ART. XXIII.—*On some Interesting Developments of Calcite Crystals*; by S. L. PENFIELD and W. E. FORD.

1. CALCITE FROM UNION SPRINGS, CAYUGA COUNTY, N. Y.

THE crystals under consideration were found during the summer of 1899 by Mr. J. M. Clarke, Director of the Geological Survey of the State of New York, and were sent to New Haven for examination. Mr. Clarke had observed that the crystals presented certain features of unusual interest, and it was his wish that they should be described and that the specimens should be deposited in the Yale Collection. The crystals occur in the Onondaga limestone, in a region where slight tectonic disturbances have taken place, giving rise to fissures in which calcite has deposited as vein material. The most interesting feature presented by the crystals is their diversity of habit, shown often on a single hand specimen, and due to different methods of twinning together with peculiarities in the development of certain crystal faces.

Most of the crystals were not well adapted for measurement with the reflecting goniometer, but, using one of the smaller ones, about 5^{mm} in length and 2^{mm} in diameter, it was possible to identify the prominent forms by means of their angles. The small crystals are quite highly modified and their development is represented by fig. 1. The terminal faces are the brightest and best developed, and are those of the common scalenohedron v , $21\bar{3}1$. There was measured for the identification of this form r (cleavage) $\wedge v$, $10\bar{1}1 \wedge 21\bar{3}1 = 28^\circ 56'$, calculated $29^\circ 1' 30''$. In the zone r , v , and making a very small angle with v is the scalenohedron v_1 , $7\cdot4\bar{1}1\cdot3$, which is especially prominent on the crystals from this locality. This form was identified by von Bournon on crystals from Derbyshire and the Dauphiné Alps, and appears as form No. 37, plate 31, of his *Traité de Minéralogie*, published in 1808. The form was identified by its position in the zone r , v and the measurement $v \wedge v_1 = 3^\circ 23'$, calculated $3^\circ 55'$. On the crystals under consideration the faces of the scalenohedron v_1 have a vicinal development, and thus the contrast between them and the better developed faces of the scalenohedron v is generally quite marked. A negative rhombohedron, f_1 , truncates the edges of v_1 and appears always as a narrow face with vicinal development from which no reflection could be obtained. A rhombohedron in this

position would have the symbol $0.12\cdot\bar{1}\bar{2}\cdot 5$, and is a little steeper than the common rhombohedron f , $02\bar{2}1$, which truncates the pole edges of the scalenohedron v . The pyramid of the second order γ , $8.8\cdot\bar{1}\bar{6}\cdot 3$, was identified by the measurement $8.8\cdot\bar{1}\bar{6}\cdot 3 \wedge 8.8\cdot\bar{1}\bar{6}\cdot 3 = 25^\circ 40'$, calculated $24^\circ 46'$, and, further, by its being truncated by the positive rhombohedron M , $40\bar{1}1$. This rare pyramid was first identified by vom Rath* on crystals from Andreasberg in the Harz, and, as pointed out by the authors,† this same pyramid is the prevailing form of the siliceous calcites from the Bad Lands of South Dakota. On crystals from Union Springs there is a tendency for the upper and lower faces of the pyramid γ to round into one another, owing to vicinal development, and because of this rounding it was impossible to obtain an accurate measurement between the upper and lower γ faces.

On the majority of the specimens the crystals are not so highly modified as the one just described, but as already stated the variation in habit due to twinning and the unequal development of certain faces, gives to the specimens a peculiar interest. All the types to be described occur on a single specimen having a surface about half the size of one's hand covered with crystals. The crystals on this specimen were not suitable for measurement and therefore no angles will be given, but the forms were evidently like those identified on the small crystal previously described.

Scalenohedral type.—The scalenohedron v_1 , $7.4\cdot\bar{1}\bar{1}\cdot 3$, fig. 2, is apparently very common at the locality. It should be stated

that this form has the same middle edges as the rhombohedron r , $10\bar{1}1$, and the common scalenohedron v , $21\bar{3}1$, but is somewhat steeper than the latter form. A twinning about the basal plane, fig. 3, is quite common.

* Pogg. Annalen, cxxxii, p. 521, 1867.

† This Journal, ix, p. 352, 1900.

