

POTASSICPARGASITE, A NEW MEMBER OF THE AMPHIBOLE GROUP
FROM PARGAS, TURKU-PORI, FINLAND

GEORGE W. ROBINSON¹

A.E. Seaman Mineral Museum and Department of Geological Engineering and Sciences, Michigan Technological University, 1400 Townsend Drive, Houghton, Michigan 49931, U.S.A.

JOEL D. GRICE AND ROBERT A. GAULT

Research Division, Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

ANDRÉ E. LALONDE

Ottawa-Carleton Geoscience Centre, Department of Geology, University of Ottawa, Ottawa, Ontario K1N 6N5

ABSTRACT

Potassicpargasite, ideally $(K,Na)Ca_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$, is a new member of the amphibole group, presumed to be from Pargas, Turku-Pori, Finland. The holotype specimen is a $3 \times 3 \times 5$ cm aggregate of randomly intergrown vitreous black prismatic crystals displaying the dominant forms $\{110\}$, $\{011\}$ and $\{010\}$, associated with minor pale yellow calcite. It has a brownish green streak and is nonfluorescent in ultraviolet light. The mineral is brittle, with an uneven to conchoidal fracture, perfect $\{110\}$ cleavage, and no observed parting. Its Mohs hardness is 6 to $6\frac{1}{2}$, $D(\text{meas.})$ 3.25(1) g/cm³, $D(\text{calc.})$ 3.25 g/cm³ for the observed empirical formula and $Z = 2$. Optically, potassicpargasite is biaxial negative, with α 1.654(1), β 1.664(1), γ 1.670(1), $2V(\text{meas.})$ 101(1)°, $2V(\text{calc.})$ 105°, $X \wedge \alpha$ 40° (β obtuse) and $Y = b$; absorption $Z > Y > X$, pleochroism Z dark olive green, Y olive green and X pale gray-green. The mineral is monoclinic, space group $C2/m$, with refined unit-cell parameters a 9.9199(4), b 18.0591(8), c 5.3180(3) Å, β 105.36(1)°, V 918.65(5) Å³, $Z = 2$, $a:b:c$ 0.5493:1.0:0.2945. The seven strongest lines in the X-ray powder-diffraction pattern [d in Å (1) (hkl)] are 3.140 (100)(310), 8.451 (95)(110), 2.344 (70)(421), 3.283 (45)(240), 1.652 (40)(461), 2.707 (35)(151) and 2.018 (35)(351). Combined electron-microprobe, wet chemical, crystal structure, Mössbauer and combustion – IR analyses gave SiO₂ 41.63, TiO₂ 0.87, Al₂O₃ 13.13, Fe₂O₃ 2.20, FeO 11.00, MgO 11.86, MnO 0.16, CaO 12.33, K₂O 2.83, Na₂O 1.55, H₂O 0.90, F 1.78, O = F – 0.75, total 99.49 wt.%, corresponding to $(K_{0.54}Na_{0.44})_{\Sigma 0.98}(Ca_{1.99}Na_{0.01})_{\Sigma 2.00}(Mg_{2.66}Fe^{2+}_{1.38}Al_{0.59}Fe^{3+}_{0.25}Ti_{0.10}Mn_{0.02})_{\Sigma 5.00}(Si_{6.26}Al_{1.74})_{\Sigma 8.00}O_{22}[(OH)_{0.90}F_{0.85}O_{0.25}]_{\Sigma 2.00}$ on the basis of 24 anions. The structure, which is that of a clin amphibole, was refined to an R of 3.6%. The name is that provided by the current IMA nomenclature for amphiboles.

Keywords: potassicpargasite, new mineral species, amphibole group, crystal structure, Mössbauer spectrum, Pargas, Finland.

