

SAPPHIRINE-BEARING ROCK, VAL CODERA, ITALY

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ABSTRACT

The sapphirine-bearing rock found in talus near Alpe Brasciadega, Val Codera, Italy, originally described by Cornelius and Dittler, has been re-examined. This locality is in the root zone of the Alps, near the Bergell granitic massif. Reaction rims and veins indicate that four successive assemblages formed; these are:

- 1) garnet-pleonaste,
- 2) biotite-cordierite-hypersthene-sapphirine,
- 3) biotite-cordierite-sapphirine-sillimanite, and
- 4) biotite-cordierite-orthoclase-sillimanite.

Garnet and the four mafic minerals of assemblage 2 were analyzed. Their ratios MgO: (MgO+FeO) are: garnet (0.54), biotite (0.83), cordierite (0.89), hypersthene (0.81), and sapphirine (0.85).

INTRODUCTION

The unique sapphirine-bearing rock of the Val Codera, Italy, has been described by Cornelius (1916; Cornelius and Dittler, 1929). The purpose of this paper is to present additional data on the assemblages and minerals found in this rock. The Val Codera is northeast of Lake Como and meets the Mera River at Novate Mezzola. The locality is at Alpe Brasciadega, in talus at the foot of a cliff (Cornelius and Dittler, 1929, p. 28-29). The terrain is precipitous, and the outcrop of sapphirine-bearing rock has not yet been found. Rocks underlying this area are highly metamorphosed gneisses and schists containing cordierite, garnet, and hypersthene (Reposi, 1915, 1917), and granitic rocks, some of which probably are related to the nearby Bergell massif. The area is in the so-called root zone of the Alps, and lies north of the Insubric dislocation-line (de Sitter, 1959, p. 177-179).

The writer visited the locality in 1960, and, after a thorough search, found one boulder only of Cornelius' and Dittler's "normal type" of sapphirine rock (1929, p. 30-38), which was described very carefully by them. The rock is coarse-grained and massive. Scattered garnets 5 to 25 mm in diameter are embayed by and set in a matrix of intergrown biotite, cordierite, hypersthene, and sapphirine. This fabric is cut by anastomosing veinlets of biotite, fine-grained cordierite and sapphirine, sillimanite, and minor orthoclase. Proportions of minerals in this rock vary greatly from place to place.

The rims on the garnets and the veinlets cutting the rock indicate that successively stable assemblages were:

- 1) garnet-pleonaste-(± other minerals),
- 2) biotite-cordierite-hypersthene-sapphirine,

TABLE 1. CHEMICAL ANALYSES OF SAPPHIRINE-BEARING ROCKS AND MAFIC MINERALS, VAL CODERA, ITALY

	Rock ¹	Rock ²	Biotite ⁵	Cordierite ⁵	Garnet ³	Garnet ³	Hypersthene ⁵	Sapphirine ⁴	Sapphirine ⁵
SiO ₂	39.93	42.4	39.9	50.1	39.04	41.1	50.5	15.19	14.8
TiO ₂	0.87	0.59	2.5	<0.1	0.12	0.16	0.20	0.25	0.12
ZrO ₂	0.09	n.a. ⁸	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Al ₂ O ₃	25.91	23.5	17.6	33.8	19.90	21.8	9.4	61.69	59.2
Fe ₂ O ₃	5.40	10.2 ⁶	2.7	0.9	5.03	1.3	2.4	n.a.	1.2
FeO	4.98	n.a. ⁶	6.8	2.6	19.13	20.3	10.8	4.31	5.6
MgO	17.24	16.7	17.9	11.7	13.97	13.2	25.4	16.23	18.0
CaO	1.30	0.21	0.3	0.2	2.17	1.4	0.3	0.49	<0.1
MnO	0.11	0.10	0.04	0.12	0.17	0.52	0.16	0.12	0.10
Na ₂ O	1.06	0.51	0.42	0.23	n.a.	0.13	0.15	n.a.	0.25
K ₂ O	2.25	3.0	9.0	0.12	n.a.	0.10	0.74	n.a.	0.18
H ₂ O	—	0.15			0.25			0.19	
H ₂ O ⁺	0.79	1.1	3.2 ⁷	0.6 ⁷	0.33	0.3 ⁷	0.2 ⁷	1.60	0.5 ⁷
P ₂ O ₅	0.03	0.08	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
CO ₂	n.a.	<0.05	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
S	0.04	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
F	n.a.	n.a.	0.78	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
TOTAL	100.00	98.5	100.8	100.4	100.11	100.3	100.3	100.07	100.0

