

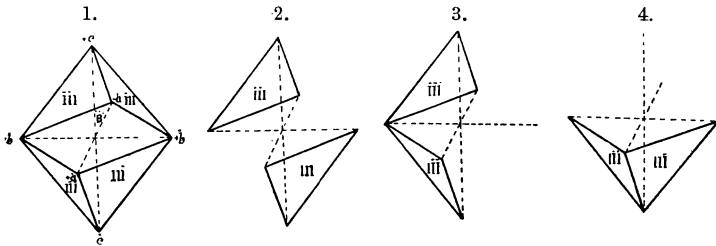
ART. XIII.—*On the possibility of Hemihedrism in the Monoclinic Crystal System, with especial reference to the Hemihedrism of Pyroxene*; by GEORGE H. WILLIAMS.

IN a recent "Note on some remarkable Crystals of Pyroxene from Orange Co., N. Y.,"* I described an unusual monoclinic habit of this mineral which showed the planes of different forms grouped about opposite extremities of the vertical axis. These crystals were then called hemimorphic with reference to the vertical axis, although it was recognized that such an expression did not accord strictly with the accepted nomenclature, because in the monoclinic system the vertical axis is not an axis of symmetry.

During the past summer it was suggested to me by Professor Rosenbusch that these crystals might possibly be regarded as hemihedral rather than hemimorphic, and such upon more mature consideration appears to be the case. I therefore venture to refer once more to the Orange Co. crystals, both because their apparently anomalous form receives a new interest when viewed in this light, and also because they have been found, upon further investigation, to offer by no means an isolated instance of this peculiar development in pyroxene.

As they are at present used in crystallography, the terms *hemihedrism* and *hemimorphism* both express the independent occurrence of one-half of the planes belonging to a crystalline form. They differ, however, in the manner in which these planes are grouped; the former representing half the planes as occurring equally about both extremities of an axis of symmetry, while the latter implies the presence of all the planes of a form at one end of such an axis, and none of them at the other.

The most general holohedral form consistent with the symmetry of the monoclinic system is a hemipyramid ($\pm P$), composed of four planes, one in each of the four similar octants.



It is evidently possible to select one-half of these four planes in three and only three different ways :

* This Journal, III, xxxiv, pp. 275-276, Oct., 1887.

1. We may select two planes which are parallel ($\bar{1}\bar{1}1$) and ($11\bar{1}$); and, if the other pair of parallel planes, ($1\bar{1}\bar{1}$) and ($\bar{1}11$) disappear, there results a tetrapyramid composed of two planes, which is the most general form possible in the triclinic system (fig. 2). Such a form would be truly hemihedral because the planes are similarly grouped about each extremity of the axis of symmetry. A combination of such forms similarly developed would not, however, differ from a triclinic combination and this system may therefore be regarded as a kind of monoclinic hemihedrism. Orthoclase is sometimes quoted as an instance of this triclinic hemihedrism because its imperfect prismatic cleavage is often developed parallel to only one face of the prism. This was first noticed by Haüy and has been substantiated by many subsequent observers.

2. We may select the two planes which meet at an end of the axis of symmetry, \bar{b} , ($\bar{1}\bar{1}1$) and ($1\bar{1}\bar{1}$). If the corresponding pair, ($\bar{1}11$) and ($11\bar{1}$) should disappear (fig. 3) there would result, as Groth remarks,* not a hemihedral, but a hemimorphic form. By this method of selection those holohedral forms belonging to the orthodiagonal zone must remain unaltered, while all others, including the clinopinacoid, may occur with only half of their planes developed. The plane of symmetry here disappears as in the preceding case.

This case is illustrated by the crystals of several organic compounds, among which are tartaric acid ($C_4H_6O_6$),† cane sugar (sucrose, $C_{12}O_{22}H_{11}$)‡ and quercite (pentacid alcohol, $C_6H_{12}O_6$).§ These crystals have furthermore all been shown to be pyroelectric—a property which is especially characteristic of hemimorphic substances.

3. We may, as a last possibility, select two of the planes of the monoclinic hemipyramid which intersect in the plane of symmetry, ($1\bar{1}\bar{1}$) and ($\bar{1}\bar{1}1$). If the corresponding pair, ($\bar{1}\bar{1}1$) and ($\bar{1}11$), disappear (fig. 4) there results an apparent hemimorphism with reference to either or both of the axes in the plane of symmetry—vertical or clinodiagonal. The only holohedral form which cannot appear with only half its planes by this method of selection is the clinopinacoid. All others may be present with only half their planes, although of course both halves of a form may appear on the same crystal. If this be the case in the vertical zone there results apparent hemi-

* *Physikalische Krystallographie*, 2d Ed., p. 481. 1885.

† De la Provostaye, *Ann. Ch. et Phys.*, III, vol. iii, p. 139. 1841.

