

Stellerite from Villanova Monteleone, Sardinia

E. GALLI & E. PASSAGLIA

Galli, E. & Passaglia, E. 1973: Stellerite from Villanova Monteleone, Sardinia. *Lithos* 6, 83-90.

Stellerite (a zeolite) occurs as polycrystal aggregates filling cavities and fractures in the andesite near Villanova Monteleone (Sassari). Principal forms are {100}, {010}, {001} and {111}. The indexed X-ray diffraction powder pattern is reported. The mineral is orthorhombic, with space group Fmmm (or F222 or Fmm2). The unit cell dimensions, chemical formula, density and optical properties are given.

E. Galli & E. Passaglia, Istituto di Mineralogia e Petrologia, Università di Modena, Via S. Eufemia 19, 41100 Modena, Italy.

The name 'stellerite' was first proposed by Morozewicz (1909) for an orthorhombic zeolite similar to stilbite, from the Komandor Islands (Bering Sea).

Rosický & Thugutt (1913) proposed the name 'epidesmine' for a similar mineral from Saxony. It is thus clear that the first name, stellerite, has priority. The above mentioned authors based their discoveries (namely, that the crystals were orthorhombic) on the morphology of the minerals in question. Monoclinic stilbite is pseudo-orthorhombic with a β angle very close to 90° . Thus the differences between the two minerals are very small indeed.

Pabst (1939) first denied that stellerite was an independent species distinct from stilbite, but it was later strongly confirmed by Erd et al. (1967).

Nowadays it is a routine operation to determine whether or not a mineral is orthorhombic; for instance, by means of a precession photograph. Furthermore, this zeolite is associated with a specific 'habitus', a very low Na content (in any case lower than that found in stilbite), a SiO_2 content higher than that of stilbite, and, of course, parallel extinction in accordance with the orthorhombic symmetry.

Real stellerites have been studied and fully described by Neumann (1944), Mattinen (1952), Barabanov (1955) and Young Men-chin (1965). The following authors also have described stellerites: Fersman (1922), Hawkins & Shannon (1924), Shannon (1924), Wheeler (1927), Koritnig (1940), Shaka-bara (1941), Erdélyi (1943), Gavelin (1945), Pelloux (1949), Franco (1952) and Sæbø et al. (1959). Although their descriptions are not complete they leave very little doubt as to the correct identification of the mineral.

Relations between the lattice symmetry of stellerite and stilbite

The relation between the unit cells of stellerite and stilbite is shown in Fig. 1. Both the C base-centred monoclinic and the F face-centred ortho-

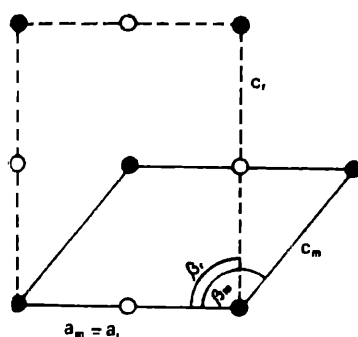


Fig. 1. Relation between the base-centred C (continuous lines) and the face-centred F (dashed lines) unit cells of stilbite.

rhombic cells have been used in the literature for stilbite. Stellerite cell dimensions are very close to those of a pseudo-orthorhombic cell of stilbite, the only difference being the value of β which, in the case of stellerite, is exactly 90° while it is slightly less than 90° in stilbite (see Table 1).

The maximum lattice symmetry allowed for stilbite is that of the space group $C2/m$ (Galli 1971), hence the symmetry of stellerite is that of the space group $Fmmm$.

The relations between the two minerals are due to the presence in stilbite of a topologically orthorhombic framework of $(Si,Al)O_4$ tetrahedra; the lowering of the symmetry is due to the Si-Al distribution and/or to the distribution of the cations and the water molecules in the channels. Although the two minerals can be distinguished by simply observing their extinction angles in the microscope, we think it more appropriate to take a zero-level precession photograph $[010]$. This is ideal not only for measuring β but also for observing the diffraction-spot intensities of types $(h0l)$ and $(\bar{h}0l)$, which are equal in the orthorhombic but different in the monoclinic system. The diffraction intensities of the couple (604) and $(\bar{6}04)$ (orthorhombic indices) are quite different in stilbite but equal in stellerite.

Occurrence and paragenesis

The sample of stellerite comes from a small outcrop of volcanic rock on the right side of the road Villanova Monteleone-Monteleone Rocca Doria (SS. 292) about 1.5 kilometres from Villanova Monteleone cemetery. The locality is known as 'Bena e Luna'.

Table 1. Relations between the base-centred C and the face-centred F unit cells of stilbite (Galli 1971).

	Base-centred C cell	Face-centred F cell (pseudo-orthorhombic)
<i>a</i>	13.64 Å	13.64 Å
<i>b</i>	18.24 Å	18.24 Å
<i>c</i>	11.27 Å	17.70 Å
β	$128^\circ 15'$	91°

The rock commonly appears homogeneous. It is light brown in colour with reddish shades, and is very compact when fresh, but much less so where weathered. Occasionally, it is like a breccia with almost black and very hard fragments of varying size. The homogeneous rock is an andesite rock type, belonging to the 'pre-Helvetian' volcanic formation (lower Miocene) which is widespread throughout the central area of northwest Sardinia.