^{1,3,4} Analyses from Cornelius and Dittler (1929), p. 47, 54, and 50 respectively.

² Analysis by rapid methods, U. S. Geological Survey chemists, of split from 3 lbs. of crushed rock.

⁵ Analyses by U. S. Geological Survey: SiO₂, TiO₂, Al₂O₃, CaO, and MnO determined by x-ray fluorescence; Fe₂O₃, FeO, MgO, and K₂O by combination of x-ray fluorescence methods and chemical analyses by H. Smith, P. L. D. Elmore, and M. Schnepfe; and Na₂O, H₂O, and F by chemical analyses of M. Schnepfe, B. L. Ingram, and H. Smith.

⁶ Value given is total iron as Fe₂O₃. Rock not fully decomposed by rapid methods, and thus iron determination uncertain.

⁷ Values given are for total water.

⁸ n.a. = not analyzed.

3) biotite-cordierite-sapphirine-sillimanite, and

4) biotite-cordierite-orthoclase-sillimanite.

This sequence is similar to that of Cornelius and Dittler (1929, p. 33). Assemblages 2 and 3 are more magnesian, aluminous, and potassic than the first one, and assemblage 4 is both less ferrous and less magnesian than the preceding three, as shown by the mineral analyses of Table 1. Assemblages 1, 2 and 3 are roughly shown in an A-FM-S diagram in Fig. 1. The bulk composition of assemblage 1 lies very close to that of the garnet. Biotite has been shown in Fig. 1 as an isolated point, but the reader should bear in mind that it is part of both assemblages 2 and 3.

Two major reactions are inferred for the alteration of assemblage 1 to assemblage 2 and of assemblage 2 to assemblage 3; these are approximately:

- A) assemblage 1→assemblage 2:
 pyropic garnet (+pleonaste)+K₂O→biotite+cordierite₁+hypersthene+sapphirine₁, and
 B) assemblage 2→assemblage 3:
 cordierite₁+hypersthene+sapphirine₁→cordierite₂+sapphirine₂+sillimanite,

in which 2 generations of cordierite and sapphirine are indicated by subscripts. Orthoclase also was formed either during or after reaction B,

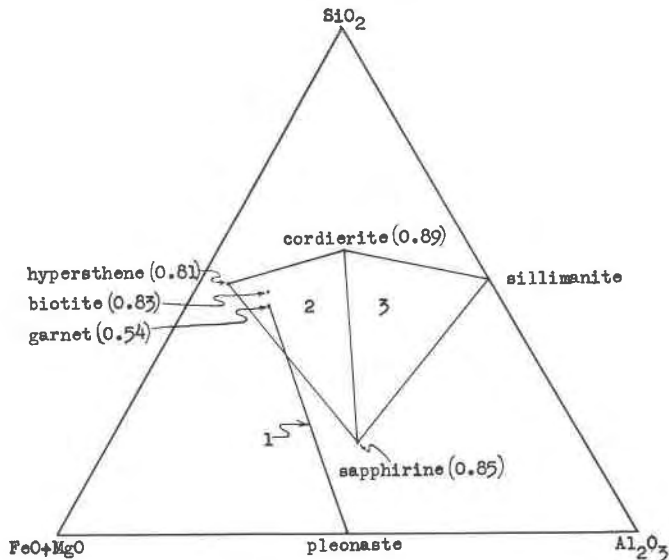


FIG. 1. Diagram of molar proportions of Al_2O_3 , $FeO+MgO$, and SiO_2 , showing assemblages 1, 2, and 3. The ratio $MgO:(MgO+FeO)$ is given in parentheses next to each ferromagnesian mineral name (biotite is also part of assemblages 2 and 3).

