CRYSTALLOGRAPHY OF CALCITE FROM LAKE SUPERIOR COPPER MINES

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In 1898 the writer published a paper (Palache, 1898) on the crystallography of Lake Superior calcite. Although a large number of new calcite forms were described and illustrated in this paper, the measurements upon which they were based were omitted; the statement made there (page 183) that the observational data for the new forms would appear shortly in the *Zeitschrift für Krystallographie* was never justified by fulfillment of the promise. However, twenty-four of the thirty-two forms then proposed were included in the *Winkeltabellen* of V. Goldschmidt (1897), with calculated position angles, much of the study having been conducted in his laboratory. The figures were all reproduced in the same author's *Atlas der Krystallformen*, Vol. II, Plates 112–114, figures 1887–1910.

The author can offer no adequate excuse for this failure to publish his observations save the fact that the study continued from year to year as new and often very interesting material came into his hands. The summer of 1906 was partly spent on the Copper Range, examining the local collections and collecting material for an intended study of the local mineralogy, which was never completed. Again in 1920 and 1921 the author worked with the group of geologists who gathered the materials for *U. S. G. S. Professional Paper* **144** on the copper deposits and thus collected at first hand a great variety of calcite crystals. A paper containing all the results and elaborate zonal discussion of the forms was prepared but for forgotten reasons was never sent to press.

This paper is now presented in abbreviated form after a review of the older results and an examination of new crystals. The paper of 1898 may still serve as giving an adequate general description of the occurrence of calcite in the Lake Superior region.

Table 1 contains a list of 138 forms found on the nearly 200 crystals measured—a number which may be compared with 87 forms found on the 150 crystals described in the first paper. This increase shows how enormously rich and varied in development these crystals really are. The last column of the table states the number of crystals on which each form was observed and may serve as sufficient description of their relative importance. Those forms preceded by an asterisk were new for

* Contribution from the Department of Mineralogy and Petrography, Harvard University, No. 260.

calcite in 1898, or have since been discovered; they number thirty-two and are collected in Table 2 together with the observed angles, range, and calculated position angles. These forms vary in importance from a few which are characteristic for the region and have since been found elsewhere, to the other extreme of purely local development. They will be briefly described in the order of enumeration.

TABLE 1. FORMS FOUND ON LAKE SUPERIOR CALCITE

		Bravais	Miller	No. of. xls.			Bravais	Miller	No. of xls
1	*o*	0 0 0 1	1 1 1	57	78	ϕ.	0 2 $\bar{2}$ 1	1 1 $\bar{1}$	45
2	*a*	1 1 $\bar{2}$ 0	1 0 $\bar{1}$	11	80	*F*.	0.12.$\overline{12}$.5	17.17.$\overline{19}$	1
3	*b*	1 0 $\bar{1}$ 0	2 $\bar{1}$ $\bar{1}$	7	82	ω.	0.11.$\overline{11}$.4	5 5 $\bar{6}$	1
5	θ	2 1 $\bar{3}$ 0	5 $\bar{1}$ $\bar{4}$	3	83	Γ.	0 3 $\bar{3}$ 1	4 4 $\bar{5}$	1
6	ζ	3 1 $\bar{4}$ 0	7 $\bar{2}$ $\bar{5}$	2	86	Δ.	0 7 $\bar{7}$ 2	3 3 $\bar{4}$	3
8	ψ	10.1.$\overline{11}$.0	7 $\bar{3}$ $\bar{4}$	14	87	Θ.	0 4 $\bar{4}$ 1	5 5 $\bar{7}$	1
9	π	1 1 $\bar{2}$ 3	2 1 0	2	92	*Q*.	0 7 $\bar{7}$ 1	8.8.$\overline{13}$	1
11	λ	2 2 $\bar{4}$ 3	3 1 $\bar{1}$	2	93	Π.	0 8 $\bar{8}$ 1	3 3 $\bar{5}$	15
12	ν	1 1 $\bar{2}$ 1	4 1 $\bar{2}$	2	96	Σ.	0.11.$\overline{11}$.1	4 4 $\bar{7}$	1
13	α	4 4 $\bar{8}$ 3	5 1 $\bar{3}$	2	98	*C*.	0.13.$\overline{13}$.1	14.14.$\overline{25}$	1
14*	ω	16.16.$\overline{32}$.9	19.3.$\overline{13}$	5	99	Φ.	0.14.$\overline{14}$.1	5 5 $\bar{9}$	1
15	ξ	2 2 $\bar{4}$ 1	7 1 $\bar{5}$	5	113	*W*:	13.11.$\overline{24}$.2	13.0.$\overline{11}$	1
17	γ	8.8.$\overline{16}$.3	9 1 $\bar{7}$	5	117	*U*:	5 4 $\bar{9}$ 1	5 0 $\bar{4}$	2
26	*p*.	1 0 $\bar{1}$ 1	1 0 0	121	119	*x*:	4.3.$\bar{7}$.10	7 3 0	3
28	*R*.	2 0 $\bar{2}$ 1	5 $\bar{1}$ $\bar{1}$	1	122	*T*:	4 3 $\bar{7}$ 1	4 0 $\bar{3}$	1
29	*K*.	5 0 $\bar{5}$ 2	4 $\bar{1}$ $\bar{1}$	6	125	ζ:	7.5.$\overline{12}$.2	7 0 $\bar{5}$	1
31	*m*.	4 0 $\bar{4}$ 1	3 $\bar{1}$ $\bar{1}$	128	129	*Q*:	19.13.$\overline{32}$.6	19.0.$\overline{13}$	1
40	*r*.	10.0.$\overline{10}$.1	7 $\bar{3}$ $\bar{3}$	7	133	*P*:	3 2 $\bar{5}$ 1	3 0 $\bar{2}$	11
43	*s*.	13.0.$\overline{13}$.1	9 $\bar{4}$ $\bar{4}$	1	135	*p*:	17.11.$\overline{28}$.6	17.0.$\overline{11}$	2
45	*v*.	18.0.$\overline{18}$.1	37.$\overline{17}$.$\overline{17}$	1	136*	*j*:	11.7.$\overline{18}$.4	11.0.$\bar{7}$	4
48	*z*.	28.0.$\overline{28}$.1	19.$\bar{9}$.$\bar{9}$	1	137		8.5.$\overline{13}$.6	9 1 $\bar{4}$	1
55	δ.	0 1 $\bar{1}$ 2	1 1 0	37	141	*N*:	5 3 $\bar{8}$ 2	5 0 $\bar{3}$	10
58	η.	0 4 $\bar{4}$ 5	3 3 $\bar{1}$	1	145	*v*:	7.4.$\overline{11}$.15	11.4.0	3
61	θ.	0 7 $\bar{7}$ 8	5 5 $\bar{2}$	1	146	𝔴:	7.4.$\overline{11}$.6	8 1 $\bar{3}$	6
64	λ.	0 8 $\bar{8}$ 7	5 5 $\bar{3}$	12	147	*M*:	7.4.$\overline{11}$.3	7 0 $\bar{4}$	5
65	μ.	0 6 $\bar{6}$ 5	11.11.$\bar{7}$	3	425*	*q*:	9.5.$\overline{14}$.3	26.$\bar{1}$.$\overline{16}$	2
66	ν.	0 5 $\bar{5}$ 4	3 3 $\bar{2}$	3	151*	𝔥	20.11.$\overline{31}$.15	22.2.$\bar{9}$	5
67	ξ.	0 4 $\bar{4}$ 3	7 7 $\bar{5}$	8	153	*M*:	15.8.$\overline{23}$.10	16.1.$\bar{7}$	2
68	π.	0 7 $\bar{7}$ 5	4 4 $\bar{3}$	5	446		4 2 $\bar{6}$ 3	13.1.$\bar{5}$	1
70	ρ.	0 3 $\bar{3}$ 2	5 5 $\bar{4}$	7	155	𝔜:	19.10.$\overline{29}$.6	18.$\bar{1}$.$\overline{11}$	1
71	σ.	0.11.$\overline{11}$.7	6 6 $\bar{5}$	10	156*	𝔞	37.19.$\overline{56}$.21	38.1.$\overline{18}$	9
73	τ.	0.13.$\overline{13}$.8	7 7 $\bar{6}$	6	154	*L*:	17.9.$\overline{26}$.8	17.0.$\bar{9}$	1
75	*M*.	0 7 $\bar{7}$ 4	11.11.$\overline{10}$	1	158	𝔵	8.4.$\overline{12}$.7	9 1 $\bar{3}$	1

