Fluoro-edenite from Biancavilla (Catania, Sicily, Italy): Crystal chemistry of a new amphibole end-member

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ABSTRACT

Fluoro-edenite, ideally $NaCa_2Mg_5(Si_7Al)O_{22}F_2$, was found both as prismatic or acicular crystals of millimetric size and as fibers in the rock cavities in gray-red altered benmoreitic lavas occurring at Biancavilla (Etnean Volcanic Complex, Catania, Italy). It is associated with feldspars, quartz, clino- and orthopyroxene, fluoro-apatite, ilmenite, and hematite, and probably crystallized from late-stage hydrothermal fluids. Fluoro-edenite is transparent, intense yellow, non-fluorescent, has vitreous to resinous luster, and gives a yellow streak parallel to the c axis; Mohs' hardness 5–6, $D_{calc} = 3.09$ g/cm^3, perfect cleavage on {110}, and conchoidal fracture. In plane-polarized light, fluoro-edenite is birefringent (1st order), biaxial negative, $\alpha = 1.6058(5)$, $\beta = 1.6170(5)$, $\gamma = 1.6245(5)$, $2V_{calc} = 78.09°$, $Y \equiv \beta \perp (010)$, and γ:$Z = 26°$. No pleochroism is observed. Fluoro-edenite is monoclinic, space group $C2/m$, $a = 9.847(2)$ Å, $b = 18.017(3)$ Å, $c = 5.268(2)$ Å, $\beta = 104.84(2)°$, $V = 903.45$ Å^3, $Z = 2$; the ten strongest X-ray diffraction lines in the powder pattern are [$d(I, hkl)$]: 3.125(10, 310), 8.403(6,110), 3.271(5,240), 2.807(4,330), 2.703(3,151), 1.894(2,$\bar{5}$10), 2.938(2,221), 1.649(2, 461), 3.376(2,131), 1.438(2,$\bar{6}$61). IR analysis showed absorption bands at 1066, 991, 791, 738, 667, 517, 475 cm^{-1}, and no bands in the OH-stretching region. Structure refinement allowed determination of cation site-preference and ordering. Microprobe analysis of the refined crystal gave SiO_2 52.92, TiO_2 0.29, Al_2O_3 3.53, FeO_t 2.50, MnO 0.46, MgO 22.65, CaO 10.83, Na_2O 3.20, K_2O 0.84, F 4.35, Cl 0.07 wt%, and the crystal-chemical formula obtained by combining all the available data is: $^A(Na_{0.56} K_{0.15})$ $^B(Na_{0.30} Ca_{1.62} Mg_{0.03} Mn_{0.05})$ $^C(Mg_{4.68} Fe^{2+}_{0.19} Fe^{3+}_{0.10} Ti^{4+}_{0.03})$ $^T(Si_{7.42} Al_{0.58})$ O_{22} $^{O3}(F_{1.98} Cl_{0.02})_2$.

INTRODUCTION

Chemical and structural data for amphibole along the edenite-fluoro-edenite join, ideally $NaCa_2Mg_5Si_7AlO_{22}(OH,F)_2$, are reported sporadically in the literature and mostly refer to synthetic samples.

Edenitic compositions are rare in amphiboles, and their paucity might suggest a structural instability. Leake (1971), while providing some analyses of amphiboles approaching edenitic composition, commented on the rarity of edenite, which is confirmed in the latest report on amphibole nomenclature (Leake et al. 1997). Raudsepp et al. (1991) did a detailed investigation of amphibole synthesis at low P conditions, and concluded that edenite is not stable, and can only be considered as a non-predominant component of the amphibole compositional space.

Thirty-five analyses referring to the edenite root-name (two of which are from synthetic samples) are reported in Deer et al. (1997) but only some of them have significant fluorine contents. Laitakari (1921) described an edenite with 0.90 F, 0.19 Fe^{2+} and