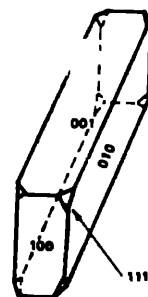


Fig. 2. Morphology of the stellerite from Villanova Monteleone, Sardinia.

The walls of large cavities and fractures are lined with polycrystal aggregates of stellerite sometimes accompanied by heulandite in large, prismatic, clear-white crystals that flake off easily. Worth noticing is the presence of tridymite in hexagonal-shaped lamellae in the cavities of the black fragments only.

Morphology

The single clear-white crystals may reach a maximum size of $5 \times 2 \times 0.5$ millimetres. The goniometric measurements on single crystals (Fig. 2) indicate the constant presence of the forms: $\{100\}$, $\{010\}$, $\{001\}$, $\{111\}$, the best developed being the $\{010\}$, which is also the perfect cleavage plane and contact face for the aggregates.

X-ray data

A zero-level precession photograph (010)(Ni-filtered $\text{CuK}\alpha$ radiation) yielded the following observations: (a) $\beta = 90^\circ \pm 5'$; (b) the photograph shows two mutually perpendicular mirror planes, and the intensity of the (604) reflection is equal to that of $(\bar{6}04)$. Therefore, the mineral is orthorhombic.

X-ray powder data of stellerite from Villanova Monteleone are reported in Table 2. The d_{obs} values were obtained by means of a Philips diffractometer with Ni-filtered $\text{CuK}\alpha$ radiation. Cubic $\text{Pb}(\text{NO}_3)_2$ with an $a_0 = 7.8568 \text{ \AA}$ (see 6-0151 JCPDS card) was used as internal standard. The intensities were estimated visually. Cell dimensions were derived by a least-squares computer programme using only the reflections marked by a star in Table 2 for the refinement cycles. The others were discarded because they could not be univocally referred to a set of indices or because they were too far from the standard lines. The values obtained are reported in Table 3 which also

Table 2. X-ray diffraction powder data for stellerite from Villanova Monteleone.^a

h k l ^b	I/I ₀	d _{obs.} (Å)	d _{calc.} (Å)	h k l ^b	I/I ₀	d _{obs.} (Å)	d _{calc.} (Å)
0 2 0}	100	9.03	{9.11	4 0 6}	1	2.2390	{2.2398
0 0 2}			{8.93				3 7 1}
0 2 2	<1	6.365	6.378	0 0 8*	1	2.2325	
2 2 0	2	5.444	5.449	3 5 5*	1	2.2225	2.2233
2 0 2	3	5.410	5.410	3 1 7}	1	2.2060	{2.2073
1 3 1	4	5.289	5.297	0 8 2}			{2.2071
2 2 2*	15	4.655	4.652	6 2 0}	1	2.2010	{2.1995
0 4 0*	4	4.557	4.556	6 0 2}			{2.1969
0 0 4*	2	4.466	4.466	4 6 2}	<1	2.1675	{2.1954
3 1 1*	6	4.275	4.271	0 2 8			2.1687
1 3 3}	45	4.057	{4.058	5 5 1}	<1	2.1610	{2.1637
0 4 2}			{4.058	2 8 0}	{2.1598		
0 2 4*	6	4.013	4.010	0 6 6*	1	2.1240	2.1260
2 4 0*	1	3.784	3.785	2 0 8*	1	2.1196	2.1214
2 0 4*	5	3.734	3.733	2 8 2*	1	2.0972	2.0993
2 4 2*	3	3.482	3.485	1 7 5}	<1	2.0775	2.0792
4 0 0*}	7	3.397	{3.400	2 2 8}	2	2.0657	{2.0661
1 1 5 }			{3.395	1 5 7			{2.0661
0 4 4 }	7	3.181	{3.189	5 3 5*	2	2.0373	2.0385
4 2 0}			{3.185	6 4 0}			{2.0292
4 0 2}			{3.177	2 6 6}			{2.0291
3 3 3*	3	3.100	3.101	0 8 4}	2	2.0305	{2.0291
0 6 0}	23	3.028	{3.037	6 4 2			<1
1 5 3}			{3.030	6 2 4	<1	1.9733	1.9731
1 3 5}	10	3.003	{3.003	4 8 0*	2	1.8930	1.8923
4 2 2}			{3.000	5 5 5	<1	1.8613	1.8607
0 0 6*	1	2.976	2.977	0 10 0*	5	1.8216	1.8222
2 4 4}	2	2.875	{2.887	6 6 0*	5	1.8168	1.8164
0 6 2}			{2.875	3 1 9}	2	1.8117	{1.8092
0 2 6*	1	2.827	2.830	0 8 6}			{1.8090
3 5 1*	1	2.804	2.805	0 0 10}	1	1.7855	{1.7863
3 1 5}	8	2.771	{2.773	0 10 2}			{1.7854
2 6 0}			{2.773	6 6 2}	1	1.7803	{1.7800
4 0 4*	2	2.703	2.705	5 3 7}	1	1.7394	{1.7793
2 2 6}	2	2.608	{2.613	2 6 8*			1B
4 4 2}			{2.606			<1	1.6993
3 5 3*	4	2.562	2.564		1	1.6883	
3 3 5	1	2.5455	2.5472		1	1.6703	
1 7 1*	1	2.5320	2.5309		2	1.6625	
0 6 4*	1	2.5115	2.5113		1	1.6415	
1 5 5*	1	2.5075	2.5075		1	1.6380	
0 4 6*	2	2.4935	2.4922		2	1.5893	
1 1 7*	2	2.4850	2.4847		1	1.5664	
5 3 1}	1	2.4515	{2.4587		1	1.5577	
5 1 3}			{2.4514		2	1.5539	
2 6 4}	2	2.3510	{2.3558		1	1.5504	
1 7 3}			{2.3493		1B	1.4444	
4 4 4}	1	2.3175	{2.3259		1B	1.3555	
1 3 7}			{2.3182		1	1.3004	
6 0 0}	1	2.2670	{2.2665				
4 6 0}			{2.2649				