TABLE 1—*continued*

		Bravais	Miller	No. of xls			Bravais	Miller	No. of xls
159	ℨ	6 3 $\bar{9}$ 4	19.1.$\bar{8}$	3	238*	*x*	4.5.$\bar{9}$.14	9 5 0	4
160*	*M*	8.4.$\overline{12}$.5	25.1.$\overline{11}$	10	240*	*s*	16.20.$\overline{36}$.5	19.3.$\overline{17}$	5
161		12.6.$\overline{18}$.7	37.1.$\overline{17}$	2	243*	*t*	9.13.$\overline{22}$.5	12.3.$\overline{10}$	5
162	*K*:	2 1 $\bar{3}$ 1	2 0 $\bar{1}$	75	244	*y*:	2 3 $\bar{5}$ 8	5 3 0	2
165	𝔅⁝	16.8.$\overline{24}$.5	15.$\bar{1}$.$\bar{9}$	1	250*	*u*:	3.5.$\bar{8}$.13	8 5 0	9
453*	*r*⁝	32.14.$\overline{46}$.9	29.$\bar{3}$.$\overline{17}$	3	251	*b*⁝	3 5 $\bar{8}$ 4	5 2 $\bar{3}$	71
455*	*s*⁝	16.7.$\overline{23}$.1	40.$\bar{8}$.$\overline{29}$	1	673?	*E*	32.56.$\overline{88}$.69	63.31.$\overline{25}$	1
180	*g*:	5 2 $\bar{7}$ 9	7 2 0	8	526*	*S*⁝	32.56.$\overline{88}$.45	55.23.$\overline{33}$	38
181	*J*:	5 2 $\bar{7}$ 3	5 0 $\bar{2}$	4	258	*C*	14.26.$\overline{40}$.21	25.11.$\overline{15}$	26
183*	*U*⁝	10.4.$\overline{14}$.3	9 $\bar{1}$ $\bar{5}$	31	263		7.14.$\overline{21}$.11	13.6.$\bar{8}$	Irby
189	*w*:	3 1 $\bar{4}$ 5	4 1 0	8	264	*E*⁝	5.10.$\overline{15}$.7	9 4 $\bar{6}$	3
190*	*N*	12.4.$\overline{16}$.11	13.$\bar{1}$.$\bar{3}$	14	265	𝔉⁝	4.8.$\overline{12}$.5	7 3 $\bar{5}$	7
191	*H*:	3 1 $\bar{4}$ 2	3 0 $\bar{1}$	27	268	𝔮⁝	2 4 $\bar{6}$ 1	3 1 $\bar{3}$	1
194	ℑ⁝	6 2 $\bar{8}$ 1	5 $\bar{1}$ $\bar{3}$	31	270	*F*	5.11.$\overline{16}$.6	9 4 $\bar{7}$	4
196	*f*:	7.2.$\bar{9}$.11	9 2 0	6	544*	*I*.	17.38.$\overline{55}$.24	32.15.$\overline{23}$	3
197	*G*:	7 2 $\bar{9}$ 5	7 0 $\bar{2}$	1	549?	*A*	6.14.$\overline{20}$.7	11.5.$\bar{9}$	2
203	*e*:	4 1 $\bar{5}$ 6	5 1 0	2	274	*J*	8.20.$\overline{28}$.9	15.7.$\overline{13}$	10
204*	*Z*	16.4.$\overline{20}$.15	17.1.$\bar{3}$	13	276*	*D*	3.8.$\overline{11}$.4	6 3 $\bar{5}$	8
206	*F*:	4 1 $\bar{5}$ 3	4 0 $\bar{1}$	1	277	*Y*	12.32.$\overline{44}$.13	23.11.$\overline{21}$	19
211	𝔓⁝	5 1 $\bar{6}$ 1	4 $\bar{1}$ $\bar{2}$	11	282	𝔣𝔭⁝	1 3 $\bar{4}$ 1	2 1 $\bar{2}$	77
214	*D*:	6 1 $\bar{7}$ 5	6 0 $\bar{1}$	1	283		6.20.$\overline{26}$.13	15.9.$\overline{11}$	4
215	*A*⁝	24.4.$\overline{28}$.5	19.$\bar{5}$.$\bar{9}$	3	285*	*B*	12.40.$\overline{52}$.11	25.13.$\overline{27}$	4
217	*b*:	7 1 $\bar{8}$ 9	8 1 0	1	287	ℭ⁝	2 7 $\bar{9}$ 4	5 3 $\bar{4}$	1
219	Ξ⁝	14.2.$\overline{16}$.3	11.$\bar{3}$.$\bar{5}$	19	292	𝔤⁝	1 4 $\bar{5}$ 3	3 2 $\bar{2}$	2
220	*a*⁝	8.1.$\bar{9}$.10	9 1 0	2	293	*R*	8.32.$\overline{40}$.21	23.15.$\overline{17}$	1
221*	Λ⁝	32.4.$\overline{36}$.7	25.7.$\overline{11}$	15	296	𝔬⁝	2.8.$\overline{10}$.3	5 3 $\bar{5}$	1
222	*B*:	17.2.$\overline{19}$.15	17.0.$\bar{2}$	1	297	*Q*⁝	7.28.$\overline{35}$.9	17.10.$\overline{18}$	2
224*	Φ⁝	9.1.$\overline{10}$.2	7 $\bar{2}$ $\bar{3}$	5	298	𝔵⁝	4.16.$\overline{20}$.3	9.5.$\overline{11}$	15
501*	*t*⁝	37.4.$\overline{41}$.36	38.1.$\bar{3}$	1	299	𝔱	3.13.$\overline{16}$.8	9 6 $\bar{7}$	8
226*	Π⁝	10.1.$\overline{11}$.3	8 $\bar{2}$ $\bar{3}$	12	301	𝔠	4.20.$\overline{24}$.17	15.11.$\bar{9}$	15
227*	Θ⁝	40.4.$\overline{44}$.9	31.$\bar{9}$.$\overline{13}$	14	303	𝔏⁝	2.10.$\overline{12}$.7	7 5 $\bar{5}$	1
229*	Σ⁝	22.2.$\overline{24}$.5	17.$\bar{5}$.$\bar{7}$	7	304	𝔒⁝	4.20.$\overline{24}$.11	13.9.$\overline{11}$	3
231*	Δ⁝	13.1.$\overline{14}$.3	10.$\bar{3}$.$\bar{4}$	2	315	*D*⁝	2.13.$\overline{15}$.4	7 5 $\bar{8}$	1
503*	Ω⁝	32.2.$\overline{34}$.9	25.7.$\bar{9}$	1	319*	𝔡	4.36.$\overline{40}$.31	25.21.$\overline{15}$	6
232*	Γ⁝	17.1.$\overline{18}$.4	13.$\bar{4}$.$\bar{5}$	11	322*	*K*	1.11.$\overline{12}$.8	7 6 $\bar{5}$	4
233*	*y*	6 7 $\overline{13}$.20	13.7.0	3	300	𝔅⁝	2.9.$\overline{11}$.5	6 4 $\bar{5}$	1

