Fluoro-magnesiohastingsite from Dealul Uroi (Hunedoara county, Romania): Mineral data and crystal structure of a new amphibole end-member

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Abstract: The new mineral fluoro-magnesiohastingsite, ideally $(Na,K,Ca)Ca_2(Mg,Fe^{3+},Al,Ti)_5(Si,Al)_8O_{22}F_2$, a member of the calcic-amphibole-group, occurs in small cavities of an altered hematite-rich xenolith in the quaternary trachyandesite at Dealul Uroi, Hunedoara county, Romania. Associated minerals are: titaniferous hematite, augite, phlogopite, enstatite, feldspar, tridymite, titanite, fluorapatite, ilmenite and pseudobrookite. The mineral is reddish-brown to yellowish, with a light reddish-brown streak, and has a perfect {110} cleavage. The tenacity is brittle and the Mohs hardness is 6. Optically the mineral is biaxial (+) and weakly pleochroic, $\alpha = 1.642$ (yellow-brown), $\beta = 1.647$ (light brown), $\gamma = 1.662$ (light brown) at 589 nm 2V (meas. and calc.) is 61°, dispersion was not observed. The orientation of β is parallel to *b*. The axial plane is (010) ($\gamma \wedge c = 26º$). It is monoclinic, $C2/m$, with the unit-cell parameters $a = 9.871(1)$ Å, $b = 18.006(2)$ Å, $c = 5.314(1)$ Å, $\beta = 105.37(1)°$, $V = 910.7(2)$ Å^3, $Z = 2$. The calculated density is 3.18 g/cm^3. The strongest lines in the X-ray powder diffraction pattern (d_{obs} in Å, (*hkl*), *I*) are: 9.008, (020), 27; 8.421, (110), 61; 3.377, (131), 44; 3.271, (240), 61; 3.124, (310), 100; 2.932, (221), 35; 2.805, (330), 28; 2.700, (151), 54.

The crystal structure of fluoro-magnesiohastingsite was refined to $R(F) = 0.054$ using reflection intensities collected with Mo$K\alpha$ X-radiation. Refined site-scattering values and considerations of mean bond lengths demonstrated an ordering of Fe^{3+} at M2. Electron-microprobe data and the A site-scattering values show significant Ca (0.19 apfu) together with K and Na at the Am and A2 sites. The site-scattering value and bond-length of O3 to cations indicate that this site is occupied by F, which was indirectly confirmed by infrared spectroscopy. The emp-analyses correspond to the empirical formula: $^A(Na_{0.50}K_{0.22}Ca_{0.17})_{0.89}{}^BCa_{2.00}$ $^C(Mg_{4.03}Fe^{3+}{}_{0.70}Al_{0.13}Ti_{0.13})_{4.99}{}^T(Si_{5.89}Al_{2.11})_{8.00}O_{22.00}F_{2.00}$.

Most companion minerals of fluoro-magnesiohastingsite containing fluorine, like phlogopite, fluorapatite and chondrodite, have a $X_F = F/(F+OH) > 0.79$. Amphiboles of the hosting trachyandesite are fluoro-members (fluoro-edenite to fluoro-magnesiohastingsite) as well but they have a more variable Si/Al-ratio as the xenolith-hosted fluoro-magnesiohastingsites.

Key-words: fluoro-magnesiohastingsite, new mineral, amphibole group, crystal structure, Dealul Uroi, Romania.

Introduction

Fluorine-rich amphibole-group minerals may be more common than is generally recognized. Significant fluorine contents in amphiboles are reported since about a century (*e.g.* Doelter, 1914). An examination of the mineral-chemistry of amphiboles based on literature data done by Petersen *et al.* (1982) revealed a number of amphiboles in which $X_F = F/(F+OH)$ is higher than 0.50. Since this publication, nine fluoro-members of the amphibole group have been accepted by the IMA-CNMMN and published. Three of them are members of the calcic-amphibole group: fluor-cannilloite (Hawthorne *et al.*, 1996), fluoro-edenite (Gianfagna & Oberti, 2001) and fluoropargasite (Lupulescu *et al.*, 2005).