SOMMAIRE

La potassicpargasite, de composition idéale $(K,Na)Ca_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$, est un membre nouvellement défini du groupe des amphiboles; la localité-type se trouverait à Pargas, Turku-Pori, en Finlande. L'échantillon holotype de $3 \times 3 \times 5$ cm est un agrégat de cristaux prismatiques noirs à aspect vitreux, en intercroissance aléatoire. Ils montrent les formes dominantes $\{110\}$, $\{011\}$ et $\{010\}$, et sont associés à la calcite jaune pâle accessoire. Sa rayure est vert brunâtre, et elle est non fluorescente en lumière ultra-violette. Il s'agit d'un minéral cassant, à fracture inégale ou conchoïdale, avec clivage $\{110\}$ parfait, et sans plan de séparation évident. Sa dureté (échelle de Mohs) est 6 ou $6\frac{1}{2}$. La densité mesurée est de 3.25(1), et la densité calculée pour le cas de la formule empirique et $Z = 2$ est 3.25. La potassicpargasite est biaxe négative, avec α 1.654(1), β 1.664(1), γ 1.670(1), $2V(\text{mes.})$ 101(1)°, $2V(\text{calc.})$ 105°, $X \wedge \alpha$ 40° (dans l'angle β obtus) et $Y = b$; le schéma d'absorption est $Z > Y > X$, et le pléochroïsme est Z vert olive foncé, Y vert olive, et X gris-vert pâle. C'est un minéral monoclinique, groupe spatial $C2/m$, ayant les paramètres réticulaires suivants: a 9.9199(4), b 18.0591(8), c 5.3180(3) Å, β 105.36(1)°, V 918.65(5) Å³, $Z = 2$, $a:b:c$ 0.5493:1.0:0.2945. Les sept raies les plus intenses du spectre de diffraction [d en Å(1)(hkl)] sont: 3.140 (100)(310), 8.451 (95)(110), 2.344 (70)(421), 3.283 (45)(240), 1.652 (40)(461), 2.707 (35)(151) et 2.018 (35)(351). Une combinaison de données chimiques obtenues par microsonde électronique et voie humide, ainsi que par ébauche de la structure cristalline, spectroscopie de Mössbauer et combustion avec spectroscopie dans l'infrarouge, a donné SiO₂ 41.63, TiO₂ 0.87, Al₂O₃ 13.13, Fe₂O₃ 2.20, FeO 11.00, MgO 11.86, MnO 0.16, CaO 12.33, K₂O 2.83, Na₂O 1.55, H₂O 0.90, F 1.78, O = F – 0.75,

¹ E-mail address: robinson@mtu.edu

pour un total de 99,49% par poids, ce qui correspond à $(K_{0.54}Na_{0.44})_{\Sigma 0.98}(Ca_{1.99}Na_{0.01})_{\Sigma 2.00}(Mg_{2.66}Fe^{2+}_{1.38}Al_{0.59}Fe^{3+}_{0.25}Ti_{0.10}Mn_{0.02})_{\Sigma 5.00}(Si_{6.26}Al_{1.74})_{\Sigma 8.00}O_{22}[(OH)_{0.90}F_{0.85}O_{0.25}]_{\Sigma 2.00}$, en supposant 24 anions. La structure, qui correspond à celle d'une clinoamphibole, a été affinée jusqu'à un résidu R de 3,6%. Le nom découle du schéma de nomenclature approuvé par l'Association minéralogique internationale.

(Traduit par la Rédaction)

Mots-clés: potassicpargasite, nouvelle espèce minérale, groupe de l'amphibole, structure cristalline, spectre de Mössbauer, Pargas, Finland.

INTRODUCTION

Potassium-dominant pargasite has been reported from Einstödingen, Lützow-Holm Bay, East Antarctica (Matsubara & Motoyoshi 1985), the Nogo-Hakusan area of central Japan (Sawaki 1989) and Tíree, Argyllshire, Scotland (Hallimond 1947), but the mineral has not been formally described as a species until now. Potassicpargasite first came to our attention during a systematic electron-microprobe investigation of amphiboles in the collection of the Canadian Museum of Nature, Ottawa, where the holotype specimen is deposited (as CMNMI81529). The mineral has been approved as a new species by the IMA Commission on New Minerals and Mineral Names, and its name complies with the current IMA nomenclature for amphiboles.

OCCURRENCE

The holotype specimen of potassicpargasite (Fig. 1) seems to have come from a metasomatic or skarn-type deposit. The only associated mineral is coarse pale yellow-gray calcite. Originally labeled as "hornblende" from Franklin, New Jersey, the holotype specimen of potassicpargasite does not resemble other amphiboles from Franklin either in composition or physical appearance, and we suspect that the locality given on the original label is wrong. Potassium-bearing pargasite and hornblende are known from Franklin, but they have significantly higher Zn and Mn and lower Si contents than potassicpargasite (Pete J. Dunn, pers. commun.). The absence of Zn and the relatively low Mn content of the holotype potassicpargasite, as well as the nonfluorescence of the associated calcite in ultraviolet light, suggest that, if it were from Franklin, it would probably be from the Franklin marble, rather than the Franklin orebody. Furthermore, the holotype specimen was once part of the John Calvert collection. This arrived in the United States from Great Britain in 1938 with many of the specimens separated from their labels; it was then dispersed by the mineral dealer, Martin Ehrmann (Louis Moyd pers. commun.; Smith & Smith 1994).

