CELESTITE FROM CHITTENANGO FALLS, NEW YORK

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About three-quarters of a mile northwest of the village of Chittenango Falls, N. Y., a hitherto undescribed occurrence of celestite is to be found in an abandoned quarry bordering the State highway which follows Chittenango Creek.

The celestite, which is associated with a large amount of "dogtooth" calcite, and smaller amounts of quartz and chalcedony, occurs as well-developed crystals lining very irregular geodic cavities, and as massive and fibrous veins which commonly connect the geodes. The cavities occur in several well-defined horizons near the base of the quarry face in a light gray dolomitic limestone which is probably the same formation that Hartnagel* observed eight miles west at Stone Quarry falls, and which he has correlated with the Silurian Rondout waterlime of eastern New York.

The indices of refraction of several crystals were measured by the oil immersion method. In each case there was almost complete agreement of the measurements. The results obtained for sodium light are:

$\alpha = 1.622,\qquad \beta = 1.624,\qquad \gamma = 1.632.$

The probable limit of error is $\pm .002$. Since celestite cleaves perfectly parallel to the base, $c(001)$, and since the slow ray (Z) and the intermediate ray (Y) vibrate in the basal plane, γ and β were easily determined. The smallest n obtained on any fragment was taken as α. This would occur on a fragment exhibiting cleavage parallel to $b(010)$ which in celestite is distinct. For comparison the following published indices of refraction are given:

Dana:[1]	$\alpha = 1.622,$	$\beta = 1.624,$	$\gamma = 1.631.$
Winchell:[2]	$\alpha = 1.622,$	$\beta = 1.623,$	$\gamma = 1.631.$

The specific gravity was determined by the pycnometer method. About 25 small crystals were obtained from various widely scattered geodes. The average of three specific gravity determinations

* Hartnagel, C. A., Preliminary Observations on the Cobleskill ("Coralline") Limestone of New York: *N. Y. State Mus. Bull.* **69,** Report of the State Paleontologist for 1902, pp. 1160–1163, **1903.**

[1] Dana, E. S., and Ford, W. E., *A Textbook of Mineralogy,* 4th Edition, p. 750. John Wiley and Sons, New York, **1932.**

[2] Winchell, N. H., and A. N., *Elements of Optical Mineralogy,* vol. **2,** p. 101. John Wiley and Sons, New York, 1927.

gave a value of 3.939. A determination made on five perfectly developed and exceptionally transparent crystals gave 3.968. In general the published values for the specific gravity of pure celestite range from 3.94 to 4.00.

A spectroscopic analysis of the Chittenango celestite, made by Professor David Trainer, Jr., of Colgate University, indicates no barium, and but little calcium isomorphously replacing the strontium.

Crystallography

As is common with celestite, two types of crystals were observed, tabular parallel to the base, *c*(001), and prismatic parallel to the crystallographic *a*- axis, the latter being so much more productive of forms that nearly all crystals measured were of this type. The crystals vary from the minutely prismatic types less than a millimeter in height and two millimeters long, to large, usually tabular, varieties some of which are as much as forty millimeters wide and ten millimeters thick. The average crystals, which are about six millimeters high and four to five millimeters wide, commonly exhibit rare forms.

As is indicated in Figures 1 and 2, the crystals are always attached roughly normal to the *a*-axis with the result that only one set of terminations about the brachy axis is developed.

About 75 crystals were examined under the high power of a binocular microscope. All the faces present on six of these were measured on the Goldschmidt two-circle reflecting goniometer, while only the rarer forms were measured on eight others.

