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CRYSTALLOGRAPHIC STUDIES OF PYRITE

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Among the extensive suite of crystallized pyrite specimens comprised in the Bement Collection presented to The American Museum of Natural History by the late J. Pierpont Morgan, Esq., are several which by reason of their unusual habit or the complexity of their modifications invited study from a crystallographic point of view. The examination of these was undertaken by the writer with the especial object in view, that all contributions to the crystallography of a species rich in forms tend to shed light on the obscure problems involved in the relation of crystal habit to crystallogenesis.

PYRITE FROM RUSSELL GULCH, COLORADO

The crystals which furnish the material for this study were obtained from specimen No. 5290, acquired from Lazard Cahn, through the Bruce Fund. This specimen consists of a close aggregate of pyrite crystals ranging in size from 8 mm. to 1 mm. in diameter. In habit the crystals conform quite closely with Type 9, given by Kraus and Scott¹ and ascribed by them to an unknown Colorado locality. Both the crystals described by these authors and the subject of the present note are octahedral-dodecahedral in habit, the Russell Gulch crystals showing a zone of pyritohedrons somewhat richer in forms than the Kraus and Scott type. Figure 1 shows this habit in ideal proportions.

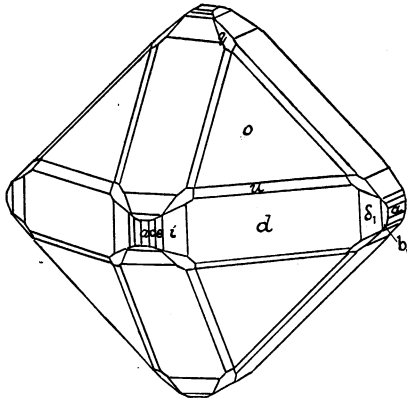


Fig. 1. Pyrite crystal from Russell Gulch, Colo.

The following forms were identified by means of a Goldschmidt two-circle goniometer:

¹Kraus, E. H., and Scott, I. D. 1907. *Zeitschr. f. Kryst.*, XLIV, p. 152, Fig. 23.

a (100), d (110), c (710), e (210), i (430), ζ (650), δ_1 (450), b (230), o (111), q (112), m (113), u (122).

PYRITE FROM OURAY, COLORADO

The material studied was obtained from specimen No. 1828, acquired with the Bement Collection, and bearing a label showing that it was originally obtained from Lazard Cahn, prior to 1903. The specimen, which measures $9 \times 7 \times 5$ cm. in dimensions, consists of a close grouping of pyrite crystals of unusual regularity of development, some of which measure 12 mm. in diameter. Several of those of a size ranging from 2–3 mm. were selected for measurement.

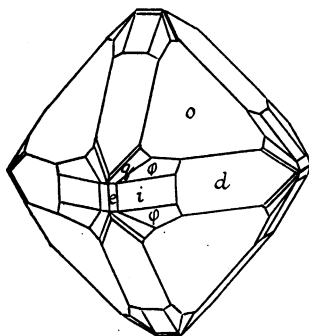


Fig. 2. Pyrite crystal from Ouray, Colo.

In habit, the larger crystals are strongly octahedral, resembling those from Russell Gulch, but showing the modifying planes of the rare diploid ϕ (12.9.1), present in more marked development in the smaller individuals. The habit of these latter is shown in figure 2, drawn in ideal proportions, but closely picturing the actual crystals which show little distortion. Planes of the cube are entirely lacking in the crystals of this type.

The following forms were observed:

e (210), i (430), d (110), o (111), q (112), ϕ (12.9.1).

