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Cascandite and jervisite, two new scandium silicates from Baveno, Italy

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Abstract

Two new silicate minerals, cascandite and jervisite, were found as small crystals in a geode from Cava Diverio, Baveno, Italy.

Cascandite $Ca(Sc_{0.74}Mg_{0.02}Al_{0.01}Fe^{2+}_{0.22})(Na_{0.01}Ca_{0.04}Mn_{0.10}\square_{0.85})Si_3O_{8.02}(OH)$ or ideally $CaScSi_3O_8OH$, has triclinic symmetry, space group $P\bar{1}$ with lattice dimensions a = 7.529(11)Å, b = 7.051(12)Å, c = 6.755(9)Å,α = 92°7′(5), β = 93°40′(5), γ = 104°39′(5). The X-ray powder diffraction pattern has the strongest reflections at d = 3.62(m)(200), 3.10(m)(201,$1\bar{2}1$,$0\bar{1}2$), 2.968(m)(021,102,012), 2.821(s)(120), 1.429(m). Cascandite is structurally related to the wollastonite–pectolite–serandite group of minerals.

Jervisite $(Na_{0.43}Ca_{0.31}Fe^{2+}_{0.14}\square_{0.12})(Sc_{0.66}Fe^{2+}_{0.15}Mg_{0.19})Si_2O_6$ has monoclinic symmetry, space group $C2/c$ with lattice dimensions a = 9.853(11)Å, b = 9.042(10)Å, c = 5.312(7)Å, β = 106°37′(7). The X-ray powder diffraction pattern has the strongest reflections at d = 6.51(w)(110), 4.51(w)(021,$\bar{1}11$), 3.038(s)($\bar{2}21$), 2.979(m)(310), 2.543 (m)(221,002), 1.647(m)($\bar{5}31$,440). Jervisite is a scandium pyroxene and a natural analogue of the synthetic phase $NaScSi_2O_6$.

Introduction

We have recently studied some small crystals that occur in the granite from Baveno, Italy. The sample was obtained through the kindness of Dr. Enzo De Michele of the Museo Civico di Storia Naturale, Milan. The crystals are platy in habit (Fig. 1), light pink in color, and are associated with quartz, orthoclase and albite. The results of a qualitative energy dispersive analysis, which showed scandium as a major component, led to further study. A subsequent electron microprobe analysis, made on various crystal fragments, clearly indicated the presence of two different phases, both rich in scandium, but differing in sodium and calcium content.

We then reexamined the sample and found additional platelets that were light green in color. The results of the X-ray crystallographic study, together with the microprobe analytical data and the results of the subsequent crystal structure analyses, clearly indicated that the pale pink and the light green platelets corresponded to two distinct mineral phases, a scandium pyroxenoid and a scandium pyroxene, respectively. For these minerals we proposed the names cascandite from the chemical composition and jervisite in honor of William P. Jervis, who was curator of the Museo Industriale Italiano di Torino and author of the book "I Tesori sotterranei dell' Italia" on italian minerals. The new minerals and their names were approved by the I.M.A. Commission on New Minerals and Mineral Names.

X-ray crystallography

Rotation and Weissenberg photographs indicate that cascandite is triclinic, with unit cell parameters $a \simeq 7.5$Å, $b \simeq 7.1$Å, $c \simeq 6.8$Å, $\alpha \simeq 92°$, $\beta \simeq 93°$, $\gamma \simeq 104°$, space group $P1$ or $P\bar{1}$; whereas jervisite is monoclinic with unit cell parameters $a \simeq 9.8$Å, $b \simeq 9.0$Å, $c \simeq 5.3$Å, $\beta \simeq 107°$, with space group $C2/c$ or Cc, on the basis of the systematic absences (hkl absent for $h + k = 2n + 1$, $h0l$ absent for $l = 2n + 1$). Space groups $P\bar{1}$ and $C2/c$, for cascandite and