The forms observed on the fourteen crystals are as follows:

c(001); *o*(011); *m*(110); *z*(111); *d*(102); *l*(104);
Φ(106); *σ*(221); *y*(122); *g*(103); *b*(010); *v*(324);
Δ_1(109)*; Σ(1.0.11)*; (3.0.29)?*; (3.0.31)?*

All the letters are those of Dana,[3] with the exception of Φ which was first used by Buchrucker[4] but which does not appear in Dana's 6th Edition or any of its Appendices, and Δ_1 and Σ which are those of the author. The four forms designated by an asterisk (*) are new for celestite, although (3.0.29) and (3.0.31) may be question-

[3] Dana, J. D., and E. S., *A System of Mineralogy*, 6th Edition, p. 905. John Wiley and Sons, New York, **1914.**

[4] Buchrucker, Die Mineralien der Erzlagerstätten von Leogang in Salzburg: *Zeit. f. Kryst.*, vol. **19,** 1891.

able because of the quality of the signal and the complexity of the indices.

The combinations observed on the fourteen crystals are as follows:

TABLE 1.

1.	*c*	*o*	*m*	*z*	*d*	*l**	Φ	.	.	.	.	.	Δ_1	Σ	(3.0.29)?	(3.0.31)?
2.	*c*	*o*	*m*	*z*	*d*	*l*	.	.	.	.	.	.	.	.	.	.
3.	*c*	*o*	*m*	*z*	*d*	.	.	.	*y*	.	.	.	.	.	.	.
4.	*c*	*o*	*m*	*z*	*d*	*l*	Φ	.	.	.	*b*	.	.	.	.	.
5.	*c*	*o*	*m*	*z*	*d*	*l*	.	.	*y*	.	.	.	.	.	.	.
6.	*c*	*o*	*m*	*z*	*d*	.	.	σ	.	.	.	.	.	.	.	.
7.	*c*	*o*	*m*	*z*	*d*	*l*	.	.	.	.	.	.	.	.	.	.
8.	*c*	*o*	*m*	*z*	*d*	*l*	Φ	.	.	.	.	.	.	.	.	.
9.	*c*	*o*	*m*	*z*	*d*	.	.	σ	.	.	.	.	.	.	.	.
10.	*c*	*o*	*m*	*z*	*d*	*l*	.	.	.	*g*	.	.	.	.	.	.
11.	*c*	*o*	*m*	*z*	*d*	*l*	.	.	.	.	.	.	.	.	.	.
12.	*c*	*o*	*m*	*z*	*d*	.	.	σ	.	.	.	.	.	.	.	.
13.	*c*	*o*	*m*	*z*	*d*	*l*	.	.	.	.	.	.	.	.	.	.
14.	*c*	*o*	*m*	*z*	*d*	.	.	σ	.	.	.	*v*	.	.	.	.

* Represented only by vicinal planes.

Figure 1 is a clinographic projection of the simplest crystal form (see Table 1) which, except for the relative sizes of the faces, is similar to one described by Gordon[5] from Franklin Furnace, N. J. Figure 2 shows a composite clinographic projection of all the forms observed except (3.0.29)? and (3.0.31)?

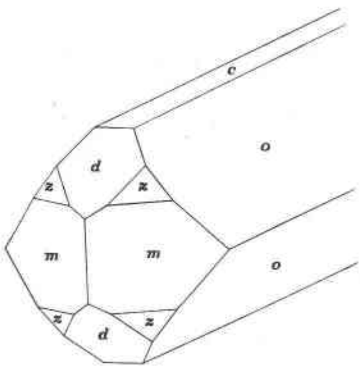

FIG. 1. Clinographic projection showing faces common to all crystals.

[5] Gordon, S. G., Crystallographic Notes on Glaucochroite, Willemite, Celestite, and Calcite from Franklin, N. J.: *Proc. Acad. Nat. Sci., Philadelphia*, vol. **74**, pp. 105–112, 1923.

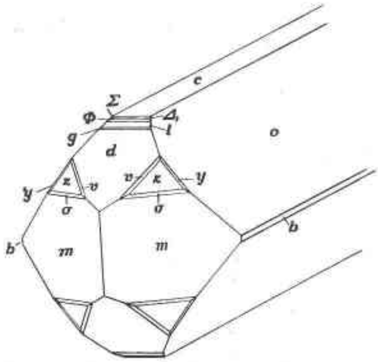

FIG. 2. Composite clinographic projection showing all faces observed except (3.0.29) and (3.0.31).