Table 3. Data for stellerite from Villanova Monteleone.

<i>a</i>	13.599 ± 0.004 Å
<i>b</i>	18.222 ± 0.004 Å
<i>c</i>	17.863 ± 0.003 Å
Cell volume	4426 ± 2 Å ³
Space group	Fmmm (or F222 or Fmm2)
Chemical formula	(Ca _{3.78} Mg _{0.03} Sr _{0.01} Na _{0.17} K _{0.14}) _{tot=4.13} [(Al _{7.93} Fe _{0.06}) _{tot=7.99} Si _{28.02}] O ₇₂ · 28.10 H ₂ O
Z	2
D _{calc.}	2.12 g · cm ⁻³
D _{meas.}	2.13 ± 0.01 g · cm ⁻³

gives the chemical formula and the calculated and observed densities. The latter was experimentally determined by means of a torsion microbalance using toluene as the liquid (Berman 1939).

Optical properties

The refractive indices were derived by the double variation method and the optical axial angle was measured by means of the Universal Stage. Due to the low birefringence of the mineral, the calculated $2V\alpha$ is obviously very uncertain. The data are reported in Table 4.

Chemical composition

SiO₂ was determined by the gravimetric method, Al₂O₃ by complexometric titration and Na, K, Mg, Ca, Sr, Ba, Fe^{III} and Mn by atomic absorption spectrometry using a Perkin-Elmer 303 instrument. H₂O was determined by TG using a thermal analyser manufactured by B.D.L. (Bureau de Liaison, Paris).

The chemical analysis gave the following results:

SiO ₂	59.15	SrO	0.05
Al ₂ O ₃	14.21	BaO	0.02
Fe ₂ O ₃	0.17	Na ₂ O	0.19
MgO	0.04	K ₂ O	0.23
MnO	tr.	H ₂ O	17.79
CaO	7.45	Total	99.30

^a Experimental settings for the Philips diffractometer: Ni-filtered CuKα₁ radiation (λ = 1.54051 Å); tube current 40 Kv, 20 mA; angular speed 1/4° per minute; 1-0.1-1 slits for 2φ < 40° and 1-0.2-1 for 2φ > 40°; internal standard: Pb(NO₃)₂.

^b Only the reflections marked with a star have been used for the refinement of the unit-cell dimensions.

Table 4. Optical properties of stellerite from Villanova Monteleone.

α	1.4848 ± 0.0005	2 V α (calc.)	$39^\circ \pm 8^\circ$
β	1.4964 ± 0.0005	2 V α (meas.)	$47^\circ \pm 2^\circ$
γ	1.4979 ± 0.0005	Orientation	$\alpha \rightarrow a$
$\gamma - \alpha$	0.0131		$\beta \rightarrow c$
Sign	(—)		$\gamma \rightarrow b$

The chemical formula calculated on the basis of 72 oxygens is:



These values show that the SiO₂ content in stellerite is higher than in stilbite and that the exchangeable cations are mainly Ca and small amounts of Na and K.

Conclusions

The sample from Villanova Monteleone is certainly an orthorhombic zeolite. Our conclusion is based on the following observations:

X-ray examination shows an orthorhombic symmetry. Morphologically the mineral is characterized by the three principal pinacoids {100}, {010}, {001} and the dipyrmaid {111}. Parallel extinction occurs (under crossed nicols). There is no twinning whatsoever, as is particularly evident in the case of crystals belonging to the monoclinic system. Since the powder diffractogram is rather close to that of stilbite, it is obvious that we are dealing with a stellerite.

The chemical analysis also shows typical abundance of Si and scarcity of Na.

Acknowledgement. — This work was made possible through the financial support of Consiglio Nazionale delle Ricerche, Roma.

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Accepted for publication October 1972

Printed January 1973