The serial numbers used for each form in this table are taken from a recent paper by the author, Calcite, An Angle Table and Critical List, privately published in May, 1943, by the Dept. of Mineralogy and Petrography of Harvard University as Contribution No. 259. A limited number of copies of this paper are available at publication cost, 50 cents.

Numbers from 1 to 328 indicate the certain forms; from 329 to 630 the probable and uncertain forms; 631 to 696 the discarded forms.

* New forms.

TABLE 2. OBSERVED ANGLES OF NEW FORMS, LAKE SUPERIOR CALCITE

		Number		Range		Mean Value		Calculated Value	
		faces	xls.	ϕ	ρ	ϕ	ρ	ϕ	ρ
ω	16.16.$\overline{32}$.9	15	4	0°00′– 0°42′	71°35′–72°08′	0°06½′	71°47′	0°00′	71°46½′
j:	11.7.$\overline{18}$.4	5	3	7 10 – 7 24	75 14 –75 37	7 19	75 26	7 18½	75 32
q:	9.5.$\overline{14}$.3	3	2	9 26 – 9 28	76 05 –76 21	9 27	76 11	9 22	76 06
r:	32.14.$\overline{46}$.9	8	2	12 27 –12 53	77 17 –77 47	12 38½	77 33½	12 44	77 24½
s:	16.7.$\overline{23}$.1	4	1	12 34 –12 45	87 00 –87 05	12 41½	87 02½	12 44	87 09½
t:	37.4.$\overline{41}$.36	4	1	24 45 –25 10	46 58 –47 03	24 55½	47 01	24 55½	47 01
𝔟	20.11.$\overline{31}$.15	7	2	9 09 – 9 33	60 16 –60 47	9 21	60 31	9 31	60 49
𝔞	37.19.$\overline{56}$.21	14	5	10 43 –11 33	65 68 –66 59	11 10	66 23	10 31	66 39½
M	8.4.$\overline{12}$.5	26	9	10 30 –11 08	64 00 –64 44	10 48	64 20	10 53½	64 24½
U:	10.4.$\overline{14}$.3	35	10	13 43 –14 05	76 14 –76 28	13 54	76 19	13 54	76 19
N	12.4.$\overline{16}$.11	13	6	16 00 –16 13	52 16 –52 20	16 07	52 18½	16 06	52 17½
Z	16.4.$\overline{20}$.15	7	3	18 52 –19 25	50 19 –50 38	19 05½	50 25	19 06½	50 19½
Λ:	32.4.$\overline{36}$.7	12	7	24 00 –24 25	78 10 –78 24	24 12	78 18½	24 11	78 16
Φ:	9.1.$\overline{10}$.2	4	3	24 47 –24 58	78 00 –78 08	24 51½	78 05	24 47½	78 05
Π:	10.1.$\overline{11}$.3	21	9	24 35 –25 12	73 40 –73 58	24 53½	73 47	25 17	73 54
Θ:	40.4.$\overline{44}$.9	8	3	24 58 –25 27	77 42 –77 58	25 16	77 49½	25 17	77 47
Σ:	22.2.$\overline{24}$.5	12	7	25 22 –25 56	77 31 –77 48	25 39½	77 38½	25 41½	77 36½
Δ:	13.1.$\overline{14}$.3	4	2	26 14 –27 02	77 06 –77 22	26 33	77 16	26 20	77 20
Ω:	32.2.$\overline{34}$.9	2	1	26 49 –27 01	74 34 –74 34	26 55	74 34	26 59½	74 34
Γ:	17.1.$\overline{18}$.4	5	3	26 56 –27 19	76 57 –77 05	27 07½	77 00½	27 10	76 58
y	6.7.$\overline{13}$.20	7	4	1 57 – 3 04	28 59 –29 18	– 2 28	29 08	– 2 32½	29 04
x	4.5.$\overline{9}$.14	9	3	3 15 – 4 19	28 35 –29 09	– 3 53	28 49	– 3 40	28 49½
u:	3.5.$\overline{8}$.13	6	4	8 13 – 8 28	27 57 –28 06	– 8 20½	27 59	– 8 13	27 58½
s	16.20.$\overline{36}$.5	16	5	3 28 – 3 48	80 36 –80 50	– 3 40	80 43½	– 3 40	80 47
t	9.13.$\overline{22}$.5	17	5	5 51 – 6 10	75 00 –75 28	– 5 59	75 10½	– 5 59½	75 11
E	32.56.$\overline{88}$.69	3	1	9 02 – 9 11	47 32 –47 58	– 9 07	47 42	– 8 57	47 48
S:	32.56.$\overline{88}$.45	30	17	8 33 – 9 06	59 13 –59 52	– 8 50	59 24½	– 8 57	59 24½
I·	17.38.$\overline{55}$.24	11	3	11 42 –12 22	63 07 –63 45	–12 04½	63 32	–12 26	63 29½
D	3.8.$\overline{11}$.4	21	8	14 20 –14 52	67 27 –67 41	–14 39	67 33½	–14 42½	67 37½
B	12.40.$\overline{52}$.11	4	2	17 12 –17 17	76 37 –76 43	–17 14	76 40	–17 16	76 42
𝔡	4.36.$\overline{40}$.31	12	6	24 35 –24 54	50 24 –50 34	–24 44	50 28½	–24 47½	50 31½
K	1.11.$\overline{12}$.8	19	4	25 21 –25 43	54 48 –54 58	–25 36	54 52½	–25 41½	54 53