Because the holotype specimen of potassicpargasite closely resembles the dark crystals of pargasite from Pargas, Turku-Pori, Finland, five specimens of pargasite (and their associated calcite) from that

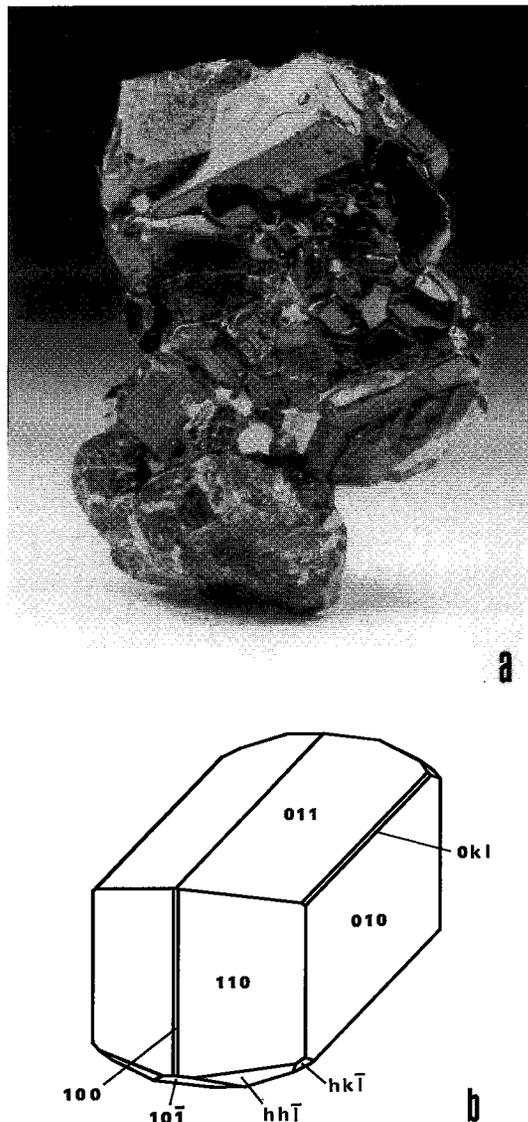


FIG. 1. a. The holotype specimen of potassicpargasite, $3 \times 3 \times 5$ cm. b. Idealized drawing of the crystal of potassicpargasite, showing forms $\{011\}$, $\{110\}$, $\{010\}$, $\{100\}$, $\{101\}$, $\{0kl\}$, $\{hh\bar{1}\}$ and $\{hk\bar{1}\}$.

locality were analyzed by electron microprobe and compared to the holotype specimen. Calcite from the Franklin orebody and from the Franklin marble was analyzed. The calcite samples show considerably different concentrations of Mg, Fe, Mn and Sr (in ppm): Franklin marble: ~4800 Mg, ~1650 Fe, ~250 Mn and ~2800 Sr; Franklin orebody: ~1350 Mg, ~400 Fe, ~33700 Mn and ~550 Sr; Pargas: ~1200 Mg, ~2000 Fe, ~400 Mn and ~300 Sr. The latter closely resemble the values obtained for calcite associated with the holotype potassicpargasite: ~1250 Mg, ~2650 Fe, ~650 Mn and ~350 Sr.

The chemical analyses of the five samples of pargasite from Pargas gave results similar to those obtained from the holotype specimen. One composition was nearly identical, with K/(Na + K) 0.52, Si/(Si + Al) 0.77, and Mg/(Mg + Fe + Mn) 0.59 compared to 0.55, 0.78 and 0.62, respectively, for the holotype sample. These data and its overall physical appearance suggest that the holotype specimen is more likely from Pargas than from Franklin.

