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OVERITE AND MONTGOMERYITE: TWO NEW MINERALS FROM FAIRFIELD, UTAH

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ABSTRACT[1]

Overite, $Ca_3Al_8(PO_4)_8(OH)_6 \cdot 15H_2O$, is a new mineral from the variscite nodules of Fairfield, Utah. It is orthorhombic and occurs as pale green to colorless prismatic crystals, flattened on $b\{010\}$, in cavities in altered variscite. Cleavage: {010} perfect, {100} poor. H=4; G=2.53. Biaxial negative, $2V=75°\pm10°$; $r>v$, weak; $X=c$, $Z=b$. $\alpha=1.568$, $\beta=1.574$, $\gamma=1.580$; all ±0.002. Elements (morphological): $a:b:c=0.7864:1:0.3795$. Structural lattice: space group *Bmam;* $a_0=14.75$ Å, $b_0=18.74$ Å, $c_0=7.12$ Å; $a_0:b_0:c_0=0.7871:1:0.3799$; cell contains $2[Ca_3Al_8(PO_4)_8(OH)_6 \cdot 15H_2O]$.

The mineral is named after Mr. Edwin Over of Colorado Springs, Colorado.

Montgomeryite, $Ca_4Al_5(PO_4)_6(OH)_5 \cdot 11H_2O$, is a new mineral from cavities in the variscite nodules of Fairfield, Utah. It is monoclinic and occurs as green to colorless lath-shaped crystals much flattened parallel to $b\{010\}$. Cleavage: $b\{010\}$ perfect, {100} poor. Hardness 4; specific gavity 2.530 ± 0.005. Biaxial negative, $2V=75°\pm10°$; $r<v$, easily perceptible; $Z=b$, $X\wedge c=+60°$. $\alpha=1.572$, $\beta=1.578$, $\gamma=1.582$; all ±0.002. Elements (morphological): $a:b:c=0.4145:1:0.2580$, $\beta=91°\ 34'$. Structural lattice: space group $C2/c$; $a_0=9.99$ Å, $b_0=24.10$ Å, ±0.02 Å, $c_0=6.25$ Å ±0.05 Å; $a_0:b_0:c_0=0.414:1:0.259$, $\beta=91°\ 28'$; $V_0=1505$ cubic Å; $M_0=2308$. Cell contains $2[Ca_4Al_5(PO_4)_6(OH)_5 \cdot 11H_2O]$.

The name montgomeryite is proposed after Mr. Arthur Montgomery of New York City.

OVERITE

INTRODUCTION

Larsen and Shannon (1930) in their paper on the mineralogy of the phosphate nodules from Fairfield, Utah, described briefly the physical and optical properties of this mineral; lack of material at that time made further description impossible. They list the mineral as number 8 of the unnamed minerals found by them in the nodules. Although the material they worked with was not seen by this writer, the close agreement in the physical and optical properties of their mineral and the present material leaves no doubt as to their identity.

The name overite is proposed for the mineral after Mr. Edwin Over of Colorado Springs, Colorado, who, with Mr. Arthur Montgomery, recognized the mineral as new and was able to collect sufficient material for an adequate description.

[1] Abstract of overite previously published in *Am. Mineral.*, **32,** no. 12, pt. 2, p. 6 (1938). Some of the data here given is a revision of the earlier data.

Occurrence and Association

Overite occurs as pale green to colorless vitreous crystals in cavities in the variscite nodules. The nodules in which it is found are made up chiefly of banded intergrowths of pseudowavellite and what is believed to be deltaite, and generally have a kernel of variscite which is slightly smaller than the cavity it occupies. The overite partially surrounds and cements the variscite kernels to the surrounding pseudowavellite.

One nodule contains massive overite as irregular patches replacing variscite, pseudowavellite, and possibly deltaite. The same nodule contains small masses of a colorless mineral, x-ray powder picture of which is identical with apatite, but whose optical properties indicate it to be different from lewistonite, a member of the apatite group.

Morphology

Overite is orthorhombic and nearly always occurs in well-formed crystals. There is a marked tendency toward parallel growths, although the individual crystals are easily separable. Many of the crystals measured on the goniometer gave trains of reflection in the prism zone, probably due to this tendency toward subparallelism.