$\omega\{16.16.\overline{32}.9\}$—This dipyramid is well established by concordant measurements on a number of crystals. Its faces are of good quality and often of large size. It is illustrated in Fig. 9 of the 1898 paper and in Figs. 1 and 2 of this paper. It has been reported at Långban, Sweden, by Flink and Aminoff, and at French Creek, Pennsylvania, by Gordon.

j: $\{11.7.\overline{18}.4\}$—This scalenohedron of the principal zone is a minor form well established by the measurements shown in the table. It is not figured.

q⁚ $\{9.5.\overline{14}.3\}$, *r*⁚ $\{32.14.\overline{46}.9\}$, *s*⁚ $\{16.7.\overline{23}.1\}$, *t*⁚ $\{37.4.\overline{41}.36\}$.—These four new scalenohedrons were found on the crystal from the Tamarack Mine shown in Figs. 3 and 4. This unique crystal was loaned for study by the late Mr. Reeder of Houghton. It is a twin crystal of perfect symmetry and superb quality, its greatest dimension about one inch. The twin and contact plane is $(01\overline{1}2)$. The crystal was first measured with one individual in a normal position, and this is figured with approximate fidelity in Fig. 3. Besides the familiar Lake Superior forms, such as *p.*, *N*, *m.*, *U*⁚, *K:* and *Y*, there were found the new forms, developed in part as the largest and most brilliant faces on the crystal, each with two faces on each individual of the twin. *q*⁚ and *r*⁚ are particularly well developed and despite their large size gave single signals on the goniometer of great brilliance. So surprising was the presence of these new forms that they were measured four times with repeated re-adjustment of the somewhat unwieldy crystal, but the measurements were concordant. The table of angles shows that the forms give mean position angles in reasonably good agreement with the calculated values. There are no zonal relations which aid materially in establishing their symbols. The form $\{28.16.\overline{44}.9\}$ with phi 8°57′ and rho 76°41½′ is the known form nearest to *q*⁚. However, this form is in a zone determined by *m.* and *U*⁚, a zone in which the new form does not lie as may be seen in the drawing. *r*⁚ is close to the form $\{7.3.\overline{10}.2\}$ found by Flink at Långban but apparently not as well substantiated by Flink's measurements as is *r*⁚. In the fig. *K:* seems to symmetrically truncate the edge between *N* and *q*⁚ but in reality it is not quite in the zone. *t*⁚ is, on the other hand, in the zone determined by *p.* and *N;* but to make the symbol, complicated at best, conform to this zone prevents one from identifying it with either of the known forms near it in angle, all of which belong to the principal zone.

		ϕ	ρ
t⁚	$37.4.\overline{41}.36$	24°55½′	47°01′
A:	$11.1.\overline{12}.10$	25 41½	48 41
B:	$17.2.\overline{19}.15$	24 30	49 56½
	$10.1.\overline{11}.9$	25 17	49 06½

The four forms are put forward as highly probable, although not established by this one observation.

The crystal was also completely measured with the twin plane and the two basal planes vertical. The result is shown in Fig. 4, which is an orthographic projection normal to a face of $\{11\bar{2}0\}$. The figure is slighly idealized and some of the minor planes are omitted. No other crystal remotely like this one was seen among the many hundreds examined during this study.

𝔟$\{20.11.\overline{31}.15\}$, 𝔞$\{37.19.\overline{56}.21\}$—These two scalenohedrons are in a zone between K:$\{21\bar{3}1\}$ and $\pi\{11\bar{2}3\}$. They are weak forms but occur persistently, either together as shown on Fig. 6 (Palache, 1898) or each by itself as in Figs. 7 and 24. In the zone with them, well shown in Fig. 6, is another, more common Lake Superior form, 𝔴: $\{7.4.\overline{11}.6\}$, first found by Irby and repeatedly in this study. M: $\{15.8.\overline{23}.10\}$, found by Whitlock (1927) on New Jersey crystals and once on a Lake Superior crystal, is also in this zone.

$M\{8.4.\overline{12}.5\}$—This scalenohedron is an important member of the Lake Superior form series. It is shown in minor development in Fig. 9 (Palache, 1898). In Fig. 1 of this paper it is a major form and was seen on many crystals, always of good quality and in good position. It has been found also by Whitlock in New Jersey and by Gordon at French Creek, Pennsylvania.