PHYSICAL AND OPTICAL PROPERTIES

Potassicpargasite occurs as randomly intergrown euhedral crystals up to 2 × 1 × 0.7 cm. Dominant forms include {110}, {011} and {010}, with minor forms {100}, {101}, {0kl} (probably {031}), {hkl} and {hhl} (possibly {131} and {332}). Individual crystals are elongate on [100] and slightly tabular on {010} (Fig. 1). Smaller crystals and minor forms tend to be rounded, precluding accurate goniometric measurement. The mineral is opaque and black in hand specimen, but is translucent in thin splinters and is brownish green in powdered form. It is nonfluorescent in both short- and long-wave ultraviolet light. It is brittle with a conchoidal to uneven fracture, has perfect {110} cleavage, and no observed parting. It has a Mohs hardness of 6 to 6½, and its density, measured by hydrostatic weighing in toluene, is 3.25(1) g/cm³, which equals that calculated from its observed empirical formula and unit-cell volume. Optically, potassicpargasite is biaxial negative, with α 1.654(1), β 1.664(1), γ 1.670(1), 2V_z(meas.) 101(1)°, 2V_z(calc.) 105°, and X ∧ a 40° (β obtuse) and Y = b. It is pleochroic, with Z dark olive green, Y olive green and X pale gray-green, absorption Z > Y > X, and no visible dispersion.

CHEMICAL COMPOSITION

Major cation contents were obtained by wavelength-dispersion electron-microprobe analysis, using a JEOL Superprobe 733 operating at 15 kV, beam current of 20 nA measured on a Faraday cup, and a beam diameter of 20 μm. Standards used were sanidine (Si,K), almandine (Al,Fe), tephroite (Mn), diopside (Mg), gehlenite (Ca), albite (Na), rutile (Ti) and sodic

TABLE 1. CHEMICAL COMPOSITION OF POTASSICPARGASITE

SiO ₂ wt.%	41.63	Si <i>apfu</i>	6.26
TiO ₂	0.87	Ti	0.10
Al ₂ O ₃	13.13	Al	2.33
Fe ₂ O ₃	2.20	Fe ³⁺	0.25
FeO	11.00	Fe ²⁺	1.38
MgO	11.86	Mg	2.66
MnO	0.16	Mn	0.02
CaO	12.33	Ca	1.99
K ₂ O	2.83	K	0.54
Na ₂ O	1.55	Na	0.45
H ₂ O	0.90	OH	0.90
F	1.78	F	0.85
O = F	-0.75		
Total	99.49		

apfu: atoms per formula unit.

amphibole (F). Chlorine was sought, but not detected. Data were reduced using the Tracor Northern 5600 computer program TASK, which uses a conventional ZAF-correction routine. FeO and Fe₂O₃ were determined by Mössbauer spectroscopy, F by wet-chemical analysis, and H₂O by combustion and IR analysis (Table 1). An average of five electron-microprobe analyses, combined with the wet-chemical and Mössbauer data, give the empirical formula (K_{0.54}Na_{0.44})_{Σ0.98}(Ca_{1.99}Na_{0.01})_{Σ2.00}(Mg_{2.66}Fe²⁺_{1.38}Al_{0.59}Fe³⁺_{0.25}Ti_{0.10}Mn_{0.02})_{Σ5.00}(Si_{6.26}Al_{1.74})_{Σ8.00}O₂₂[(OH)_{0.90}F_{0.85}O_{0.25}]_{Σ2.00} based on 24 anions. There is only very minor zoning. The determination of the Fe²⁺/Fe³⁺ value obtained by Mössbauer spectroscopy [Fe³⁺/Fe_(Total) = 0.153] agrees closely with that obtained by wet-chemical methods (0.171) and crystal-structure analysis. Gladstone-Dale calculations give a K_p of 0.2039 and a K_c of 0.2004, for a compatibility index of -0.0175, indicating superior agreement between the physical and chemical data (Mandarino 1979, 1981).

CRYSTALLOGRAPHY

X-ray precession photographs of potassicpargasite are consistent with Laue symmetry 2/m, and the conditions for reflections to be present show the lattice to be C-centered; thus the possible space-groups are C2/m, C2 and Cm. The crystal-structure refinement confirmed the space group C2/m. The X-ray powder data obtained with a Philips X-ray diffractometer with Ni-filtered CuKα radiation and using BaF₂ as an internal standard are given in Table 2. The unit-cell parameters refined from these data are a 9.9199(4), b 18.0591(8), c 5.3180(3) Å, β 105.36(1)°, V 918.65(5) Å³; Z = 2.