The crystals are invariably flattened on {010} and are elongated parallel to the c-axis, although the larger crystals are sometimes platy rather than lath-shaped. One small nodule contains a few doubly terminated crystals which are attached on the front pinnacoid {100}, but in general the crystals are attached on the base. The crystals range in size from 0.3 to 4 mm. in maximum dimension. All of the crystals measured on the goniometer were small, about $0.3\times0.1\times0.05$ mm. The larger crystals all give multiple reflections from most of the faces and, therefore, generally inconsistent measurements.

Of more than 25 crystals examined on the goniometer, the measurements of twelve were used in preparing the angle table. All of the small crystals measured were taken from a single nodule; they were present as tiny single crystals in a cavity in which were many larger crystals in a crude subparallel band. The dominant forms on all the crystals are: $b\{010\}$; $q\{121\}$; and $m\{110\}$. The front pinnacoid $a\{100\}$ is always present but often very narrow. The unit prism $m\{110\}$ is small on several of the small crystals measured, but is always dominant on the larger crystals. Four prism faces $e\{150\}$, $h\{120\}$, $f\{130\}$, $k\{320\}$ can be established from their frequency of occurrence, although none are ever more than line faces, and their measured angles vary considerably. The dome $y\{021\}$ was found on one large crystal as two small faces in good position and giving good reflections; it should be considered a well established form. The same crystal had two very rough and rounded faces in the position of {101} and $\{\bar{1}01\}$, but no signal was reflected

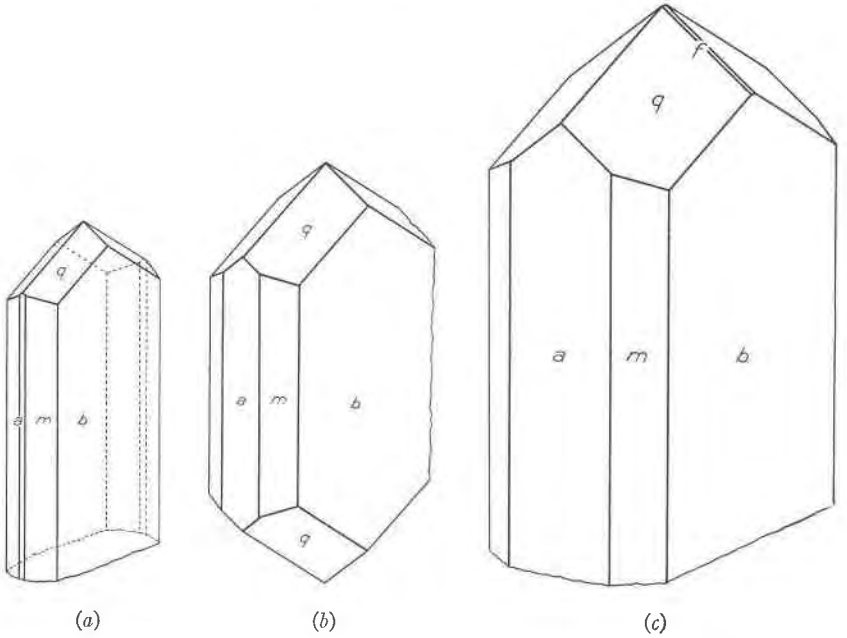

FIG. 1. Crystal drawings of overite: (*a*) usual habit; (*b*) and (*c*) less common habits.

TABLE 1. OVERITE—RANGE AND WEIGHTED AVERAGE OF OBSERVED ANGLES TOGETHER WITH THE CALCULATED ANGLES

Form	No. obs.	Measured Range		Best Average		Calculated	
		ϕ	ρ	ϕ	ρ	ϕ	ρ
b 010	24	—	—	0°00′	90°00′	0°00′	90°00′
a 100	21	—	—	90 00	90°00	90 00	90 00
e 150	13	12°11′– 15°18′	—	14 29	90 00	14 16	90 00
f 130	5	21 58 – 26	—	23 19	90 00	22 58	90 00
g 250	6	26 48 – 29 32	—	28 16	90 00	26 58	90 00
h 120	10	29 35 – 33 07	—	31 53	90 00	32 27	90 00
i 350	3	37 54 – 38 09	—	38 03	90 00	37 21	90 00
m 110	40	51 36 – 53 01	—	52 10	90 00	51 49	90 00
j 430	3	59 22 – 60 30	—	59 50	90 00	59 28	90 00
k 320	13	61 05 – 63 54	—	62 23	90 00	62 20	90 00
l 310	2	74 57 – 75 23	—	75 10	90 00	75 19	90 00
n 410	2	78 56 – 78 58	—	78 57	90 00	78 53	90 00
y 021	2	−0 02 –+0 03	36°58′–372°2′	0 00	37 10	0 00	37 12
q 121	48	32 04 – 32 55	41 47 –421°0	32 27	41 58	32 27	41 58

from them; the form is thus very doubtful. Figure 1*a* shows the usual habit of the crystals while Figs. 1*b* and 1*c* represent less common habits.