High fluorine content in magnesiohastingsite is rarely reported. Forty-one magnesiohastingsite and hastingsite analyses are reported in Deer *et al.* (1997) but only five of them have significant fluorine-contents ($X_F > 0.25$), and none of them have $X_F > 0.50$. Gaeta & Freda (2001) reported strontian fluoro-magnesiohastingsite from Alban Hills (Central Italy) with X_F up to 0.787. These submillimetric fluoro-magnesiohastingsite crystals are poikilitic with numerous inclusions. Therefore they were not suitable for crystallographic investigations.

The fluoro-magnesiohastingsite described in this paper has been approved by the Commission on New Mineral and Mineral Names of the International Mineralogical Association (#2005-002). The type material is deposited at the Department of Mineralogy of the Landesmuseum
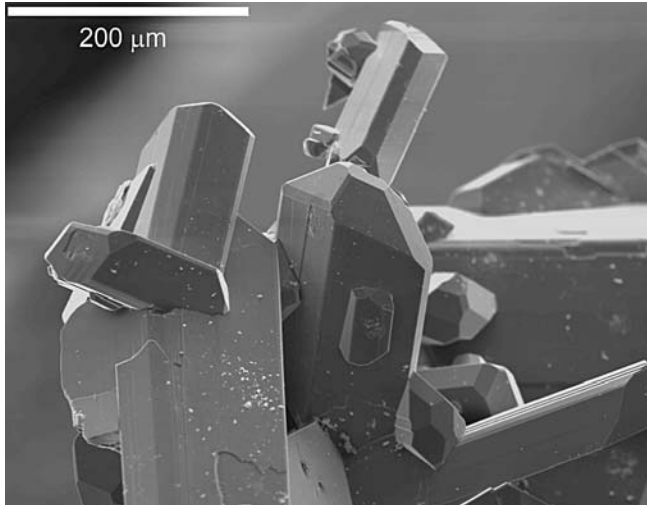
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Fig. 1. Fluoro-magnesiohastingsite crystals from Dealul Uroi, Hunedoara district, Romania, SEM photograph.

Joanneum Graz (no. 83854-83855). The name is in accordance with the amphibole nomenclature scheme of the subcommittee on amphiboles of the IMA-CNMMN (Leake *et al.*, 1997).

Occurrence and paragenesis

Fluoro-magnesiohastingsite (Fig. 1) was found in a long abandoned trachyandesite quarry at Dealul Uroi, about 10 km east of Deva, Hunedoara county, Romania (23°02'E, 45°52'N). Magmatic rocks of neogene age are widespread in the Apuseni Mountains, western Romania. These magmatites belong to the calc-alkaline and alkaline series and most of these rocks plot in the andesite field. In this region the magmatic activity developed mainly between 14.7 and 7.4 Ma. After a gap of 6 million years the volcano Dealul Uroi was active at 1.6 Ma, so it is the far youngest magmatic rock in the Apuseni Mountains. Beside the age, also the higher K_2O content distinguish this volcanic rock from the other magmatites of the Apuseni Mountains. Because of the higher K_2O content the Uroi rocks are classified as trachyandesites (Roşu *et al.*, 2001, 2004).

Koch (1878) published the first very detailed petrography of the rock and mineralogical study of the Dealul Uroi (including the original description of pseudobrookite). König *et al.* (2001) give a brief mineralogical description of Dealul Uroi. Conspicuous are countless thermally altered xenoliths of sedimentary/low metamorphic origin. Three major types can be distinguished: quartzites, limestones and hematite-rich xenoliths. The latter have commonly a layered texture with Ti-hematite-rich and plagioclase-rich layers. These xenoliths show a high porosity with small cavities hosting augite, fluoro-magnesiohastingsite, fluorine-rich phlogopite, tridymite, feldspar, pseudobrookite and subordinately titanite, fluorapatite, enstatite, ilmenite and fluorite. Fluoro-magnesiohastingsite forms idiomorphic, long-prismatic crystals up to 3 mm and is often found on green augite, frequently associated with fluorine-rich phlogopite.