‡ Wulff, *Jour. für prakt. Chemie*, vol. xxviii, p. 129, 1843. L. Wulff, in his recent article on the crystallization of cane-sugar (*Zeitschr. für Kryst.*, vol. xiv, pp. 552–562, 1888), finds that the face g , $P_{\infty}(011)$ generally occurs with only a single plane, which forces him to regard the substance as an instance of either monoclinic tetartohedrism or triclinic hemihedrism.

§ Lewis, *Proc. Cryst. Soc.*, p. 51, 1882: cf. also Groth, *Physikalische Krystallographie*, 2d Ed., pp. 512 and 514.

morphism with reference to the vertical axis, as shown in figs. 5 to 8. It might, however, be the case that the forms of the clinodiagonal zone were fully developed, when the crystal would appear hemimorphic in the direction of the a axis.

This selection of the planes in reality satisfies all the conditions of hemihedrism since its planes are equally distributed about both extremities of the axis of symmetry. The hemihedrism is moreover inclined-faced, because its forms possess no center of symmetry;* or, in other words, their planes do not have others parallel to them. In this case alone of the three does the monoclinic plane of symmetry remain.

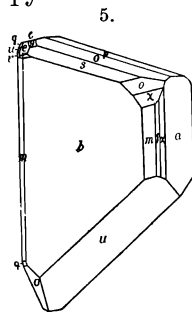
There is therefore possible in the monoclinic system :

1. Parallel-faced hemihedrism. Triclinic system.
2. Hemimorphism.
3. Inclined-faced hemihedrism.

A similar suggestion has been offered by L. Wulff,† and in his recent paper on the crystallization of cane-sugar the same author has given figures very much like those here presented,‡ although I was not cognizant of his work until this article was ready for publication.

The theoretical possibility of such hemihedral and hemimorphic forms in the monoclinic system has, however, for mineralogists but little interest apart from their actual occurrence in nature. The first two are already well known and recognized; the third has heretofore lacked recognition on account of the want of examples, and it is the especial object of this paper to show that it is by no means uncommon on such an important mineral as pyroxene, while it may possibly occur on sphene.

The earliest recorded, as well as one of the most remarkable instances of this inclined-face hemihedrism in pyroxene which has come to my notice, is to be found in a perfectly developed crystal of diopside, probably from the Mussa Alp in Piedmont, figured and described by Hessenberg§ in 1856. His figure is here reproduced (fig. 5), drawn so as to show the clinopinacoid as the principal face. Here, as in all other cases, the prismatic zone is holohedral with the forms a , $\infty P\bar{\infty}$ (100); b , $\infty P\infty$ (010); m , ∞P (110); f , ∞P^3 (130); and χ , ∞P^5 (150). The hemihedrism manifests itself as an apparent hemimorphism in the direction of the vertical axis, at one end of which are the forms p , $+P\bar{\infty}$ ($\bar{1}01$); θ , $+P^3$



* For an explanation of this term, see Sohncke, *Zeitschr. für Kryst.*, vol. xiv, p. 134, 1888.

† *Ibid.*, vol. xiii, p. 499, 1888.

‡ *Ibid.*, vol. xiv, p. 557, 1888. Pl. XI, figs. 3^a, 3^b and 3^c.

§ *Mineralogische Notizen*, No. 1. Pl. II, fig. 18.

(133); s , $+P$ (111); o , $+2P$ ($\bar{2}21$); λ , $+3P$ ($\bar{3}31$); y , $+\frac{5}{3}P$ ($\bar{5}53$); c , $0P(001)$; e , P_{∞} (011); z , $2P_{\infty}$ (021); σ , $-\frac{1}{3}P$ (112); u , $-P(111)$; and v , $-2P$ (221). At the opposite extremity occur only the three forms u , o , and λ . The source of this remarkable crystal is not definitely given. It agrees in all respects with the well-known diopsides from Mussa Alp, except in the matter of attachment.

Inquiry has shown that inclined-faced hemihedrism is not altogether rare among the yellowish white pyroxene crystals from near Warwick, in Orange Co., N. Y. These are usually tabular, parallel to the base, and occur either singly or in groups, imbedded in crystalline limestone. A figure of one of these crystals given by DesCloizeaux,* shows above the forms c , s , o , e and μ , $-2P\bar{2}$ (211). At the lower end there are present c , u and a , $+\frac{3}{2}P\bar{3}$ ($31\bar{2}$).

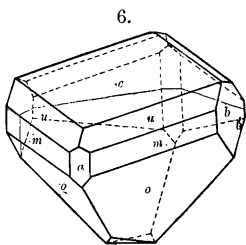


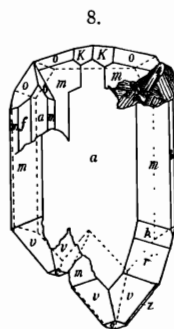
Fig. 6, taken from my above-mentioned "Note," shows a crystal with the usual combination above c , s , o and u , while below are the two halves of a crystal in twinning position showing only the two forms o and p . The crystal was carefully tested for pyro-electricity, but no trace of this property could be discovered even with a delicate Thomson electrometer.

