A Study of the Crystallography of the Calcites of the New Jersey Diabase Region

By Herbert P. Whitlock

BULLETIN

OF

THE AMERICAN MUSEUM OF NATURAL HISTORY

Vol. LVI, Art. V, pp. 351-377

New York

Issued December 9, 1927

54.9,(78 74.9)

Article V.—A STUDY OF THE CRYSTALLOGRAPHY OF THE CALCITES OF THE NEW JERSEY DIABASE REGION

By Herbert P. Whitlock

INTRODUCTION

The detailed crystallographic study of the commoner mineral species provides a field of investigation which supplements the general process of adding to the knowledge of occurring crystal forms, by furnishing the data by which the occurrence of these forms under similar conditions in related mineralogical provinces may be compared. It is the opinion of the writer that such critical comparisons may lead to the establishment of a basis of relationship between crystal habit and the genetic conditions under which certain widely distributed mineral species have been formed. There is, perhaps, no single mineral which seems to present a more favorable field for such study than Calcite. The multitude of its observed forms, indicating, as they do, a delicate balance between the crystallizing tendencies, seems to here provide a mineral species in which these tendencies are influenced to a considerable degree by the chemical and physical conditions incident to its crystallization.

The Calcite crystals that are to be found in the amygdaloidal cavities and veins in the basaltic rocks of the Palisade and Watchung outcrops of northern New Jersey constitute a promising mineralogic province for a study of this nature, because they are rich in forms, and because they accompany rock types that can be correlated with similar formations in other parts of the world with a certain degree of ease and certainty.

Much of the material for such a study was comprised in the General Mineral Collection of The American Museum of Natural History, prior to 1925, some of the older occurrences, such as Bergen Hill, having been acquired with the Bement Collection. The most productive material studied, however, was collected during 1925 from the quarry situated at Garrett Rock, West Paterson, then operated by Ferguson Brothers, and known as the "lower quarry" of West Paterson. This suite, which includes about fifty selected specimens constitutes the main basis of the following study. In addition to the calcite from West Paterson specimens from the following localities were studied: Bergen Hill (older finds), Bergen Hill (Erie Cut), Haledon, Plainfield, Prospect Park, Upper Montclair, Great Notch, and Snake Hill.

The thanks of the author are extended tc Mr. Herman Papke, through whose energy and intelligence as a collector most of the West

Paterson specimens were obtained. The author also expresses his thanks to Mr. Frederick A. Canfield of Dover, N. J., Mr. James G. Manchester of New York City, Mr. William H. Broadwell of Newark, N. J., and Mr. James F. Morton of Patersoh, N. J., for the loan of specimens from their private collections, or those of which they are in charge.

PREVIOUS WORK

Prior to the year 1902, little work on the crystallography of the calcites of the region under consideration had been done. J. D. Dana in the fifth edition of his "System of Mineralogy," published in 1868, figured a calcite crystal from Bergen Hill, This combination shows the forms—$\frac{5}{4}R = (05\bar{5}4)$ and $-\frac{7}{5}R\frac{3}{2} = (7.35.\bar{4}2.20)$. No measurements were given as a basis for identification of these forms, and the last-named has been regarded as uncertain by all subsequent writers.

In 1877 G. vom Rath[1] published a paper on the crystallography of the New Jersey calcites in which he figured five combinations from Bergen Hill. Some of these figures approach closely in habit combinations from West Paterson. Of the 16 forms listed by vom Rath from Bergen Hill, 7 were also found by Rogers, who places 6 of the remaining 9 in his list of doubtful forms.

In 1902, A. F. Rogers[2] published a paper on the Crystallography of the Calcites of the New Jersey Trap Region. The table of forms which accompanied this paper lists 35 established and 7 doubtful forms, including those of Dana and vom Rath. Of the 35 forms in Rogers' list, 21 are in the zone of the rhombohedrons and 10 are scalenohedrons of the principal zone $[01\bar{1}2.11\bar{2}0]$, so that, considering the basal pinacoid and the first- and second-order prisms as falling in these two zones, the only form exterior to them is the negative scalenohedron Y $(12.32.\bar{4}\bar{4}.20)$ of vom Rath. The gnomonic projection which accompanies Rogers' paper further emphasizes the fact that all the observed forms to which he has assigned definite indices fall into the two main zones noted. He notes the fact that several other scalenohedrons, mostly negative, appeared on some of the crystals that he studied, but failed to obtain from them measurements of a sufficiently satisfactory character to warrent him in assigning definite indices to them. The six types of crystals of Rogers are based upon predominance of steep or obtuse rhombohedrons and scalenohedrons and not on the presence of dominant forms and zones; in other words, his types are based on superficial crystal habit, as appealing to the

[1] Zeitschr. f. Kryst., I, pp. 604–614; Pl. xxv; ff. 2–6.
[2] The School of Mines Quarterly, XXIII, p. 336.

eye, and not on the more rational crystal habit of form combinations and zones. That this inconsistency was recognized by him is apparent in his notes on Combination 1 of Type 1 and Combination 11 of Type IV, combinations involving identical forms, which he characterized as grading into each other although of different types. Rogers noted three twinning laws, namely, (0001), $(01\bar{1}2)$ and $(10\bar{1}1)$; the latter is very rare, and the three occurrences of it given in his paper represent its first record among American calcites. No illustrations, other than the gnomonic projection mentioned, accompany Rogers' paper.

In 1907, Whitlock[1] published a short paper on calcite crystals from the Haledon Quarry in the West Paterson area. The three combinations figured in this paper represented three distinct types of crystal habit, identical with Types II, V, and VI of the present discussion.

Krentz[2] published in 1907 a discussion of the Twinning Habit of Calcite Crystals, in which he figures crystals from Bergen Hill twinned parallel to $(10\bar{1}1)$ and $(01\bar{1}2)$, both twinning laws having been previously noted by Rogers.

In 1908, Whitlock[3] published a short paper on Some Parallel Groupings of Calcite Crystals from the New Jersey Trap Regions, in which he described and figured parallel groupings of calcite of two generations from Plainfield and ffom Bergen Hill (Erie Cut).

The crystal forms noted in these various papers are included for comparison in the table of forms given on pages 372–373 of the present discussion.

DESCRIPTION OF TYPES

TYPE I.—The dominant form which characterizes crystals of this type is the steep scalenohedron P: $(31\bar{5}1)$ of the principal zone $[01\bar{1}2: 10\bar{1}1: 11\bar{2}0]$. Although this form appears in combinations of other types, it here assumes a strongly marked crystal habit, and it is the controlling form about which the rhombohedrons occurring with it are grouped in very obvious zones. Occasionally steeper scalenohedrons of the principal zone occur, notably V: $(6.5.\bar{1}\bar{1}.1)$, and the limiting form of the zone, $(11\bar{2}0)$, occurs on one combination noted. The type represents the earliest generation of calcite observed, its place in the successive generations being attested by the superposition of other types upon it in parallel grouping, and by the fact that it was in many observable instances deposited earlier than the prehnite, upon which later crystals of the other types are implanted.

---

[1] Whitlock, H. P., Amer. Journ. Sci., XXVI, p. 426.
[2] Krentz, St, Denkschr. Akad. Wien, LXXX, p. 15.
[3] Whitlock, H. P., Report of Director of New York State Museum for 1908, p. 217.

COMBINATION 1 (Figure 1).—Minute, needle-like crystals, showing the form *P:* (32$\bar{5}$1), often terminated by rounded planes of φ. (0221), by small bright planes of *m.* (4041), or by both in combination, occur at West Paterson and at Sowerbutt Quarry, Prospect Park. These average from 1 to 10 mm. in vertical length, are usually water clear and occur encrusting the datolite which at West Paterson lies next to the diabase of the cavity walls. One specimen from this locality showed laumontite of a generation subsequent to the calcite of this habit and implanted upon crystals of the latter.

It is not uncommon to encounter crystals of this combination on which are developed scalenohedrons of principal zone of steeper inclination. *T*: (43$\bar{7}$1) was observed from Great Notch and West Paterson in dominant habit, and *V:* (6.5.1$\bar{1}$.1) on crystals from an old opening in Jersey City. Figure 1 represents a limiting habit of this combinotion, studied from a West Paterson specimen, in which the second order prism *a* (11$\bar{2}$0) occurs in oscillatory combination with steep scalenohedrons.

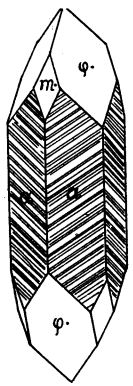

Fig. 1

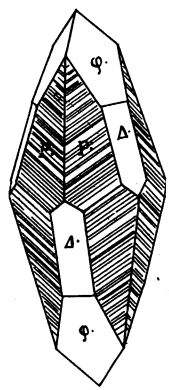

Fig. 2

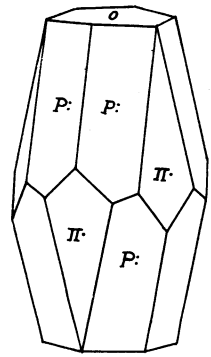

Fig. 3

COMBINATION 2 (Figure 2).—Crystals of this habit, which differs only slightly from the preceding one, were noted at Sowerbutt Quarry, Prospect Park. They are clear, colorless to slightly yellow, and average from 8 to 22 mm. in vertical length. The following forms are present in combination: φ. (02$\bar{2}$1), Δ. (07$\bar{7}$2) and *P*: (32$\bar{5}$1). The planes of φ. and *P:* are smooth and yield good reflections, those of φ. being sufficiently distinct to admit of their being used for adjustment. Δ. is present as a series of somewhat rounded planes and was identified by zonal relations. Figure 2 shows a generalized crystal of this habit.

COMBINATION 3 (Figure 3).—The crystals of this combination were found upon two specimens from the Erie Cut opening at Bergen Hill, and are from the collection of Mr. Canfield. They differ considerably in size and general appearance from the preceding combinations of this habit. They average from 25 to 35 mm. in vertical length, are transparent, slightly yellowish in color and are considerably roughened on all planes but those of the rhombohedron.