Chemical composition

Microchemical analyses were performed with a JEOL JSM-6310 electron microprobe, equipped with ED- and WD-spectrometers. The working conditions were 15 kV with a beam current of 5 nA on aluminium. Minerals and synthetic phases have been used as standards (F: synthetic fluor-phlogopite; Na: jadeite; Ca, Ti: titanite; Mg: olivine; Al: corundum; Si: kaersutite; K: adularia; Fe: garnet, Cr: chromite, P: apatite) and Phi-Rho-Z as data reduction. The mean element concentration from analyses and the range of the values are listed in Table 1. The unit formula was calculated on the basis of O+F = 24. The empirical formulas for fluoro-magnesiohastingsite are (analyses 1 & 2, Table 1):

$$^A(Na_{0.50}K_{0.22}Ca_{0.17})_{0.89}{}^BCa_{2.00}{}^C(Mg_{4.03}Fe^{3+}_{0.70}Al_{0.13}Ti_{0.13})_{4.99}{}^T(Si_{5.89}Al_{2.11})_{8.00}O_{22.00}F_{2.00}$$

$$^A(Na_{0.53}K_{0.21}Ca_{0.18})_{0.92}{}^B(Ca_{1.93}Mg_{0.07})_{2.00}{}^C(Mg_{4.11}Fe^{3+}_{0.65}Al_{0.10}Ti_{0.14})_{5.00}{}^T(Si_{5.86}Al_{2.14})_{8.00}O_{21.99}F_{2.01}$$

Analysis 1 represents the crystal used for crystallographic investigations.

Infrared spectroscopy

Fourier-transform infrared spectra were obtained with a Perkin-Elmer Paragon 500 spectrometer in the far to near infrared region (400-4000 cm⁻¹). Powdered fluoro-magnesiohastingsite was diluted with KBr and dehydrated at 110°C. The measurements were performed with a KBr-disc (13 mm diameter). Absorption bands occur at (w – weak,

Table 1. Electron-microprobe analyses of fluoro-magnesiohastingsite from Dealul Uroi, Hunedoara district, Romania.

oxides				Formula based on 24 (O + F)			
	1	2	Range	1		2	
SiO_2	40.77	41.10	39.12-42.37	Si	5.89	Si	5.86
TiO_2	1.21	1.30	0.87-1.68	[T]Al	2.11	[T]Al	2.14
Al_2O_3	13.11	13.33	12.29-14.20	ΣT	8.00	ΣT	8.00
Fe_2O_3	6.44	6.09	5.10-6.99	[C]Al	0.13	[C]Al	0.10
MgO	18.70	19.64	18.03-20.82	Fe^{3+}	0.70	Fe^{3+}	0.65
CaO	13.99	13.78	12.89-14.72	Mg	4.03	Mg	4.11
Na_2O	1.79	1.90	1.58-2.36	Ti	0.13	Ti	0.14
K_2O	1.17	1.14	1.02-1.33	ΣC	4.99	ΣC	5.00
F	4.39	4.45	3.56-4.83	[B]Ca	2.00	[B]Mg	0.07
-O=F	1.84	1.87		ΣB	2.00	[B]Ca	1.93
Σ	99.73	100.86		[A]Ca	0.17	ΣB	2.00
				Na	0.50	[A]Ca	0.18
				K	0.22	Na	0.53
				ΣA	0.89	K	0.21
				F	2.00	ΣA	0.92
						F	2.01

1: average analysis of the crystal used for crystal-structure refinements (mean of 35 analyses) and 2: average analysis of 4 other crystal fragments from the same sample (mean of 16 analyses).
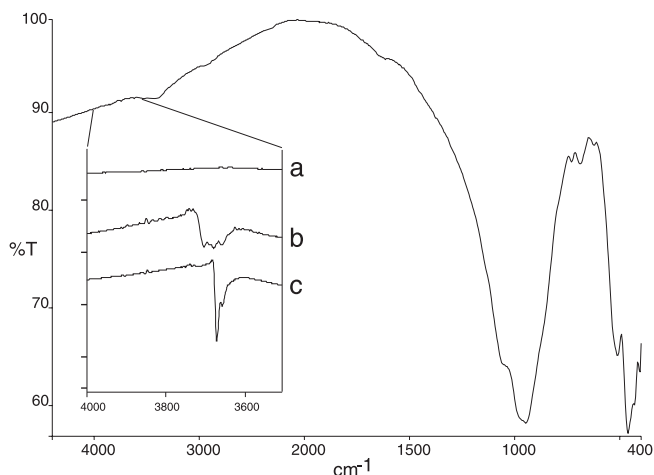
Fig. 2. FTIR spectra of fluoro-magnesiohastingsite from Dealul Uroi, Hunedoara district, Romania. The insert shows an enlargement of the near-infrared area. The (OH)-stretching bands of fluoro-magnesiohastingsite (a) are lacking in comparison with pargasite (b), Hunza-valley, Afghanistan and actinolite (c), Großer Greiner mountain, Zillertal, Austria.