Twins, with the rhombohedron e , $01\bar{1}2$, as twinning plane.—The habit resulting from this kind of twinning is like that of the well known Guanajuato calcites, fig. 4, described by Pirsson,* and it should also be stated that as early as 1837 Lévy† also described and figured calcite twins of this same type from Streifenberg, Nertschinsk, Siberia. Fig. 4 is analogous to the figures of Pirsson and Lévy, though drawn in a different position, and represents the common scalenohedron v , $21\bar{3}1$, drawn with the twinning plane vertical and having a position like that of the side face of a cube, or the pinacoid 010 of any of the three axial systems. This position has been adopted for representing the twin crystals as it gives the best idea of their peculiar development. Fig. 5 represents the scalenohedron v_1 ,

$7\cdot4\cdot\bar{1}\bar{1}\cdot3$ twinned without distortion, a type which has not been observed on any of the specimens, but the figure is introduced in order to show how, by the extension of the two lettered faces in front and the parallel faces behind, together with the suppression of the four small faces below, the Guanajuato type, fig. 4, results. Most of the Union Springs crystals of the Guanajuato type show in addition to the scalenohedron certain modifications at the reëntrant angle, fig. 6. The faces forming the reëntrant angle are the pyramid of the second order γ , $8\cdot8\cdot\bar{1}\bar{6}\cdot3$, and a rhombohedron designated as Δ , apparently in the zone with v_1 and γ , which would cause it to have the symbol $80\bar{8}3$. The surfaces forming the gash or reëntrant angle, however, are curved to such an extent that exact symbols cannot be assigned to portions of them.

Twins with the rhombohedron f , $02\bar{2}1$, as twinning plane.—The rhombohedron f is one of the rare twinning planes of calcite, and the habit presented by the crystals from Union Springs is very striking. The scalenohedron v_1 , $7\cdot4\cdot\bar{1}\bar{1}\cdot3$, twinned about f , and drawn with the twinning plane vertical, as previously

* This Journal III, xli, p. 61, 1891.

† Description d'une Collection de Minéraux formée par H. Heuland. vol. i. p. 10, fig. 5, Plate 1.

described, is represented by fig. 7. In the Union Springs crystals representing this twinning law the reëntrant angle at the top wholly fails, and a peculiar, pointed, spear-head devel-

opment, fig. 8, results from the extension of the two front lettered faces of fig. 7 and the corresponding faces at the back. The crystals observed have always been attached at the lower end. Several crystals of this peculiar type were observed on the specimens sent by Mr. Clarke, and they are said to be quite common at the locality. On a crystal with a broken point the reëntrant angle measured from the rhombohedral cleavages was found to be $35^{\circ} 38'$, calculated $35^{\circ} 27'$.

Lévy, in fig. 6 of the atlas to his work already cited, gives a representation of a crystal from Kongsberg in Norway, of identically the same habit as fig. 8 of this article; however, the habit is apparently a very unusual one, and it is interesting to record it at a new locality.

On a single specimen or even at one locality, as a rule, all crystals of a certain mineral have the same or nearly the same habit, resulting undoubtedly from crystallization under uniform conditions, and therefore it seems a matter of more than usual interest to note on a single hand specimen from the Union Springs locality, the occurrence of simple scalenohedrons, fig. 2, and of three distinct types of twinning, figs. 3, 6 and 8. The calcite crystals seem to be all of one generation. Associated with them are a few crystals of dolomite, apparently of later growth.

2. BUTTERFLY TWINS FROM EGREMONT, CUMBERLAND, ENGLAND.

The so-called butterfly twins from Egremont are well-known and are figured in many mineralogies. Lévy in his work, already cited, gives three figures of them, No. 17, 68, and 69 of his atlas. A few words concerning them and new figures

are introduced in the present article for the sake of comparison with the two types of rhombohedral twinning previously described. The twinning plane in these crystals is the rhombohedron ν , $10\bar{1}1$, and the common scalenohedron ν , $21\bar{3}1$, thus twinned and drawn, as in previous cases, with the twinning plane vertical, is represented by fig. 9. Fig. 10 represents a

crystal of the butterfly twin type in the Brush collection, and, by comparison with fig. 9, it may be seen that the upper faces of the crystal result from the development of the two front, lettered faces of fig. 9 and corresponding faces behind, to the complete obliteration of the reëtrant angle. The faces at the lower extremity of fig. 10 are those of the prism m , $10\bar{1}0$.

It is a matter of interest to observe how the scalenohedron when twinned as described according to the three rhombohedral laws gives apparently simpler shapes by distortion, or unequal development of some of its faces, than if the distortion had not taken place.