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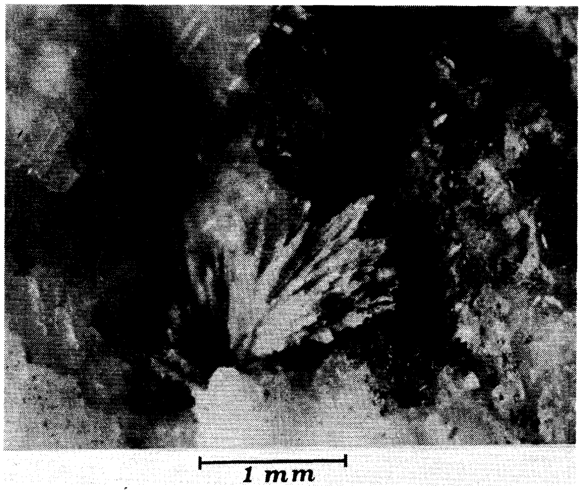

Fig. 1. Tuft in the center of the photograph is composed of platy crystals of jervisite and cascandite.

jervisite, respectively, were subsequently confirmed by the structure analysis.

The crystals of cascandite are pale pink platelets with vitreous luster, elongated along [100] and flattened parallel to {001}, with good {100} and {001} cleavages. The dimensions of the platelets are up to 0.20 × 0.08 × 0.02 mm, with observed forms {001} {100}, {120}, and {5$\bar{3}$0} as shown in Figure 2. The only optical properties measured were n_1 (= 1.663) and n_2 (= 1.684) on (001).

The crystals of jervisite are light green in color, vitreous in luster, and have perfect (110) cleavage. Their habit and dimensions are similar to those of cascandite.

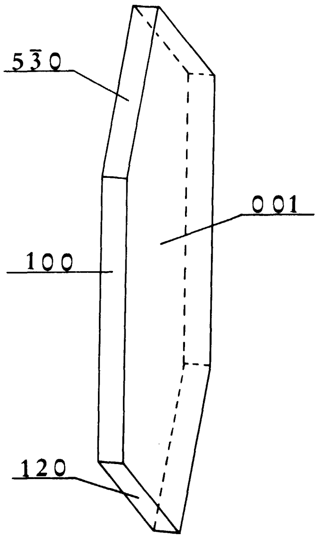

Fig. 2. Typical habit of cascandite.

Table 1 gives the X-ray powder diffraction pattern for cascandite. Because of the small quantity of available material, we obtained the powder pattern by the Gandolfi technique with Ni-filtered Cu*Ka* radiation (λ = 1.5418Å), using a small crystal previously examined by single crystal methods. The same crystal was used to collect the intensity data for structure refinement (Mellini and Merlino, 1982). In addition, single crystal intensity data offered a check on the indexing of the powder pattern lines.

Table 2 compares the X-ray powder diffraction pattern of jervisite and the synthetic scandium analogue of aegirine, which was synthesized by Ito and Frondel (1968). The powder patterns, obtained by means of a Gandolfi camera with crystals previously examined with rotation and Weissenberg pho-

Table 1. X-ray powder diffraction pattern of cascandite

Cascandite			Cascandite		
d(A)	hkl	I	d(A)	hkl	I
7.22	100	w	2.249	$\bar{1}\bar{2}2$	w
				003	
6.75	001	w			
4.46	110	w	2.220	220	w
3.84	$\bar{1}\bar{1}1$	w	2.190	$\bar{1}03$	w
				$\bar{1}31$	
3.62	200	m			
3.39	020	w		$\bar{3}21$	
	002		2.158	$0\bar{1}3$	w
3.25	$\bar{2}11$	w		$\bar{2}\bar{2}1$	
3.14	$\bar{1}02$	w	2.128	$3\bar{2}1$	w
				310	
	201				
3.10	$1\bar{2}1$	m	2.060	221	w
	$0\bar{1}2$		2.040	$\bar{3}02$	w
	021		1.779		w
2.968	102	m	1.717		w
	012		1.688		w
2.924	$\bar{1}12$	vw	1.642		w
2.821	120	s	1.623		w
2.753	$\bar{2}\bar{1}1$	vw	1.595		w
2.675	$\bar{1}\bar{2}1$	w	1.564		w
2.595	211	w	1.524		w
	112		1.447		w
2.421	300	w	1.429		m
2.337	$\bar{3}01$	w	1.398		w
	022		1.331		w
2.300	$\bar{2}\bar{1}2$	w	1.296		w
	$3\bar{1}1$		1.257		w