REFINEMENT OF THE CRYSTAL STRUCTURE

A fragment from the holotype was ground to a sphere. X-ray intensity data were collected on a Nicolet R3m automated four-circle diffractometer using the method of Grice & Ercit (1986). Selected data relevant to data collection and structure refinement

TABLE 2. X-RAY POWDER-DIFFRACTION DATA FOR POTASSICPARGASITE

L_{int}	d_{max} (Å)	d_{calc} (Å)	hkl	L_{int}	d_{max} (Å)	d_{calc} (Å)	hkl
<5	9.06	9.03	020	15	1.903	1.902	510
95	8.45	8.45	110	5	1.889	1.890	461
5	4.78	4.78	200	5	1.823	1.823	530
10	4.51	4.51	040	40	1.652	1.652	461
20	3.383	3.383	131	5	1.618	1.618	1,11,0
45	3.283	3.283	240	15	1.594	1.594	600
100	3.140	3.140	310	5	1.586	1.586	753
<5	3.057	3.056	311	5	1.556	1.555	402
25	2.941	2.941	221	5	1.550	1.551	602
25	2.816	2.818	330	10	1.523	1.522	263
20	2.756	2.757	331	15	1.505	1.505	0,12,0
35	2.707	2.708	151		1.504	1.504	551
20	2.596	2.596	061	<5	1.459	1.460	3,11,0
15	2.559	2.560	202	25	1.448	1.448	861
20	2.391	2.391	350	25	1.444	1.444	0,12,1
<5	2.353	2.353	351	10	1.366	1.365	512
70	2.344	2.344	421	5	1.342	1.342	1,11,2
15	2.303	2.304	171	5	1.333	1.334	263
		2.302	312			1.333	4,10,1
25	2.166	2.165	332			1.333	681
25	2.163	2.163	261			1.332	730
15	2.045	2.045	202	10	1.319	1.319	751
35	2.018	2.018	351	5	1.314	1.314	714
5	2.006	2.006	370	5	1.297	1.297	2,12,2

are given in Tables 3, 4 and 5. Observed and calculated structure-factors are available from the Depository of Unpublished Data, CISTI, National Research Council of Canada, Ottawa, Ontario, Canada K1A 0S2. The refined scattering power (in electrons per formula unit) are $M1$ (64.8) + $M2$ (65.4) + $M3$ (32.8) = 163(5), $M4$ = 80(3) and $A(m)$ (27.6) + $A2$ (1.5) = 29(1). This agrees

TABLE 3. POTASSICPARGASITE: DATA-COLLECTION INFORMATION

Space Group	$C2/m$ (# 12)	Measured unique reflections	1396
a (Å)	9.930(2)	Observed reflections $> 5\sigma$ (I)	1257
b (Å)	18.057(4)	Minimum transmission	0.523
c (Å)	5.316(1)	Maximum transmission	0.495
β (°)	105.37(2)	R / R_w (%)	3.6/3.5
V (Å ³)	919.0(3)	$R_w = [\sum w(F_o - F_c)^2] / \sum w F_o^2$	$w = [\sigma^2(F_o)]^{-1}$
End member unit-cell contents	2[KCa ₂ Mg ₆ Si ₆ O ₂₂ (OH) ₂]		
μ (mm ⁻¹)	2.76	Sphere diameter (mm)	0.21

TABLE 4. POTASSICPARGASITE: ATOM COORDINATES AND DISPLACEMENT FACTORS (Å × 10³)

Atom	x	y	z	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}	U_{21}
M1	0	0.08992(6)	1/4	110(5)	111(5)	85(5)	0	35(4)	0	100(3)
M2	0	0.17721(5)	0	73(4)	69(4)	72(4)	0	20(3)	0	71(3)
M3	0	0	0	97(6)	77(6)	74(6)	0	16(5)	0	84(4)
M4	0	0.28025(5)	1/2	125(4)	98(4)	128(4)	0	59(3)	0	112(3)
Am	0.0261(5)	1/2	0.052(1)	459(22)	351(17)	651(23)	0	464(16)	0	427(13)
A2	0	0.474(2)	0	400						
T1	0.27870(9)	0.08573(5)	0.3040(2)	91(4)	99(4)	92(4)	4(3)	18(3)	-8(3)	95(3)
T2	0.29038(9)	0.17323(5)	0.8137(2)	76(4)	89(4)	79(4)	7(3)	21(3)	5(3)	81(2)
O1	0.1051(2)	0.0891(1)	0.2164(4)	95(10)	158(10)	92(10)	-28(8)	22(8)	-31(8)	115(6)
O2	0.1201(2)	0.1742(1)	0.7329(4)	82(9)	121(10)	121(10)	10(8)	11(8)	8(8)	111(6)
O3	0.1076(3)	0	0.7137(6)	167(13)	168(13)	174(13)	0	47(11)	0	169(8)
O4	0.3673(2)	0.2501(1)	0.7919(4)	154(10)	100(9)	130(10)	7(8)	64(9)	-13(9)	123(6)
O5	0.3489(2)	0.1389(1)	0.1098(4)	103(10)	109(8)	152(10)	126(10)	34(8)	10(8)	131(6)
O6	0.3441(2)	0.1187(1)	0.6078(4)	111(10)	155(10)	137(11)	-37(9)	26(9)	6(9)	135(7)
O7	0.3375(3)	0	0.2908(7)	154(14)	106(13)	207(15)	0	32(13)	0	159(9)