Of these the positive diploid (12.9.1) is rare, having been observed but once by Rogers¹ on pyrite crystals from Bingham, Utah. This diploid lies in the zone [430.001] emphasized in this habit by the strong development of (430). It was further identified by the following measurements:

	MEASURED		CALCULATED	
	ϕ	ρ	ϕ	ρ
(12.9.1)	$53^\circ 13'$	$86^\circ 32'$	$53^\circ 8'$	$86^\circ 11'$
(9.1.12)	$84^\circ 15\frac{1}{2}'$	$36^\circ 47'$	$83^\circ 40'$	$37^\circ 4'$
(1.12.9)	$4^\circ 8'$	$53^\circ 11\frac{1}{2}'$	$4^\circ 46'$	$53^\circ 12\frac{1}{2}'$

PYRITE FROM NEAR CENTRAL CITY, COLORADO

A close group of crystals of remarkable brilliancy and rich in small faces is listed under No. 1808 and was acquired with the Bement Collection. The original label, antedating 1901, bears the locality designation as above. The individual crystals are very variable in size, the largest measuring 20 mm. in diameter. The material studied consisted of five of

¹Rogers, A. F. 1909. Amer. Journ. Sci., XXVII, p. 467.

the smaller crystals, these averaging 2 mm. in diameter and furnishing only one or two octants each. In habit, the larger crystals have a marked cube-dodecahedral aspect due to the prominent planes of the pyritohedron (650), these being sufficiently near (110) to simulate the habit of the latter form which is presented in inconspicuous development.

The following table gives the occurrence of forms on the five crystals measured:

FORM	I	II	III	IV	V	
<i>a</i> 100	×	×	×	×	×	
<i>a</i> ₁ 310	×					
<i>e</i> 210	×	×	×	×		
ζ 650	×	×	×	×	×	
<i>d</i> 110	×	×				×
δ ₁ 450	×	×	×	×	×	
<i>m</i> 113	×					
<i>q</i> 112	×	×	×	×	×	
<i>o</i> 111	×	×	×	×	×	
<i>u</i> 221	×	×	×	×	×	
<i>x</i> 321	×	×	×	×	×	
<i>T</i> 851	×	×	×			
φ 12.9.1	×	×	×	×	×	
S ₁ 14.8.1	×	×	×	×	×	new
<i>x</i> ₁ 753		×	×			
q ₁ 743			×	×		new
S 10.6.1			×	×		

φ (12.9.1). This positive diploid appeared on all of the crystals measured as small but well-developed planes which yielded good reflections. As noted in describing the preceding occurrence, the form was first observed by Rogers.

S₁ (14.8.1). This positive diploid is new for pyrite. It was observed on all of the crystals studied as small but bright planes lying close to the pyritohedron *e*. The form lies in zone [011.210], a zone emphasized in this habit by also including the forms (221) and (10.6.1).

*x*₁ (753). This rare diploid has been previously noted on but one occurrence, Cornwall, Pa.¹ In the present instance it was observed as a very narrow face beveling the edge between (111) and (321). It was found but once on each of the two crystals furnishing readings on it and the reflections were poor. The zonal relations to other forms present are good.

q₁ (743). This positive diploid is new for pyrite. Like the preceding form it was observed but once on each of two crystals studied, both times in the same position, *i.e.* beveling the edge between (211) and (321). The planes were very narrow and the reflections poor. Its zonal relations are good, since besides lying in the zone [101.110] containing (211) and (321), it also lies in zone with (121) and (311).

¹Travis, C. 1906. Proc. Amer. Phil. Soc., XLV, p. 131.

The following measurements served to identify these new and rare forms:

	MEASURED		CALCULATED	
	ϕ	ρ	ϕ	ρ
(12.9.1)	53° 11'	86° 16'	53° 8'	86° 11'
(1.12.9)	4° 49'	53° 17'	4° 46'	53° 12½'
(14.8.1)	60° 25'	86° 33'	60° 15'	86° 27½'
(8.1.14)	82° 46'	29° 53'	82° 52½'	29° 56'
(1.14.8)	4° 9'	60° 22'	4° 5'	60° 49½'
(753)	54° 18'	70° 38'	54° 28'	70° 46'
(743)	60° 17½'	69° 48½'	60° 16'	69° 36'
(6.1.10)	80° 12'	31° 35'	80° 32'	31° 18'
(1.10.6)	5° 52'	59° 4'	5° 43'	59° 6'

Figure 3 shows a portion of crystal III in actual proportions.