Table 2. X-ray powder diffraction pattern of jervisite and its synthetic analogue

jervisite			$NaScSi_2O_6$ syn	
d(A)	hkl	I	d(A)	I
6.51	110	w	6.52	m
4.51	021	w	4.52	m
	$\bar{1}11$			
3.68	111		3.68	w
3.389	021	w	3.39	w
3.255	220	w	3.25	w
3.038	$\bar{2}21$	s	3.045	vs
2.979	310	m	2.952	m
2.607	$\bar{1}31$	w	2.607	m
2.543	221	m	2.523	s
	002			
2.304	400	vw	2.329	w
	311			
2.233	112	vw	2.234	w
	022			
2.161	330	vw	2.169	mw
	$\bar{3}31$			
2.132	$\bar{4}21$	vw	2.135	w
2.067	041	vw	2.068	mw
	202		2.009	vw
	$\bar{1}32$			
	$\bar{2}41$		1.984	vw
1.922	$\bar{5}11$	vw	1.916	vw
	$\bar{4}22$		1.876	vw
	222			
	510		1.839	vw
	132			
1.778	150	w	1.778	mv
	421			
	312		1.714	vw
1.689	042	vw	1.697	m
1.647	$\bar{5}31$	m	1.645	w
	440		1.631	w
1.573	600	w	1.579	w
	$\bar{3}51$		1.564	vw
	$\bar{6}02$		1.549	vw
	$\bar{6}21$			
1.528	402	w	1.525	w
	332		1.511	vw
	060			
	$\bar{6}22$		1.471	vw
	620			
1.435	260	w	1.435	w
	351			
	152		1.425	w
	531			
	$\bar{2}43$		1.397	vw
	223			
	261			
	$\bar{7}12$		1.352	w
	$\bar{5}33$			
1.336	710	w	1.328	w
	621			
1.304	$\bar{3}14$	w	1.301	w
1.259	352	w	1.257	w

tographs, were indexed using single crystal diffractometer data as a check.

The unit cell parameters for cascandite and jervisite were refined by a least squares method using the powder pattern lines and are reported in Table 3, together with the unit cell parameters of synthetic $NaScSi_2O_6$, as given by Hawthorne and Grundy (1973).

Chemical composition

Two crystal fragments, identified as cascandite and jervisite by X-ray single crystal methods, were analyzed by electron microprobe. The standards used in the analysis were metallic scandium for Sc, analyzed actinolite for Fe, Na, Mn, Ti. Raw data were corrected by the MAGIC IV program of J. Colby. Three electron probe analyses were made on each crystal fragment, and the average values are reported in Table 4 as oxide weight percent. It was assumed that the iron present was Fe^{2+}, and that the water content in cascandite corresponded to one molecule in the unit cell, as indicated by the structural data discussed in the following paragraph. In Table 4 the cell contents for jervisite and cascandite are given, on the basis of three and two silicon atoms in the unit cell, respectively.

Structural and crystal chemical considerations

The crystal structure of cascandite was determined by Mellini and Merlino (1982) and that of jervisite by Mellini and Merlino and Rossi (to be published). The structures refined to *R* values of 0.04 and 0.05, respectively.

Jervisite is isostructural with the synthetic phase $NaScSi_2O_6$, which was synthesized by Ito and Frondel (1968), and whose structure was refined by

Table 3. Unit cell parameters of cascandite, jervisite and its synthetic analogue

	cascandite	jervisite	syn $NaScSi_2O_6$
Space group	$P\bar{1}$	C2/c	C2/c
a	7.529(11)Å	9.853(11)Å	9.8438(4)Å
b	7.051(11)	9.042(10)	9.0439(4)
c	6.755(9)	5.312(7)	5.3540(2)
α	92° 7'(5')		
β	93°40'(5')	106°37'(7')	107.215°(2)
γ	104°39'(5')		

Hawthorne and Grundy (1973). From the chemistry (unit cell contents) given in Table 4, $(Na_{0.43}Ca_{0.31}MN_{0.01}Fe^{2+}_{0.29}Mg_{0.17}Sc_{0.66}Al_{0.02}Ti_{0.01})_{tot.=1.89}Si_2O_{6.02}$, the following crystal chemical formula may be derived on the basis of structural data: $(Na,Ca,Fe^{2+})(Sc,Mg,Fe^{2+})Si_2O_6$ with Na > Ca, Fe^{2+}; Sc > Mg,Fe^{2+}. Thus jervisite is a scandium pyroxene, that is intermediate in the $Ca(Mg,Fe)Si_2O_6$–$NaScSi_2O_6$ series, analogous to the aegirine–augite series.