very well with the number of electrons calculated from the formula based on chemical analysis: $M1 + M2 + M3 = (\text{Mg}_{2.66}\text{Fe}^{2+}_{1.36}\text{Al}_{0.59}\text{Fe}^{3+}_{0.28}\text{Ti}_{0.10}\text{Mn}_{0.02}) = 169.9$, $M4 = (\text{Ca}_{1.98}\text{Na}_{0.02}) = 79.6$, $A(m) + A2 = (\text{K}_{0.54}\text{Na}_{0.43}) = 30.0$. The $<M(2) - O>$ distance indicates that the minor amount of Fe^{3+} present is probably at that site. At the tetrahedrally coordinated sites, the $<T1 - O>$ distance indicates that Al has a preference for T1. Boschmann *et al.* (1994) discussed in detail A-site disorder in amphiboles. In the structure refinement of potassicpargasite, all models of A-site disorder were tested. With the cation fixed at A 0, 1/2, 0, anisotropic displacement factors were large and non-positive definite. By allowing the site to disorder within the mirror plane [site $A(m)$], along the 2-fold axis (site A2) and completely off the 2/m or b site symmetry (site A1), A1 was found not to contribute significantly to the refinement of the disordered distribution, and A2 to only the small proportion given above. Thus our model is in keeping with K and Na disorder primarily within the mirror plane.

MÖSSBAUER SPECTROSCOPY

The value of $\text{Fe}^{3+}/\text{Fe}_{\text{(Total)}}$ was determined by transmission Mössbauer spectroscopy. The spectrum was taken with a ⁵⁷Co rhodium-matrix source, with both source and absorber at room temperature (22°C). The transducer was operated in constant-acceleration mode. Data were accumulated in 1024 channels, which covered twice the Doppler velocity range of ± 4.0 mm/s. Two calibration spectra were obtained with a ⁵⁷Fe-enriched iron foil before and after the experiment. All positions are given with respect to these calibration spectra (*i.e.*, with respect to the center shift of α -Fe at room temperature). The spectrum was folded to obtain a flat background profile and is presented on a velocity scale of -2.5 to $+4.0$ mm/s. The signal-to-noise ratio is greater than 55.

To prepare the Mössbauer absorber, 70.2 mg of the amphibole was powdered in ethanol to prevent

TABLE 5. POTASSICPARGASITE: SELECTED INTERATOMIC DISTANCES (Å)

M1-O1 x 2	2.049(3)	M2-O1 x 2	2.076(2)
M1-O2 x 2	2.118(2)	M2-O2 x 2	2.083(3)
M1-O3 x 2	2.104(2)	M2-O4 x 2	1.977(2)
(M1-O)	(2.090)	(M2-O)	(2.045)
M3-O1 x 4	2.089(2)	M4-O2 x 2	2.417(2)
M3-O3 x 2	2.079(3)	M4-O4 x 2	2.351(3)
(M3-O)	(2.086)	M4-O5 x 2	2.652(2)
		M4-O6 x 2	2.555(3)
Am-O5 x 2	3.126(4)	(M4-O)	(2.494)
Am-O5 x 2	3.022(4)		
Am-O6 x 2	3.342(4)	A2-O5 x 2	2.69(3)
Am-O6 x 2	2.880(4)	A2-O5 x 2	3.46(4)
Am-O7	2.528(7)	A2-O6 x 2	2.80(3)
Am-O7	3.398(6)	A2-O6 x 2	3.45(3)
Am-O7	2.341(8)	A2-O7 x 2	2.56(1)
Am-O7	3.982(6)	A2-O7 x 2	3.72(1)
T1-O1	1.663(2)	T2-O2	1.630(2)
T1-O5	1.690(3)	T2-O4	1.604(3)
T1-O6	1.681(2)	T2-O5	1.648(2)
T1-O7	1.662(2)	T2-O6	1.662(3)
(T1-O)	(1.674)	(T2-O)	(1.636)

