For domes: If $x = 0$, $\tan \varphi = 0$, $\varphi = 0$; $\tan \rho = qq_0$.
If $y = 0$, $\tan \varphi = \infty$, $\varphi = 90°$; $\tan \rho = pp_0$.

For prisms:

$$\frac{p}{q}\infty, \tan \varphi = \frac{pp_0}{qq_0}; \tan \rho = \infty, \rho = 90°.$$

ILLUSTRATION OF THE ORTHORHOMBIC SYSTEM. MEASUREMENTS AND CALCULATIONS ON HIGGINSITE

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As an illustration of the application of the formulas given in the preceding article, the following discussion of a crystal of the new mineral higginsite, described above, may well serve. The measurements of one crystal are given in full in Table 1, the form of calculation being that used thruout in Goldschmidt's work. In this table, columns 1, 2, 5, and 6 contain the record of actual observation on the goniometer. The numbers of col. 1 are those used to mark the faces in the note-book sketch of the crystal; the letters of col. 2 stand for good, fair and poor, depending on the quality of the reflected signals; col. 5 contains the angles read on the vertical circle, V, col. 6 those on the horizontal circle, H, of the goniometer.

These angles were plotted in gnomonic projection yielding a diagram similar to figure 33. The next step was the choice of the unit form. Either of the pyramids, o and p, might have been taken for this and its coördinates would then have been the elements, p_0 and q_0. The choice fell upon o because this form is more prominently developed on the crystals; the zonal relations with other forms are at least as good; and its selection brings to expression the isomorphism of the new species with descloizite, as will be shown below.

The unit form chosen, the Goldschmidt symbols could be read at once from the projection; they are entered in col. 3. The letters of col. 4 follow the usage for the mineral descloizite.

Determination of the value v_0 was next in order. The projection showed that the face 1 will have $\varphi = 0$, and therefore v_0 would be close to 77°28′, the V reading of face 1. Each of the pairs of faces: 2 and 3; 4 and 5; 8 and 9; are symmetrically dis-

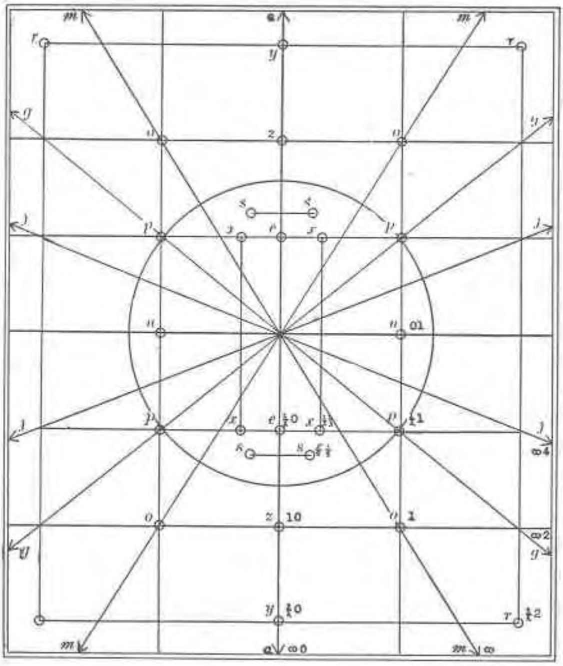

FIG. 33

posed to 1, and the half-sums of the V readings of each pair gave independent values for v_0. Faces 6 and 7 should be 90° from face 1 in φ, and the prism faces also yielded, either directly or by taking the half-sum of symmetrical readings, other values of v_0. The average of all is 77°29′ which, subtracted from each angle in col. 5, gives the values of φ entered in col. 7.

Col. 8 contains the values of ρ obtained from col. 6 by subtracting each from h_0 = 260°, a constant for the instrument.

The calculation of p_0 and q_0 followed. In col. 9 was written first, lg tan ρ for each face (except prisms); then lg sin φ and lg cos φ respectively above and below the first. Col. 10 contains the sums of these logarithms, above the upper two, below the lower two, the logarithms respectively of x and y. This addition proceeds most rapidly if done beginning at the left hand side of the numbers to be added, the sum being then written in col. 10 in order from left to right, a trick of addition (or subtraction)

TABLE 1, on following page and half of page 162, gives the measurements on the higginsite and the calculations therefrom.