3. CRYSTALS FROM PALLAFLAT, CUMBERLAND, ENGLAND.

A feature of the crystals from this locality, as represented by specimens in the Brush collection, is the prominent development of the negative scalenohedron $\bar{\nu}$, $13\bar{4}1$. This form, as shown by fig. 11, has its shorter pole edges bevelled by the common scalenohedron ν , $21\bar{3}1$, and has the same middle edges as the negative rhombohedron, $\bar{\rho}$, $02\bar{2}1$. Fig. 11 was drawn by Mr. W. Valentine of the Sheffield Laboratory. It presents nothing new, and is practically identical with fig. 674 of von Bourdon's *Traité de Minéralogie* published in 1808. The figure is introduced in the present article, because by understanding its simple zonal relations, the same forms can be easily identified as they occur on a twin crystal to be described.

Fig. 12 represents the development of two beautiful twin crystals in the Brush collection, both occurring on the same hand specimen. The twinning plane is the unit rhombohedron, and the development is analogous to that of the butterfly

twins from Egremont, fig. 10. A prominent feature of the twins is the vertical zone r , f and x of the individual to the

right, extending over the twinning plane to x , f , and r of the left hand individual, and so on around the crystal. Thus with this method of twinning four x faces, two in front and two behind, form as it were a vertical prism, analogous to the prism formed by four faces of the scalenohedron v , fig. 4, when the flat rhombohedron e , $01\bar{1}2$, is the twinning plane.

In figs. 4 and 12 the rhombohedral symmetry is not apparent, and the habit is like that of twin crystals of the monoclinic system, having the vertical faces v and x , respectively, as prisms and a pinacoid as twinning plane. The twin crystals represented by fig. 12 are so attached that only a portion of the lower x and v faces are visible.

4. CRYSTALS FROM THE STANK MINE, LANCASHIRE, ENGLAND.

This locality is represented in the Brush collection by a suite of eleven groups of crystals. A form which appears on all of the crystals, and which seems to be especially characteristic for the locality, is the negative scalenohedron B , $2\cdot8\cdot10\cdot3$, having the same *middle edges* as the rhombohedron f , $02\bar{2}1$. On all of the specimens the faces of the scalenohedron have a decided vicinal character. Some of the specimens are simply groups of scalenohedral points without modifications. Generally, however, as shown by fig. 13, the flat negative rhombohedron e , $01\bar{1}2$, is slightly developed, and long narrow faces of the positive scalenohedron v , $21\bar{3}1$, modify the pole edges, while some portions of the negative rhombohedron s , $05\bar{5}1$, may be seen near the attachment of the crystals. Another prominent type which seems to be common is represented by fig. 14. In

this type of crystal the rhombohedron s is prominent and is bevelled by the scalenohedron v ; the pole edges of v are truncated by the rhombohedron f , and B and e appear as slight modifications only. The type of crystal, however, which it is desired especially to call attention to is represented by fig. 15, there being several almost ideally developed crystals of this type in the collection. The peculiar feature presented by the crystals consists in the termination of the prism m , $10\bar{1}0$, by twelve faces of almost equal size and shape, thus giving the appearance of a prism terminated by a dihexagonal pyramid. Six of these terminal faces belong to the positive scalenohedron v , and the remaining six to the negative scalenohedron B , while the negative rhombohedron e appears at the end of the crystal. The distinction between the v and B faces is at

first glance not at all apparent, but the forms may be distinguished by their relative positions with reference to the rhombohedron e and by slight differences in their surface markings, the v faces being finely striated parallel to their intersection with the unit rhombohedron, while slightly undulating, smooth, vicinal surfaces characterize the form B .

5. CRYSTALS FROM ELÆOLITE-SYENITE, MONTREAL, CANADA.

The crystals under consideration are small tabular individuals, fig. 16, measuring about 8^{mm} in diameter, and were found by Mr. W. F. Ferrier of Rossland, B. C., at the Corporation Quarry, Outremont near Montreal. Only a few crystals were found, and one of these was presented to the Brush collection by Mr. Ferrier. A tabular habit is not at all uncommon for calcite, but the crystals deserve brief men-

tion because of the peculiar combination of forms. Besides the basal planes only two forms are present, the negative rhombohedron f , $02\bar{2}1$, a very common form, and the positive scalenohedron F , $42\bar{6}1$, a rare form for the species. The scalenohedron F has the same parameter relation on the horizontal axis as the common scalenohedron v , $21\bar{3}1$, but is twice as steep, F intersecting the vertical axis at 6 and v at 3. Fig. 16 was drawn by Dr. H. E. Gregory while a student in the laboratory.

Sheffield Laboratory of Mineralogy and Petrography,
Yale University, New Haven, May, 1900.