The measurements are given in Table 2.

The axial ratio calculated from the two largest forms capable of yielding results gives:

	average ρ	average ϕ	p_0	q_0
o	52° 04½′	0° 00′	—	1.2834
d	39° 24′	89° 55′	1.6428	—

$a:b:c=0.7812:1:1.2834$

TABLE 2
AXIAL RATIO $a:b:c=0.7811:1:1.2830$ (GOLDSCHMIDT[6,7])

	Forms	Number of faces	Calculated angles ϕ	Calculated angles ρ	Measured angles ϕ	Measured angles ρ
o	(011)	8	0° 00′	52° 04′	0° 00′	52° 04½′
m	(110)	12	52° 00′	90° 00′	52° 00′	90° 02′
z	(111)	12	52° 00′	64° 22′	52° 01′	64° 27½′
d	(102)	6	90° 00′	39° 23′	89° 55′	39° 24′
l	(104)	6	90° 00′	22° 19′	89° 56′	22° 21½′
Φ	(106)	4	90° 00′	15° 19′	89° 55′	15° 10′
σ	(221)	4	52° 00′	76° 30′	52° 00′	76° 37′
y	(122)	3	32° 37′	56° 43′	32° 38′	56° 49′
g	(103)	2	90° 00′	28° 42′	89° 56′	28° 49½′
b	(010)	1	0° 00′	90° 00′	0° 03½′	90° 01′
v	(324)	1	62° 29′	54° 15′	62° 28′	54° 24′
Δ_1	(109)	1	90° 00′	10° 21′	89° 59′	10° 22½′
Σ	(1.0.11)	1	90° 00′	8° 30′	89° 58′	8° 26½′
	(3.0.29)?	1	90° 00′	9° 39′	89° 58′	9° 40½′
	(3.0.31)?	1	90° 00′	9° 02′	89° 57′	9° 00′

[6] Goldschmidt, V., *Krystallographische Winkeltabellen*, p. 98. Julius Springes, Berlin, **1897.**

[7] Goldschmidt, V., *Atlas der Krystallformen*, Text, Vol. **2**, p. 163, Carl Winters Universitätsbuchhandlung, Heidelberg, 1913.

For comparison the following published ratios are given:

Goldschmidt:[8,9]	
Goldschmidt and Gordon:[10]	$a:b:c=0.7811\ :1:1.2830$
Dana[11] following Auerbach:[12]	$a:b:c=0.77895:1:1.28005$
Rogers:[13]	$a:b:c=0.78058:1:1.28306$

The different forms may be characterized as follows:

c(001), which is always present, is almost always striated parallel to the *b*-axis of the crystal. The striae, which are to be found only on this form, usually consist of many distinct V-shaped grooves, of which that side nearest *d*(102) is very nearly perpendicular to *c*(001) while the other side is inclined from *c* less than eight degrees toward *d*. This inclination is by no means uniform among the various striae on the same crystal, with the result that upon rotation of the crystal from *c* toward *d*, a blur of images is usually to be noted.

o(011) and *m*(110), which are always present, are usually the largest and most perfect forms.

z(111), although always present except on a few large crystals, varies in size and shape according to the development of the larger adjacent forms.

d(102) is also always present, but on five crystals vicinal faces are associated with it. The presence of similar vicinal planes has been observed by Hintze[14] on celestite from Lüneburg, Germany, and by Artini[15] on crystals from Romagna, Italy. The only vicinal planes on the Chittenango celestite are in each case situated between *d* and *c*, as was also observed by Artini on the Romagna crystals. The angle between *d* and the vicinal planes varies considerably with the individual crystals, but in no case does it exceed 1°15′. This variation is so great for the ten vicinal faces observed on the Chittenango celestite that a computation of indices would mean little. Although two vicinal planes, $\rho=38°55'$ and 38°53′ agree well with Hintze's observation of 38°55′ on crystals from Lüneburg, the agreement may be merely coincidence since the other eight faces diverge widely from any of his measurements. In several cases the vicinal planes are so arranged that very slight reëntrant angles are present, for, upon examining the faces in order from *c* to *d*, the observed angle does not constantly increase toward *d*. On badly weathered crystals face *d* curves slightly inward toward *z* and *o*, the axis of curvature being parallel to *d*, and also in the plane of the crystallographic *a*- and *c*-axes.