For permission to use the following figure, 7, I am indebted to the U. S. Geological Survey, and also to Professor S. L. Penfield, of New Haven, by whom it was drawn. It represents a perfectly formed pyroxene crystal, $3\frac{1}{2}$ inches in length, from Grassy Lake, near Rossie, St. Lawrence Co., N. Y., upon which the hemihedral distribution of planes is very apparent. At the upper end occur the planes u , very large, s and o . At the lower end are the forms p , c , u , small; s and o . In the prismatic zone are the pinacoids a , b and the prism m . This crystal was probably formed in calcite, as it is doubly terminated. It was collected by Professor Penfield during the summer of 1888, and is now deposited in the U. S. National Museum at Washington.

Prof. E. S. Dana has called my attention to the fact that certain of the tabular white pyroxene crystals occurring in the dolomite at Canaan, Conn., also show different forms at opposite extremities of the vertical axis. Indications of such a de-

* Manuel de Minéralogie, vol. i, p. 54. Atlas, fig. 58, 1862.

velopment are apparent on several of these crystals in the Johns Hopkins University mineral collection, but I am indebted to the kindness of Professor Dana for the opportunity of establishing it by an examination of a fine crystal from Canaan, belonging to the Yale University cabinet. This crystal, which is slightly over two inches in length, is represented in fig. 8. Its planes are for the most part broken or uneven from contact with the dolomite and the substance of the crystal is superficially changed to fibrous white hornblende (uralite), which renders measurement with a reflecting goniometer impossible. The size of the crystal, however, allowed of the satisfactory determination of most of the planes with a contact-goniometer. In this way the following forms were identified: prismatic zone: *a*, *f*, *m*, *b*. Upper extremity: *c*, large, *r*, $-\frac{5}{2}P$ (552); *o*, *K*, +*mPn* (?). Lower extremity: *c*, small; *h*, $-4P$ (441); *r*, *v*, *o*, *z*. The following approximate measurements of interfacial angles^s were obtained with a contact-goniometer, for comparison with which the corresponding values as calculated by von Kokscharow are also given:



<i>c</i> : <i>r</i> back above	126°	} 125° 26'	<i>c</i> : <i>o</i> front above	114°	114° 40'
<i>c</i> : <i>r</i> front below	125½°		<i>m</i> : <i>o</i> back below	145½°	144° 36'
<i>a</i> : <i>r</i> back above	133°	} 133° 24'	<i>c</i> : <i>v</i> front below	129½°	130° 5'
<i>a</i> : <i>r</i> front below	133° +		<i>h</i> : <i>m</i> " "	165° (ca)	163° 36'
<i>c</i> : <i>z</i> " "	132°	131° 24'	<i>f</i> : <i>m</i> " "	153½°	152° 52'

The positive hemi-orthopyramid, *K*, allowed of no definite determination as its planes were small and roughened by the projecting ends of little hornblende needles. It seems, however, to lie in the zone *o* : *o*, and may be the form, $+2P^2$ (211).

It is a striking feature of this crystal that a small portion of its upper half, represented on the left side of the figure, is of quite normal habit, being terminated only by the positive hemi-pyramid, *o*, as is the case below.

The paragenesis of the Canaan crystals is identical with those from Orange Co., N. Y., which are also superficially changed to tremolite. This is a point of some interest, since crystals from both localities show the same hemihedrism in spite of a wide difference in habit.

In a recent conversation with Professor C. W. Brögger, of Stockholm, I also learned that he had not infrequently observed a similar inclined-faced hemihedrism on aegirine crystals occurring in the nepheline rocks of southern Norway.

With such an amount of evidence there can therefore be little doubt that pyroxene illustrates a hemihedrism in the monoclinic system, producing an apparent hemimorphism in the direction of the vertical axis.

Hessenberg's well-known figures of sphene crystals from Rothenkopf in the Zillerthal, Tyrol, exhibit a similar hemihedral development which he at first interpreted as hemimorphism in the direction of the clinodiagonal.* Von Zepharovich, however, subsequently showed that some of these forms could be explained as twins,† and Hessenberg also expressed himself as convinced that even the simplest of these crystals were in reality contact-twins of the ordinary kind where one of the individuals was reduced to an almost invisibly thin lamella.‡

One of Hessenberg's figures is given on p. 385 of Dana's *System of Mineralogy* (f. 372). I have been permitted through the kindness of Mr. C. S. Bement, of Philadelphia, to examine his fine suite of sphene crystals from the Rothenkopf, which includes the finest crystal ever found there, figured in the *Neues Jahrbuch für Min., etc.*, 1874, p. 828. These all appear to be contact-twins, and it is probable that Hessenberg's second explanation of their apparent hemimorphism or hemihedrism is the correct one. Nevertheless their peculiar habit is of interest in connection with the hemihedral development of pyroxene.

Petrographical Laboratory, Johns Hopkins University,
Baltimore, March, 1889.