4 | | |
| 0100 | 1.8040* | 1.803 | 5 | 1.8038 | 5 | 1.805 | 6 | | |
| 461 | 1.6690* | 1.669 | 5 | 1.6612 | 5 | 1.659 | 10 | | |
| 192 | 1.5285* | 1.528 | 3 | 1.5279 | 1 | | | | |
| 063 | 1.4963* | 1.494 | 3 | 1.4968 | 1 | | | | |
| $\bar{1}73$ | | 1.458 | | 1.4609 | 1 | | | | |
| 532 | | 1.359 | | 1.3510 | 2 | | | | |

Table 4. Unit-cell dimensions of amphibole.

| Sample | a Å | b Å | c Å | β° | v Å ³ | Reference |
|--|-----------|------------|----------|---------------|------------------|-----------------------------------|
| Magnesio-arfvedsonite (K _{0.33} Na _{0.64}) _{0.97} (Na _{1.89} Ca _{0.11} Fe ²⁺ Mg _{3.06} Fe ³⁺ Cr _{0.22} Ti _{0.21} Al _{0.02}) ₇ (Al _{0.01} Si _{7.99}) ₈ O ₂₂ (OH) ₂ | 9.836(12) | 18.034(15) | 5.305(6) | 103.08(12) | 916.6(1) | this study |
| Magnesio-riebeckite Na ₂ Mg ₃ Fe ³⁺ ₂ Si ₈ O ₂₂ (OH) ₂ | 9.73 | 17.95 | 5.30 | 103.3 | 901 | Ernst (1963) |
| riebeckite Na ₂ Mg ₃ Fe ³⁺ ₂ Si ₈ O ₂₂ (OH) ₂ | 9.73 | 18.06 | 5.33 | 103.3 | 913 | Ernst (1962) |
| riebeckite (Na, Ca, K) ₂₂ (Fe ²⁺ _{2.39} Mg _{0.07} Mn _{0.3} Zn _{0.03} Cu _{0.02} Li _{0.09}) _{3.0} Fe ³⁺ _{1.77} Al _{0.13} Ti _{0.07} O _{22.1} (Si, Al) ₈ (OH,F) _{1.9} | 9.769 | 18.048 | 5.335 | 103.59 | 914 | Borg (1967) |
| riebeckite-arfvedsonite Na _{2.4} Fe ²⁺ _{4.9} Fe ³⁺ _{0.7} Si _{7.7} Fe ³⁺ _{0.3} O ₂₂ (OH) ₂ | 9.85 | 18.15 | 5.32 | 103.2 | 926.0 | Ernst (1962) |
| arfvedsonite (NaK) _{2.6} Fe ₅ (SiAl) ₈ O ₂₂ (OH) ₂ | 9.94 | 18.17 | 5.34 | 104.4 | 934.2 | Kawahara (1963) |
| eckermannite (Na _{1.96} Ca _{0.04}) ₂ (Mg _{0.84} Fe ²⁺ _{0.74} Al _{1.82} Fe ³⁺ _{0.18}) ₅ Si ₈ O ₂₂ (OH) ₂ | 9.762 | 17.892 | 5.284 | 103.168 | | Phillips & Rowbotham (1963) |

because of $0.67 < \text{Ca in M4 site} < 1.34$ and $\text{Na} + \text{K in A site} < 0.5$.

The major and trace element analyses of magnesio-arfvedsonite bearing albitite are given in Table 2, together with other data reported by Sakai and Akai (1994). The analyses use an X-ray fluorescence spectrometer (Rigaku Rix S3030) at Joetsu University of Education. As compared to the chemical compositions of the melanocratic albitite reported by Sakai and Akai (1994), the magnesio-arfvedsonite bearing albitite in this study has the higher CaO content and the lower Ba and Sr contents. The result suggested that the chemical composition of the host rock is variable.