In Table 1 are given two-circle goniometer measurements of 12 crystals, together with the calculated angles. Table 2 presents the formal angle table.

TABLE 2. OVERITE-ANGLE TABLE

Orthorhombic dipyramidal—*Bmam*

$a:b:c=0.7864:1:0.3795$ $p_0:q_0:1=0.4826:0.3795:1$

$q_1:r_1:1=0.7864:2.0721:1$ $r_2:p_2:1=2.6350:1.2717:1$

Form		ϕ	$\rho=C$	ϕ_1	$\rho_1=A$	ϕ_2	$\rho_2=B$
b	010	0°00′	90°00′	90°00′	90°00′	—	0°00′
a	100	90 00	90 00	—	0 00	0°00′	90 00
e	150	14 16	90 00	90 00	75 44	0 00	14 16
f	130	22 58½	90 00	90 00	67 01½	0 00	22 58½
g	250	26 57½	90 00	90 00	63 02½	0 00	26 57½
h	120	32 27	90 00	90 00	57 33	0 00	32 27
i	350	37 20½	90 00	90 00	52 39½	0 00	37 20½
m	110	51 49	90 00	90 00	38 11	0 00	51 49
j	430	59 28	90 00	90 00	30 32	0 00	59 28
k	320	62 20	90 00	90 00	27 40	0 00	62 20
l	310	75 18½	90 00	90 00	14 41½	0 00	75 18½
n	410	78 52½	90 00	90 00	11 07½	0 00	78 52½
y	021	0 00	37 12	37 12	90 00	90 00	52 48
q	121	32 27	41 58	37 12	68 58½	64 14½	55 38½

PHYSICAL AND OPTICAL PROPERTIES

Overite has a perfect and easy cleavage parallel to *b*{010}, and a poor one parallel to {100}. Most crushed fragments in a liquid under the microscope lie on this perfect cleavage, and because of the poorer cleavage are commonly elongated in the *c* direction with roughly parallel edges. It has a hardness near 4 (Larsen and Shannon give 3½). Its specific gravity, determined by suspension in bromoform, is 2.53. Where it does not contain inclusions it is clear and vitreous; its color ranges from a light apple green to colorless. It is colorless under the microscope.

Optical constants:

	n (Na)		
X=*c*	1.568	all ±0.002	Biaxial negative
Y=*a*	1.574		$2V=75°\pm10°$
Z=*b*	1.580		*r*>*v*, weak

PYROGNOSTICS

Before the blowpipe overite fuses at 2 with intumescence and leaves

a white chalky mass. In the closed tube it gives off abundant water which is neutral. It is readily soluble in hot nitric acid.

Structural Elements and Space Group

Weissenberg photographs were taken of the zero, first, and second layer lines with both [100] and [001] as axes of rotation, giving the following structural elements:

$a_0 = 14.75$ Å, $b = 18.74$ Å, $c_0 = 7.12$ Å;
all ± 0.02 Å.
$a_0 : b_0 : c_0 = 0.7871 : 1 : 0.3799$.
$V_0 = 1968$ cubic Å. $M_0 = 3018$.

Overite belongs to the space group $Bmam - D_{2h}(21)$ as given by the following observed reflections:

hkl, $h+l$ even
$0kl$, l even
$h0l$, h even, l even
$hk0$, h even

Chemistry

Table 3 gives the analysis of overite, together with the molecular and atomic proportions and the atomic content of the unit cell. The analysis by F. A. Gonyer was made on a 180 mg. sample, 99 per cent pure. The cell content of overite, as derived from column 4 in the table, is

$$Ca_6Al_{16}(PO_4)_{16}(OH)_{12} \cdot 30\ H_2O$$

or

$$2[Ca_3Al_8(PO_4)_8(OH)_6 \cdot 15H_2O],$$

assuming $M_0 = 3018$ as derived from the x-ray data, and the measured gravity of 2.53. The calculated number of atoms given in column 3 are all high, indicating that the measured gravity is high. The calculated gravity for the above formula with $V_0 = 1968$ cu. Å. is 2.47.