m – medium, s – strong): 1056 (w), 950 (s), 731(w), 691(w), 627(w), 515 (m), 465 (s), 434 (w) and 408 (m) cm^{-1}. The spectrum (Fig. 2) does not show any absorption bands in the (OH)-stretching region (3800-3600 cm^{-1}). In Fig. 2, the (OH)-stretching region is also compared with that of actinolite from Großer Greiner-mountain, Zillertal, Austria and pargasite from Hunza valley, Afghanistan.

Physical and optical properties

Fluoro-magnesiohastingsite is reddish-brown with a vitreous lustre. Especially small crystals are transparent. Larger crystals have inclusions of hematite, chondrodite, augite and rarely fluorite. The streak is light reddish-brown. No fluorescence was observed under short- or long-wave ultraviolet light. The Mohs hardness is 6 and the tenacity is brittle. It has the usual perfect {110} cleavage of monoclinic amphiboles. The calculated density is 3.18 g/cm^3. The density could not be measured because of the small grain size of the homogenous crystals and mineral inclusions in the larger ones.

Fluoro-magnesiohastingsite is biaxial (+) and weakly pleochroic with α = 1.642 (yellow-brown), β = 1.647 (light brown) and γ = 1.662 (light brown) at 589 nm, 2V(meas. and calc.) is 61°. The Orientation of β is parallel to b. The axial plane is (010) ($\gamma \wedge c$ = 26º). Dispersion was not observed.

X-ray diffraction experiments and structure refinement

Powder X-ray diffraction data were recorded at 295 K using a D5000 diffractometer (Bruker AXS, twin-Goebel

Table 2. X-ray powder diffraction data for fluoro-magnesiohastingsite.

h k l	d_{obs}	d_{calc}	I/I_0
0 2 0	9.008	9.003	27
1 1 0	8.421	8.415	61*
-1 1 1	4.920	4.918	8
0 4 0	4.502	4.501	15
2 2 0	4.207	4.207	6*
-1 3 1	3.893	3.892	4
1 3 1	3.377	3.376	44
2 4 0	3.271	3.270	61
3 1 0	3.124	3.125	100
2 2 1	2.932	2.932	35
3 3 0	2.805	2.805	28*
-3 3 1	2.746	2.746	31
1 5 1	2.700	2.701	54
0 6 1	2.590	2.589	25
-2 0 2	2.557	2.556	31
4 0 0	2.3801	2.3796	12
-3 5 1	2.3445	2.3444	26
-4 2 1	2.3339	2.3341	23
-3 1 2	2.2969	2.2968	18
-2 4 2	2.2223	2.2228	4
2 6 1	2.1565	2.1566	25
2 0 2	2.0409	2.0413	10
-4 0 2	2.0323	2.0327	11
3 5 1	2.0114	2.0115	11
-3 7 0	1.9980	1.9981	7
-1 9 0	1.9579	1.9578	7
-5 1 0	1.8933	1.8931	15
5 3 0	1.8144	1.8146	9
4 6 1	1.6458	1.6458	26
-4 8 0	1.6353	1.6352	7
1 11 0	1.6130	1.6132	22
-4 0 3	1.6035	1.6034	3
6 0 0	1.5864	1.5864	10
-6 6 1	1.4413	1.4415	23

d in Å, * preferred orientation caused by cleavage, unit-cell parameters refined from these data are: a = 9.871(1) Å, b = 18.006(2) Å, c = 5.314(1) Å, β = 105.37(1)˚, V = 910.7(2) Å^3.

mirrors, Cu$K\alpha$). The indexed powder pattern and refined unit-cell dimensions are given in Table 2.