U: $\{10.4.\overline{14}.3\}$—This is the most important of the new forms. It was measured on ten crystals and seen on twenty others, always with faces of great perfection and in extremely accurate position. Its zonal position between $m.\{40\bar{4}1\}$ and $\gamma\{8.8.\overline{16}.3\}$ helps to identify it, as $m.$ truncates it with parallel edges. It is shown in greater or less development in Figs. 2, 4, 5, 7, and 14 (Palache, 1898), indicated by the letter U without dots; in this paper it is shown in Figs. 3, 5, and 6. It was new in 1898 but has since been found at such widely separated localities as New York State (Whitlock, 1910); Långban (Aminoff, 1918); Terlingua, Texas (Eakle, 1907); Blaton, Belgium (Buttgenbach, 1920); and Lionsville, New South Wales (Smith, 1927). It takes rank as one of the common forms of calcite.

$N\{12.4.\overline{16}.11\}$—This is a strongly developed and rather common scalenohedron in Lake Superior crystals. Seen on fourteen crystals and measured on six, it shows a notable stability of position. It was figured on two combinations in 1898, Figs. 6 and 19. The relation of N to the group of negative scalenohedrons b:, C and S: which are described later, is of special note. N has a strong tendency to form with b: an oscillatory striation made up of brilliant facets parallel to the two forms. This stepped surface impinges upon C or S:, one of which forms is almost invariably present, in an irregular zig-zag intersection which cannot be accurately shown in a formal crystal drawing. Figure 7 is an attempt to show this relation, but the steps of the striation surface are too broad and too few to bring out the characteristic irregularity of the intersection with *C*. The relation is found repeatedly, often on large crystals of magnificent brilliancy and clearness. The zone *N–b*: contains a pole of *φ*.$\{02\bar{2}1\}$ and one of *Z*, next to be described. *N* and *Z* also form a simple zone with *p*. which contains $\{7.4.\overline{11}.6\}$, mentioned in a previous paragraph, and the important form $\{4.4.\bar{8}.3\}$. These zonal relations establish the importance of this new form, which has not as yet been found elsewhere.

Z$\{16.4.\overline{20}.15\}$—This scalenohedron was seen on as many as thirteen crystals but was measurable on only three. Its typical occurrence is on crystals of negative scalenohedral habit with narrow triangular facets as shown in Fig. 17 (Palache, 1898). But on Fig. 15 of the same plate the form *N* is shown with a similar appearance, and measurement is necessary to distinguish them. It is also shown with *N* in Fig. 6, and its zonal relation to that form has already been described.

The series of eight positive scalenohedrons beginning in Table 2 with the form Λ: $\{32.4.\overline{36}.7\}$ and ending with Γ: $\{17.1.\overline{18}.4\}$ were all reported in 1898, with the exception of the only doubtful one, Ω:. They form an interesting and very complex zone series lying on both sides of $\{40\bar{4}1\}$ in the direction of a face of the prism $\{11\bar{2}0\}$. Included with them in the zone are the much more important and common forms $\{14.2.\overline{16}.3\}$, $\{51\bar{6}1\}$, and $\{62\bar{8}1\}$, all of which, as shown in Table 1, are frequently occurring Lake Superior forms. The varied developments of this series on crystals of a variety of habits produce one of the most characteristic features of the calcite of this region. As may be seen from the angle table, they lie very near to each other, and therefore tend to produce a more or less striated surface when several are present. Even then, however, the signals from them are distinct, and each one of them has been observed at least once without another of the series. With the exception noted they are regarded as well established although but one of them, Φ: has as yet been found elsewhere. The series is shown in full development in Fig. 2 (Palache, 1898) and less fully developed in Figs. 5, 7, 14, and 19. Figures 3 and 5 of this paper also show some of these forms. Ω: $\{32.2.\overline{34}.9\}$ is shown in Fig. 5. Its position is good, but it is doubtful because not seen except on this one crystal.

y$\{6.7.\overline{13}.20\}$, *x*$\{4.5.\bar{9}.14\}$, and *u*:$\{3.5.\bar{8}.13\}$—These three negative scalenohedrons belong to that part of the crowded terminal principal zone of calcite lying between $\{01\bar{1}2\}$ and $\{11\bar{2}3\}$. The first two were found on several crystals of one specimen. The faces were distinct, present on each crystal in full number, and show little variation of position. They are shown in Fig. 8 in typical development. The third form, *u*:, was reported in 1898 and has a wider distribution, having been measured on four crystals and identified on several others. It is shown in Figs. 13 and 23 (Palache, 1898), in the latter truncating the edge between the base and *b*: $\{3.5.\bar{8}.4\}$. All three may be regarded as weak but well-established forms.

s$\{16.20.\overline{36}.5\}$, *t*$\{9.13.\overline{22}.5\}$—These two forms were found on the five measured crystals taken from a group from the Allouez Mine and were seen to be present on every crystal. They are generally small facets but in a few crystals are more largely developed. The reflections obtained from them were very good and the position angles show little variation, so the forms may be deemed established. They are shown in Fig. 6. Their zonal relations are not marked.

Probably more than half of the calcite crystals from Lake Superior Mines are dominated by negative scalenohedrons. This feature was stressed in the earlier report and many figures illustrate it. Figure 9 is introduced here to show the character of the simplest of these negative forms when symmetrically developed. The two forms *b*: $\{3.5.\bar{8}.4\}$ and 𝔭: $\{13\bar{4}1\}$ compose it and give character to many of the crystals. These two are also the most common negative scalenohedrons to be found on calcite the world over, but elsewhere they generally occur as minor modifying forms.