0.07 Fe^{3+} atoms per formula unit (apfu), in a metamorphosed limestone from Pargas, Finland. Moore and Kerrick (1976) reported 0.67 F apfu in an edenite with 0.01 Fe^{2+} atom per formula unit, found in metadolomites in the Alta aureole, Utah. Kearns et al. (1980) reported an edenite with 0.82 F apfu and 0.15 Fe^{2+} apfu in marbles at Franklin, Orange County, New Jersey. Petersen et al. (1982) discussed the frequent incorporation of fluorine in micas and amphiboles, and reported two analyses of fluoro-edenites with 1.1 and 1.2 apfu of F and one analysis of a fluoroferro-edenite. More crystal-chemical information on a Fe-rich fluoro-edenite from pyroxene-hornblende andesites in the Ishigamiyama, Kumamoto Prefecture, Japan, was provided in an abstract by Tomita et al. (1994); however, approval of the International Mineralogical Association Commission on New Minerals and Mineral Names (hereafter IMA-CNMMN) has not been requested by these authors, and no paper has never been published, at least to our knowledge. In the amphibole database built up at the CNR-Centro di Studio per la Cristallochimica e Cristallografia (hereafter CNR-CSCC), which presently contains more than one thousand structure refinements, there is only one sample of ferro-edenite, which also has a significant F content (around 0.80 apfu).

Kohn and Comeforo (1955) provided unit-cell parameters for

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a synthetic fluoro-edenite, and structure refinements of synthetic fluoro-edenite and of synthetic manganoan fluoro-edenite were provided by Oberti et al. (1997, 1998). These latter authors proposed that the significant presence of Mg and Mn at the B-sites might depend on the Mn site-preference in fluoro-amphiboles and/or on the synthesis conditions including rapid quenching. Available unit-cell parameters and crystal-chemical formulae for amphiboles related to the root-name edenite are reported in Table 1.

Fluoro-edenite samples with composition close to ideal stoichiometry have been recently found near Biancavilla (Catania, Sicily, Italy), on the southwest side of the Etnean Volcanic Complex (Eastern Sicily). In a previous environmental health investigation related to a high incidence of malignant pleural mesothelioma in the Biancavilla area, Gianfagna et al. (1997) pointed out the worrying presence of acicular and asbestiform Ca-amphiboles (besides the more frequent prismatic crystals) in the volcanic products often used as building materials. Recently, Paoletti et al. (2000) suggested that these amphiboles, previously referred to as Na- and F-rich tremolites and actinolites, could be responsible for the occurrence of the malignant mesothelioma. Therefore a detailed crystal-chemical analysis of these amphiboles was undertaken to provide more information for both environmental health and petrologic studies.

The sample used in this work has been recognized as the fluoro-edenite holotype by IMA-CNMMN (vote 2000-049). It is deposited at the Museo di Mineralogia, Dipartimento di Scienze della Terra, Università degli Studi di Roma "La Sapienza," Italy, with the code 30006/1.

OCCURRENCE

Fluoro-edenite from Biancavilla occurs in autoclasts of grayred altered benmoreitic lavas, where it is generally associated with microgranular K-feldspar and plagioclase, quartz, clino- and orthopyroxenes, fluoro-apatite, ilmenite, and abundant hematite (Romano 1982; Gianfagna et al. 1997). The crystals may have prismatic or acicular habit and often occur as parallel bundles. The largest prismatic crystals (≥2 mm) are embedded in the matrix, whereas smaller acicular crystals line cavities where they are often perched on bright lamellar hematite and commonly show fibrous and asbestiform terminations; SEM-EDS analysis shows less Ca than in the prismatic crystals.

PHYSICAL AND OPTICAL PROPERTIES

Crystals of fluoro-edenite are prismatic to acicular with forms {110}, {010}, and {0kl}. The mineral is intense yellow and is transparent, with a vitreous to resinous luster, and gives a white-yellow streak parallel to the **c** axis. Mohs' hardness is 5–6,

the calculated density is 3.09 g/cm³; there is perfect cleavage on {110} and conchoidal fracture. In plane-polarized light, fluoro-edenite is birefringent (1st order), biaxial negative, $\alpha = 1.6058(5)$, $\beta = 1.6170(5)$, $\gamma = 1.6245(5)$, $2V = 78.1°$ $Y \equiv \beta \perp (010)$, $\gamma \perp Z = 26°$. There is no visible pleochroism.

CHEMICAL COMPOSITION

The fluoro-edenite crystals were analyzed with a Cameca SX-50 electron microprobe (EMP) operating in the WDS and EDS mode (analytical conditions: 15 kV, 20 nA, 3 μ beam size, peak count-time 20 s, background count-time 10 s; 100 s livetime in EDS mode). The following natural standards were used for calibration: wollastonite (Si$K\alpha$, Ca$K\alpha$), rutile (Ti$K\alpha$), corundum (Al$K\alpha$), magnetite (Fe$K\alpha$), metallic Mn (Mn$K\alpha$), periclase (Mg$K\alpha$), orthoclase (K$K\alpha$), jadeite (Na$K\alpha$), fluorophlogopite (F$K\alpha$), and sylvite (Cl$K\alpha$).