proposed that substitution of K for Na in sadanagaite is due to the unusually high ¹⁴¹Al of that mineral, and both groups of investigators noted that Hinrichsen & Schürmann (1977) were unable to synthesize K-dominant Fe-free pargasite at temperatures between 750 and 1000°C, and at pressures between 1 and 4 kbar. The samples of pargasitic amphibole from Pargas analyzed during this study show compositional variation in F, K, Na, Al, Mg and Fe, providing no clear distinction whether Fe content or ¹⁴¹Al is the more important factor regulating K-for-Na substitution. Microprobe-determined concentrations of F range from 1.90 to 2.46 wt%, suggesting that a fluorine-dominant potassicpargasite also exists at Pargas. The lack of detectable H₂O in one TGA analysis (no significant weight loss to 800°C), and the results of the crystal-structure analysis further substantiate the occurrence of F-dominant zones in this amphibole. The new amphibole fluor-cannilloite from Pargas (Hawthorne *et al.* 1996) also is F-dominant, with the ideal formula CaCa₂(Mg₄Al)(Si₅Al₃)O₂₂F₂.

ACKNOWLEDGEMENTS

Support for this project was made possible in part by Canadian Museum of Nature RAC research Grant ENPE100. The authors thank Frank Hawthorne (University of Manitoba) for the use of the four-circle diffractometer, D. Conrad Grégoire and Peter Bélanger (Geological Survey of Canada) for the wet-chemical

oxidation, and then suspended in a 6-mm-thick 1.27-cm-diameter petroleum-jelly mount. This method ensures that the orientation of crystal fragments in the absorber is sufficiently random to impose equality in area of corresponding high- and low-energy lines from the site-specific doublets (Rancourt 1994). The mass of sample used in the absorber represented 83% of the mass determined by the method of Rancourt *et al.* (1993) to maximize the signal-to-noise ratio.

Spectral lines were obtained by fitting the spectrum with the Voigt-based quadrupole-splitting distribution method of Rancourt & Ping (1991). Details of the fitting procedure can be found in Rancourt *et al.* (1994) or Lalonde *et al.* (1996). The fitting resolved four doublets: a single doublet centered at 0.38 mm/s, with a quadrupole splitting of 0.80, and three doublets centered at 1.13 mm/s, with quadrupole splittings of 2.04, 2.30, and 2.60 (Fig. 2). The four doublets were interpreted according to the work of Goldman (1979), and respectively assigned to Fe³⁺ at M2, Fe²⁺ at M4, and M2, and Fe²⁺ at M1 and M3. The Fe³⁺/Fe_{Total} value of the amphibole is 0.153(3) (Lalonde *et al.* 1996). The complete Mössbauer dataset, along with all fitting parameters, is available from the Depository of Unpublished Data, CISTI, National Research Council of Canada, Ottawa, Ontario, Canada K1A 0S2.

DISCUSSION

The role played by Fe and ¹⁴¹Al in stabilizing the structures of K-bearing clin amphiboles has been previously discussed. Matsubara & Motoyoshi (1985) suggested that the presence of Fe may have favored the crystallization of potassium-dominant pargasite from Einstödingen, East Antarctica. Shimazaki *et al.* (1984)

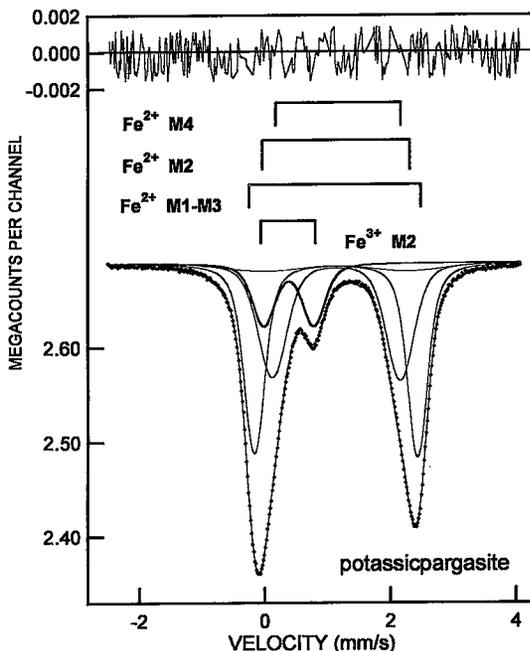


FIG. 2. Room-temperature Mössbauer spectrum of potassicpargasite.