$\{13\bar{4}1\}$ is a peculiarly stable form, faces measured on different crystals rarely varying more than a few minutes from the calculated position. This is not true of $\{35\bar{8}4\}$, however; when crystals bearing this form are measured, it is found that the position angles are variable through a considerable range of angle and often the faces are faceted and yield two or more sets of position angles. In other words, a vicinal development is common. In the following table are brought together the various forms found in the literature of calcite that group themselves about *b*:

			ϕ	ρ	
b:	$35\bar{8}4$	$52\bar{3}$	$-8°13'$	$59°55'$	Common
S:	$32.56.\overline{88}.45$	$55.23.\overline{33}$	$-8\ 57$	$59\ 24\frac{1}{2}$	New
C	$14.26.\overline{40}.21$	$25.11.\overline{15}$	$-9\ 49\frac{1}{2}$	$58\ 48\frac{1}{2}$	Irby (1)
	$29.51.\overline{80}.41$	$50.21.\overline{30}$	$-9\ 0\frac{1}{2}$	$59\ 21\frac{1}{2}$	Irby (2)
	$6.11.\overline{17}.9$	$32.14.\overline{19}$	$-9\ 38\frac{1}{2}$	$58\ 34\frac{1}{2}$	Irby (3)
	$56.98.\overline{154}.81$		$-8\ 57$	$58\ 41\frac{1}{2}$	Hessenberg (calculation in error due to false zone)
	$29.53.\overline{82}.43$	$154.\overline{67}.92$	$-9\ 35$	$58\ 49$	Cesàro (1891)

After studying the measurements of scores of crystals it was finally concluded that the existence of two vicinals to *b*: must be recognized: *C*, established by Irby after remeasurement of a crystal of Hessenberg, on which he had determined the very complex symbol of the table; *S*: corresponding to a set of angles found even more frequently than those related to *C*. Each of these forms may occur alone on a crystal, along with either of the others or with both. There is nothing to choose between the quality of reflections obtained from all three. Of the other four forms in the table, Irby (2) may be merged with *S*: ; Irby (3), Hessenberg and Cesàro with *C*. Cesàro's symbol was the result of an elaborate calculation of the measurements of a single Lake Superior crystal which chanced to be dominated by the vicinal form *C*. The choice of the particular symbols of *C* and *S*: was in part fixed by the condition that they both lie in the zone determined by *b*: and λ., a rather common rhombohedron. This zone also contains two forms still to be mentioned, $\mathfrak{c}$ and $\mathfrak{b}$.

b: determines with {13$\bar{4}$1} a dominant zone on at least half of the crystals studied. In this zone lie the following forms:

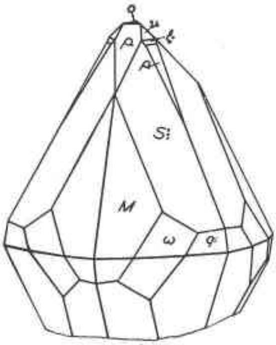
$\mathfrak{F}$: (4.8.$\overline{12}$.5) one of the most common negative scalenohedrons.
F (5.11.$\overline{16}$.6) Schnorr, 1896. Palache 1898 as new. Established.
A (6.14.$\overline{20}$.7) Palache, 1898. A weak form seen but twice.
J (8.20.$\overline{28}$.9) Pirsson, 1891. See below.
I (7.17.$\overline{24}$.8) Palache, 1898. Now united with J.
Y (12.32.$\overline{44}$.13) vom Rath, 1877. See below.
B (12.40.$\overline{52}$.11) Palache, 1898. A weak form but established.

Concerning the forms *J* and *Y* there is much the same story to be told as about *b*:; each is the center of a group of poorly established forms.

			φ	ρ	
J	8.20.$\overline{28}$.9	15.7.$\overline{13}$	−13°54′	69°56′	Pirsson, 1891
I	7.17.$\overline{24}$.8	13.6.$\overline{11}$	−13 31½	69 13½	Palache, 1898
	25.64.$\overline{90}$.32	49.24.$\overline{41}$	−14 23½	68 02½	Dana, 1873, no angles
	9.23.$\overline{32}$.10	17.8.$\overline{16}$	−14 10½	70 28½	Gonnard, 1897

The form *J* was found by Pirsson on a crystal supposed to have come from Guanajuato, Mexico. It gave good measurements and was in the zone defined above. Had this form been known to the writer in 1898, the form *I*, which is very near to it, would not have been proposed and is now withdrawn. Gonnard's form from Couzon, France, gave measurements which are almost as close to the angles of Pirsson's form as to the more complex one proposed.

			φ	ρ	
Y	12.32.$\overline{44}$.13	23.11.$\overline{21}$	−14°42½′	71°30½′	vom Rath, 1877, New Jersey
	5.13.$\overline{18}$.5	28.13.$\overline{26}$	−14 23½	72 31	Sella, 1856
	11.29.$\overline{40}$.12	21.10.$\overline{19}$	−14 34	71 13½	Levy-vom Rath, 1876, Elba
	9.24.$\overline{33}$.10	52.25.$\overline{47}$	−14 42½	71 04	Franzenau & Vendl, 1930
	3.8.$\overline{11}$.3	17.8.$\overline{16}$	−14 42½	72 50½	Buttgenbach, 1920
	18.49.$\overline{67}$.20	35.17.$\overline{32}$	−14 57½	71 21	vom Rath, 1876: Vendl, 1921



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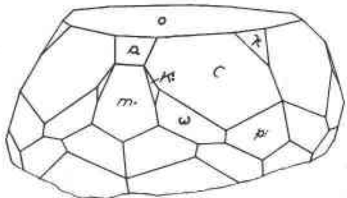

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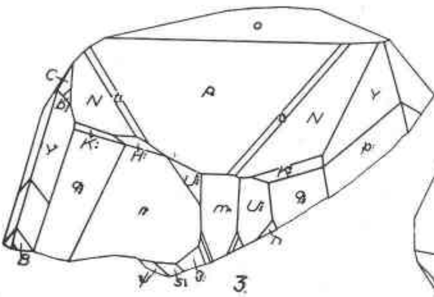

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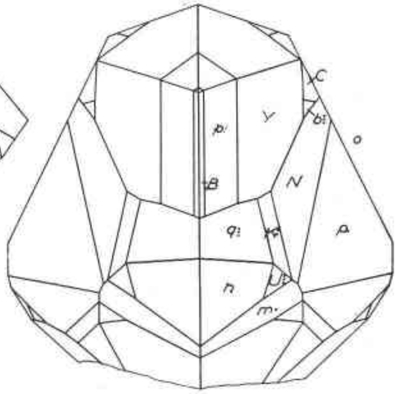

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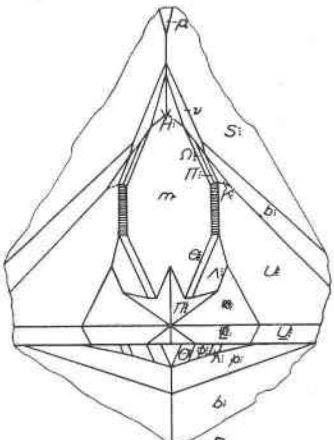

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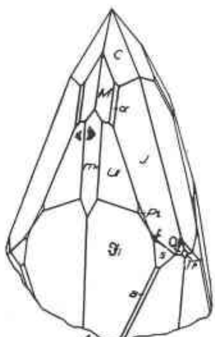


6.