A single crystal (0.31 × 0.05 × 0.05 mm) of fluoro-magnesiohastingsite was mounted on a Bruker Apex CCD diffractometer using graphite-monochromated Mo$K\alpha$ X-radiation. Data were collected at 100 K and a total of 4754 reflections were measured with $-12 \leq h \leq 12$, $-22 \leq k \leq 22$ and $-6 \leq l \leq 6$ and $\theta_{max} = 26.3°$. Systematic absences, intensity statistics and the crystal structure refinement confirmed the space group $C2/m$. The refined cell parameters from single crystal data are a = 9.858(2) Å, b = 17.975(4) Å, c = 5.297(1) Å, β = 105.45(3)º, V = 904.8 Å^3. Data reduction included background, Lorentz-polarisation correction, and an empirical absorption correction (SADABS, Bruker Nonius). Reflections with $I < 2\sigma(I)$ were excluded leaving 953 unique data with R(int) = 0.040. The structure was refined with SHELXL-97 (Sheldrick, 1997) using neutral-atom scattering factors and corrections

Table 3. Crystal data and experimental details for fluoro-magnesiohastingsite.

$a = 9.858(2)$ Å, $b = 17.975(4)$ Å, $c = 5.297(1)$ Å, $\beta = 105.45(3)°$, $V = 904.8$ Å³,	$C2/m$
Frame width, scan time, number of frames	0.3˚, 10 s, 2400
Temperature, detector distance:	100 K, 6 cm
Effective transmission	0.814 – 1.000
R(int) before – after SADABS absorption correction:	0.0493 – 0.0276
Measured reflections, unique reflections – refined parameters	4754, 953 – 107
$R1(F) = 0.054$ for 903 $F_o > 4\_(F_o)$	
$wR2(F^2) = 0.140$ and Goodness-of-Fit = 1.108 for all 953 data	
Largest difference-Fourier peaks	+ 0.80 – 0.75 e/Å³

Table 4. Refined site-scattering (ss, electrons per formula unit, epfu), atomic fractional coordinates and equivalent isotropic displacement parameters.

Site	ss	x	y	z	U_{eq}
O1		0.1074(4)	0.0865(2)	0.2197(7)	0.0069(7)
O2		0.1191(4)	0.1715(2)	0.7318(7)	0.0076(7)
O3	18.30	0.1049(5)	0	0.7130(9)	0.0127(9)
O4		0.3660(4)	0.2510(2)	0.7885(7)	0.0086(8)
O5		0.3520(4)	0.1404(2)	0.1145(7)	0.0101(8)
O6		0.3470(4)	0.1167(2)	0.6132(7)	0.0106(8)
O7		0.3451(6)	0	0.2807(11)	0.0155(12)
T1		0.2822(2)	0.0852(1)	0.3053(3)	0.0059(4)
T2		0.2914(1)	0.1730(1)	0.8143(3)	0.0056(4)
M1	25.84	0	0.0871(1)	½	0.0073(5)
M2	32.64	0	0.1754(1)	0	0.0068(4)
M3	12.76	0	0	0	0.0067(7)
M4	39.95	0	0.2794(1)	½	0.0073(4)
Am	5.10	0.0500(14)	½	0.1032(28)	0.024(5)
A2	8.20	0	0.4819(4)	0	0.017(2)

$U_{eq} = \frac{1}{3}[U_{22} + 1/\sin^2\beta(U_{11} + U_{33} + 2U_{13}\cos\beta)]$; expression from Fischer & Tillmanns (1988).

Table 5. Selected interatomic distances (Å) and bond angles (º) for fluoro-magnesiohastingsite.

T1-O1	1.661(4)	T2-O2	1.637(4)
T1-O5	1.688(4)	T2-O4	1.607(4)
T1-O6	1.684(4)	T2-O5	1.650(4)
T1-O7	1.671(3)	T2-O6	1.664(4)
<T1-O>	1.676	<T2-O>	1.640
M1-O1 x 2	2.041(4)	M3-O1 x 4	2.059(3)
M1-O2 x 2	2.103(4)	M3-O3 x 2	2.054(4)
M1-O3 x 2	2.042(3)	<M3-O>	2.057
<M1-O>	2.062		
M4-O2 x 2	2.425(4)	M2-O1 x 2	2.091(4)
M4-O4 x 2	2.336(4)		
M2-O2 x 2	2.072(4)	M4-O5 x 2	2.605(4)
M2-O4 x 2	1.991(4)	M4-O6 x 2	2.569(4)
<M2-O>	2.051	<M4-O>	2.484
A2-O5 x 2	2.793(7)	Am-O5 x 2	3.037(8)
A2-O6 x 2	2.823(6)	Am-O5 x 2	3.201(9)
A2-O7 x 2	2.421(6)	Am-O6 x 2	2.622(10)
		Am-O7	2.445(14)
A2-O3	3.799(6)	Am-O7	2.515(14)
Am-O3	3.279(14)	Am-O7	3.150(16)
O5-O6-O5	161.6(2)		
O5-O7-O5	140.7(3)		
T1-O5-T2	133.2(2)	A2-Am	0.71(1)
T1-O6-T2	136.0(2)	A2-A2	0.65(1)
T1-O7-T1	133.0(4)	Am-Am	1.26(3)