and combustion-IR analyses for ferrous and ferric iron, fluorine and water, Marie-Claude Corbeil (Canadian Conservation Institute) for thermogravimetric analyses, and Denis G. Rancourt for access to the Mössbauer spectrometer. Information and helpful discussions were provided by Pete J. Dunn (Smithsonian Institution), Joseph Mandarino (Royal Ontario Museum), Louis Moyd (Canadian Museum of Nature) and G. Della Ventura (Università degli Studi di Roma). H. Gary Ansell (Geological Survey of Canada) provided additional specimens for analysis.

REFERENCES

- BOSCHMANN, K.F., BURNS, P.C., HAWTHORNE, F.C., RAUDSEPP, M. & TURNOCK, A.C. (1994): A-site disorder in synthetic fluor-edenite, a crystal-structure study. *Can. Mineral.* **32**, 21-30.
- GOLDMAN, D.S. (1979): A re-evaluation of the Mössbauer spectroscopy of calcic amphiboles. *Am. Mineral.* **64**, 109-118.
- GRICE, J.D. & ERCIT, T.S. (1986): The crystal structure of moydite. *Can. Mineral.* **24**, 675-678.
- HALLIMOND, A.F. (1947): Pyroxenes, amphibole and mica from the Tیره marble. *Mineral. Mag.* **28**, 230-243.
- HINRICHSSEN, T. & SCHÜRMAN, K. (1977): Experimental investigations on the Na/K-substitution in edenites and pargasites. *Neues Jahrb. Mineral., Abh.* **130**, 12-18.
- LALONDE, A.E., RANCOURT, D.G. & CHAO, G.Y. (1996): Fe-bearing trioctahedral micas from Mont Saint-Hilaire, Québec, Canada. *Mineral. Mag.* **60**, 447-460.
- MANDARINO, J.A. (1979): The Gladstone-Dale relationship. III. Some general applications. *Can. Mineral.* **17**, 71-76.
- _____ (1981): The Gladstone-Dale relationship. IV. The compatibility concept and its application. *Can. Mineral.* **19**, 441-450.
- MATSUBARA, S. & MOTOYOSHI, Y. (1985): Potassium pargasite from Einstödingen, Lützow-Holm Bay, East Antarctica. *Mineral. Mag.* **49**, 703-707.
- RANCOURT, D.B. (1994): Mössbauer spectroscopy of minerals. I. Inadequacy of Lorentzian-line doublets in fitting spectra arising from quadrupole splitting distributions. *Phys. Chem. Minerals* **21**, 244-249.
- _____, CHRISTIE, I.A.D., ROYER, M., KODAMA, H., ROBERT, J.-L., LALONDE, A.E. & MURAD, E. (1994): Determination of accurate $^{54}\text{Fe}^{3+}$, $^{56}\text{Fe}^{3+}$, and $^{56}\text{Fe}^{2+}$ site populations in synthetic annite by Mössbauer spectroscopy. *Am. Mineral.* **79**, 51-62.
- _____, McDONALD, A.M., LALONDE, A.E. & PING, J.Y. (1993): Mössbauer absorber thicknesses for accurate site populations in Fe-bearing minerals. *Am. Mineral.* **78**, 1-7.
- _____ & PING, J.Y. (1991): Voigt-based methods for arbitrary-shape static hyperfine parameter distributions in Mössbauer spectroscopy. *Nucl. Instrum. Methods Phys. Res.* **B58**, 85-97.
- SAWAKI, T. (1989): Sadanagaite and subsilicic ferroan pargasite from thermally metamorphosed rocks in the Nogo-Hakusan area, central Japan. *Mineral. Mag.* **53**, 99-106.
- SHIMAZAKI, H., BUNNO, M. & OZAWA, T. (1984): Sadanagaite and magnesio-sadanagaite, new silica-poor members of calcic amphibole from Japan. *Am. Mineral.* **69**, 465-471.
- SMITH, B. & SMITH, C. (1994): Martin Leo Ehrmann (1904-1972). *Mineral. Rec.* **25**, 347-370.

Received May 9, 1997, revised manuscript accepted September 12, 1997.