FIG. 1. Calcite showing the forms; o $\{0001\}$, ω $\{16.16.\overline{32}.9\}$, $p.$ $\{10\bar{1}1\}$, $\nu.\{05\bar{5}4\}$, $\xi.$ $\{04\bar{4}3\}$, $\rho.$ $\{03\bar{3}2\}$, M $\{8.4.\overline{12}.5\}$, q⁚ $\{24\bar{6}1\}$, S⁚ $\{32.56.\overline{88}.45\}$.

FIG. 2. Calcite showing the forms; o $\{0001\}$, ω $\{16.16.\overline{32}.9\}$, $p.$ $\{10\bar{1}1\}$, $m.$ $\{40\bar{4}1\}$, $\lambda.$ $\{08\bar{8}7\}$, K: $\{21\bar{3}1\}$, C $\{14.26.\overline{40}.21\}$, 𝔭⁚ $\{13\bar{4}1\}$.

These various symbols show that Y is in a disturbed region similar to b⁝ . The form last listed is maintained by Vendl after extensive discussion of the various alternatives. The measured angles of {9.24.$\overline{33}$.14} are as well satisfied by the angles of Y. Buttgenbach's symbol is simpler and rather far removed from Y in position, but it is based on poor and widely varying angles. Y, on the other hand, was found repeatedly in good position on the author's crystals and by Whitlock at Rondout, New York. It has been observed again on Elba crystals by Grill (1912) who found it a characteristic form for that locality. It seems well justified to regard all these forms as vicinals to Y, especially as it alone falls into the important zone under discussion.

I.{17.38.$\overline{55}$.24}, D{3.8.$\overline{11}$.4}—These two scalenohedrons form with {01$\bar{1}$2} a zone which very nearly, but not quite, contains C. I. bears to the strong form {4.8.$\overline{12}$.5} the same relation that C bears to b⁝ that is of a vicinal to its simpler, stronger form. D is also near to A, but it is a more definite form and was recognized on ten crystals. I. and D are shown in Figs. 10 and 11, and their zonal relations are best seen in gnomonic projection (Palache, 1898).

$\mathfrak{c}${4.20.$\overline{24}$.17}, $\mathfrak{d}${4.36.$\overline{40}$.31}—The first of these forms was reported as new in 1898 but had been recorded from Üto, Sweden, by Sansoni in 1890. The second is met with repeatedly in good position. The two forms lie in the zone determined by b⁝ and {08$\bar{8}$7}, already mentioned. They are well shown in Fig. 12 (Palache, 1898).

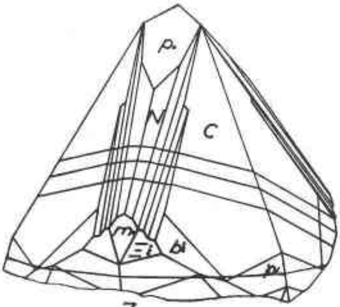
K{1.11.12.8}—The interest attaching to this form was fully described in the first report. It is a common form but is generally so etched as to be unmeasurable but may be recognized by its sub-cubic shape.

FIG. 3. Calcite, Tamarack Mine, Lake Superior. One half of a twin, drawn in normal position, showing the forms: o {0001}, Ψ {10.1.$\overline{11}$.0}, p. {10$\bar{1}$1}, m. {40$\bar{4}$1}, K: {21$\bar{3}$1}, N {12.4.$\overline{16}$.11}, U⁝ {10.4.$\overline{14}$.3}, $\mathfrak{J}$⁝ {62$\bar{8}$1}, q⁝ {9.5.$\overline{14}$.3}, r⁝ {32.14.$\overline{46}$.9}, s⁝ {16.7.$\overline{23}$.1}, t⁝ {37.4.$\overline{41}$.36}, b⁝ {35$\bar{8}$4}, C {14.26.$\overline{40}$.21}, Y {12.32.$\overline{44}$.13}, $\mathfrak{p}$⁝ {13$\bar{4}$1}, B {12.40.$\overline{52}$.11}.

FIG. 4. Calcite, Tamarack Mine; same crystal as Fig. 3. Drawn normal to the twin plane, {01$\bar{1}$2} and to a face of the prism {11$\bar{2}$0}. Idealized symmetry of development and smaller faces omitted.

FIG. 5. Calcite, Lake Superior. One coign of a crystal showing the forms: ν {11$\bar{2}$1}, p. {10$\bar{1}$1}, m. {40$\bar{4}$1}, K: {21$\bar{3}$1}, H: {31$\bar{4}$2}, U⁝ {10.4.$\overline{14}$.3}, $\mathfrak{P}$⁝ {51$\bar{6}$1}, Λ⁝ {32.4.$\overline{36}$.7}, Φ⁝ {9.1.$\overline{10}$.2}, Π⁝ {10.1.$\overline{11}$.3}, Θ⁝ {40.4.$\overline{44}$.9}, Ω⁝ {32.2.$\overline{34}$.9}, b⁝ {35$\bar{8}$4}, S⁝ {32.56.$\overline{88}$.45}. Shows also a basal twin lamella.

FIG. 6. Calcite, Allouez Mine, Lake Superior, showing the forms: a {11$\bar{2}$0}, α {44$\bar{8}$3}, m. {40$\bar{4}$1}, Π. {08$\bar{8}$1}, P: {32$\bar{5}$1}, M {8.4.$\overline{12}$.5}, U⁝ {10.4.$\overline{14}$.3}, $\mathfrak{J}$⁝ {62$\bar{8}$1}, s {16.20.$\overline{36}$.5}, t {9.13.$\overline{22}$.5}, C {14.26.$\overline{40}$.21}, J {8.20.$\overline{28}$.9}, Q⁝ {7.28.$\overline{35}$.9}. Drawn by Howard T. Evans, Jr.