A small compact group of pyrite crystals listed under No. 1809 from the Bement Collection and bearing the same label as No. 1808 was lent for study to Professors Kraus and Scott in 1907. These authors' measured and described the largest crystal of the group as crystal No. 1 of the Central City Mine occurrence. The writer has measured four of the prominent crystals of this group, crystal III of the present note being the same as that measured by Kraus and Scott.

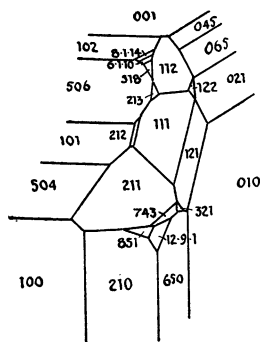


Fig. 3. Pyrite crystal from Central City, Colo.

In general habit these crystals, which average 10 mm. in diameter, are cubo-pyritohedral. The zone of the pyritohedrons is richer in forms than is the case with specimen 1808, Kraus and Scott having found seven forms from cube face to cube face and the present writer

eight. Figure 4 shows the general habit of crystals of this type in ideal development. The following table shows the distribution of forms on the four crystals measured:

FORM	I	II	III	IV	
<i>a</i>	100	×	×	×	×
<i>h</i>	410	×	×	×	×
<i>f</i>	310	×	×	×	×
<i>e</i>	210	×	×	×	×
<i>i</i>	430		×	×	×
<i>v</i>	650		×	×	×
<i>d</i>	110		×	×	×

¹Loc. cit., p. 145.

FORM		I	II	III	IV	
γ_1	670	×	×	×	×	
κ_1	450	×	×	×	×	
m	113	×		×	×	
q	112	×	×	×	×	
o	111	×	×	×	×	
n	332				×	
p	221	×	×	×	×	
x	321	×	×	×	×	
Y	621		×	×	×	
	641		×		×	
ϕ	12.9.1	×				
A_2	12.2.1		×		×	new
π	13.6.2		×			new
π_2	13.3.2			×		new
T_2	831				×	new

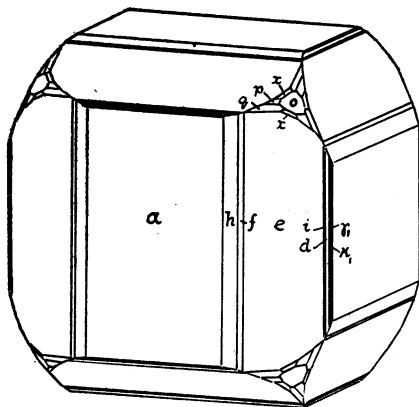


Fig. 4

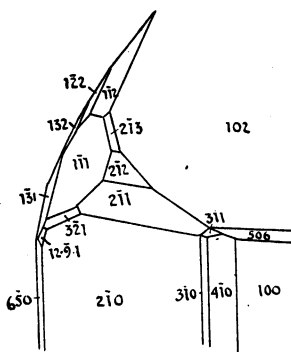


Fig. 5

Fig. 4. Pyrite crystal from Central City, Colo. General habit.

Fig. 5. Pyrite crystal from Central City, Colo. Crystal I.

(641). This rare diploid was observed by Ungemach¹ on crystals from Langeac, Haute-Loire, France. No letter was assigned to it by him. With respect to the present occurrence, it was noted once on crystal II and twice on crystal IV, as very minute but relatively bright planes giving good reflections. The form falls in zones [001.210] and [310.021], also in the zone [112.753] of which the diploid (753) was noted on crystals of specimen No. 1808.

ϕ (12.9.1). This form, which has already been noted on two previous specimens, occurs again on crystal I.

A_2 (12.2.1). This new positive diploid was observed, as a single plane in each instance, on crystals II and IV. The reflections of the goniometer signal were dim,

¹Ungemach, H. 1916. Bull. Soc. fr. Min., XXXIX, p. 127.

but the readings agreed well with theory in both observations. Moreover, the form falls in the zone [045.211].