Table 2 shows the average analysis (3 points) of the crystal used for crystal structure refinement and the compositional ranges observed in all crystals analyzed (14 analyses; column 2). The major compositional variations are in SiO$_2$, Al$_2$O$_3$, and MgO contents. SiO$_2$ and Al$_2$O$_3$ wt% are inversely related, showing that the Al is incorporated at the T sites; the MgO contents are inversely related to those of the other C-group cations, and also to CaO. The unit-formulae were calculated on the basis of 24 (O + F) apfu, with Fe^{2+}/Fe^{3+} ratios in accord with the results of the structure refinement.

INFRARED SPECTROSCOPY

Fourier-transform infrared spectra were obtained with an Equinox-55 Bruker spectrometer from the far to the near infrared (400–4000 cm^{-1}) after 200 scans collected with a detector resolution of 1 cm^{-1}. Powdered fluoro-edenite (grain size maximum 20 μ), diluted by KBr and dehydrated at 110 °C, was used to obtain the IR spectrum by the diffuse-reflectance method. The spectrum does not show any absorption band in the OH-stretching region (3800–3600 cm^{-1}), and in the 1300–450 cm^{-1} range, significant absorption bands occur at 1066, 991, 791, 738, 667, 517, and 475 cm^{-1}. In Figure 1, the IR spectrum of fluoro-edenite from Biancavilla is compared (in the range 3900-3500 cm^{-1}) with that of tremolite (Cargille standard), which show the typical band at 3670 cm^{-1} (OH-stretching) observed in calcic amphiboles (Robert et al. 1989; Hawthorne et al. 1996a; Hawthorne et al. 2000).

X-RAY ANALYSIS

A powder X-ray diffraction pattern in the 2θ range 5–80° (Table 3) was obtained with a Seifert MZ IV diffractometer op-

TABLE 1. Unit-cell parameters and composition of the edenite and fluoro-edenite samples reported in the literature

Sample	a (Å)	b (Å)	c (Å)	β (°)	Crystal-chemical formula
Tomita et al. (1994)	9.861(4)	18.05(1)	5.282(1)	104.841(1)	(Na$_{0.63}$K$_{0.19}$) (Ca$_{1.70}$Na$_{0.15}$ Mg$_{0.15}$) (Mg$_{3.97}$Fe$_{0.87}$Ti$_{0.14}$Mn$_{0.02}$) (Si$_{7.07}$Al$_{0.93}$)O$_{22}$ (F$_{1.45}$OH$_{0.55}$)
Kohn and Comeforo (1955)	9.847(5)	18.004(4)	5.282(6)	104.50(8)	Na$_{0.99}$ (Ca$_{1.84}$Na$_{0.16}$) (Mg$_{4.79}$Al$_{0.18}$) (Si$_{7.12}$Al$_{0.88}$) O$_{22}$ F$_{2.15}$
Oberti et al. (1997)	9.829(4)	18.024(9)	5.284(2)	104.66(2)	Na$_{1.00}$ (Ca$_{1.42}$Na$_{0.14}$ Mn$_{0.44}$) (Mg$_{4.35}$Al$_{0.18}$ Mn$_{0.47}$) (Si$_{6.96}$Al$_{1.04}$) O$_{22}$ F$_2$
Oberti et al. (1998)	9.845(3)	18.010(5)	5.275(1)	104.74(2)	Na$_{0.82}$ (Ca$_{1.67}$Na$_{0.26}$Mg$_{0.07}$) (Mg$_{4.98}$Al$_{0.02}$) (Si$_{7.42}$Al$_{0.58}$) O$_{22}$ F$_2$
This work	9.846(4)	18.009(6)	5.277(2)	104.77(2)	(Na$_{0.56}$K$_{0.15}$) (Ca$_{1.62}$Na$_{0.30}$Mg$_{0.03}$ Mn$_{0.05}$) (Mg$_{4.68}$Fe$^{2+}_{0.19}$Fe$^{3+}_{0.10}$Ti$^{4+}_{0.03}$) (Si$_{7.42}$ Al$_{0.58}$) O$_{22}$ (F$_{1.98}$Cl$_{0.02}$)$_2$