Table 3. Analysis and Ratios of Overite

	A	B	C	1		2	3	4
P_2O_5	37.91	38.08	38.70	.268	P	.536	16.18	16
Al_2O_3	27.99	28.11	27.78	.276	Al	.552	16.67	16
CaO	11.62	11.67	11.45	.208	Ca	.208	6.28	6
H_2O	22.04	22.14	22.08	1.224	H	2.460	74.24	72
Insol.	0.11				O	3.606	108.83	106
	99.67	100.00	100.01					

A. Analysis of overite by F. A. Gonyer. Sample weighed 180 mg. and was 99 per cent pure.
B. Analysis A recalculated to 100 per cent.
C. Theoretical composition of $2[Ca_3Al_8(PO_4)_8(OH)_6 \cdot 15H_2O]$.
1. Molecular proportions.
2. Atomic proportions.
3. Number of atoms in unit cell, assuming $M_0=3018$, and $d=2.53$.
4. Theoretical number of atoms in the unit cell.

Overite bears no structural or chemical analogy to any other mineral. It is poorest in Ca of those minerals in the nodules where $Al:PO_4$ is 1:1, as shown in the diagram Fig. 2.

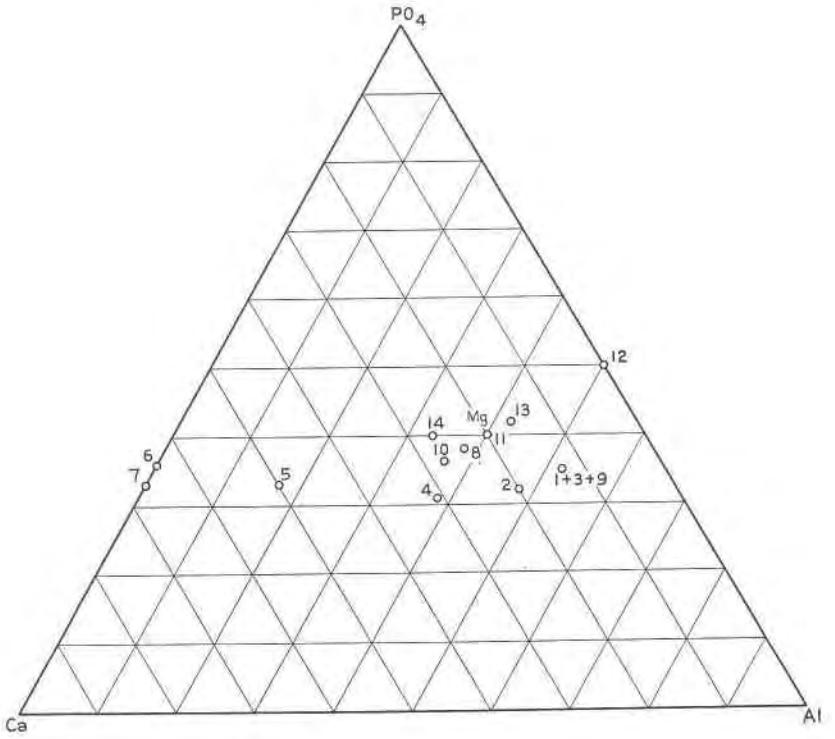

FIG. 2. The atomic ratios of $Ca:Al:PO_4$ in the minerals of the phosphate nodules from near Fairfield, Utah. 1 wardite, 2 pseudowavellite, 3 pseudowavellite?, 4 deltaite, 5 dennisonite, 6 dehrnite, 7 lewistonite, 8 englishite, 9 millisite, 10 lehiite, 11 gordonite, 12 variscite, 13 overite, 14 montgomeryite.

MONTGOMERYITE

INTRODUCTION

Green crystals and massive green material replacing principally variscite, previously thought to be gordonite, prove to be distinct from gor-

donite. All green material labelled "gordonite" seen by the writer has proved to be the mineral described here. The present mineral is similar optically to overite, but not in other critical properties.

The name montgomeryite is proposed for this mineral after Mr. Arthur Montgomery of New York City, who, with Mr. Edwin Over, collected the material and very kindly made it available for this study.