X-ray powder study: Amphibole separated by a isodynamic magnetic separator (Frantz LB-1) was used to study X-ray analysis. The X-ray powder data for magnesio-arfvedsonite in the present study are given in Table 3 together with riebeckite and arfvedsonite in the other literatures (Kawahara 1963, Colvills and Gibbs 1965, Borg 1967). As compared with the X-ray powder data of riebeckites, their data for magnesio-arfvedsonite in the present study are close to those of arfvedsonite reported by Kawahara (1963).

The unit-cell dimensions obtained from the 18 sharp reflections with asterisk by using silicon as an external standard. They were refined by a least-squares method (Sakurai,

1968). The results were given in Table 4, together with other data for comparison. The unit-cell dimensions of magnesio-arfvedsonite are $a=9.836(12) \text{ \AA}$, $b=18.034(15) \text{ \AA}$, $c=5.305(6) \text{ \AA}$, $\beta=103.08(12)^\circ$ and $v=916.6(16) \text{ \AA}^3$. The cell dimensions of magnesio-arfvedsonite except for b dimension in the present study are comparatively similar to those of a synthetic riebeckite-arfvedsonite solid solution reported by Ernst (1968), in Table 4.

In conclusion, the chemical composition and the cell dimensions indicate that alkali amphibole from leucosphenite, ohmilite, strontio-orthojoaquinite bearing albitite is magnesio-arfvedsonite.

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References

- Deer, W. A., Howie, R. A. and Zussman J. 1963. Amphibole group. 203-374. in "Rock-forming minerals." Vol. 2, Longman.
- Borg, I. Y. 1967. Optical properties and cell parameters in the glaucophane-riebeckite series. *Contrib. Mineral. Petrol.*, 15, 67-92.
- Chihara, K. 1987. New minerals as ohmilite, nunakawaite, leucosphenite and benitoite from the Omi district. 96-108. Professor Kazuya Chihara Commemorial Volume, "Science of jadeite". Dept. Geol. Mineral., Niigata Univ., 6, 243pp (in Japanese).
- Chihara, K., Komatsu, M. and Mizota, T. 1978. Mineralogy and paragenesis of new minerals, ohmilite and nunakawaite, in the riebeckite-albitite associated with serpentinites from the Ohmi area, central Japan. *Intnl. Mineral. Assoc.* 11, 75 (abstract).
- Colville, A. A. and Gibbs, G. V. 1965. Refinement of the crystal structure of riebeckite. *Geol. Soc. Am. Spec. Pap.*, 82, 31.
- Ernst, W. G. 1962. Synthesis, stability relations, and occurrence of riebeckite and riebeckite-arfvedsonite solid solutions. *Jour. Geol.*, 70, 689-736.
- Ernst, W. G. 1963. Polymorphism in alkali amphiboles. *Am. Mineral.*, 48, 241-260.
- Ernst, W. G. 1968. *Amphiboles*. 125pp. Springer-Verlag, New York.
- Kawahara, A. 1963. X-ray studies on some alkaline amphibole. *Mineral. Jour.*, 4, 30-40.
- Leake, B. E. 1978. Nomenclature of amphiboles. *Canadian Mineral.*, 16, 501-520.
- Oba, T. 1997. Note on rock-forming minerals in the Joetsu district, Niigata Prefecture, Japan. (11) Chromian andradite from the Omi district. *Bull. Joetsu Educ.* Vol. 16, No. 2, 671-676.
- Papike, J. J. and Clark, J. R. 1968. The crystal structure and cation distribution of glaucophane. *Am. Mineral.*, 53, 1156-1173.
- Sakai, M. and Akai, J. 1994. Strontium, barium and titanium-bearing minerals and their host

- rocks from Ohmi, Japan. Sci. Rep. Niigata Univ. , Ser. E (Geol. Mineral.). No. 9 , 97-118.
- Sakurai, T. 1968. Universal crystallographic computation programm system (in Japanese).
Crystallogr. Soc. J. Publ.
- Spear, F. S. and Kimball, K. L. 1984. RECAMP a fortran IV program for estimating Fe³⁺
contents in amphiboles. Computers & Geosci. , 10, 317-325.