The following forms are present: *o* (0001), II. (08$\bar{8}$1) and *P*: (32$\bar{5}$1). Figure 3 shows a crystal of this habit.

In the absence of figures illustrating Rogers' types, it is assumed that his combinations 26, 27 and 28 from Upper Montclair, Bergen Hill and Snake Hill, respectively, represent crystals of Type I of the present discussion.

A stereographic projection of the forms present on crystals of Type I is given in figure 4. It will be noted that the zonal relations between

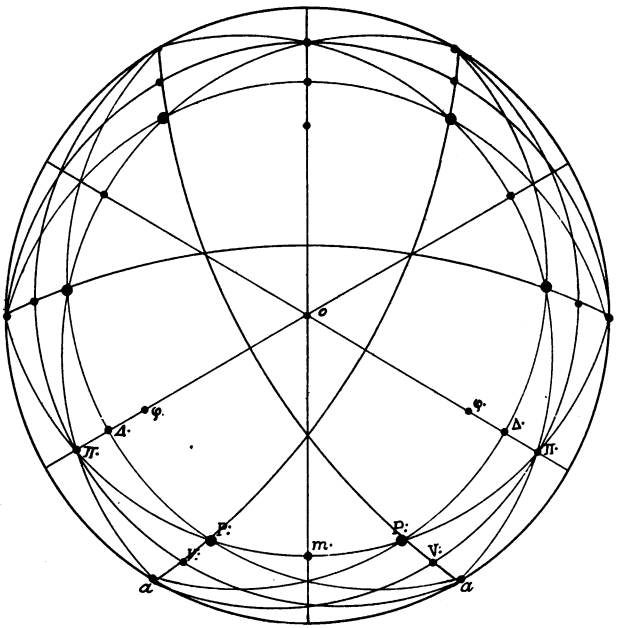

Fig. 4

these forms are both simple and obvious, and that although $\varphi.\ (02\bar{2}1)$ is present on two of the Combinations it does not enter essentially into these relations. *P:* and not $\varphi.$ must be regarded as the controlling form of this Type.

The following measurements made on a Goldschmidt 2-circle goniometer served to identify the forms (the brilliant faces of $\varphi.\ (02\bar{2}1)$ were used to effect the adjustment of the crystals):

	Measured		Calculated	
	φ	ρ	φ	ρ
m. $(40\bar{4}1)$	0° 1′	75°50′	0°	75°47′
π. $(08\bar{8}1)$	0 0	82 52	0	82 46
P: $(32\bar{5}1)$	23 34	77 1	23 25	76 54½
T: $(43\bar{7}1)$	25 17	79 51	25 17	80 32
V: $(6.\bar{5}.\bar{11}.1)$	26 56	83 47	27 0	83 56

TYPE II.—In crystals of this type the controlling forms are the rhombohedrons φ. $(02\bar{2}1)$ and m. $(40\bar{4}1)$, the former of which is in many instances developed to a dominant habit, and the zone of the controlling

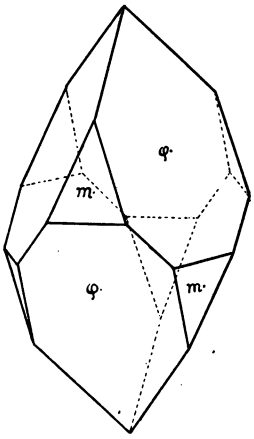

Fig. 5

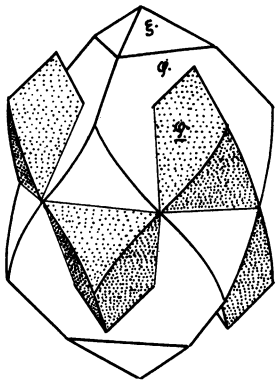

Fig. 6

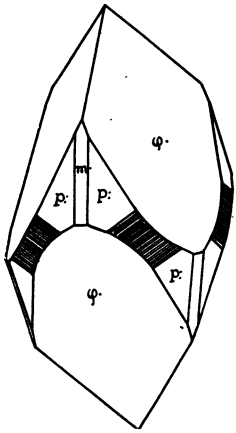

Fig. 7

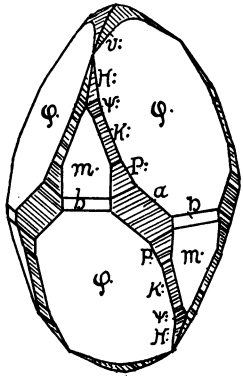

Fig. 8

forms $[02\bar{2}1, 40\bar{4}1]$ in the instances of combinations 7 and 8 are well emphasized. Genetically crystals of this type are in general of a generation subsequent to Type I and are characterized by the fact that they occur implanted on prehnite.

COMBINATION 4 (Figure 5).—Crystals of this habit, representing the simplest expression of the type, are common throughout the area. The dominant negative

rhombohedron φ. $(02\bar{2}1)$ is present in considerable development and the positive rhombohedron m. $(40\bar{4}1)$ to a less extent. Well-developed crystals of the uncombined rhombohedron φ. occur at Snake Hill in considerable size, averaging 4 cm. in vertical length. They are translucent and colorless. Deep yellow calcite crystals of the form φ., with slightly rounded faces and averaging 2 cm. in vertical length, occur at the Sowerbutt Quarry, Prospect Park. Clear colorless crystals, combining φ. and m. in the proportions shown in figure 5, and 3 mm. in vertical length, occur at the West Paterson Quarry. Yellowish translucent crystals, twinned parallel to o (0 01) and combining the negative rhombohedrons φ. $(02\bar{2}1)$ and ξ. $(04\bar{4}3)$ from Upper Montclair, were studied on a specimen from the collection of Mr. Manchester. Figure 6 shows the curved planes of φ. and the proportions of these twinned crystals which average 2 cm. in vertical length.

COMBINATION 5 (Figures 7 and 8).—Crystals of this habit differ from those of Combination 4 in that they show a development of the scalenohedrons of the principal zone, linking them to some of the combinations of the previous type. A specimen from West Paterson showed calcite crystals of the habit illustrated in figure 7, combining the following forms: m. $(40\bar{4}1)$, φ. $(02\bar{2}1)$, P: $(32\bar{5}1)$, and an undeterminable series of scalenohedrons in zone $[01\bar{1}2: 11\bar{2}0]$ which round the lateral edges of *P:* Crystals of this habit, as studied on the above specimen, are clear, colorless and about 5 mm. in vertical height. Slightly yellowish crystals of this combination, also from West Paterson, were developed to a vertical length of 4 cm. Very faintly yellowish crystals, also of this combination, occur on white prehnite from the Sowerbutt Quarry at Prospect Park, and average 12 mm. in vertical length.

A variant of Combination 5, in which the scalenohedrons of the principal zone are more strongly developed, is shown in figure 8, and occurs on crystals from West Paterson. These are clear, colorless, and average 5 mm. in vertical length. On the specimen studied they are intimately associated with albite in minute white to colorless crystals of the same generation as the calcite and encrusting prehnite of a light greenish yellow color.

The following forms were identified:

a $(11\bar{2}0)$, b $(10\bar{1}0)$, m. $(40\bar{4}1)$, φ, $(02\bar{2}1)$, v: $(7.4.\bar{1}1.15)$, *H:* $(31\bar{4}2)$, *K:* $(21\bar{3}1)$, and *P:* $(32\bar{5}1)$.

On one crystal measured, four planes of the rare scalenohedron ψ: $(15.7.\bar{2}\bar{2}.8)$, lying between H: and K:, were observed. This scalenohedron was observed by Schnorr[1] on crystals from Neumark, Prussia. The portion of the zone between v. $(7.4.\bar{1}1\ 15)$ and δ. $(01\bar{1}2)$ is present as a curved band, deeply straited, in which no definite reflections of the goniometer signal could be distinguished. The zone is broken aud striated.

In general, Combination 5, and particularly the habit represented in figure 7, corresponds to Type I from the Haledon Quarry as described in the writer's earlier paper as previously cited.

COMBINATION 6 (Figure 9).—This combination was observed on a small specimen from West Paterson, collected many years ago, and was loaned for study by the Paterson Public Museum, through the courtesy of Mr. James E. Morton, Curator of the Museum. The specimen consisted of three closely aggregated crystals of calcite, which were clear, colorless and averaged 25 mm. in vertical length.

The following forms were identified:

[1] 1896, Wissensch. Beil. z. Programme des Realgyne, zu Zwickau, XVI.

ψ (1.10.$\bar{1}\bar{1}$.0), m. (40$\bar{4}$1), φ. (02$\bar{2}$1), Σ. (0.11.11.1.), K: (21$\bar{3}$1), and P: (32$\bar{5}$1).

The combination, which is shown in figure 9, differs from those of the Type previously described in the presence of well-developed planes of the rare dihexagonal prism ψ (1.10.$\bar{1}\bar{1}$.0). This prism has been hitherto observed on but one occurrence of calcite. Like ψ: of Combination 5, it was noted by Schnoor[1] on crystals from Neumark, Prussia.

The crystals of this Combination, like those of Combination 5, are much rounded on the termination by undeterminable scalenohedrons of the principal zone. Owing to the fact that the specimen studied consisted of a close grouping of three crystals, relatively few faces could be observed on any one crystal. Of the rare forms, ψ (1.10.$\bar{1}\bar{1}$.0) was noted twice on each crystal and Σ: (0.11.$\bar{1}\bar{1}$.1) once on each crystal.