and is separated from sapphirine by rims of cordierite (see Schreyer and Yoder, 1961, Pl. 7, Fig. 52). Reaction A is shown largely by reaction rims on 0.5 to 3 cm garnets, with only small amounts of pleonaste present. Reaction B produced the anastomosing vein system of products in the reactants. The biotite shows no discernible changes from one assemblage to another. Also, the fine-grained cordierite and sapphirine found in the veinlets could not be separated for determination of optical constants, but use of Becke lines in thin sections suggests that their indices of refraction are very close to those of their coarse-grained neighbors. Thus, the compositions of the two generations of cordierite

and sapphire are believed to be very similar. Ideally, in the system $\text{Al}_2\text{O}_3\text{-FeO-MgO-SiO}_2$ one would expect the three-phase fields cordierite-hypersthene-sapphire and cordierite-sapphire-sillimanite to be separated by a two-phase field cordierite-sapphire, in which the MgO:FeO ratios of both cordierite and sapphire would vary. This two-phase field must be rather narrow.

The bulk chemical analysis of this complex rock, a mixture of the four assemblages, is notably high in Al_2O_3 and MgO , as shown in Table 1.

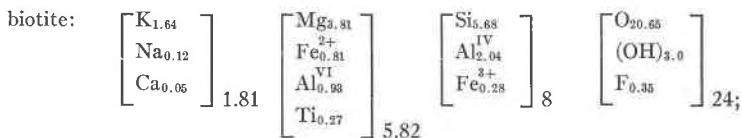
MINERALOGY

Analyses of garnet and sapphire made by Dittler (Cornelius and Dittler, 1929, p. 50, 54) are given in Table 1 with new analyses of biotite, cordierite (from assemblage 2), garnet, hypersthene, and sapphire (from assemblage 2). These minerals were hand-picked; the separates are free of visible inclusions. Semiquantitative spectrographic data for the newly analyzed minerals are given in Table 2. All five minerals are relatively magnesian, and the hypersthene is aluminous—its 9.4 per cent of Al_2O_3 is analogous to amounts found in hypersthene of the classical granulite facies.

Optical data for the five newly analyzed minerals are shown in Table 3. Most grains of garnet have refractive indices 1.773 to 1.774, but a few grains in each mount showed $n = 1.775$ to 1.776, indicating slight zoning. Values of $(2V)$ were measured with a Universal stage. The inclined dispersion of sapphire is such that— $(2V)$ is 52° in Na light and 59° in white light. Pleochroic formulae are: biotite-X=very pale brown, Y=Z=deep brown; hypersthene-X=deep pink, Y=pale pink, Z=greenish-gray; and sapphire-X=pale greenish-gray, Y=deep sky blue, and Z=pale pink.

The cordierite was x-rayed; its Miyashiro Δ -value is 0.28 ± 0.04 , as determined from relatively broad peaks. B. J. Skinner very kindly determined the unit-cell edge of the garnet as $11.5125 \pm 0.0019 \text{ \AA}$ at 25° C. , where 0.0019 is the standard error of the mean. He reports that the doublets indicate slight inhomogeneity of this garnet, as independently suggested by the range of refractive index.

Chemical formulae of the five analyzed minerals were calculated. These are:



(Continued on page 151)

TABLE 2. SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES OF MINERALS FROM VAL CODERA, ITALY

[M=major constituent, O=looked for but not detected]