TABLE 2. Electron-microprobe analyses of fluoro-edenite from Biancavilla: (1) average analysis of the crystal used for crystal-structure refinement and (2) average analysis and compositional variations observed in thin section

wt%	Oxides		Observed ranges	Formulae based on 24(O+F)	
	1*	2†		1*	2†
SiO_2	52.92	52.31	50.21–53.70	Si 7.39	Si 7.31
Al_2O_3	3.53	3.87	2.97–5.26	Al 0.58	Al 0.64
TiO_2	0.29	0.28	0.00‾–0.76	Σ T = 7.97	Σ T = 7.95
Fe_2O_3	1.00	1.00		Ti 0.03	Ti 0.03
FeO	1.60	1.66	2.26–2.93‡	Fe^{3+} 0.11	Fe^{3+} 0.11
MnO	0.46	0.40	0.29–0.60	Fe^{2+} 0.19	Fe^{2+} 0.20
MgO	22.65	22.78	21.77–23.19	Mn 0.05	Mn 0.05
CaO	10.83	10.86	10.45–11.55	Mg 4.71	Mg 4.75
K_2O	0.84	0.89	0.75–1.16	Σ C = 5.09	Σ C = 5.14
Na_2O	3.20	3.10	2.94–3.27	Δ C(Mn,Fe) = 0.09	Δ C(Mn,Fe) = 0.14
F	4.35	4.47	4.28–4.72	Ca 1.62	Ca 1.63
Cl	0.07	0.08	0.03–0.29	Na 0.29	Na 0.23
Σ	101.74	101.70		Σ B = 5.00	Σ B = 5.00
–F = O	1.83	1.88		Na 0.58	Na 0.61
Total	99.88	99.82		K 0.15	K 0.16
				Σ A = 0.73	Σ A = 0.77
				F 1.92	F 1.98
				Cl 0.02	Cl 0.02
				O^{2-} 22.06	O^{2-} 22.00

Note: Calculated ss at the group sites: (1) A: 9.23, B: 37.88, C: 63.94 electrons per formula unit (2) A: 9.75, B: 38.72, C: 63.38 electrons per formula unit.
* Mean of 3 analyses.
† Mean of 14 analyses.
‡ as FeO_t.
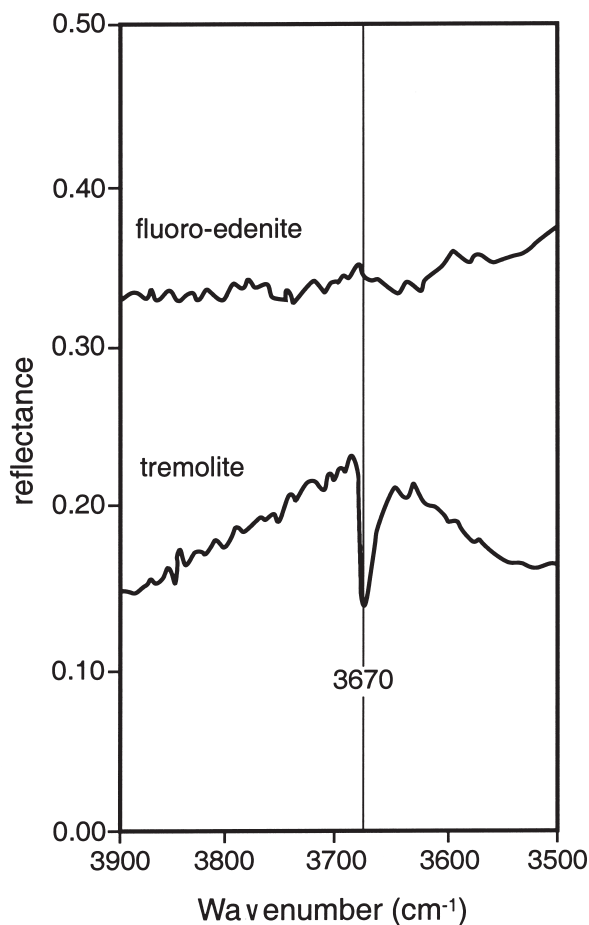
FIGURE 1. A comparison of the IR spectra (in the region 3900–3500 cm^{-1}) recorded for fluoro-edenite from Biancavilla, and for tremolite (Cargille standard) shows the absence of OH-stretching bands.

erating at 40 kV and 20 mA with Ni-filtered CuKα X-radiation. Unit-cell parameters were refined using the program LSUCRIPT, Fargo version (Appleman and Evans 1973): $a = 9.847(2)$, $b = 18.017 (3)$, $c = 5.268(2)$ Å, b = 104.84(2)°, $V = 903.45$ Å³.