for anomalous dispersion. The refinement was done with anisotropic displacement parameters, only the split A-site was refined isotropically, the extinction factor refined to zero. All cation sites were refined with variable occupancy with restraints based on the chemical data. According to the chemical analyses the O3 site was refined as being fully occupied by fluorine. The refinement converged at $R1(F) = 0.054$ for 903 $F_o > 4\sigma(F_o)$ and $wR2(F^2) = 0.140$ with Goodness-of-Fit = 1.108 for all data. The final difference-Fourier map did not exhibit peaks higher than ± 0.80 e/Å³. The highest peak at 0, 0.2342, ½ may indicate a very low occupancy of the M4' site but these coordinates could not be refined.

Crystal data and experimental details given in Table 3. Atomic coordinates, equivalent isotropic displacement factors and refined site-scattering values in epfu (electrons per formula unit) are given in Table 4. Anisotropic displacement parameters can be obtained from the authors (or through the E.J.M. Editorial Office – Paris). Selected interatomic distances and bond angles are summarized in Table 5.

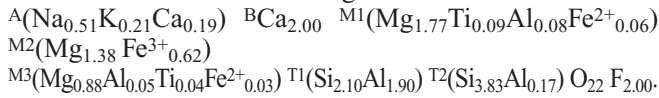## Site populations

The <T1-O> and <T2-O> distances indicate that [4]Al is partially ordered at T1. Using the equation (2) in Oberti et al. (1995a) the Al content in T1 is 1.90 apfu. The calculation of Al in T2 was done with the modified equation (5) of Oberti et al. (1995a) given in Sokolova et al. (2000): T(2)Al = [<T2-O>-<T2-O>$_c$] / 0.02836, and resulted in 0.17 apfu T(2)Al with <T(2)-O>$_c$ = 1.6352. The sum of Al = 2.07 apfu in T1 and T2 is in good agreement with the empirical formula (TAl = 2.11) given above.

The refined site-scattering for M2 and the mean <M2-O> distance of 2.051 Å indicate that Mg and Fe occupy this site and nearly all iron of this fluoro-magnesiohastingsite is ordered at M2 and trivalent (M2: $Mg_{1.38}$ $Fe^{3+}_{0.62}$). The refined lower site-scattering values for M1 and M3 and their similar mean bond-distances indicate an equal occupation of Mg+Ti+Al+Fe at these sites. The ordering of a trivalent cation at M2 could also be affected by the identity of the O3 anion, which was reported from the ordering of Al at M2 in synthetic fluor-pargasite (Oberti et al., 1995b). In fluoro-magnesiohastingsite the short M1-O3 and M3-O3 distances (2.042 and 2.054 Å respectively) indicate the presence of fluorine at O3, also confirmed by the refined high O3 site-scattering (18.3 epfu), the microprobe data

and from infrared spectroscopy. The M4 site is fully occupied by Ca.

The A cations are distributed at Am and A2 (split site) and the difference-Fourier map indicates A2 > Am. The refined site-scattering for Am and A2 equals 13.3 epfu. Calculating the epfu contribution of Na and K from the empirical formula (9.6 epfu Na+K), the residue of 3.7 epfu in Am + A2 was assigned to calcium. The site population of Ca = 0.19 apfu in A from site-scattering refinement is in good agreement with the empirical formula (^{A}Ca$_{0.17}$). The presence of Ca at the A site was first reported from the structure refinement of fluor-cannilloite (Hawthorne *et al.*, 1996) combined with an excess of Al in the T1 site (> 2.0) and no Al at T2.