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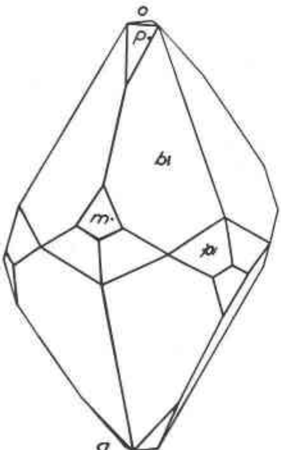

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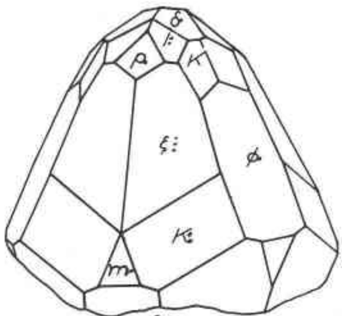

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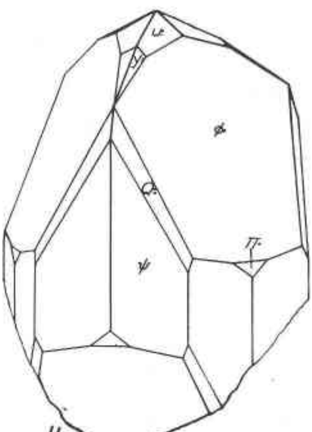

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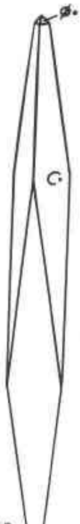

12.

The crystal of Fig. 13 (Palache, 1898) shows it, and it was found with good faces on the crystal shown here as Fig. 10. This form is well established.

Two figures have been added to this paper to show unusual habits for Lake Superior crystals. Figure 11 is remarkable for the large development of the prism $\psi\{10.1.\overline{11}.0\}$, which is found frequently but is generally very subordinate. It was reported as new in 1898 but was found later to have been described elsewhere. Figure 12 shows what is very rare in the whole Lake Superior region, a simple rhombohedral type. However, the form is a rare one $\{0.13.\overline{13}.1\}$.

The paper to which constant reference has been made is "The Crystallization of the Calcite from the Copper Mines of Lake Superior," by Charles Palache, *Geological Survey of Michigan*, Vol. VI, Pt. II—Appendix, pp. 161–184, Plates 11–16, with 24 figures and a gnomonic projection. It will be noticed by any reader who refers to the 1898 paper that the Goldschmidt G_2 and the Naumann crystallographic symbols there used have been discarded. This is in accordance with recent usage in this laboratory. The Bravais symbols used here are given in the older form list along with the others. The letters used for the forms are the same.

The review of the early study has shown the need of the following changes:

A form $P\{13.7.\overline{20}.3\}$ was described on page 176 of that paper and illustrated as a tiny facet in Fig. 7. As this form was not found again, the crystal was remeasured and no measurable face was found at the place indicated. The form is, therefore, withdrawn as based on an inexplicable error.

FIG. 7. Calcite, Lake Superior, showing the forms: *p*. $\{10\overline{1}1\}$, *m*. $\{40\overline{4}1\}$, *N* $\{12.4.\overline{16}.11\}$, Ξ: $\{14.2.\overline{16}.3\}$, *b*: $\{35\overline{8}4\}$, *C* $\{14.26.\overline{40}.21\}$, 𝔭: $\{13\overline{4}1\}$. Twin lamellae parallel to $\{01\overline{1}2\}$ are indicated.

FIG. 8. Calcite, Lake Superior, showing the forms: *p*. $\{10\overline{1}1\}$, *m*. $\{40\overline{4}1\}$, δ. $\{01\overline{1}2\}$, ν. $\{05\overline{5}4\}$, ξ. $\{04\overline{4}3\}$, φ. $\{02\overline{2}1\}$, *y* $\{7.6.\overline{13}.20\}$, *x* $\{4.5.\overline{9}.14\}$, *C* $\{14.26.\overline{40}.21\}$, *E*: $\{5.10.\overline{15}.7\}$, 𝔱 $\{3.13.\overline{16}.8\}$.

FIG. 9. Calcite, Lake Superior. Illustrating the commonest type of habit in the region. The forms are *o* $\{0001\}$, *p*. $\{10\overline{1}1\}$, *m*. $\{40\overline{4}1\}$, *b*: $\{35\overline{8}4\}$, and 𝔭: $\{13\overline{4}1\}$.

FIG. 10. Calcite from Champion Mine, Lake Superior, showing the forms: *p*. $\{10\overline{1}1\}$, *m*. $\{40\overline{4}1\}$, δ. $\{01\overline{1}2\}$, φ. $\{02\overline{2}1\}$, *l*: $\{32\overline{5}7\}$, *K*: $\{21\overline{3}1\}$, ξ: $\{7.3.\overline{10}.4\}$, and *K* $\{1.11.\overline{12}.8\}$. Drawn by Howard T. Evans, Jr.

FIG. 11. Calcite from Lake Superior. Unusual habit showing as dominant the prism Ψ $\{10.1.\overline{11}.0\}$, with φ. $\{02\overline{2}1\}$, Π. $\{08\overline{8}1\}$, *y*: $\{23\overline{5}8\}$, *u*: $\{3.5.\overline{8}.13\}$, and *Q*: $\{19.13.\overline{32}.6\}$.

FIG. 12. Calcite, Lake Superior. Very unusual habit for the region showing chiefly the rhombohedron *C*. $\{0.13.\overline{13}.1\}$, an uncommon form on calcite, with φ. $\{02\overline{2}1\}$.

Figure 11 of the report shows a form letter $\mathfrak{B}\!:\ \{2.9.\overline{11}.5\}$. This form was by an oversight omitted from the list of forms.

The form $E\{21.35.\overline{56}.44\}$ was listed in the report and shown in Fig. 5, where it truncates the edge between $\{0001\}$ and $b\!:\ \{35\bar{8}4\}$. It was afterwards found that that part of $b\!:$ which meets the base was actually $S\!:$ and that E was in the zone between the base and $\{32.56.\overline{88}.45\}$. To meet this condition the symbol of E had to be changed and took the form $\{32.56.\overline{88}.69\}$. This substitution was reported by Whitlock (1910) in his list of calcite forms. The form was not seen again and is regarded as extremely doubtful.

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