COMBINATION 7 (Figure 10).—This combination was observed on two specimens from the "lower quarry," West Paterson, obtained in the summer of 1925. The

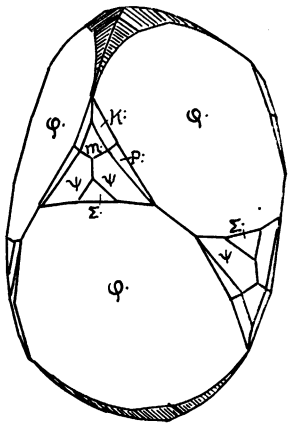

Fig. 9

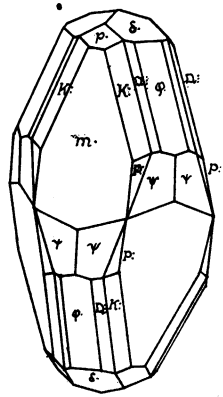

Fig. 10

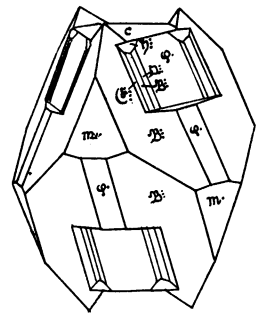

Fig. 11

crystals are clear, colorless, and brilliant, and averaged 4 mm. in vertical length. They were closely associated with leek green prehnite, suggesting by their intermixture with the prehnite aggregates that the two minerals belonged to the same generation of mineral deposition.

The following forms were observed.

ψ (1.10.$\bar{1}\bar{1}$.0), *p.* (10$\bar{1}$1), *m.* (40$\bar{4}$1), δ. (01$\bar{1}\bar{2}$), φ. (02$\bar{2}$1), *K:* (21$\bar{3}$1), *P:* (32$\bar{5}$1), and Ω: (4.16.20.9).

ψ(1.10.$\bar{1}$1.0).—This rare dihexagonal prism, which was also present on crystals of the previous combination, is beautifully developed in smooth brilliant planes, giving fine reflections, and was observed 24 times on the three crystals measured.

Ω: (4.16.$\bar{2}$0.9) —This scalenohedron was noted by Sansoni[2] on crystals from Andreasberg, Harz, which were associated with pink apophyllite of pyramidal habit. It falls in the zone [02$\bar{2}$1: 40$\bar{4}$1], which in this instance is further emphasized by the

[1] *Loc. cit.*
[2] Sansoni, F. R., 1884, Acad. d. Linc., XLX, Plate III, Fig. 29.

presence of the scalenohedron K: $(21\bar{3}1)$, both forms occurring as narrow planes beveling the edges between the controlling rhombohedrons. This relation is shown in figure 10.

The rare forms of this combination were identified by the following measurements:

	Measured		Calculated		N
	φ	ρ	φ	ρ	
ψ $(1.10.\bar{1}\bar{1}.0)$	4°44′	90° 2′	4° 43′	90′ 0′	24
Ω: $(4.16.\bar{2}\bar{0}.9)$	10 41½	63 59	10 54	63 32½	13

COMBINATION 8 (Figure 11).—Crystals showing this combination occur on an old specimen from West Paterson. They show a parallel grouping of two generations of calcite as shown in figure 11, implanted on small drusy crystals of quartz, the latter exhibiting a slight surface stain of hematite. The earlier generation crystals are clear and colorless and conform closely to the type; the superposed individuals are pinkish yellow, transparent and protrude slightly in termination above the basal plane of the earlier generation crystals. The composite crystals average 5 mm. in vertical length.

The following forms were observed

o $(00\bar{0}1)$, *m.* $(40\bar{4}1)$, φ. $(02\bar{2}1)$, Ω: $(4.16.\bar{2}\bar{0}.9)$, $\mathfrak{B}$: $(2.9.\bar{1}\bar{1}.5)$, $\mathfrak{E}$: $(25\bar{7}3)$, and $\mathfrak{h}$: $(2.10.\bar{1}2.7)$.

In this combination the zone $[40\bar{4}1:02\bar{2}1]$ is more strongly marked than in the preceding one, the prominence of $\mathfrak{B}$: $(2.9.\bar{1}\bar{1}.5)$ in the later generation, superposed crystals amounting to a pronounced crystal habit.

Ω: $(4.16.\bar{2}\bar{0}.9)$.—This negative scalenohedron of the zone $[40\bar{4}\bar{1}:02\bar{2}1]$, which was noted on Combination 7. is repeated on crystals of this habit.

$\mathfrak{B}$: $(2.9.\bar{1}\bar{1}.5)$.—This negative scalenohedron, also of the zone $[40\bar{4}\bar{1}: 02\bar{2}\bar{1}]$, was first recorded by Sella[1] on calcite crystals from Traversella, Piedmont, Italy. In the combination drawn by Sella, the planes of $\mathfrak{B}$: are shown as beveling the acute polar edges of *K*: $(21\bar{3}1)$, a relation incompatible with zonal relation as stated above. All zonal and harmonic relations combine to give to this rare form a high degree of probability.

$\mathfrak{E}$: $(25\bar{7}3)$.—This negative scalenohedron in zone $[40\bar{4}1: 02\bar{2}1]$ was early established in the literature of calcite, being first observed on crystals from the Harz region.[2] Lévy in 1836 also shows a combination from Derbyshire involving this form. It has subsequently been recorded several times, and has always been regarded as a well-established, although uncommon, form in the calcite form system.

$\mathfrak{h}$: $(2.10.\bar{1}2.7)$.—This negative scalenohedron is rare on calcite crystals, having been observed by Wimmer[3] on crystals from Andreasberg, Harz, Germany. It lies in the zone $[10\bar{1}1:02\bar{2}1]$, and shows excellent zonal and harmonic relations. In the present instance it was observed as small but brilliant planes giving excellent reflections.

The following measurements served to identify the rarer forms of this Combination:

---

[1]Sella, Q., 1856, Accad. R. della Sc. di Torino, XVII, Fig. 34.
[2]Naumann, C. F., 1826, Pogg. Ann., XIV.
[3]Wimmer, W., 1854, Zeitschr. f. Ges. Naturwiss., Berlin, III, p. 334.

	Measured		Calculated		N
	φ	ρ	φ	ρ	
$\mathfrak{Q}$: (4.16.$\bar{2}$0.9)	11° 0′	63° 1′	10°54′	63°32½′	3
$\mathfrak{B}$: (2.9.$\bar{1}$1.5)	9 26	63 16	9 50	63 27	15
$\mathfrak{E}$: (25$\bar{7}$3)	16 6	63 51	16 6	64 2	3
$\mathfrak{h}$: (2.10.$\bar{1}$2.7)	8 56½	57 30	8 57	57 29½	4

The zonal relations of the forms observed on the combinations of Type II are shown in stereographic projection in figure 12. It will be

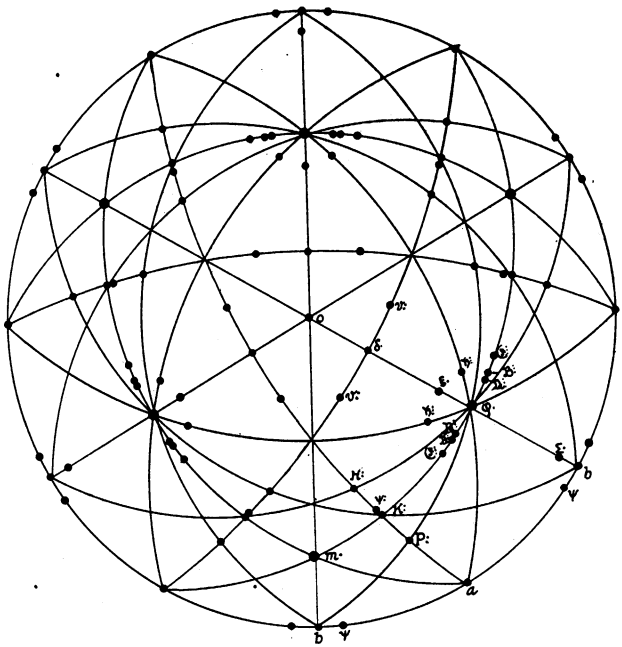

Fig. 12

noted that the characteristic forms of the type, i.e., *m*. (40$\bar{4}$1) and φ. (02$\bar{2}$1), are also conspicuous as controlling forms in the form system. The distribution of the type over the area studied suggests the possibility that calcite, having for the dominant forms of its habit these controlling forms, may have a wider connection with basaltic rocks than would be accounted for by merely local conditions of deposition.

TYPE III.—The chief characteristic of this type is a rhombohedral habit involving the predominating planes of negative rhombohedrons of more obtuse inclination to the vertical than φ. and comprising a series,

which, as will be shown later, constitute with φ. one of the outstanding characters of the combinations of Type V.

Genetically the position of crystals of this type is somewhat enigmatic. Their position in the mineral sequence clearly indicates that they represent a calcite generation later than Type I, and they belong to a stage of deposition previous to Types V and VI, but the writer has been unable to place them with respect to Types II and IV.

COMBINATION 9 (Figure 13).—Small, colorless, transparent crystals of this habit were observed on a specimen taken from the upper quarry at West Paterson in 1925. These occur on drusy quartz crystals associated with occasional specular hematite. They average 4 mm. in vertical length. They are rhombohedral in habit, showing prominent planes of the negative rhombohedron λ. $(08\bar{8}7)$, combined with η. $(04\bar{4}5)$ and φ. $(02\bar{2}1)$ in small development. In aspect they are nearly cubical.

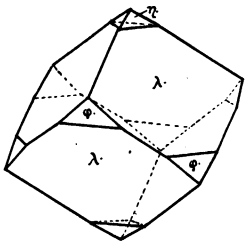

Fig. 13

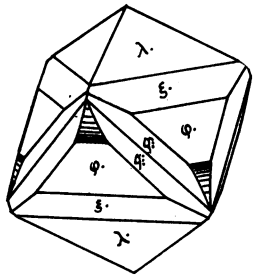

Fig. 14

COMBINATION 10 (Figure 14).—Crystals of this combination occurred on a specimen taken from the West Paterson quarries previous to 1925, and from the collection of Mr. Manchester (No. 1185). These crystals average about 12 mm. in vertical length. In habit they combine three negative rhombohedrons, λ. $(08\bar{8}7)$, ξ. $(04\bar{4}3)$ and φ. $(02\bar{2}1)$, in about equal development; the basal edges of φ. are beveled by narrow planes of the negative scalenohedron q: $(24\bar{6}1)$, and the zone cf the negative rhombohedrons is much rounded by vicinal rhombohedrons between φ. and the prism b. These forms were identified by contact measurements.