π (13.6.2). This new positive diploid was observed only once on crystal II as a minute face giving a dim reflection of the signal. The reading however agreed with theory, within reasonable limits of accuracy. The form falls in the zone [045.520] which also contains the prominent pole 112.

π_2 (13.3.2). Like the last, this new positive diploid was observed as a single plane on one crystal. The reflection of the signal was fair, but the observed value of the ρ angle was not as consistent with theory as for the other new forms. On the other hand, its zonal relations are good, the pole (13.3.2) falling in zones [132.100], [374.753] and [321.110].

T_2 (831). This new positive diploid appears as a single plane on crystal IV. Its zone relations are extremely good, the pole (831) lying at the intersection of the following well defined zones: [031.100], [321.110], [112.211] and [132.321].

The following measurements served to identify the rarer of the forms observed:

	MEASURED		CALCULATED	
	ϕ	ρ	ϕ	ρ
(621)	71° 43'	80° 47'	71° 34'	81° 1'
(162)	9° 32'	71° 45'	9° 27'	71° 48'
(641)	56° 25½'	82° 21½'	56° 19'	82° 6½'
(416)	75° 26'	34° 20'	75° 58'	34° 30'
(12.9.1)	53° 1'	85° 56'	53° 8'	86° 11'
(1.12.2)	4° 37'	80° 10½'	4° 46'	80° 34'
(2.13.6)	8° 33'	65° 38'	8° 45'	65° 28½'
(2.13.3)	8° 54'	76° 46'	8° 45'	77° 7½'
(183)	7° 13'	69° 56'	7° 7½'	69° 38'

Figure 5 shows a portion of crystal I in actual proportion.

PYRITE FROM HIGHLAND BOY MINE, BINGHAM CANYON, UTAH

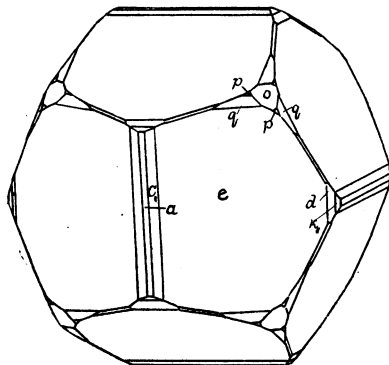


Fig. 6. Pyrite crystal from Bingham Canyon, Utah. General habit.

The material for this study was obtained from a close grouping of crystals measuring 10×7 cm., numbered 18187 in the catalogue of our collection and bearing a recent label of Lazard Cahn, as above. The crystals vary in size from 15 mm. to about 1 mm. in diameter, and are notably brilliant and well developed. Nine of the smaller of these were selected for measurement.

In habit the crystals are strongly pyritohedral, the dominant form

being the very common pyritohedron e (210). They are notable in having the pyritohedral edges modified, and it was among these modifications that the new and rare forms were observed. Figure 6 shows the general habit in ideal proportion.

The distribution of forms on the nine crystals measured is given in the following table:

FORM	I	II	III	IV	V	VI	VII	VIII	IX
a 100	×	×	×	×	×	×	×	×	×
e 720									×
C_1 16.5.0				×	×				new
e 210	×	×	×	×	×	×	×	×	×
d 110		×	×	×	×	×	×	×	×
κ_1 450		×	×						×
q 112	×	×	×	×	×	×	×	×	×
o 111	×	×	×	×	×	×	×	×	×
p 221	×	×		×					
441							×	×	×
x 321		×							
865						×		×	×
\mathcal{D} 654						×			new
x_2 975			×						new
y_1 423	×	×	×	×	×	×	×	×	×
z_1 512	×	×			×	×			×

C_1 (16.5.0). This new positive pyritohedron was observed on crystals IV and V, twice on each, as very narrow planes giving blurred images. The average of the readings, however, agrees well with theory, and the limits indicate a new form in this position.