Occurrence

Montgomeryite occurs as bright green to colorless crystals in cavities in the variscite nodules. More abundantly it occurs in the nodules as massive bands in the variscite and separating the variscite kernels from the outer alterations (principally pseudowavellite) of the nodules. These massive bands frequently contain cavities into which crystals have grown. Overite has not been found associated with montgomeryite, and gordonite has been found with it in only one nodule. Englishite, one of the rarest of the minerals, very commonly occurs with it.

Montgomeryite was one of the late minerals to form, but was followed by granular coatings of pseudowavellite and a member of the apatite group which occurs as sheafs of radiating needles on montgomeryite crystals.

Morphology

Montgomeryite is monoclinic and its crystals are always lath-shaped, flattened on {010} and elongated parallel to [001]. Wherever it occurs in open spaces it forms good crystals. Most of the crystals occur in subparallel growths in contact on $b\{010\}$. Only small crystals which grew free of others were suitable for measurement on the goniometer.

The crystals range in size from two millimeters to a half millimeter in longest dimension. The average dimensions of the crystals measured on the goniometer are $0.8\times0.5\times0.1$ mm. About thirty crystals were measured, of which eighteen were used in the calculations of the angle table (Table 5). Most of the crystals measured were taken from cavities in two nodules and occurred as isolated crystals attached by one end of the lath.

The habit of the crystals is very constantly lath-shaped with pyramidal terminations. The dominant form is always $b\{010\}$, generally striated parallel to [001], produced by vicinal forms in the zone [001] such that a continuous train of reflections, made up of sharp to indistinct signals less than a degree apart, is seen on the goniometer to extend as much as 40 degrees on either side of the b-face proper. In the center of the train is usually one or more very strong signals close together, one

of which can usually be established as the {010} reflection. The vicinal faces are distributed randomly over the {010} face, and no consistency in their angles, regardless of position or strength of signal, could be found, so that no indexing of any of these forms was possible. The pyramid $P\{\bar{1}11\}$ is always the principal terminal form; $p\{111\}$ is nearly always present, but usually small. $R\{\bar{1}31\}$ is usually present as a line face, and on a few crystals is large.

The prism forms are generally not well defined. Most of the crystals are so thin parallel to $b\{010\}$ that of necessity all prism faces are little more than lines. Added to this is the fact that most of the prism faces reflect blurred or multiple signals. The prism $m\{110\}$ is well established as the most frequent form, although it is rarely large. The form $j\{270\}$ seems well established from its frequency even though its ϕ angle is but a few degrees smaller than that of $k\{130\}$, the more reasonable form; moreover, on a very few crystals both $j\{270\}$ and $k\{130\}$ occur side by side. Other forms which seem to be established by their frequency, but

TABLE 4. MONTGOMERYITE—RANGE AND WEIGHTED AVERAGE OF OBSERVED ANGLES TOGETHER WITH THE CALCULATED ANGLES

Form	No. obs	Measured Range		Best Average		Calculated	
		ϕ	ρ	ϕ	ρ	ϕ	ρ
a 100	2	89°25′– 90°00′	—	90°00′	90°00′	90°00′	90°00′
b 010	36	—	—	0 00	90 00	0 00	90 00
190	4	14 13 – 15 52	—	15 40	90 00	15 00½	90 00
f 170	9	18 00 – 20 42	—	19 47	90 00	19 01	90 00
g 150	15	24 26 – 26 54	—	25 46	90 00	25 46	90 00
h 290	27	27 26 – 29 46	—	28 39	90 00	28 12	90 00
i 140	12	30 21 – 32 35	—	31 19	90 00	31 06	90 00
j 270	32	32 58 – 36 21	—	34 31	90 00	34 35	90 00
k 130	15	37 11 – 39 30	—	38 11	90 00	38 48½	90 00
l 120	2	50 20 – 50 57	—	50 20	90 00	50 20½	90 00
350	5	55 47 – 56 24	—	56 08	90 00	55 22	90 00
230	1	59 15	—	59 15	90 00	58 08	90 00
340	3	60 12 – 61 56	—	61 13	90 00	61 04½	90 00
450	2	62 55 – 64 28	—	63 42	90 00	62 37	90 00
m 110	35	64 47 – 70 59	—	67 33	90 00	67 29½	90 00
x 021	2	3 02	27°24′	3 02	27 24	3 03	27 19½
y 041	3	− 1 29 –+1 22	46 08 –47°12′	0 40	46 40	1 31½	45 58
p 111	34	67 02 – 68 43	34 51 –35 24	68 21	34 58	68 21	34 58
$P\ \bar{1}11$	36	−64 52 – 67 06	32 26 –33 35	−66 34	32 58	−66 33½	32 58
q 151	10	25 18 – 28 26	55 06 –55 34	26 44	55 22	26 44½	55 18½
$R\ \bar{1}31$	33	−36 04 – 38 34	43 44 –45 50	−37 28	44 22	−37 33½	44 18½
$Q\ \bar{1}51$	2	−26 36 – 29 28	53± –53 14	−26 36	53 14	−24 46	54 51½