Inasmuch as the forms involved in Type III are almost exclusively in the rhombohedral zone, no interest would be attached to a projection of them.

TYPE IV.—The outstanding characteristic of Type IV is the predominance of one of a series of negative scalenohedrons. Figures 3 and 5 of vom Rath's paper, as previously cited, from Bergen Hill, evidently conform to this Type. Crystals of this habit were noted by the writer from Bergen Hill (Erie Cut,)[1] on which a doubtful negative scalenohedron of irrational indices was observed, approximating in measurements that of vom Rath's figure 5. No crystals of this type were observed by Rogers.

[1] *Loc. cit.*

Genetically this Type is evidently later than Types I and II, since in one combination observed it encloses an earlier crystal of Type II in parallel grouping.

COMBINATION 11 (Figure 15).—Crystals of this habit appear on a specimen from Bergen Hill (Erie Cut) from the collection of Mr. Manchester (No. 686). They are clear, faintly yellowish to colorless, and measure about 15 mm. in vertical length. The negative scalenohedron Ω: (4.16.$\bar{2}$0.9) is present as the dominant form terminated by the negative rhombohedron ξ. (04$\bar{4}$3) and having its terminal edges truncated in the negative sextants by narrow planes of the negative rhombohedron φ. (02$\bar{2}$1). The planes of both negative rhombohedrons lie in zone with those of Ω: The planes were somewhat uneven and the forms were identified by contact measurements and zonal relations.

Since the poles of the scalenohedron Ω: lie reasonably close to those of vom Rath's doubtful form (22.55.$\bar{7}\bar{7}$.36) in φ value, it is suggested that the more rational scalenohedron (4.16.$\bar{2}$0.9) may represent his form.

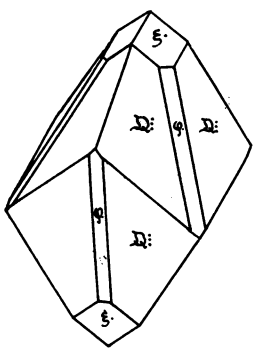

Fig. 15

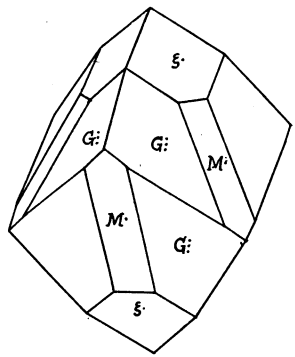

Fig. 16

COMBINATION 12 (Figure 16).—Crystals showing this combination were collected from the "upper quarry" of West Paterson in the spring of 1925. They occur in close association with and in some instances are implanted on quartz in small crystals. They are clear, colorless and average 4 mm. in vertical length.

The negative scalenohedron which dominates this habit differs only slightly in indices from Ω: of the last combination. A number of consistent measurements, however, seem to justify the assigning to it of the indices (5.29.$\bar{3}\bar{4}$.18), corresponding to a form new for calcite. The negative rhombohedron M. (07$\bar{7}$4) truncates the terminal edges of G: (5.29.$\bar{3}\bar{4}$.18) in the negative sextants, the two forms lying in zone in these sextants.

The negative rhombohedron ξ. (04$\bar{4}$3), common throughout the Type, terminates this combination, also lying in zone with G: (5.29.$\bar{3}\bar{4}$.18).

COMBINATION 13 (Figure 17).—Crystals of this combination were obtained from the "lower quarry" of West Paterson in the spring of 1925. They occur in close association with chabazite and analcite, somtimes superposed upon these minerals. The crystals are clear, colorless and average 8 mm. in vertical length. They represent

a parallel growth of two generations of calcite, the inner, earlier individuals conforming to Type II of the present discussion. The superposed individuals are scalenohedral—rhombohedral in habit.

The forms present on the Type II individuals are:

φ. $(02\bar{2}1)$, O:$(8.5.\bar{1}3.3)$, and in some instances m. $(40\bar{4}1)$.

The forms present on the Type IV individuals are:

ξ. $(04\bar{4}3)$, φ. $(02\bar{2}1)$, H: $(3.11.\bar{1}4.7)$, and on one crystal measured λ. $(08\bar{8}7)$, an o (0001).

H: $(3.11.\bar{1}4.7)$.— This negative scalenohedron is new to calcite. It was determined by large series (16), consistent measurements, and, although close to G: of the previous combination in ρ value and to $\mathfrak{D}$: in both φ and ρ values, appears to be well estabished. In aspect the Type IV crystals of this Combination strongly resemble those figured by vom Rath from BergenHill as his figure 3, the negative scalenohedron being given by him as $(2.8.\bar{1}0.5)$. There is a difference in calculated angles between

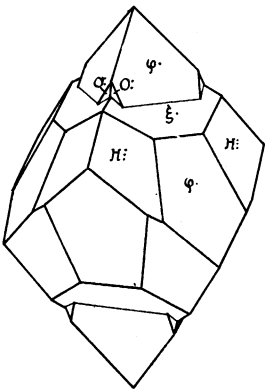

Fig. 17

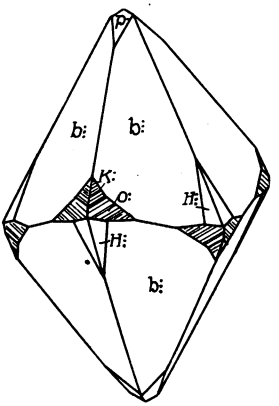

Fig. 18

the two forms, i.e., $(2.8.\bar{1}0.5)$ and $(3.11.\bar{1}4.7)$ of 50′ of φ angle and 7′ of ρ angle a difference which seems to justify the substitution of H: $(3.11.\bar{1}4.7)$ for vom Rath's form.

COMBINATION 14 (Figure 18).—Crystals of this combination occur on several specimens from Snake Hill, intimately associated with datolite and apparently of the same generation as that mineral. They are brilliant, clear and colorless, and average 2 cm. in vertical length. In habit they are more distinctly scalenohedral than those previously described under this Type.

The following forms were noted:

p. $(10\bar{1}1)$, K: $(21\bar{3}1)$ O: $(8.5.\bar{1}3.3)$ b: $(35\bar{8}4)$ and H: $(3.11.\bar{1}4.17)$.

The planes of all forms are bright and yielded good reflections; those of K: and O: are striated in the zone $[10\bar{1}1:11\bar{2}0]$, but the reflections were clear and definite.

The following series of measurements served to identify the rarer and new forms above listed. Where present, the planes of φ. and ξ. were used for adjustment; in the case of Combination 14, adjustment was made on the planes of p.

	Measured		Calculated	
	φ	ρ	φ	ρ
M. $(07\bar{7}4)$	0° 8′	59°30′	0° 0′	59°55′
ξ. $(04\bar{4}3)$	0 1	52 44	0 0	52 45
λ. $(08\bar{8}7)$	0 0	48 28	0 0	48 25½
O: $(8.5.1\bar{3}.3)$comb. 13	22 21	75 35½	22 24½	75 0
O: $(8.5.1\bar{3}.3)$ comb. 14	22 8½	74 47	22 24½	75 0
b: $(35\bar{8}4)$	20°58	60 15	20 47	59 55
G: $(5.29.\bar{3}4.18)$	8 34	60 22	8 46	60 12
H: $(3.11.1\bar{4}.7)$ comb. 13	11 34	60 49	11 44½	60 56
H: $(3.11.1\bar{4}.7)$ comb. 14	11 42	61 13	11 44½	60 56

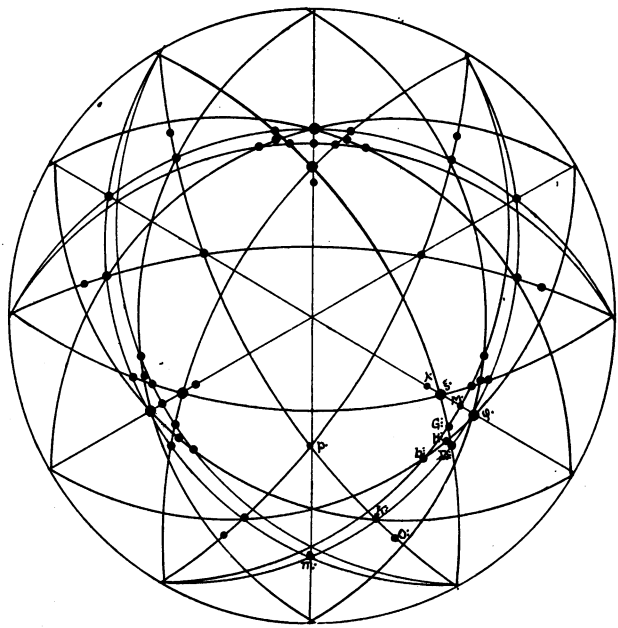

Fig. 19

Figure 19 gives in stereographic projection the zonal relations of the forms occurring on crystals of Type IV, It will be noted that the negative scalenohedrons, charcteristic of the type, are controlled by the negative rhombohedrons ξ. and φ.

These rhombohedrons, particularly ξ., are prominent in the crystal habit of the type. The zonal relations of the rare negative scalenohedrons with these control forms are exceptionally good.

Type V.—The crystals of this type differ in several respects from those previously discussed. They are, as far as the area under discussion

is concerned, found only in the immediate neighborhood of West Paterson. They are by far the most highly complex of the types hitherto described and are further unique in that they conform more closely to type than these foregoing types.