(441). This trisoctahedron was first observed by Ungemach¹. It was recorded twice on each of crystals VII and VIII and once on crystal IX, as narrow planes beveling the edges of the dominant pyritohedron e . The zonal relations of this form with the form system of the occurrence are excellent. Besides its obvious position in the zones [001.100] and [021.210], the pole (441) also lies in the zones [221.311] and [212.211].

(865). This new positive diploid was observed three times on crystal VI, twice on crystal VIII and once on crystal IX. The pole (865) falls in the prominent zones [101.221] and [021.211].

x_2 (975). This positive diploid is also new for pyrite. It was observed once on crystal III. In spite of the fact that the measured ρ angle does not conform with theory within the usual limit of error, the form seems fairly probable. The pole (975) lies at the intersection of the zones [111.321], [211.131] and [021.311].

z_1 (512). This new negative diploid seems fairly constant for the occurrence, having been noted on five of the nine crystals measured, and furnishing ten measurements. The pole (512) lies at the intersection of the zones [211.031] and [112.100], both well defined in the form system of the occurrence.

¹Ungemach, H. 1916. Bull. Soc. fr. Min., XXXIX, p. 216.

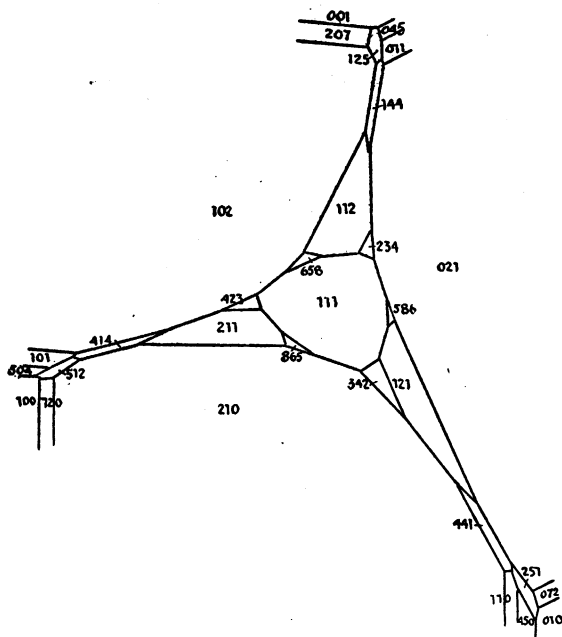


Fig. 7. Pyrite crystal from Bingham Canyon, Utah.
Crystal IX.

The following measurements served to identify the rare and new forms:

	MEASURED		CALCULATED	
	ϕ	ρ	ϕ	ρ
(16.5.0)	$72^{\circ} 40\frac{1}{2}'$	$90^{\circ} 0'$	$72^{\circ} 39'$	$90^{\circ} 0'$
(414)	$76^{\circ} 6'$	$45^{\circ} 22'$	$75^{\circ} 58'$	$45^{\circ} 52'$
(865)	$53^{\circ} 54'$	$62^{\circ} 37'$	$53^{\circ} 8'$	$63^{\circ} 27'$
(658)	$49^{\circ} 44'$	$43^{\circ} 58'$	$50^{\circ} 12'$	$44^{\circ} 18'$
(586)	$32^{\circ} 8'$	$58^{\circ} 33'$	$32^{\circ} 0'$	$57^{\circ} 33'$
(975)	$52^{\circ} 7'$	$67^{\circ} 14'$	$52^{\circ} 7\frac{1}{2}'$	$66^{\circ} 19'$
(512)	$78^{\circ} 44\frac{1}{2}'$	$68^{\circ} 38\frac{1}{2}'$	$78^{\circ} 41'$	$68^{\circ} 35'$
(125)	$26^{\circ} 37'$	$24^{\circ} 5'$	$26^{\circ} 34'$	$24^{\circ} 6'$
(251)	$22^{\circ} 2\frac{1}{2}'$	$79^{\circ} 43'$	$21^{\circ} 48'$	$79^{\circ} 29'$

Figure 7 shows the position of the new forms on crystal IX.