1	2	3	4	5	6	7	8	9	10	11	12	13
No.	Qual.	Symbol	Letter	v	h	φ $v_0 = 77° 29'$	ρ $h_0 = 260°$	lg sin φ lg tan ρ lg cos φ	lg x lg y	$x = pp_0$ $y = qq_0$	$\frac{1}{2}p_0$	q_0
1	G	01	u	77°28′	221°46′	00°01′	38°14′	∞ 989645 0	989645	.7879		.7879
2	G	$\frac{1}{2}1$	p	38 44	214 37	−38 45	45 23	979652 000581 989203	980233 989784	.6343 .7904	.6343	.7904
3	P	$\frac{1}{2}1$	p	116 15	214 37	38 46	45 23	979668 000581 989193	980249 989774	.6346 .7902	.6346	.7902
4	P	1	o	19 35	203 49	−57 54	56 11	992795 017401 972542	010196 989943	1.264 .7933	.6320	.7933
5	F	1	o	135 15	204 06	57 46	55 54	992731 016938 972703	009669 989641	1.249 .7878	.6245	.7878
6	P	$\frac{1}{2}0$	e	348 25	227 37	−89 04	32 23	999994 980223 ∞	980217 —	.6341	.6341	
7	G	$\frac{1}{2}0$	e	167 00	227 33	89 31	32 27	999998 980335 ∞	980333 —	.6358	.6358	
8	F	$\frac{3}{2}2$	r	127 19	191 56	49 50	68 04	988319 039505 980957	027824 020642	1.898 1.602	.6326	.8010
9	F	$\frac{3}{2}2$	r	27 13	191 58	−50 16	68 02	988594 039432 980565	028026 019997	1.907 1.585	.6356	.7925
10	P	$\frac{5}{8}\frac{1}{4}$	s	153 55	222 06	76 26	37 54	998771 989125 937028	987896 926153	.7568 .1826	.6056	.7304

Average $\frac{1}{2}p_0$ .6327 q_0 .7919

No.	Qual.	Symbol	Letter	v	h	φ	ρ	lg tan φ = lg $\frac{pp_0}{qq_0}$	$\frac{pp_0}{qq_0}$	$\frac{p_0}{q_0}$
11	P	∞0	a	347°13′	170°00′	−89°16′	90°00′	∞		
12	F	∞	m	19 22	"	−58 07	"	020618	1.608	1.608
13	G	∞2	g	38 58	"	−38 31	"	990061	.7954	1.5908
14	P	∞4	j	55 54	"	−21 35	"	959725	.3956	1.5814
15	P	∞4	j	99 35	"	22 06	"	960859	.4061	1.6244
16	F	∞2	g	115 56	"	38 27	"	989983	.7940	1.588
17	F	∞	m	135 40	"	58 11	"	020731	1.612	1.612
18	P	∞0	a	167 27	"	89 58	"	∞	—	—

Average $\frac{p_0}{q_0}$ 1.599

soon learned with a little practice. All the logarithms of col. 10 having been obtained, the numbers corresponding to each were found from the table, and entered in col. 11 opposite each. The upper number of each horizontal line in col. 11 is a value of $x = pp_0$; the lower a value of $y = qq_0$. p and q having been determined graphically (symbol, col. 3) the numbers of col. 11 yielded a series of values for p_0 ($\frac{1}{2}p_0$ in col. 12) and q_0 (col. 13) the average of which gave the elements of the crystal. The prisms yielded the ratio of p_0 to q_0 by a simple calculation as shown. The result of the calculation of this crystal were as follows:

$$p_0 = 1.2654;\ q_0 = 0.7919;$$

$$\frac{p_0}{q_0} = 1.597 \text{ (from prisms} \frac{p_0}{q_0} = 1.599).$$

A similar calculation may be made for each crystal measured and the results averaged. Possibly a simpler method is to average the angles for each form, make one calculation from these angles, and, weighting the resulting element values according to the number and quality of the readings for each form, find a final average. Table 2 shows the observed forms and angles (averaged) measured on eight crystals of higginsite together with the range of variation of each angle. The values of the elements p_0 and q_0 there given are the basis for the calculation of the φ and ρ angles of the same table. Table 3 shows the method of this calculation. The columns are numbered and the nature of the content of each is indicated by the heading. The lowest group of figures in each heading indicates the operation by which the values of the column were obtained. For example in col. 3, (1 + lg. p) means that lg. p is added to each logarithm of col. 1; in col. 5, (3–4) means that the logarithm of col. 4 is to be subtracted from that of col. 3; in col. 9 (3–6 = 4–7) means that the result of subtracting each logarithm of col. 6 from that of col. 3 should equal the result of subtracting each logarithm of col. 7 from that of col. 4. Incidentally this identity is a check on the calculation of each set of angles. After the values of lg. tan φ are obtained in col. 5, the angle is found from the table, entered in col. 8 and at the same time the lg. sin and lg. cos entered in cols. 6 and 7. ρ is obtained from lg. tan ρ of col. 9.

Each operation is thus a horizontal addition or subtraction or the result of adding a common value to a vertical series of numbers. All operations are supposed to be done mentally or with the aid of a slip of paper on which a commonly used value may be written. With comparatively little practice they become very easy and rapid.

In the Introduction to Goldschmidt's *Winkeltabellen* will be found forms similar to this for the calculation of crystals of each system. It was in this way that the enormous labor of calculating all the angles contained in that work was accomplished.

TABLE 2

HIGGINSITE. ANGLE TABLE OF CALCULATED AND OBSERVED VALUES.