For fluoro-magnesiohastingsite the proposed formula based on refined site-scattering values is:
^{A}(Na$_{0.51}$K$_{0.21}$Ca$_{0.19}$) ^{B}Ca$_{2.00}$ ^{M1}(Mg$_{1.77}$Ti$_{0.09}$Al$_{0.08}$Fe$^{2+}_{0.06}$) ^{M2}(Mg$_{1.38}$ Fe$^{3+}_{0.62}$) ^{M3}(Mg$_{0.88}$Al$_{0.05}$Ti$_{0.04}$Fe$^{2+}_{0.03}$) ^{T1}(Si$_{2.10}$Al$_{1.90}$) ^{T2}(Si$_{3.83}$Al$_{0.17}$) O$_{22}$ F$_{2.00}$.

Conclusions

The new xenolith-hosted mineral fluoro-magnesiohastingsite is part of the Ca-amphibole group. Si is > 5.5 and < 6.5, Mg > Fe, Fe^{3+} > Al$^{[6]}$, (Na+K)^A > 0.5 and Ti < 0.5 apfu, thus classifying this amphibole as a member of the calcic-amphibole group (Fig. 3). The O3-site is completely occupied by fluorine (2 apfu). As the fluorine occupies more than 50% of the O3-site, the correct name according to the IMA-CNMMN rules (Leake *et al.*, 1997) is: fluoro-magnesiohastingsite.

The charge balance Fe^{2+}/Fe^{3+} recalculation (sum of all cations exclusive Na and K is 15 (15eNK), *i.e.* minimum ferric estimate) according to Schumacher (1997) gives the total iron as ferric. Therefore, iron is given in Table 1 as
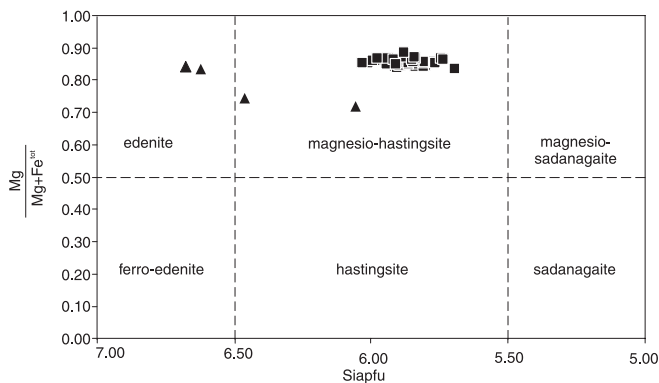
Table 6. Representative electron-microprobe analyses of mineralogical phases associated with fluoro-magnesiohastingsite from Dealul Uroi, Hunedoara district, Romania.

	1 phl	2 ttn	3 apt	4 chd	5 psb	6 hem
SiO$_2$	43.97	31.34	-	34.88	-	-
P$_2$O$_5$	-	-	42.03	-	-	-
TiO$_2$	3.00	34.19	-	-	49.54	3.87
Al$_2$O$_3$	10.83	3.61	-	-	1.01	2.54
Cr$_2$O$_3$	-	-	-	-	0.44	0.7
FeO	2.45	1.58	-	0.73	-	-
Fe$_2$O$_3$	-	-	-	-	44.67	89.71
MnO	-	-	-	0.34	-	-
MgO	25.32	-	-	58.3	5.23	2.16
CaO	-	28.32	55.09	-	-	-
Na$_2$O	0.48	-	0.20	-	-	-
K$_2$O	9.61	-	-	-	-	-
F	7.20	2.52	3.09	11.09	-	-
-O = F	3.03	1.06	1.30	4.67	-	-
Σ	99.83	100.50	99.11	100.67	100.89	98.98
Si	6.12	1.03	-	1.99	-	-
P	-	-	6.00	-	-	-
Ti	0.31	0.85	-	-	1.38	0.08
Al	1.78	0.14	-	-	0.04	0.08
Cr	-	-	-	--	0.01	0.01
Fe^{2+}	0.29	0.04	-	0.04	-	-
Fe^{3+}	-	-	-	-	1.24	1.75
Mn	-	-	-	0.02	-	-
Mg	5.26	-	-	4.96	0.29	0.08
Ca	-	1.00	9.96	-	-	-
Na	0.13	-	0.07	-	-	-
K	1.71	-	-	-	-	-
F	3.17	0.26	1.65	2.00	-	-
F/(F+OH)	0.79	0.26	0.83	1.00	-	-

Number of cations on the basis of: 1: 22 O (phlogopite), 2: 5 O (titanite), 3: 25 O (fluorapatite), 4: 9 O (chondrodite), 5: 5 O (pseudobrookite) and 6: 3 O (hematite).

