The relation of stellerite and epidesmine to stilbite.[1]

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[Read November 3, 1938; communicated by F. A. Bannister.]

THE recent finding of a stellerite-like mineral in California has led to this study of its relations to epidesmine and stilbite. The mineral was found by Mr. Allen Nichol, mineralogist of the Division of Highways, in the quarry of the Calavera Materials Company near Oceanside, San Diego County. Some specimens reached the writer through the State Division of Mines. The mineral occurs as sheaf-like clusters of small glistening white crystals in cracks and cavities of andesite. The largest crystals are nearly a quarter of an inch long, but tend to aggregate formation so that they do not lend themselves to accurate goniometric measurement. They are apparently orthorhombic, of tabular habit, showing the three pinakoids and small bright faces of a pyramid. The excellent pinakoid cleavage has a pearly lustre, and if this is taken as (010) the crystals, which show parallel extinction, have the same optical orientation as stellerite.

Stellerite was described from the Commander Islands, Bering Sea, by Morozewicz[2] and classed as orthorhombic at least in part because of its parallel extinction. Measurement of the rather poor crystals led to an axial ratio similar to the one given for stilbite by Victor Goldschmidt and others using the orthorhombic setting of that mineral. This similarity seems to have been overlooked by Morozewicz, who rightly considered stilbite to be monoclinic. The formula he assigned to stellerite, $CaAl_2Si_7O_{18}.7H_2O$, differed from the formulae then usually given to stilbite, but it proves to be just a special case of the general stilbite formula which will be referred to again below.

Stellerite has since been reported from near Juneau, Alaska, by Wheeler,[3] who obtained the same axial ratio as Morozewicz, but also

[1] Work done in the Mineral Department of the British Museum during leave of absence as Fellow of the John Simon Guggenheim Memorial Foundation.

[2] J. Morozewicz, Über Stellerit, ein neues Zeolithmineral. Bull. Intern. Acad. Sci. Cracovie, Cl. Sci. Math. Nat., 1909, 2me semestre, pp. 344–359.

[3] E. P. Wheeler, Stellerite from near Juneau, Alaska. Amer. Min., 1927, vol. 12, pp. 360–364. [M.A. 4–325.]

failed to notice its similarity to that of stilbite in the orthorhombic setting.

Epidesmine was described from Schwarzenberg, Saxony, by Rosický and Thugutt[1] as an orthorhombic mineral having the same formula '$3Ca(Na_2,K_2)Al_2Si_6O_{16}.20H_2O$', as stilbite (German—Desmin). The crystals showed mainly just three pinakoids at right angles and the parallel extinction which seemed to confirm the orthorhombic character.

Epidesmine has since been recorded from various localities by several American mineralogists. Shannon,[2] describing 'stilbite of "epidesmine" habit bounded only by three pinacoids', affirmed the identity of stilbite with epidesmine, but, following Goldschmidt, considered them to be orthorhombic. He did point out that the optical orientation of epidesmine becomes similar to that of stilbite if the most prominent cleavage is chosen as (010), rather than (100), as was done by Rosický and Thugutt. It may be noted that this also makes the optical orientation identical with that of stellerite as given by both Morozewicz and Wheeler.

Stilbite has generally been considered to be monoclinic, but a number of mineralogists, including Victor Goldschmidt,[3] have treated it as orthorhombic because of its peculiar habit. A recent X-ray study of stilbite[4] has shown definitely that it is monoclinic and has led to an improved formula based on the count of the cell contents of many samples.

It seems reasonable to conclude that stellerite and epidesmine are identical with stilbite and are merely pseudo-orthorhombic. In the following it will be shown that this conclusion is in harmony, not only with the X-ray evidence, but also with the goniometric, chemical, and optical evidence, if the difficulties of good interfacial angle measurements and the variability of composition and properties of such material as stilbite be taken into account.

In the monoclinic setting stilbite is given A. von Lasaulx's (1878) elements[5] 0·7623:1:1·1940, $\beta = 50° \ 50'$. It is commonly elongated parallel to the a-axis. If set up with this axis vertical the three forms,

[1] V. Rosický and S. J. Thugutt, Epidesmin, ein neuer Zeolith. Centralbl. Min., 1913, pp. 422–426.

[2] E. V. Shannon, The mineralogy and petrology of intrusive Triassic diabase at Goose Creek, Loudoun County, Virginia. Proc. U.S. Nat. Mus., 1924, vol. 66, art. 2, p. 72. [M.A. 3–204.]