A fluoro-edenite crystal was mounted on a Philips PW-1100 four-circle diffractometer and examined with graphite-monochromatized MoKα X-radiation; crystal quality was assessed via the profile and width of Bragg diffraction peaks. Unit-cell dimensions [$a = 9.846(4)$, $b = 18.009(6)$, $c = 5.277(2)$ Å, b = 104.77(2)°, $V = 904.78$ Å³] were calculated from least-squares refinement of the d values obtained from 50 rows of the reciprocal lattice by measuring the centroid of gravity of each reflection and of the corresponding anti-reflection in the range $-30 < \theta < 30°$. Intensity data were collected for the mono-clinic-equivalent pairs (hkl and $h\bar{k}l$) in the range $2 < \theta < 30°$. Intensities were then corrected for absorption, Lorentz and polarization effects, averaged and reduced to structure factors. Structure-refinement procedures were as described in Oberti et al. (1992) and Hawthorne et al. (1995). In particular, reflections with $I ≥ 3 \sigma(I)$ were considered as observed during the structure refinement. Scattering curves for fully ionized chemical species were used at sites where chemical substitutions occur; neutral vs. ionized scattering curves were used at the T and anion sites. In the difference-Fourier map, there is no electron-density maximum adjacent to O3. There was a small residue at the M4' site that shows the presence of some B-group Mg and/or Mn; due to the very low occupancy, the coordinates of the M4' site could not be refined.

The relevant agreement indexes are: $R_{sym} = 2.1\%$, $R_{obs} = 1.8\%$, $R_{all} = 3.7\%$. Atom coordinates, equivalent isotropic displacement parameters and refined site-scattering values are reported in Table 4, and selected bond distances and angles are reported in Table 5. The anisotropic components of the dis-

TABLE 3. X-ray powder diffraction data (Cu$K\alpha$ radiation) for fluoro-edenite from Biancavilla

d_{obs}(Å)	d_{calc} (Å)	I/I_o	h	k	l
8.982	9.009	7	0	2	0
8.403	8.416	57	1	1	0
5.069	5.079	5	1̄	3	0
4.870	4.873	6	1	1	1
4.498	4.504	9	0̄	4	0
4.203	4.208	10	2	2	0
3.376	3.373	13	1	3	1
3.271	3.271	48	2	4	0
3.125	3.125	100	3	1	0
2.938	2.934	17	2	2	1
2.807	2.805	33	3̄	3	0
2.733	2.733	12	3̄	3	1
2.703	2.700	25	1	5	1
2.587	2.587	9	0̄	6	1
2.528	2.531	7	2	0	2
2.382	2.381	9	3̄	5	0
2.336	2.336	11	3̄	5	1
2.296	2.294	8	1	7	1
2.159	2.158	11	2	6	1
2.036	2.038	4	2̄	0	2
2.015	2.015	5	4̄	0	2
1.9989	1.9986	5	3̄	7	0
1.8939	1.8932	18	5̄	1	0
1.8152	1.8147	7	5̄	3	0
1.6489	1.6477	14	4̄	6	1
1.6354	1.6357	7	4	8	0
1.6138	1.6142	5	1	11	0
1.5869	1.5864	13	6	0	0
1.5581	1.5581	4	2̄	10	1
1.5355	1.5344	4	6̄	0	2
1.5101	1.5098	4	2	6	3
1.5009	1.5014	8	0̄	12	0
1.4524	1.4524	3	6̄	4	2
1.4384	1.4383	14	6̄	6	1
1.4064	1.4070	3	2	12	1
1.3617	1.3621	4	5̄	1	2
1.3558	1.3559	6	7	1	0
1.3304	1.3298	4	4̄	10	1
1.3094	1.3103	5	7̄	5	1
1.2917	1.2913	3	2̄	12	2
1.2797	1.2801	3	6	6	1