The outstanding characteristics of the combinations of Type V are: a strongly marked zone of negative rhombohedrons, in most instances limited by the basal pinacoid, and three well-marked zones of scalenohedrons controlled by the rhombohedrons p. $(10\bar{1}1)$, λ. $(08\bar{8}7)$ and φ. $(02\bar{2}1)$, and by the negative scalenohedron q: $(24\bar{6}1)$. The crystals of this type are very abundant in both the upper and the lower quarry at West Paterson. They occur in thickly implanted aggregates commonly associated with heulandite, stilbite, apophyllite and other secondary minerals characteristic of the locality, and evidently belong to a late stage of calcite deposition.

COMBINATION 15 (Figure 20).—This combination may be said to represent the generalized habit of Type V, in that it was observed with greater frequency among the West Paterson crystals than other combinations of the type which may be regarded as variants of it. Crystals of this habit average 6 mm. in vertical length and are clear and colorless.

Crystals of this combination show a zone of negative rhombohedrons rich in forms, which are developed as brilliant faces, giving fine reflections. The basal pinacoid *o* (0001), which is the limit form of this zone, is present in good development, and was used as a reference plane in adjusting the crystals for measurment.

The following forms were observed:

o (0001), α $(44\bar{8}3)$, p. $(10\bar{1}1)$, η. $(04\bar{4}5)$, λ. $(08\bar{8}7)$, ξ. $(04\bar{4}3)$, ρ. $(03\bar{3}2)$, *O*. $(0.11.\bar{1}1.6)$, φ. $(02\bar{2}1)$, Θ. $(04\bar{4}1)$, Σ. $(0.11.\bar{1}1.1)$, ♄: $(2.10.\bar{1}2.7)$, o: $(2.8.\bar{1}0.3)$, q: $(24\bar{6}1)$, 𝔛: $(15.8.\bar{2}3.13)$*, Z: $(6.4.\bar{1}0.5)$,* Y: $(54\bar{9}4)$,* *k*: $(4.60.\bar{6}4.49)$,* *l*: $(18\bar{9}6)$, 𝔖: $(27\bar{9}4)$, and M: $(15.8.\bar{2}3.10)$.*

The forms marked with an asterisk (*) are new to calcite.

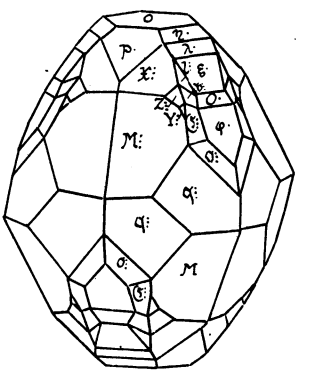

Fig. 20

The rhombohedrons p. $(10\bar{1}1)$, λ. $(08\bar{8}7)$ and φ. $(02\bar{2}1)$, and the negative scalenohedron q: $(24\bar{6}1)$ control the zones $[10\bar{1}1:02\bar{2}1]$, $[08\bar{8}7:11\bar{2}0]$ and $[10\bar{1}1:24\bar{6}1]$, into which all but the four last of the scalenohedrons given above fall.

The zone $[10\bar{1}1:02\bar{2}1:11\bar{2}0]$ includes the scalenohedrons ♄: $(2.10.\bar{1}2.7)$, o: $(2.8.\bar{1}0.3)$ and q: $(24\bar{6}1)$.

♄: $(2.10.\bar{1}2.7)$.—This negative scalenohedron has long been recognized as well established for calcite. It was first observed by Wimmer on crystals from Andreas.

berg[1] and appears on Combination 8 of Type II of the present discussion. Under the present Combination, it appears on the eight crystals measured from two specimens. The planes are brilliant and sharp and give very satisfactory readings.

With regard to zonal relations, this form is particularly rational in the present form system, since it lies at the intersection of two zones of control, that under which it is listed and also [0887.11$\bar{2}$0]. The stereographic projection, figure 23, will serve to make this clear.

o: (2.8.1$\bar{0}$.3).—This is one of the oldest-established scalenohedrons of the zone, being first observed to Bournon in 1808, on calcite from Derbyshire. It was observed nine times on three crystals of the series measured. It lies at the intersection of the control zone, as listed, and the zone [4$\bar{4}$01:04$\bar{4}$1], both well marked in the form system of the type.

The zone |0887:11$\bar{2}$0] includes the scalenohedrons *k*: (4.60.6$\bar{4}$.49) and ♄ : (2.10.1$\bar{2}$.7); the scalenohedrons *l*: (1896) and ☾: (2794) lies close to this zone.

k: (4.60.6$\bar{4}$.49).—This negative scalenohedron is new for calcite. It occurs on all four of the crystals measured from one specimen. It marks the intersection of the zone under discussion with the zones [10$\bar{1}$1:04$\bar{4}$3] and [4$\bar{4}$05:$\bar{2}$.10.$\bar{8}$.3], thus fitting into the zonal relations of the form system of the combination with rationality. Although the indices are relatively high, the agreement between measured and calculated angles seems to justify the indices assigned to it.

The zone |10$\bar{1}$1:24$\bar{6}$1] includes the scalenohedrons ☓: (15.8.$\bar{2}$3.13), Z: (6.4.1$\bar{0}$.5), Y: (54$\bar{9}$4) and the pyramid α (44$\bar{8}$3).

☓: (15.8.$\bar{2}$3.13). This positive scalenohedron is new for calcite. It occurs on 5 of the crystals measured in good development. Its poles lie very close to those of ☓ (8.4.1$\bar{2}$.7), which also falls in the zone |10$\bar{1}$1:24$\bar{6}$1] and which occurs on other combinations of Type V. There is, however, a consistant though small difference between the positions of these two forms which prohibits the idea of their identity.

Z: (6.4.1$\bar{0}$.5).—This positive scalenohedron is also new for calcite. It occurs on five of the eight crystals measured in sharp, well-defined planes. The zonal relations of this form are notably rational, since it falls into the zones [64$\bar{2}$1:02$\bar{2}$1] and [04$\bar{4}$5: 10$\bar{1}$0], in addition to that under discussion. It is interesting to note that a scalenohedron of these indices was named as hypothetical by the present writer in 1915.[2]

Y: (54$\bar{9}$4).—This new positive scalenohedron occurs on three of the eight crystals measured in small but distinct faces. It shows good zonal relations, falling in zone [1$\bar{1}$01, 10$\bar{1}$0] as well as that under discussion. The agreement between measured and calculated angles is also fair.

l: (18$\bar{9}$6).—This new negative scalenohedron occurs on three of the crystals measured. It does not lie in any of the control zones common to the type, although its poles are situated close to [0887:11$\bar{2}$0] as previously stated.

☾: (27$\bar{9}$4).—This negative scalenohedron occurs on three of the crystals measured. It is one of the oldest established forms of calcite, having been first observed by Bournon in 1808 on crystals from Derbyshire. The poles of ☾: fall in the zone [02$\bar{2}$1:40$\bar{4}$1], a zone which was emphasized in Type IV and which in the present combination also contains α (44$\bar{8}$3).

M: (15.8.$\bar{2}$3.10).—This new positive scalenohedron was observed on seven of the eight crystals studied, being represented by prominent well-developed planes. Its

---

[1]Wimmer, W., 1854, Zeitschr. f. Naturwiss., Berlin, II, p. 334.
[2]Whitlock, H. P., 1915, 'A Critical Discussion of the Crystal Forms of Calcite,' Proc. Amer. Acad. Art and Sci., L, p. 343.

poles lie close to those of M (8.4.$\bar{1}\bar{2}$.5), which latter form occurs in similar development on combinations of this type to be subsequently described. Like $\mathfrak{X}$: (15.8.$\bar{2}\bar{3}$.13), previously discussed, however, it differs with sufficient consistency in measured angles from the established form to justify its reference to the indices assigned, although it is possible that both $\mathfrak{X}$: and M: may be vicinal to $\mathfrak{X}$ and M.

Crystals of this habit were described under Type II from the Haledon Quarry by the writer in 1907.[1]

The following measurements served to identify the forms of Combination 15:

		Measured		Calculated		N
		φ	ρ	φ	ρ	
α	(44$\bar{8}$3)	29°55′	66°13′	30° 0	66°18′	16
η.	(04$\bar{4}$5)	0 0	38 19	0 0	38 17	13
λ.	(08$\bar{8}$7)	0 0	48 25	0 0	48 25	18
ξ.	(04$\bar{4}$3)	0 0	52 46	0 0	52 45	16
ρ.	(03$\bar{3}$2)	0 0	55 50	0 0	55 57	6
O.	(0.11.$\bar{1}\bar{1}$.6)	0 0	61 20	0 0	61 3½	3
φ.	(02$\bar{2}$1)	0 0	63 5	0 0	63 7	17
θ.	(04$\bar{4}$1)	0 2	74 47	0 0	74 47	4
Σ.	(0.11.$\bar{1}\bar{1}$.1)	0 0	84 47	0 0	84 44	7
$\mathfrak{h}$:	(2.10.$\bar{1}\bar{2}$.7)	−8 55½	57 36	−8 57	57 29½	28
o:	(2.8.$\bar{1}$0.3)	−10 52	69 38	−10 54	69 23	1
q:	(24$\bar{6}$1)	−19 10	79 1	−19 10	79 9½	25
$\mathfrak{X}$:	(15.8.$\bar{2}\bar{3}$.13)	+20 7½	56 37	+20 2	56 54	12
Z:	(6.4.$\bar{1}$0.5)	+23 10	59 38	+23 25	59 50	23
Y:	(54$\bar{9}$4)	+26 8	62 21	+26 19	62 34	8
k:	(4.60.$\bar{6}\bar{4}$.49)	−2 58	51 25	−3 12	51 30	15
l:	(18$\bar{9}$6)	−5 28	55 5	−5 49	54 33	7
$\mathfrak{S}$:	(27$\bar{9}$4)	−12 12	63 18	−12 13	63 39	8
M:	(15.8.$\bar{2}\bar{3}$.10)	+19 53	63 26	+20 2	63 22	21

Combination 16 (Figure 21).—Crystals of this combination do not differ appreciably in general habit from those of Combination 15. Their chief feature of differentiation is, that forms appear on them which are absent from other combinations of the type. The combination was studied from a series of five crystals occurring at the "lower quarry" of West Paterson, closely associated with heulandite, laumontite, apophyllite, babingtonite and secondary quartz, all of which occur incrusting a layer of datolite, which latter lies next to the country rock. They are clear, colorless and average 8 mm. in vertical length.