[3] V. Goldschmidt, Krystallographische Winkeltabellen, 1897, p. 113.

[4] J. Sekanina and J. Wyart, Sur la stilbite. Bull. Soc. Franç. Min., 1936, vol. 59, pp. 377–383. [M.A. 6–525.]

[5] As quoted by Dana, System of mineralogy, 6th ed., 1892, p. 583, and in Dana, Textbook of mineralogy, 4th ed., 1932, p. 648.

(001), (010), and ($\bar{1}01$), will simulate three orthorhombic pinakoids since the interfacial angles are: (001):(010) = 90° 0′, ($\bar{1}01$):(010) = 90° 0′, ($\bar{1}01$):(001) = 89° 30′. The forms ($\bar{1}12$) and ($\bar{1}10$) together will then simulate an orthorhombic pyramid as shown in the stereographic projection fig. 1. The faces of these two forms were taken by Morozewicz and by Wheeler to belong to the orthorhombic pyramid (111).

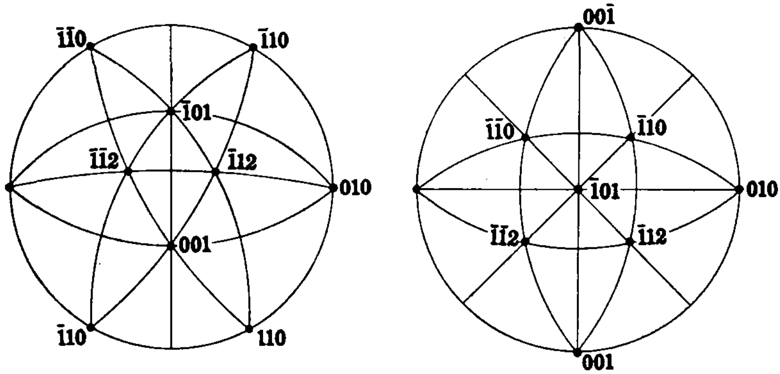

FIG. 1. Stereographic projections of stilbite on a plane normal to the c-axis and on a plane normal to the a-axis, the latter showing the pseudo-orthorhombic habit. One projection is brought into the position of the other by a rotation of 50° 50′ about the b-axis.

The angles calculated from A. von Lasaulx's elements are:

($\bar{1}01$):($\bar{1}12$) = 48° 2′	(001):($\bar{1}12$) = 56° 28′	(010):($\bar{1}12$) = 59° 45′
($\bar{1}01$):($\bar{1}10$) = 48 30	(001):($\bar{1}10$) = 57 3	(010):($\bar{1}10$) = 58 25

If the similar angles are averaged, as if the mineral were considered orthorhombic, and the (orthorhombic) axial ratio calculated from the averaged angles, the result with the pyramid as (111) is $a:b:c =$ 0·923:1:0·761. This is close to the values, 0·928:1:0·762, given by Goldschmidt and differs a little more from the values, 0·98:1:0·76 and 0·982:1:0·762, given by Morozewicz and Wheeler respectively. The discrepancy is easily explained when one considers the character of the crystals. Both Wheeler and Morozewicz relied partly on angles measured under the microscope. The writer found that in the measurement of seven crystals of the San Diego County material readings on similar interfacial angles varied over a range of three or four degrees.

Table I gives the compositions and densities of the original stellerite and epidesmine, of Shannon's 'stilbite of "epidesmine" habit', and of the stellerite-like stilbite from San Diego County. All the densities given lie within the limits, 2·094–2·205, recorded by Dana for the density of stilbite. The compositions all agree with the formula, $Na_xCa_{2+y}Al_{4+x+2y}Si_{14-x-2y}O_{36}.14H_2O$, with $x < 1$ and $-0{\cdot}15 < y < 0{\cdot}30$, found by Sekanina and Wyart for stilbite from the examination of the contents of the unit cell in many samples.

TABLE I. Chemical analyses.

	I Stellerite.	II Epidesmine.	III 'Stilbite of "epidesmine" habit'.	IV Stellerite-like stilbite.
SiO_2	59·23	56·66	54·40	58·48
Al_2O_3	14·41	16·00	17·88	14·76
Fe_2O_3	0·22	—	—	0·48
MgO	—	0·06	—	0·32
CaO	8·23	7·58	8·56	7·68
K_2O	—	0·67	—	0·29
Na_2O	trace	0·88	—	1·02
H_2O+	18·15	18·69	16·00	12·30
H_2O-			2·32	4·43
Insoluble	—	0·44	—	—
Total	100·24	100·98	99·16	99·76
Sp. gr.	2·124	2·152	—	2·120

I. Copper Island, Commander Islands, Bering Sea. J. Morozewicz (1909).
II. Gelbe Birke mine, Schwarzenberg, Saxony. V. Rosický and S. J. Thugutt (1913).
III. Goose Creek, Loudoun County, Virginia. E. V. Shannon (1924).
IV. Oceanside, San Diego County, California. W. H. Herdsman, analyst.