TABLE 4. Atom fractional coordinates, refined site scattering values (electrons per formula unit), and equivalent displacement factors (Å²) for fluoro-edenite from Biancavilla
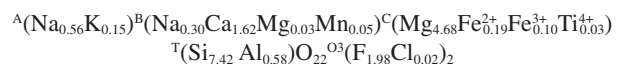
Site	ss	x/a	y/b	z/c	B_{eq}
O1		0.1108(1)	0.0850(1)	0.2186(2)	0.49(3)
O		0.1190(1)	0.1700(1)	0.7268(2)	0.54(3)
O3	17.95	0.1031(2)	0	0.7126(3)	0.70(4)
O4		0.3639(1)	0.2491(1)	0.7920(3)	0.76(3)
O5		0.3484(1)	0.1350(1)	0.1016(3)	0.90(3)
O6		0.3451(1)	0.1179(1)	0.5951(3)	0.78(3)
O7		0.3416(2)	0	0.2899(4)	0.90(4)
T1		0.2813(1)	0.0843(1)	0.2991(1)	0.40(1)
T2		0.2892(1)	0.1715(1)	0.8062(1)	0.40(1)
M1	24.24	0	0.0883(1)	0.5	0.49(2)
M2	27.11	0	0.1772(1)	0	0.47(2)
M3	12.08	0	0	0	0.49(3)
M4	37.18	0	0.2776(1)	0.5	0.87(2)
A	2.51	0	0.5	0	1.47(19)
Am	5.15	0.0393(6)	0.5	0.0923(11)	2.36(12)
A2	0.84	0	0.4700(18)	0	1.56(10)

Note: Refined ss at the group sites: A: 8.50, B: 37.18, C: 63.43 epfu.

placement parameters and the structure factors are reported in Tables 6 and 7, respectively.[1]

DISCUSSION AND COMPARISON WITH THE RELEVANT AMPHIBOLE END-MEMBERS

All analytical evidence (EMP analysis, absence of an absorption band in the principal OH-stretching region) and comparison with the unit-cell parameters (Table 1) reported by Tomita et al. (1994), Kohn and Comeforo (1955), Oberti et al. (1997, 1998), confirm that the F content of the fluoro-edenite from Biancavilla is close to the stoichiometric value.

On the whole, the structure refinement of fluoro-edenite from Biancavilla is very close to that of synthetic fluoro-edenite reported in Oberti et al. (1998). In particular, the mean bond-lengths at the M1 and M3 sites in the two samples are identical, confirming that F is close to the stoichiometric value and that Fe is preferentially ordered at the M2 site. The <M2-O>

distance is slightly shorter in the fluoro-edenite of this work (2.079 vs. 2.083 Å), in agreement with the presence of a minor amount of smaller high-charge cations (Fe^{3+} and Ti^{4+}) at the M2 site (Table 2).

Based on the above considerations for the C sites, the presence of an M4' residual, and the preference of Mn for the B sites observed in fluoro-richterite (Oberti et al. 1993), suggests assignment of the low Mn content to the M4' site. This assignment slightly but significantly improves agreement between the refined site-scattering values at the various sites and those calculated from the electron-microprobe analyses (Table 4): 63.4 vs. 64.4 electrons per formula unit (epfu) at the C sites, 37.2 vs. 37.4 epfu at the B sites, and 8.5 vs. 9.1 epfu at the A sites. The <T2-O> distances are identical in the Biancavilla and synthetic fluoro-edenite (i.e., 4.0 Si apfu at T2), whereas the small difference in the <T1-O> distances (1.637 vs. 1.639 Å) is in accord with the slightly lower Al content in fluoro-edenite from Biancavilla (0.58 vs. 0.60 apfu). The A cations are strongly ordered at the Am site, as expected for calcic amphiboles with nearly stoichiometric F contents and significant K (Hawthorne et al. 1996b).