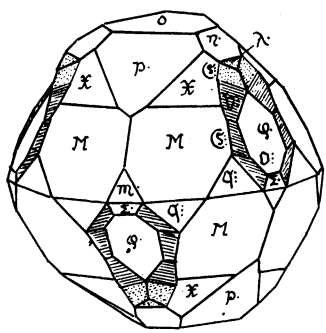

Fig. 21

The following forms were recorded on this combination:

[1] Whitlock, H. P., *loc. cit.*

o (0001), *p*. (10$\bar{1}\bar{1}$), *m*. (40$\bar{4}$1), *η*. (04$\bar{4}$5), λ. (08$\bar{8}$7), *ξ*. (04$\bar{4}$3), *φ*. (02$\bar{2}$1), Σ. (0.11.$\bar{1}\bar{1}$.1), i: (16$\bar{7}$4), ♄: (2.10.$\bar{1}\bar{2}$.7), ♅: (4.10.$\bar{1}\bar{4}$.3),* q: (24$\bar{6}$1), ℭ: (27$\bar{9}$4), ϰ (8.4.$\bar{1}\bar{2}$.7), Z: (6.4.$\bar{1}$0.5)*, and *M* (8.4.$\bar{1}\bar{2}$.5).

The forms marked with an asterisk (*) are new for calcite.

In the zone of the rhombohedrons, *m*. (40$\bar{4}$1), absent from Combination 15, appears as a well-developed series of planes. On the other hand, λ. (08$\bar{8}$7), a control form of Combination 15, is here developed only on the protruding portions which break the line of the negative rhombohedron series, and which suggest a parallel growth. It is significant in this connection that the scalenohedrons distinctive of the zone |08$\bar{8}$7: 11$\bar{2}$0], present in Combination 15, are here absent.

In the zone [10$\bar{1}$1:02$\bar{2}$1:11$\bar{2}$0], two negative scalenohedrons, absent from the previous combination i: (16$\bar{7}$4), and ♅: (4.1.$\bar{1}\bar{4}$.3), are preesnt.

i: (16$\bar{7}$4).—This negative scalenohedron was observed on one of the five crystals measured as minute but bright faces giving close and consistant readings. The form is one of old establishment, having been first observed by Lévy in 1837 on crystals from Andreasberg, Harz.

♅: (4.10.$\bar{1}\bar{4}$.3).—This negative scalenohedron is new for calcite. It was found on three of the five crystals studied, as small but bright faces. It lies at the intersection of the zone under discussion and [4$\bar{4}$03:01$\bar{1}$0] and [$\bar{2}$.10.$\bar{8}$.3:10$\bar{1}$0], relations which are highly rational when the form system of the Type is taken into consideration.

ϰ (8.4.$\bar{1}\bar{2}$.7).—This rare positive scalenohedron takes the place, in the five crystals measured, of ϰ: of the previous combination in the zone [10$\bar{1}$1:24$\bar{6}$1].

This form was first recorded by Aminoff[1] on crystals from Långban, Sweden. Like the new form Z: (6.4.$\bar{1}$0.5) in the same zone, it was given as hypothetical by the present writer in 1915. With regard to the form system of the Combination, it falls in the highly rational zone [$\bar{1}$101:40$\bar{4}$1].

M (8.4.$\bar{1}\bar{2}$.5).—This positive scalenohedron is also rare for calcite. It was observed on all five of the crystals measured, developed in considerable proportion, and takes the place of *M*: of the previous combination. The form was first noticed by Palache[2] on crystals from the Lake Superior region of Michigan. Its zonal relations in the form system of Type V are excellent.

The following measurements served to identify the rare forms observed:

	Measured		Calculated		N
	φ	*ρ*	*φ*	*ρ*	
Σ. (0.11.$\bar{1}\bar{1}$.1)	0° 0′	84° 40	0° 0′	84°44′	8
i: (16$\bar{7}$4)	—7 43	58 8	—7 35	58 16	2
♄: (2.10.$\bar{1}\bar{2}$.7)	—9 34	57 9	—8 57	57 29	6
♅: (4.10.$\bar{1}\bar{4}$.3)	—15 54	76 8	—16 6	76 19	6
ℭ: (27$\bar{9}$4)	—12 2	63 13	—12 13	63 39	5
ϰ (8.4.$\bar{1}\bar{2}$.7)	+19 6	56 12	+19 7	56 9	11
Z: (6.4.$\bar{1}$0.5)	+22 44	59 45	+23 25	59 50	3
M (8.4.$\bar{1}\bar{2}$.5)	+19 21	64 29	+19 7	64 34	14

COMBINATION 17 (Figure 22).—Like those of the previous combination, crystals of this habit may be said to represent a variant of the generalized expression of Type

[1]Aminoff, G., 1918, Geol. Fören. Förh., XL, p. 273.
[2]Palache, C., 1900, Geol. Surv. Mich., VI, p. 6.

V, as represented in Combination 15, rather than a distinctly separate combination of forms. They differ in no respect from those previously described under the type from the point of view of crystallogenesis or association. The crystal represented in figure 22 in actual development was chosen to show the rare and new forms, absent from those previously figured.

On the four crystals measured, the following forms were observed:

p. (10$\bar{1}$1), *m.* (40$\bar{4}$1), *η.* (04$\bar{4}$5), λ. (08$\bar{8}$7), ξ. (04$\bar{4}$3), *φ.* (02$\bar{2}$1), Ξ. (05$\bar{5}$1), Σ. (0.11.$\bar{1}\bar{1}$.1.), q: (24$\bar{6}$1), Ξ: (14.2.$\bar{1}\bar{6}$.3), M (8.4.$\bar{1}\bar{2}$.5), D: (5.10.$\bar{1}\bar{5}$.8)*, E: (5.10.$\bar{1}\bar{5}$.7).*

The forms marked (*) are new for calcite.

The following new and rare forms have not appeared previously in this discussion.

Ξ: (14.2.$\bar{1}\bar{6}$.3).—This positive scalenohedron appears on three of the four crystals measured in small but brilliant planes which furnished readings of fine consistency and agreement with theory. This form was first observed by Cesàro on crystals from Rhisnes, Belgium. The pole (14.2.$\bar{1}\bar{6}$.3) falls in the lower segment of the zone [02$\bar{2}$1: 13$\bar{4}$1:11$\bar{2}$0], and lies at the intersection of this zone with the zones passing through [4.10.$\bar{1}\bar{4}$.3:2$\bar{6}$4$\bar{1}$] and [2.8.$\bar{1}\bar{0}$.3: $\bar{2}$.10.$\bar{8}$.3], also, as pointed out by Cesàro, it lies in zones [2$\bar{2}$01: 11$\bar{2}$0] and [50$\bar{5}$1:0.-10.$\bar{1}\bar{0}$.1]. Ξ: (14.2.$\bar{1}\bar{6}$.3) was also found by Palache[2] on two crystals from Lake Superior.

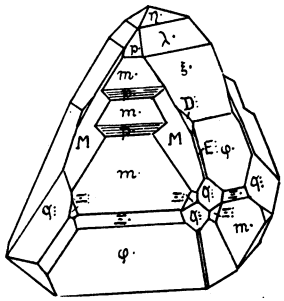

Fig. 22

D: (5.10.$\bar{1}\bar{5}$.8).—This new negative scalenohedron occurs on all four of the crystals measured as small but bright planes giving consistent readings. Although the zonal relations of this form are poor, the indices assigned seem to be jusified by measurements.

E: (5.10.$\bar{1}\bar{5}$.7).—This new scalenohedron occurs on three of the four crystals measured as narrow planes between *M* (8.4.$\bar{1}\bar{2}$.5) and *φ.* (0221). The zonal relations of the form are better than those of D: since it falls in the zone [10$\bar{1}$1:05$\bar{5}$1].

The following measurements served to identify the rare forms observed:

	Measured		Calculated		N
	φ	*ρ*	*φ*	*ρ*	
Ξ. (05$\bar{5}$1)	0° 2	78°27′	0° 0′	78°32′	4
Σ. (0.11.$\bar{1}\bar{1}$.1)	0 2	84 33	0 0	84 44	6
Ξ: (14.2.$\bar{1}\bar{6}$.3)	+6 35	78 39	+6 35	78 37	8
M (8.4.$\bar{1}\bar{2}$.5)	+19 4	64 19	+19 7	64 24	24
D: (5.10.$\bar{1}\bar{5}$.8)	—19 12	58 15	—19 7	58 5	20
E: (5.10.$\bar{1}\bar{5}$.7)	—18 52	61 27	—19 7	61 47	7

Figure 23 shows a stereographic projection of the form system of Type V. Comparing this form system with those of Types II and IV, it will be seen that with the increase in the number of forms in Type V there is an increased tendency toward the zonal control of these forms from a relatively few points in the rich rhombohedral zone.

[1]Cesàro, G., 1889, Ann. Soc. Geol. Belg., XVI, p. 165.
[2]Palache, C., *lo. cit.*

The importance of the rhombohedron φ. $(02\bar{2}1)$ as a dominating crystallizing influence increases with the later generations of calcite deposition, and in Type V forms a focus of the many occurring forms. Such a controlling tendency persisting throughout a complex and varied series of types and combinations is not without significance when the nature and extent of the area from which they are derived are taken into consideration.