$p_0 = 1.272 \quad q_0 = .7940$

	Symbol		Calculated		Measured		No. of Faces	Limits	
	Mill.	Gdt.	φ	ρ	φ	ρ		φ	ρ
a	100	∞0	90°00′	90°00′	90°00′	90°00′	12		
B	210	2∞	72 40	"	72 40	"	2	72°08′–73°12′	
C	320	$\frac{3}{2}$∞	67 24	"	68 03	"	4	67 20–68 48	
m	110	∞	58 02	"	58 03	"	7	57 48–58 15	
g	120	∞2	38 42	"	38 32	"	5	38 17–38 47	
j	140	∞4	21 50	"	21 52	"	9	20 59–22 33	
u	011	01	00 00	38 27	00 00	38 24	6		38°06′–38°47′
e	102	$\frac{1}{2}$0	90 00	32 27	90 00	32 28	6		32 18–32 50
z	101	10	"	50 51	"	52 11	1		
y	302	$\frac{3}{2}$0	"	62 20	"	62 20	3		62 04–62 39
o	111	1	58 02	56 18	58 02	56 09	7	57 39–58 18	55 54–56 30
p	122	$\frac{1}{2}$1	38 42	45 30	38 38	45 38	7	38 00–39 40	44 50–46 00
r	342	$\frac{3}{2}$2	50 14	68 04	50 15	68 06	7	50 00–50 39	67 19–68 35
s	528	$\frac{5}{8}\frac{1}{4}$	75 59	39 20	76 41	39 25	2		
A	746	$\frac{7}{6}\frac{2}{3}$	70 22	57 36	70 00	59 34	2		
x	326	$\frac{1}{2}\frac{1}{3}$	67 24	34 34	67 53	34 33	2		

TABLE 3

Table to show Method of Calculation of Angles
(See *Winkeltabellen*, pp. 18, 19 & 19a).

Mineral Higginsite Elements $p_0 = 1.272$ lg $p_0 = 010449$ $q_0 = .7940$ lg $q_0 = 989982$	Let. Symb. pq	1	2	3	4
		lg p	lg q	lg x = lg pp_0 1 + lg p	lg y = lg qq_0 2 + lg q
	o 1	0	0	010449	989982
	p$\frac{1}{2}$1	969897	0	980346	989982
	r$\frac{3}{2}$2	017609	030103	028058	020085

5	6	7	8	9	10
lg $\frac{pp_0}{qq_0}$ = lg tan φ 3 − 4	lg sin φ from 8	lg cos φ from 8	φ from 5	lg $\frac{pp_0}{\sin\varphi}$ = lg $\frac{qq_0}{\cos\varphi}$ = lg tan ρ 3 − 6 = 4 − 7	ρ from 9
020467	992858	972381	58°02′	017591 017601	56°18′
990364	979605	989233	38 42	000741 000749	45 30
007973	988573	980595	50 14	039485 039490	68 04

LISTS OF THE ORTHORHOMBIC MINERALS INCLUDED IN GOLDSCHMIDT'S WINKELTABELLEN. Edgar T. Wherry. *Washington, D. C.*—As the prism zone is on the whole most characteristic of orthorhombic crystals, it has seemed desirable to arrange the minerals of this system in the order of increasing values of axis *a*.

Orthorhombic Minerals

	a	*c*	Page
Uranophanite	0.31	1.01	355
Polycrasite (Polykras)	0.35	0.31	271
Euxenite	0.36	0.30	137
Molybdite	0.39	0.47	243
Columbite	0.40	0.36	101
Oanneroedite (Anerödit)	0.40	0.36	45
Flinkite	0.41	0.74	147
Monticellite	0.43	0.58	253
Fayalite	0.46	0.58	252
Tephroite	0.46	0.59	254
Hjelmite	0.46	1.03	177
Olivine	0.47	0.59	251
Ardennite	0.47	0.31	53
Chrysoberyl	0.47	0.58	97
Aeschynite	0.48	0.67	31
Diaphorite	0.49	0.73	115
Pyrostilpnite (Feuerblende)	0.50	0.70	145
Wavellite [old data]	0.50	0.38	362
Topaz	0.53	0.95	346
Pucherite	0.53	1.17	274
Phosphosiderite	0.53	0.88	266
Jordanite	0.54	1.02	191
Yttrotantalite	0.54	1.13	371
Rammelsbergite	0.54	——	291
Samarskite	0.55	0.52	309
Struvite	0.55	0.62	332
Mascagnite	0.56	0.73	232
Bertrandite	0.57	0.60	64
Hopeite	0.57	0.47	180
Beryllonite	0.57	0.55	66
Mica (Glimmer)	0.58	3.29	161
Dyscrasite (Antimonsilber)	0.58	0.67	49
Argentopyrite (Silberkies)	0.58	0.55	318
Stromeyerite	0.58	0.97	330
Chalcocite (Kupferglanz)	0.58	0.97	205
Sternbergite	0.58	0.84	329