Combining EMPA data and results of the structure refinement, we propose the following crystal-chemical formula for the refined crystal of fluoro-edenite from Biancavilla:

$$^A(Na_{0.56}K_{0.15})^B(Na_{0.30}Ca_{1.62}Mg_{0.03}Mn_{0.05})^C(Mg_{4.68}Fe^{2+}_{0.19}Fe^{3+}_{0.10}Ti^{4+}_{0.03})$$
$$^T(Si_{7.42}Al_{0.58})O_{22}O3(F_{1.98}Cl_{0.02})_2$$

The presence of significant Mn and/or Mg at the M4' site, which was ascribed to rapid quenching of the synthetic material by Oberti et al. (1998) occurs also in the sample from Biancavilla. This feature indicates a disordered distribution of medium-size divalent cations, and might simply be a consequence of the high temperature of crystallization from a fluid, combined with a rapid quenching. However, there is another possible crystal-chemical explanation. The smaller Mn^{2+}, Fe^{2+}, and Mg cations at the M4' site allow kinking of the double chain of tetrahedra (which is usually measured by the O5-O6-O5 angle; Table 5). This kinking reduces the chain repeat distance along the **c** axis, and promotes matching with the strip of octahedra, particularly when its dimensions are small because

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[1]For a copy of Tables 6 and 7, document item AM-01-075, contact the Business Office of the Mineralogical Society of America (see inside front cover of recent issue) for price information. Deposit items may also be available on the *American Mineralogist* web site at http://www.minsocam.org.

TABLE 5. Selected bond distances (Å) and angles (°) for fluoro-edenite from Biancavilla and for the synthetic fluoro-edenite reported in Oberti et al. (1998), for which e.s.d. are ~1 on the third digit

	Biancavilla	synthetic		Biancavilla	synthetic
T1-O1	1.624(1)	1.619	T2-O2	1.621(1)	1.621
-O5	1.645(1)	1.651	-O4	1.589(1)	1.590
-O6	1.643(2)	1.645	-O5	1.655(2)	1.653
-O7	1.635(1)	1.641	-O6	1.670(1)	1.672
<T1-O>	1.637	1.639	<T2-O>	1.634	1.634
M1-O1 ×2	2.056(1)	2.057	M2-O1 ×2	2.152(1)	2.154
-O2 ×2	2.062(1)	2.055	-O2 ×2	2.080(1)	2.079
-O3 ×2	2.059(1)	2.064	-O4 ×2	2.003(1)	2.018
<M1-O>	2.059	2.059	<M2-O>	2.079	2.083
M3-O1 ×4	2.055(1)	2.054	M4-O2 ×2	2.419(1)	2.419
-O3 ×2	2.029(2)	2.029	-O4 ×2	2.336(1)	2.324
<M3-O>	2.046	2.046	-O5 ×2	2.743(2)	2.744
-O6 ×2	2.550(2)	2.560			
<A-O>	2.926	2.915	<M4-O>	2.512	2.512
<Am-O>	2.863	2.850	O5-O6-O5	166.6	166.1
<A2-O>	2.612	2.616			

of the nearly complete Mg occupancy of the strip and the presence of 2 F apfu. Significant B-group Fe is observed in a F-rich ferro-edenite refined at the CNR-CSCC (unpublished results), in which a larger strip of octahedra (Fe = 2.6 apfu, F = 0.7 apfu) must match with a more extended double-chain of tetrahedra (Al = 1.10 apfu).

Finally, the mineralogical association observed at Biancavilla (feldspars, ortho- and clinopyroxene, fluoro-apatite, hematite) and the ubiquitous microgranular size, are in accord with a very late episode of magmatic crystallization and with a strong F enrichment in the fluid phase.