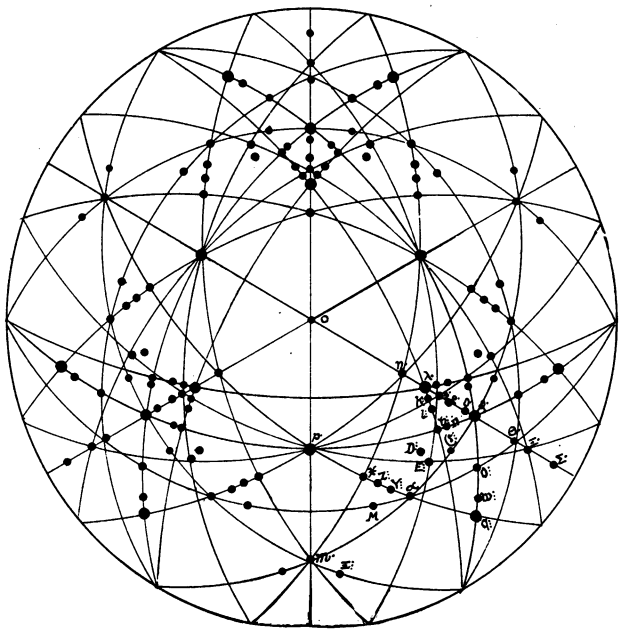

Fig. 23

TYPE VI.—The few combinations referable to this type include crystals of notably larger proportions than any hitherto discussed. The outstanding characteristic of these is the presence of the positive scalenohedron *K:* $(21\bar{3}1)$ developed to the extent of a considerable habit. In the Paterson area, crystals of Type VI are linked to those of Type V by the presence of a narrowly developed but rich zone of negative rhombohedrons embracing several of the important forms of the latter type.

COMBINATION 18 (Figure 24).—Crystals of this habit were studied from a specimen from Snake Hill furnished from the collection of Mr. Manchester. They are translucent, colorless to white, and average 3 to 8 cm. in vertical length.

The occurring forms which were identified by contact measurements are:

φ. (02$\bar{2}$1), Ξ. (05$\bar{5}$1), K: (21$\bar{3}$1), and q: (13$\bar{4}$1).

COMBINATION 19 (Figure 25).—Several specimens of this combination collected from Paterson and Great Notch are comprised in the collection of the American Museum. The specimen illustrated in actual development in figure 25 was collected about 1911 from the West Paterson quarries. This crystal, which is twinned parallel to *o* (0001), is clear, colorless and measures 8 cm. in vertical length.

The following forms were identified by contact measurements:

b (1010), *K*. (50$\bar{5}$2), *m*. (40$\bar{4}$1), ξ. (04$\bar{4}$3), φ. (02$\bar{2}$1), Ξ. (05$\bar{5}$1), *K:* (21$\bar{3}$1), and q: (13$\bar{4}$1).

TWINNING.—Crystals of Type II, twinned parallel to *o* (0001), occur at Upper Montclair, figure 6, and of Type VI. Combination 19, from West Paterson and Great Notch.

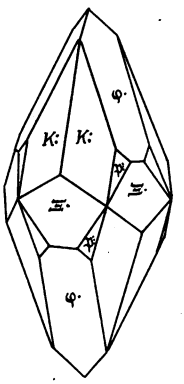

Fig. 24

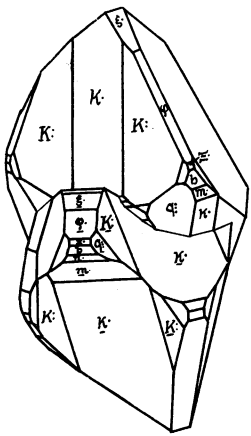

Fig. 25

Crystals of Type I, Combination 4, but with V: (6.5.$\bar{11}$.1) substituted for P: (32$\bar{5}$1), and II. (08$\bar{8}$1) entirely absent, occur on an old specimen from the opening in Jersey City mentioned under Combination 1. The specimen upon which these were studied is from the collection of Mr. Canfield. Several of the crystals, are twinned parallel to δ. (01$\bar{1}$2) and are considerably flattened parallel to the plane containing their vertical axes, giving plate-like individuals. Twin crystals according to this latter law are also common among those of Type V, Combination 15, from West Paterson, resembling the well-known "butterfly twin" crystals of some of the English localities. The present writer was unable to confirm Rogers' statement as to the occurrence of twins parallel to p. (10$\bar{1}$1) among the specimens available.

The following summary shows the crystal forms recorded from the Diabase Region of New Jersey, and includes, besides the forms listed in the present discussion, those of the authors listed under the heading "Previous Work" on pages 352–353.

DISTRIBUTION OF FORMS

		Types						New	vomRath	Rogers	Whitlock	
Letter	Symbol	I	II	III	IV	V	VI				1907	1908
o	0001	×	×			×			×	×	×	
a	$11\bar{2}0$	×	×						×	×		×
b	$10\bar{1}0$		×				×			×	×	
ψ	$10.1.\bar{1}1.0$				×							
σ	$71\bar{8}0$											×
α	$44\bar{8}3$					×						
m.	$40\bar{4}1$	×	×		×	×	×		×	×	×	×
K.	$50\bar{5}2$						×			×	×	
Q.	$12.0.\bar{1}2.5$									×		
R.	$20\bar{2}1$									×		
p.	$10\bar{1}1$		×		×	×	×		×	×	×	
γ.	$02\bar{2}5$									×		
δ.	$01\bar{1}2$		×						×	×		×
ε.	$03\bar{3}5$									×		
η.	$04\bar{4}5$			×		×				×		
λ.	$08\bar{8}7$			×	×	×				×	×	
υ.	$05\bar{5}4$									×		×
ξ.	$04\bar{4}3$		×	×	×	×	×			×	×	
π.	$07\bar{7}5$									×		×
ρ.	$03\bar{3}2$					×				×		
M.	0774				×							
H.	$0.18.\bar{1}8.13$									×		
A.	$09\bar{9}5$									×		
O.	$0.11.\bar{1}1.6$					×						
φ.	$02\bar{2}1$	×	×	×	×	×	×		×	×	×	
X.	$09\bar{9}4$										×	
E.	$0.13.\bar{1}3.4$									×		
Δ.	$07\bar{1}2$	×								×		
Θ.	$04\bar{4}1$					×						
Ξ.	$05\bar{5}1$					×	×			×	×	
Π.	$08\bar{8}1$	×								×		×
Σ.	$0.11.\bar{1}1.1$		×			×					×	
v:	$7.4.\bar{1}1.5$		×									
t:	$21\bar{3}4$									×		
w:	$31\bar{4}5$											×
f:	$7.2.\bar{9}.11$								×			
λ:	$17.5.\bar{2}2.2$									×		

DISTRIBUTION OF FORMS (Continued)

		Types						New	vomRath	Rogers	Whitlock	
Letter	Symbol	I	II	III	IV	V	VI				1907	1908
H:	$31\bar{4}2$		×							×		
ψ:	$15.7.\bar{2}2.8$		×									
K:	$21\bar{3}1$		×		×		×		×	×		
M:	$7.4.\bar{1}1.3$									×		
O:	$8.5.\bar{1}3.3$				×					×	×	
P.	$17.11.\bar{2}8.16$									×		
P:	$32\bar{5}1$	×	×							×		
s:	$17.13.\bar{3}0.4$											×
V:	$6.5.\bar{1}1.1$	×								×		
b:	$2.10.\bar{1}2.7$		×			×						
i:	$16\bar{7}4$					×						
o:	$2.8.\bar{1}0.3$					×						
w:	$4.10.\bar{1}4.3$					×		*				
p:	$13\bar{4}1$						×				×	×
q:	$24\bar{6}1$			×		×	×				×	
Ω:	$4.16.\bar{2}0.9$		×		×							
B:	$2.9.\bar{1}.5$		×									
C:	$27\bar{9}4$					×						
E:	$25\bar{7}3$		×									
Z:	$14.2.\bar{1}6.3$					×						
x:	$4.16.\bar{2}0.3$											×
b:	$35\bar{8}4$				×							×
x:	$15.8.\bar{2}3.13$					×		*				
x	$8.4.\bar{1}2.7$					×						
Z:	$6.4.\bar{1}0.5$					×		*				
Y:	$54\bar{9}4$					×		*				
G:	$5.29.\bar{3}4.18$				×			*				
H:	$3.11.\bar{1}4.7$				×			*				
k:	$4.60.\bar{6}4.49$					×		*				
l:	$18\bar{9}6$					×		*				
D:	$5.10.\bar{1}5.8$					×		*				
E:	$5.10.\bar{1}5.7$					×		*				
M	$8.4.\bar{1}2.5$					×						
M:	$15.8.\bar{2}3.10$					×		*				
t	$3.13.\bar{1}6.8$											×
H:	$36\bar{9}5$										×	
C	$1.13.\bar{1}4.10$										×	
Y	$12.32.\bar{4}4.13$								×			

COMPARISONS AND CONCLUSIONS

In seeking for concurrences in crystal development of the calcite of the area under discussion with that of other areas of diabase rocks, we should be guided by two considerations. We should look for a repetition of certain characteristic groups of forms, and we should likewise examine the recorded data for the repetition of those rare forms which seem peculiar to the form system.

Taking up the first consideration, we have seen that a crystal habit emphasizing steep scalenohedrons of the principal zone is characteristic of the first stage of calcite formation in the New Jersey area. This habit has been recorded from several areas of diabase rocks in association with secondary zeolites. At Andreasberg in the Harz, steep scalenohedrons of this zone are figured by Sansoni[1] with the dominant scalenohedron $(9.7.\bar{1}6.2)$, by Thuling[2], with the combination $(54\bar{9}1)$, $(09\bar{9}2)$ and $(11\bar{2}0)$, and by Leudecke[3] with $(32\bar{5}1)$.