not by their size or constancy of angle, are: $k\{130\}$, $h\{290\}$, $f\{170\}$, $g\{150\}$, and $i\{140\}$. $l\{120\}$ was seen only twice but in one case was a large face of excellent quality and position. The front pinnacoid $a\{100\}$ was observed twice, both times a good face of moderate size. The other prism forms given without letters in the angle table can be considered very doubtful.

TABLE 5. MONTGOMERYITE-ANGLE TABLE

Monoclinic prismatic—$C2/c$
$a:b:c=0.4145:1:0.2580$; $\beta=91°34'$
$p_0:q_0:1=0.6224:0.2579:1$; $\mu=88°26'$
$r_2:p_2:1=3.8775:2.4133:1$
$p_0'=0.6226$, $q_0'=0.2580$; $x_0'=0.02746$

Form		ϕ	ρ	ϕ_2	$\rho_2=B$	C	A
a	100	90°00′	90°00′	0°00′	90°00′	88°26′	0°00′
b	010	0 00	90 00	—	0 00	90 00	90 00
	190	15 00½	90 00	0 00	15 00½	89 35½	74 59½
f	170	19 01	90 00	0 00	19 01	89 29½	70 59
g	150	25 46	90 00	0 00	25 46	89 19	64 14
h	290	28 12	90 00	0 00	28 12	89 15½	61 48
i	140	31 06	90 00	0 00	31 06	89 11½	58 54
j	270	34 35	90 00	0 00	34 35	89 06½	55 25
k	130	38 48½	90 00	0 00	38 48½	89 01	51 11½
l	120	50 20½	90 00	0 00	50 20½	88 47½	39 39½
	350	55 22	90 00	0 00	55 22	88 42½	34 38
	230	58 08	90 00	0 00	58 08	88 40	31 52
	340	61 04½	90 00	0 00	61 04½	88 37½	28 55½
	450	62 37	90 00	0 00	62 37	88 36½	27 23
m	110	67 29½	90 00	0 00	67 29½	88 33	22 30½
x	021	3 03	27 19½	88 25½	62 43	27 17	88 36
y	041	1 31½	45 55	88 25½	44 06½	45 54	88 54½
p	111	68 21	34 58	56 58½	77 47½	33 31	57 49
P	$\bar{1}11$	−66 33½	32 58	120 45½	77 30	34 24½	119 57
q	151	26 44½	55 18½	56 59	42 45½	54 37	68 17½
R	$\bar{1}31$	−37 33½	44 18½	120 45½	56 22	45 16½	115 12½
Q	$\bar{1}51$	−24 46	54 51½	120 45½	42 03	55 31½	110 02

The pyramid $q\{151\}$ was seen on ten crystals as a very tiny face in good position, but sometimes too small to reflect a visible signal. The dome $x\{021\}$ was measured twice as a fairly large and very perfect face on one crystal and can be considered well established. $y\{041\}$ was observed as a tiny form on two crystals and on another as a fairly large face. Table 4 presents the average measured angles of each face together with the angular range and number of observations. Table 5 gives the formal angle table.

Figures 3*a* and 3*b* show the habits of the crystals; 3*a* is typical of the vast majority of the crystals; 3*b* is somewhat idealized to show $x\{021\}$ and the rare front pinnacoid $a\{100\}$. In both drawings the thickness along the *b*-axis is exaggerated for ease in drawing.