REFERENCES CITED

Appleman, D.E. and Evans, H.T. Jr. (1973) Job 9214: Indexing and least-squares refinement of powder diffraction data. U.S. National Technical Information Service, Document PB 216 188.
Deer, W.A., Howie, R.A., and Zussman, M.A. (1997) Rock-forming minerals. Vol. 2B. Double-chain silicates. The Geological Society, London.
Gianfagna, A., Paoletti, L., and Ventura, P. (1997) Segnalazione di fibre di amianto anfibolico nei prodotti lavici metasomatizzati di Monte Calvario, Biancavilla (Sicilia Orientale). Plinius (Suppl. European Journal of Mineralogy), 18, 117–119.
Hawthorne, F.C., Ungaretti, L., and Oberti, R. (1995) Site populations in minerals: terminology and presentation of results of crystal-structure refinement. Canadian Mineralogist, 33, 907–911.
Hawthorne, F.C., Della Ventura, G., and Robert, J.L. (1996a) Short-range order of (Na,K) and Al in tremolite: An infrared study. American Mineralogist, 81, 782–784.
Hawthorne, F.C., Oberti R., and Sardone, N. (1996b) Sodium at the A site in clinoamphiboles: the effect of composition on patterns of order. Canadian Mineralogist, 34, 577–593.
Hawthorne, F.C., Welch, M.D., Della Ventura, G., Liu, S., Robert, J.L, and Jenkins, D.M. (2000) Short-range order in synthetic aluminous tremolites: An infrared and triple-quantum MAS NMR study. American Mineralogist, 85, 1716–1724.
Kearns, L.E., Kite, L.E., Leavens, P.B., and Nelsen, J.A. (1980) Fluorine distribution in the hydrous silicate minerals of the Franklin marble, Orange County, New York. American Mineralogist, 65, 557–562.
Kohn, J.A., and Comeforo, J.E. (1955) Synthetic asbestos investigations. II. X-ray and other data on synthetic fluor-richterite, -edenite and -boron-edenite. American Mineralogist, 40, 410–421.
Laitakari, A. (1921) Über die Petrographie der Kalksteingerstatten von Parainen (Pargas). Bulletin de la Commission Géologique de Finlande, 10, n. 54.
Leake, B.E. (1971) On aluminous and edenitic hornblende. Mineralogical Magazine, 38, 389–407.
Leake, B.E., Woolley, A.R., Arps, C.E.S., Birch, W.D., Gilbert, M.C., Grice, J.D., Hawthorne, F.C., Kato, A., Kisch, H.J., Krivovichev, V.G., Linthout, K., Laird, Jo, Mandarino, J.A., Maresh, V.W., Nickel, E.H., Rock, N.M.S., Schumacher, J.C., Smith, D.C., Stephenson, N.N., Ungaretti, L., Whittaker, E.J.W., Youzhi, G. (1997) Nomenclature of amphiboles: report of the subcommittee on amphiboles of the International Mineralogical Association, Commission on New Minerals and Mineral Names. American Mineralogist, 82, 1019–1037.
Moore, J.N. and Kerrick, D.M. (1976) Equilibria in siliceous dolomites of the Alta aureole, Utah. American Journal of Science, 276, 502–524.
Oberti, R., Hawthorne, F.C., Ungaretti, L., and Cannillo, E. (1992) The behaviour of Ti in amphiboles: [4]Ti^{4+} in richterite. European Journal of Mineralogy, 3, 425–439.
———(1993) The behaviour of Mn in amphiboles: Mn in richterite. European Journal of Mineralogy, 5, 43–51.
Oberti, R., Hawthorne, F.C., and Raudsepp, M. (1997) The behaviour of Mn in amphiboles: Mn in synthetic fluoro-edenite and synthetic fluoropargasite. European Journal of Mineralogy, 9, 115–122.
Oberti, R., Hawthorne, F.C., Camara, F., and Raudsepp, M. (1998) Synthetic fluoro-amphiboles: site preferences of Al, Ga, Sc and inductive effects on mean bond-lengths of octahedra. Canadian Mineralogist, 36, 1245–1252.
Paoletti, L., Batisti D., Bruno C., Di Paola, M., Gianfagna, A., Nesti, M., and Comba, P. (2000) Unusually high incidence of malignant pleural mesothelioma in a town of eastern Sicily: an epidemiological and environmental study. Archives of Environmental Health, 55(6), 392–398.
Petersen, E.U., Essene, E.J., Peacor, D.R., and Valley, J.W. (1982) Fluorine end-member micas and amphiboles. American Mineralogist, 67, 538–544.
Raudsepp, M., Turnock, A.C., and Hawthorne, F.C. (1991) Amphibole synthesis at low pressure: what grows and what doesn't. European Journal of Mineralogy, 3, 983–1004.
Robert, J-L., Della Ventura, G., and Thauvin, J-L. (1989) The infrared OH-stretching region of synthetic richterites in the system Na$_2$O-K$_2$O-CaO-MgO-SiO$_2$-H$_2$O-HF. European Journal of Mineralogy, 1, 203–211.
Romano, R. (1982) Succession of the volcanic activity in the Etnean area. Memorie della Società Geologica Italiana, 23, 27–48.
Tomita, K., Makino, K., and Yamaguchi, Y. (1994) Fluor-edenite; its occurrence and crystal chemistry. I.M.A., 16th General Meeting, Abstracts, 16, 410.