In table II are shown the proportions of the constituents in the four samples here considered on the basis of oxygen equal to 36. It will be seen that the values of x and y are in all cases well within the given limits, and that the sum of Si and Al is always quite close to 18. The variation in the water content should not be disturbing, since Sekanina and Wyart found the number of water molecules in stilbite to vary from 13·35 to 14·9.

TABLE II. Contents of unit cell on the basis of 36 atoms of oxygen.

	(Na,K).	Ca.	Al.	Si.	O.	H_2O.	x.	y.	Si+Al.
I.	0·00	2·08	4·00	13·96	36	14·24	0·00	+0·08	17·96
II.	0·61	1·96	4·54	13·45	36	15·00	0·61	−0·04	17·99
III.	—	2·20	5·07	13·10	36	14·70	—	+0·20	18·17
IV.	0·56	1·95	4·12	13·76	36	13·26	0·56	−0·05	17·88

Table III shows the optical properties of the specimens whose analyses are considered above together with those of stilbite. The orientation is the same in every case, the optic axial plane being parallel to the best cleavage and α sensibly parallel to the elongation, except for stilbite which is usually stated to have $\alpha:c = 5°$.

Stellerite and epidesmine were originally taken to be orthorhombic partly on account of their parallel extinction. It may now be said that the small extinction-angle of stilbite varies with differences in composition and that stellerite and epidesmine are varieties in which this angle is sensibly zero.

TABLE *III*. *Optical data.*

	I.	II.	III.	IV.	Stilbite.
α ...	1·484		1·490	1·486	1·494[2]
β ...	1·49	mean 1·498[1]	1·500	1·494	1·498
γ ...	1·495		1·502	1·496	1·500
Sign ...	negative	negative	negative	negative	negative
2V ...	43½°	moderate	medium	48°	33° ±
Observer ...	Morozewicz	Rosický and Thugutt	Shannon	Pabst	—

[1] E. S. Larsen and H. Berman, The microscopic determination of the nonopaque minerals, Bull. U.S. Geol. Surv., 1934, no. 848, give the values 1·493, 1·501, and 1·507 for epidesmine, and other observers have given slightly different values.
[2] As given by Larsen and Berman, ibid.

The writer has been fortunate in being able to obtain samples of the original stellerite from the Commander Islands and of the original epidesmine from Schwarzenberg, Saxony, in the mineral collection of the British Museum for comparative X-ray study.

Rotation patterns on the axis of elongation of these two materials and of the stilbite from San Diego County proved to be identical with rotation patterns of excellent crystals of stilbite from the well-known locality of Naalsö, Faeroe Islands. Dimensions calculated from these patterns agree with the unit cell given by Sekanina and Wyart, a 13·60, b 18·13, c 11·29 Å., β 52°.

Laue patterns taken normal to (010) of the original stellerite are like those taken normal to (010) of twinned stilbite. As Sekanina and Wyart pointed out, stilbite may be assigned a pseudo-orthorhombic cell with β nearly 90°. This corresponds to the pseudo-orthorhombic description referred to above. The patterns of twinned stilbite and of stellerite appear orthorhombic. Lack of doubling of spots in the [100] and [101] zones in these patterns shows that the angle β of the pseudo-orthorhombic cell is sensibly 90°. Other patterns of untwinned stilbite, obtained only after repeated trials in an effort to restrict the passage of the incident beam to a single untwinned part of a crystal, show that stilbite is truly monoclinic and that the orthorhombic appearance of the other patterns is merely due to the repetition of spots by twinning. Unfortunately the crystals of epidesmine, though yielding an excellent rotation pattern whereby their relation to stilbite could be established, appear to have such a bundle structure that no good Laue patterns are obtainable from them.

The writer is very grateful to Mr. W. Campbell Smith, Keeper of Minerals, for his hospitality and for permission to use the facilities of the Department of Mineralogy of the British Museum. He is greatly indebted to Mr. F. A. Bannister for the preparation of X-ray patterns and for a critical reading of the manuscript. The cost of analysis of the stilbite from San Diego County was defrayed by a grant from the Board of Research of the University of California.