A steep scalenohedral habit in the principal zone with the indices $(7.6.\bar{1}3.1)$ is given by Lévy[4] from Fuglo in the Faröe Islands. The habit is repeated in a crystal from Oberscheld near Dillenberg in a small diabase area of Hesse-Nassau, described by Bumuller,[5] and combining $(19.13.\bar{3}2.6)$ with $(02\bar{2}1)$ in about equal development. Other combinations from the same locality by the same author give $(32\bar{5}1)$ for the dominant habit with $(02\bar{2}1)$, $(0.11.\bar{1}1.1)$ and $(10\bar{1}0)$, a habit almost identical with combination 2 of the present discussion. A small diabase area in Lenarkshire, Renfrewshire, and Dumfrieshire, Scotland, has been carefully studied for calcite by Heddle.[6] Among the combinations which he has figured are steep scalenohedral crystals with $(7.6.\bar{1}3.1)$ from Leadhills, Lanarkshire, and from Bay Vein, Dumfrieshire.

All these steep scalenohedral habits approach very closely to P: $(32\bar{5}1)$ and V: $(6.5.\bar{1}1.1)$ of Type 1, and two are in fact identical with $(32\bar{5}1)$.

The dominant negative rhombohedron φ. $(02\bar{2}1)$ of Type II is traceable with much greater ease throughout the literature of calcite. This dominant habit occurs among the crystals described from Offenbanya, Roumania; Huttenberg, Carinthia; Kandern, Baden; Andreasber, Harz; Niederbrom, Alsace; Montecchio, Maggiore; Vicenza, Italy; Oberscheld near Dillenberg, Hesse-Nassau; Fee Donald Mine,

---

[1]Sansoni, F., 1884, Atti, dei Lincei Men. Cl., Sc. 3, XIX, Pl. III, Fig. 26.
[2]Thuling, G., 1886, Neues Jahrb. f. Min., B:B. IV, Pl. XIX, Fig. 6, Pl. XXI, Fig. 2.
[3]Leudecke, O., 1896, Min. des Harzes, Pl. XIX, Fig. 3.
[4]Lévy, A., 1837, Descript. Heuland Coll., Pl. I, Fig. 7.
[5]Bumuller, C., 1909, Inaug. Dissert, Marburg, Fig. 1 and Fig. 6.
[6]Heddle, F. M., 1901, Min. of Scotland, Pl. XXXVI, Fig. 135; Pl. XLVI, Fig. 219.

Argyllshire; Binny Craig, Linlithgoshire, Kilmalcolm, Renfrewshire; and Guanajuato, Mexico. The writer has also observed this habit on crystals from the diabase outcrops at Westfield, Massachusetts, and Cape d'Or and Two Islands, Nova Scotia.

A calcite crystal from Montecatini, Lombardy, figured by Sansoni,[1] shows a strong analogy to figure 8 of Combination 5 in both habit and occurring forms.

The dominant negative scalenohedrons of Type IV, being a rarer habit for calcite, are more difficult to trace in the literature; their presence on crystals from diabase regions, however, has the greater significance.

The most important of the coincidences involving the negative scalenohedral habit is to be found among the crystals from the Lake Superior region, studied by Palache.[2] The negative scalenohedron $b{:}(35\bar{8}4)$, which was described under Combination 14, figure 18, from Snake Hill, in the present discussion, as a dominant crystal habit, occurs in practically the same development on no less than six of the twentyfour crystals figured by Palache.

A Combination from Andreasberg, figured by Thurling,[3] has for the predominating negative scalenohedron $(34\bar{7}5)$ of the zone $[02\bar{2}1;11\bar{2}0]$, combined with b $(10\bar{1}0)$ and with the negative rhombohedrons φ. $(02\bar{2}1)$, λ. $(08\bar{8}7)$, also in small development the negative scalenohedron $\mathfrak{E}{:}(25\bar{7}3)$ in the zone $[02\bar{2}1; 40\bar{4}1]$, a highly significant assemblage of forms when considered in connection with the form systems of Types II and IV of the present discussion.

In Heddle's discussion of the calcite from the Scottish diabase areas[4] is figured a crystal from Geodha Tuill, Hebrides, on which the negative scalenohedron $g{:}(14\bar{5}3)$ of the zone $[02\bar{2}1{:}11\bar{2}0]$ dominates the habit. On three of the combinations from Raith, Fifeshire, the negative scalenohedron $i{:}(16\bar{7}4)$ figures prominently in the habit, and several from Bowling Quarry, Dunbartonshire, show a development of negative rhombohedrons with $(16\bar{7}4)$ highly suggestive of Combination 13, figure 17, of the present discussion.

The rich zone of negative rhombohedrons, which is such an outstanding feature of the crystals of Type V from West Paterson, is found on the crystals of but two other localities throughout the very voluminous literature of calcite. Such a zone occurs on a crystal figured by

[1]Sansoni, F., 1888, Att. Ac. Torino, XXIII, Fig. 5.
[2]Palache, C., 1900, Geol. Surv. Mich., VI, Figs. 5, 11, 14, 17, 23, 24.
[3]Thurling, G., 1886, Neues Jahrb. f. Min., B.B. IV, Pl. xxi, Fig. 4.
[4]Heddle, 1901, Min. of Scotland, Fig. 20, also Figs. 82–84 and Figs. 92–95.

Hessenberg[1] from Agaete, Canary Islands, three of the forms, ξ. (04$\bar{4}$3), ρ. (03$\bar{3}$2) and Σ. (0.11.$\bar{1}\bar{1}$.1), corresponding to those from West Paterson.

The second repetition of a prominent zone of negative rhombohedrons occurs on a crystal from the Lake Superior region figured by Palache.[2] As in the case of the Agaete crystal, several of these negative rhombohedrons repeat those of West Paterson, i.e., ξ. (04$\bar{4}$3), ρ. (03$\bar{3}$2) and φ. (02$\bar{2}$1). Both the Agaete and the Michigan are terminated by a well-developed basal pinacoid and are further modified by p. (10$\bar{1}$1) and m. (40$\bar{4}$1).

When the comparison is made between the coincidence of rare forms on the New Jersey calcite crystals and on those from other diabase regions, we find an analogy which is even more striking.

Two of the forms observed on crystals of Type I and Type II, ψ: (15.7.$\bar{2}\bar{2}$.8) and ψ (10.1.$\bar{1}\bar{1}$.0), have been previously recorded from only one locality, Neumark, near Reichenbach, Saxony, a locality stiuated in an outcropping of diabase tuff.

Three of the rare forms occurring on crystals of Type II, $\mathfrak{O}$: (4.16.$\bar{2}\bar{0}$.9), $\mathfrak{B}$: (2.9.$\bar{1}\bar{1}$.5) and $\mathfrak{h}$: (2.10.$\bar{1}\bar{2}$.7), were first observed at Andreasberg, and, although possibly observed subsequently at other localities, mark another coincidence between forms characteristic of the diabase region of New Jersey and those of a similar outcrop in Europe. Of the rare forms occurring on the Lake Superior calcite crystals in a diabase region, *M* (8.4.$\bar{1}\bar{2}$.5) has been observed only at this locality and at West Paterson. Another rare scalenohedron, Ξ: (14.2.$\bar{1}\bar{6}$.3), observed on the Lake Superior crystals, also belongs in the form system of the crystals from the New Jersey diabase.

In the course of the foregoing discussion, several facts seemed to be suggested by the evidence gathered.

1.—The persistence of the two negative rhombohedrons ξ. (04$\bar{4}$3) and φ. (02$\bar{2}$1) throughout the crystallographic types of the New Jersey calcites suggest that these forms are characteristic, a view which is supported by the zonal control exhibited by ξ. in the form system of Type II, and by φ. in the form systems of Types II, IV and V.

2.—The marked prevalence of the habit of the negative rhombohedron φ. among calcite crystals from diabase areas which have hitherto come under observation throughout the world, appears to give to the dominance of this form, as noted in the New Jersey area, a wider significance with respect to diabase areas in general.

---

[1]Hessenberg, F., 1870, Senckenb. Abh., VII, Pl. 1, Fig. 5.
[2]Palache C., *loc. cit.*, Fig. 1.

3.—Further connections between the crystallography of the New Jersey calcites and those from other diabase regions, which have been given in detail above, lend weight to the supposition that carbonate solutions depositing secondary calcite crystals in areas of diabase rocks tend to produce crystals of definite prevailing crystal habit and occurring forms.

PUBLICATIONS

OF

THE AMERICAN MUSEUM OF NATURAL HISTORY

MEMOIRS

Volume I. Zoölogy and Palæontology.
Volumes II–VIII. Anthropology.
Volume IX. Zoölogy and Palæontology.
Volumes X–XIV. Anthropology.

Volumes II, IV, V, VII, VIII, and X–XIV form Volumes I–X of the Memoirs of the Jesup North Pacific Expedition. Separate but belonging to this series is an Ethnographical Album.

MEMOIRS—NEW SERIES

Volumes I and II. Zoölogy and Palæontology.
Volume III, part 1. Entomology.
Volume III, parts 2 and 3. Palæontology.

BULLETIN

Volumes I–XXIV; XXV, parts 1 and 2; XXVI-LIII, LV

NOVITATES

Numbers 1–289

ANTHROPOLOGICAL PAPERS

Volumes I-XXV; XXVI, parts 1 to 4; XXVII; XXVIII, parts 1 to 3; XXIX, parts 1 to 3.

MONOGRAPHS

A Review of the Primates. By D. G. Elliot, 3 volumes.

Hitherto Unpublished Plates of Tertiary Mammals and Permian Vertebrates. By E. D. Cope and W. D. Matthew.

Joel Asaph Allen: Autobiographical Notes and a Bibliography of the Scientific Publications.

Bibliography of Fishes, 3 volumes. By Bashford Dean.

NATURAL HISTORY

Volumes I–XXVI. Natural History (Journal of The American Museum of Natural History).

Natural History is a popular record of the progress of The American Museum of Natural History, issued bimonthly.

HANDBOOKS. Numbers 1–12.

GUIDE LEAFLETS. Numbers 1–68.

ANNUAL REPORTS. First (1869) to Fifty-eighth (1926).

A more detailed list, with prices, of these publications may be had upon application to the Librarian of the Museum.