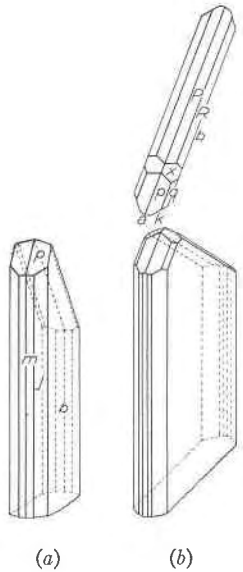

FIG. 3. Crystal drawings of montgomeryite: (*a*) usual habit; (*b*) less common forms.

PHYSICAL AND OPTICAL PROPERTIES

Montgomeryite has a perfect and easy cleavage parallel to $b\{010\}$ and a poor cleavage parallel to $a\{100\}$. This poor cleavage was observed only in immersions of the powdered mineral under the microscope.

The mineral has a hardness of 4. Its gravity is 2.530 ± 0.05 as determined on five samples, each weighing over 5 mg., on the microdensity balance. It has a vitreous luster and is usually a deep green in color, rarely pale green to colorless.

Optical constants:

	n(Na)		Pleochroism weak	Biaxial negative
$X \wedge c = +60°$	1.572	all ± 0.002	Colorless, rarely pale green	$2V = 75° \pm 10°$
	1.578		colorless	$r < v$, easily perceptible
$Z = b$	1.582		colorless	

Structural Elements

Rotation, and zero and first layer Weissenberg pictures about [010], and rotation, and zero layer Weissenberg pictures about [001] were taken. They gave the following values:

$a_0 = 9.99$ Å. ± 0.02 Å., $b_0 = 24.10$ Å. ± 0.02 Å., $c_0 = 6.25$ Å. ± 0.05 Å., $\beta = 91°28'$

$a_0 : b_0 : c_0 = 0.4145 : 1 : 0.2593$

$V_0 = 1505$ cu. Å. $M_0 = 2308$ (for G = 2.53).

The space group is $C2/c - C_{2h}6$ as given by the following observed reflections:

hkl, $h+k$ even
$h0l$, h even, l even
$0k0$, k even

Chemistry

Two analyses of montgomeryite were made by F. A. Gonyer. They are given in Table 6. Analysis A was made on a 400 mg. sample, 99% pure; analysis B was made on a 230 mg. sample, 95+% pure. Analysis A was used in the calculations.

Table 6. Analyses of Montgomeryite

	A	B	C	D	1		2	3	4
P_2O_5	37.70	37.63	37.80	37.10	.265	P	530	12.24	12
Al_2O_3	21.32	21.56	21.37	22.19	.209	Al	418	9.64	10
CaO	19.07	18.89	19.12	19.53	.341	Ca	341	7.87	8
H_2O	21.65	21.71	21.71	21.18	1.202	H	2404	55.48	54
						O	3495	80.66	80
	99.74	99.79	100.00	100.00					

A. Analysis of montgomeryite by F. A. Gonyer. Sample weighed 400 mg. and was 99% pure.
B. Analysis of montgomeryite by F. A. Gonyer. Sample weighed 230 mg. and was 95+% pure.
C. Analysis A recalculated to 100%.
D. Theoretical composition of $Ca_4Al_5(PO_4)_6(OH)_5 \cdot 11H_2O$.
1. Molecular proportions calculated from A.
2. Atomic proportions.
3. Number of atoms in the unit cell, assuming $M_0 = 2308$ and $d = 2.53$.
4. Theoretical number of atoms in the unit cell.

Column 4 yields the formula for the unit cell content

$$Ca_8Al_{10}(PO_4)_{12}(OH)_{10} \cdot 22H_2O$$

or

$$2[Ca_4Al_5(PO_4)_6(OH)_5 \cdot 11H_2O]$$

assuming $M_0 = 2308$, as given by the x-ray calculations, and the measured density of 2.53. The density calculated from this formula is 2.52.

Montgomeryite seems to have no close relation to any other known mineral. Its chemical relation to the other minerals of the phosphate nodules is shown in Fig. 2.

ACKNOWLEDGMENTS

The writer's thanks are due to Professor Charles Palache, Drs. Harry Berman and W. E. Richmond, Jr., and Mr. C. Wroe Wolfe, all of whom gave valuable assistance and advice. Mr. Arthur Montgomery spent much time and patience in sorting through his large collection of nodules for suitable material for this study.

REFERENCE

LARSEN, ESPER S., and SHANNON, EARL V., The minerals of the phosphate nodules from near Fairfield, Utah: *Am. Mineral.*, **15**, 307–337 (1930).