Cascandite is structurally related to the wollastonite–pectolite–serandite group. The crystal structure analysis clearly indicates that in cascandite, as in pectolite and serandite, there is an intrachain hydrogen bond. The hydrogen atom was located by a difference Fourier synthesis. The two octahedral sites, which are both occupied by calcium cations in pectolite and by manganese cations in serandite, host different cations in casandite: one is occupied by calcium and the other by scandium with minor Fe^{2+} cations. The site where sodium cations are located in pectolite and serandite, has an extremely low occupancy in cascandite (Mellini and Merlino, 1982).

Table 4. Chemical composition of cascandite and jervisite

Oxide	Weight per cent cascandite	Weight per cent jervisite	Element	Atoms per formula unit cascandite	Atoms per formula unit jervisite
SiO_2	51.83	50.42	Si	3.00	2.00
Sc_2O_3	14.74	18.48	Sc	0.74	0.64
FeO	4.50	8.59	Fe	0.22	0.29
MgO	0.20	2.80	Mg	0.02	0.17
TiO_2	0.08	0.55	Ti	0.01	0.02
Al_2O_3	0.11	0.42	Al	0.01	0.02
MnO	2.32	0.44	Mn	0.11	0.01
CaO	16.83	7.25	Ca	1.04	0.31
Na_2O	0.06	5.55	Na	0.01	0.43
H_2O	(2.59)		O	8.54	6.02
			H_2O	0.5	

The chemical contents reported in Table 4 can be conveniently expressed by the formula:

$$Ca(Sc_{0.74}Mg_{0.02}Al_{0.01}Fe^{2+}_{0.22}Mn_{0.01})(Na_{0.01}Ca_{0.04}Mn_{0.10}\square_{0.85})Si_3O_{8.02}(OH).$$

The crystal chemical formula that better summarizes the chemical as well as the structural data is $Ca(Sc^{3+}_{0.8}M^{2+}_{0.2})(M^{2+}_{0.2}\square_{0.8})Si_3O_{8.2}(OH)_{0.8}$ with $M^{2+} = (Fe^{2+},Mn^{2+})$, approximating the ideal composition $CaScSi_3O_8(OH)$.

Conclusions

The two new mineral phases, cascandite and jervisite, join kolbeckite $ScPO_4 \cdot H_2O$, bazzite $Be_3(Sc,Fe)_2Si_6O_{18}$ and thortveitite $(Sc,Y)_2Si_2O_7$, as rare minerals in which scandium occurs as an essential, major constituent. It seems remarkable that three of the four scandium silicates were found in the granite of Baveno. The three other phases with relatively high scandium content (Sc_2O_3 2–6 wt.%) are: Sc-ixiolite $(Ta,Nb,Sn,Mn,Fe,Sc,...)_2O_4$ (Borisenko *et al.*, 1969), Sc-perrierite $(Ce,La,Ca)_4(Fe^{2+},Sc)(Ti,Fe^{3+})_2Ti_2(O_4/Si_2O_7)_2$ (Semenov *et al.*, 1966), magbasite $KBa(Al,Sc)Fe^{2+}Mg_5F_2Si_6O_{20}$ (Semenov *et al.*, 1965).

The rarity of scandium minerals is a result of its crystal chemical behavior. In fact, in the first study of scandium geochemistry, Goldschmidt and Peter (1931) emphasized that the bulk of the element is dispersed in very small amounts among minerals formed in the early stages of magmatic differentiation, mainly pyroxenes, amphiboles and biotite. Only a very small amount passes through the magmatic stage and enters pegmatitic, pneumatolitic and hydrothermal deposits.

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