	Biotite	Cordierite	Garnet	Hypersthene	Sapphirine
Si	M	M	M	M	7.
Al	7.	M	10.	5.	M
Fe	7.	3.	M	10.	5.
Mg	M	10.	10.	M	M
Ca	.1	.07	.7	.07	.03
Na	.3	.1	.03	.07	.01
K	5.	O	O	.5	O
Ti	1.	.003	.07	.07	.02
P	O	O	O	O	O
Mn	.02	.03	.2	.07	.02
Ag	O	O	.00007	.00001	.00005
As	O	O	O	O	O
Au	O	O	O	O	O
B	.003	.015	.01	.01	.02
Ba	.03	.0007	.0005	.003	.0007
Be	O	.0005	O	O	.0003
Bi	O	O	O	O	O
Cd	O	O	O	O	O
Ce	O	O	O	O	O
Co	.0015	.0003	.0007	.001	.0015
Cr	.0007	.0005	.0007	.0007	.001
Cu	.0005	.0001	.00005	.0003	.00015
Ga	.003	.0015	.0007	.003	.007
Ge	O	O	O	O	O
Hf	O	O	O	O	O
Hg	O	O	O	O	O
In	O	O	O	O	O
La	O	O	O	O	O
Li	O	O	O	O	O
Mo	.0003	O	.0007	O	O
Nb	.005	O	.0003	.0003	O
Ni	.005	.003	.007	.005	.005
Pb	.0001	O	O	O	O
Pd	O	O	O	O	O
Pt	O	O	O	O	O
Re	O	O	O	O	O
Sb	O	O	O	O	O
Sc	.0007	O	.003	.0007	O
Sn	O	O	O	O	O
Sr	.0005	O	.0003	O	O
Ta	O	O	O	O	O
Te	O	O	O	O	O
Th	O	O	O	O	O
Tl	O	O	O	O	O
U	O	O	O	O	O
V	.007	.0003	.0007	.005	.005
W	O	O	O	O	O
Y	.001	.0007	.01	.001	O
Yb	.0001	O	.001	.0001	O
Zn	O	O	O	O	O
Zr	.015	.007	.015	.01	.015

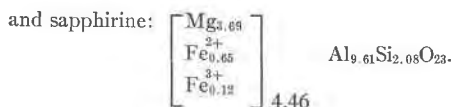
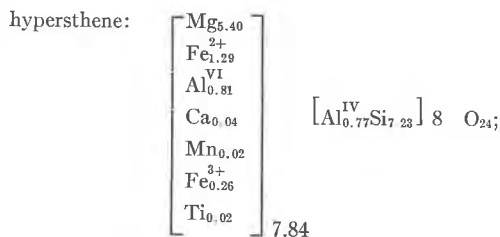
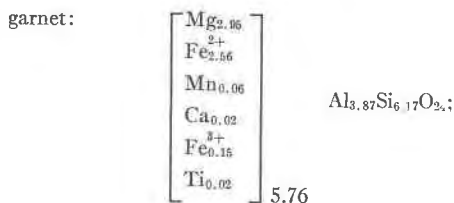
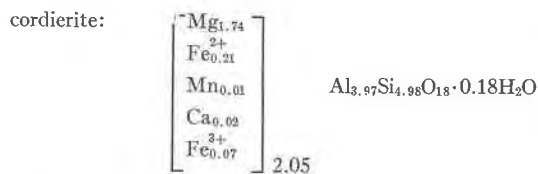


TABLE 3. OPTICAL DATA OF MINERALS FROM VAL CODERA, ITALY
(All indices of refraction for sodium light)

	η	α	β	γ	Error	(2V)	$(\gamma - \alpha)$
biotite		n.d.	n.d.	1.612	± 0.002	ca. -5°	0.05
cordierite		1.534	1.538	1.541	± 0.002	-75°	0.007
garnet	1.773 to 1.774				± 0.004		
hypersthene		1.691	1.698	1.708	± 0.003	-78°	0.017
sapphirine		1.720	1.724	1.727	± 0.003	-52° (Na)	0.007

n.d.: not determined.

The first four formulae are given with the conventional number of (O+OH+F) atoms, and H₂O for cordierite is written as water of hydration. This sapphirine has a composition rather close to that in which the ratio (MgO+FeO):Al₂O₃:SiO₂=4:5:2, and which contains 23 atoms of

oxygen in its formula. The substitution of $Al^{VI}Al^{IV}$ for $MgSi$ is not extensive.

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