Fig 3. Composition space Mg/(Mg+Fe^{tot}) – Si (apfu) of xenolith-hosted fluoro-magnesiohastingsite and rock forming fluoro-amphiboles (assuming ^{B}Ca > 0.5; ^{A}(Na+K) > 0.5; Ti < 0.5) from Dealul Uroi, Romania. Tie lines and mineral names according to the Ca-amphibole scheme. The squares refer to xenolith-hosted fluoro-magnesiohastingsite crystals (Table 1). Triangles show the chemical variation of rock-forming fluoro-amphiboles in the trachyandesite (Table 7).

Table 7. Electron-microprobe analyses of rock-forming fluoro-amphiboles from Dealul Uroi, Hunedoara district, Romania.

oxides	mean	range				
SiO$_2$	44.87	41.04 - 47.01	Si	6.41	$^{[B]}$Mg	0.22
TiO$_2$	1.87	1.22 - 3.53	$^{[T]}$Al	1.59	Ca	1.78
Al$_2$O$_3$	9.48	8.08 - 11.84	ΣT	8.00	ΣB	2.00
FeO	9.41	7.02 - 12.73				
MgO	18.23	15.63 - 19.26	$^{[C]}$Al	0.01	Na	0.61
CaO	11.65	10.50 - 12.26	Fe^{3+}	0.36	K	0.21
Na$_2$O	2.21	1.77 - 2.62	Fe^{2+}	0.77	ΣA	0.82
K$_2$O	1.14	0.70 - 1.36	$^{[C]}$Mg	3.66		
F	4.23	3.90 - 4.82	Ti	0.20	F	1.93
-O=F	1.78		ΣC	5.00	(OH)	0.07
Σ	100.22				F/(F+OH)	0.97

Average of 5 analyses. Minimum estimate of ferric iron (15 eNK) method by Schumacher (1997). Formula based on 24 (O, F, OH) assuming (F+OH) = 2.

Fe^{3+} which is also supported by the mean bond length of <M2-O>.

Ca is far above the usual "maximum"-value of 2.0 apfu observed in amphiboles. Only one member of the Ca-amphibole group, fluor-cannilloite (Hawthorne *et al.*, 1996), is in excess to this "limit" with Ca in A > 0.5. Ca-contents higher than 2.0 apfu are also observed in sadanagaite (Deer *et al.*, 1997), rarely in pargasite (Hawthorne *et al.*, 1996) and now in fluoro-magnesiohastingsite.

The major chemical variations in fluoro-magnesiohastingsite are in SiO_2 and Al_2O_3 contents (Table 1, Fig. 3). The Fe^{3+} in fluoro-magnesiohastingsite reflects strong oxidising conditions during formation. This observation is also supported by the abundance of hematite.

A pronounced fluorine enrichment of the late-stage fluid of magmatic crystallization has to be assumed. A number of minerals accompanying fluoro-magnesiohastingsite also host high amounts of fluorine. Fluorapatite, phlogopite and chondrodite have a $X_F > 0.79$ (Table 6) or are nearly end members, as demonstrated by their X_F values. Even titanite has a X_F of 0.26. Rare fluorite can be observed as tiny inclusions in fluoro-magnesiohastingsite.

Rock-forming fluoro-amphiboles at Dealul Uroi occur in fine-grained autoclasts in association with augite, plagioclase, hematite, fluorapatite and rarely fluorite. In contrast to the fluoro-magnesiohastingsite in xenoliths, the Si-content is higher and more variable (6.06 to 6.67 apfu) and $^{[4]}Al \leq 2.0$. Also the Ca-sum is < 2.0, therefore no Ca is assumed in A (Table 7). In the Ca-amphibole scheme the analyses plot in the fluoro-edenite and fluoro-magnesiohastingsite fields (Fig. 3).

Hawthorne *et al.* (1996) discussed the substitution $^ACa + ^{[4]}Al \rightarrow ^ANa + Si$ for fluor-cannilloite. The chemical analyses of all fluoro-amphiboles from Dealul Uroi confirm this substitution scheme.

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