[8] Goldschmidt, V., *Winkeltabellen, ibid.*, p. 98.

[9] Goldschmidt, V., *Atlas der Krystallformen, ibid.*, p. 163.

[10] Calculated from the p_0 and q_0 values given in: Goldschmidt, V., and Gordon, S. G., Crystallographic Tables for the Determination of Minerals: *Acad. Nat. Sci., Philadelphia.* Special Publication No. **2**, p. 32, 1928.

[11] Dana, J. D., and E. S., *ibid.*, p. 905.

[12] Auerbach, Bex and Herrengrund: *Ber. Ak. Wien.*, vol. **59**, p. 549, 1869.

[13] Rogers, A. F., Mineralogical Notes No. 3: *Sch. Mines Quar.*, vol. **23**, p. 134, 1902.

[14] Hintze, C., Ueber Cölestin von Lüneburg und das Studium von Vicinalflächen: *Zeit. f. Kryst.*, vol. **11**, pp. 226–232, 1886.

[15] Artini, E., Celestina di Romagna: *Rend. Inst. Lomb. Sc.*, series 2, vol. **26**, p. 325, 1893.

l(104), which is usually narrow, was in two cases replaced by vicinal planes, the angle in each case being:

Crystal 1. 22°08′ 22°37′
Crystal 2. 22°08′ 22°38′ 23°06′

Although the agreement is striking, an attempt to calculate indices would result in very complex forms which would be highly uncertain.

Φ(106), which is always very narrow, was described by Buchrucker[16] in 1891 although it had probably been observed before.[17]

σ(221), *g*(103), *y*(122), *b*(010), and *v*(324) are all narrow, but afford signals which are fairly good.

Δ_1(109), Σ(1.0.11), (3.0.29)?, and (3.0.31)?, all of which are new forms, appeared but once as very narrow faces on crystal 1. These forms probably represent a type of oscillatory striation, since small reëntrant angles are formed between adjacent faces. Three different readings at three different times gave the following angles:

Face	1	2	3	*Average*
109	8°26′	8°26′	8°27′	8°26½′
1.0.11	10°24′	10°23′	10°22′	10°23′
3.0.29	9°40′	9°41′	9°41′	9°40½′
3.0.31	8°58′	8°59′	9°02′	9°00′

The signals from Δ_1 and Σ were fair, and the three readings agree very favorably with the calculated values. (See Table 2.) The signals from 3.0.29 and 3.0.31, however, were poor and somewhat blurred. Although the three readings did not greatly vary, and the average value closely agrees with the calculated angles, it would probably be best to consider them doubtful forms. (3.0.29)? and (3.0.31)? probably represent symmetrical vicinal replacements of the form (1.0.10) first doubtfully observed by Panebianco.[18] From this form the vicinal planes are removed about 20′.

In conclusion the author wishes to express his appreciation to Dr. James E. Maynard and other members of the Department of Geology at Syracuse University, and to Professor Charles Palache of Harvard University, for their assistance in the preparation of this article.

[16] Buchrucker, *ibid*.

[17] Personal communication from Professor Charles Palache, Jan. 30, 1934.

[18] Panebianco, R., Krystallformen von Vicentiner Cölestin: *Att. Soc. Veneto*, vol. **9**, p. 1, 1884. Through abstract in *Zeit. f. Kryst.*, vol. **11**, p. 400, 1886.