

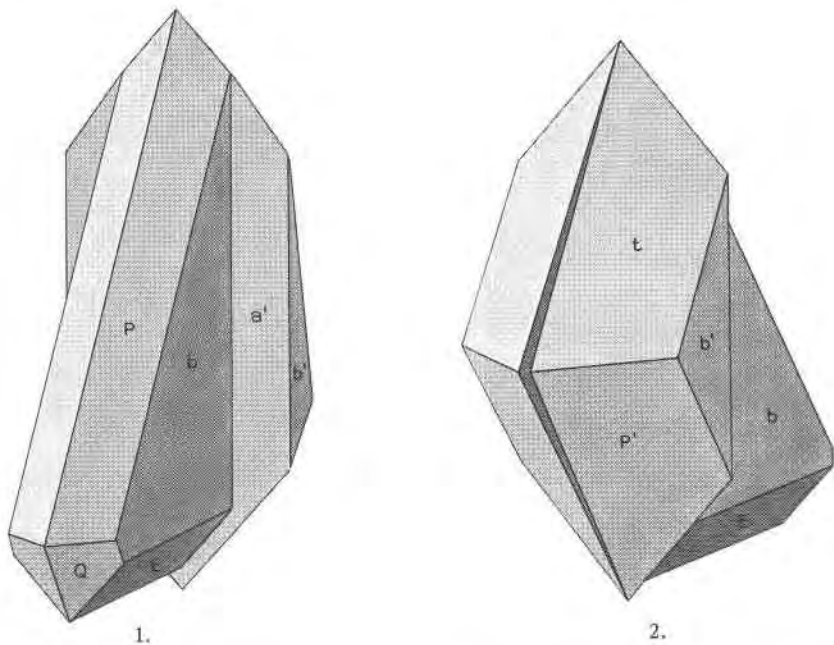
PARAHILGARDITE, A NEW TRICLINIC-PEDIAL MINERAL

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ABSTRACT

The new species, parahilgardite, found in the Choctaw Salt Dome, Louisiana, is so named because of its close similarity with hilgardite. The specimens are invariably made up of one right-hand and one left-hand individual attached to the negative end of the a -axis of a hilgardite crystal. Parahilgardite is triclinic-pedial—the second mineral to be described in this class. $a:b:c=0.5045:1:0.2783$; $\alpha=90^{\circ}00'$, $\beta=90^{\circ}00'$, $\gamma=91^{\circ}12'$. Its physical properties are identical with those of hilgardite: clear and colorless; cleavage $\{010\}$ and $\{100\}$; $H=5$, $G=2.71$. Biaxial positive, $2V=35^{\circ}$, $r>v$, $nX=1.630$, $nY=1.636$, $nZ=1.664$. The dimensions of the unit cell: $a_0=11.24\text{\AA}$, $b_0=22.28\text{\AA}$, $c_0=6.20\text{\AA}$. The chemical formula expressing the content of the unit cell can be written as: $2[\text{Ca}_8(\text{B}_6\text{O}_{11})_3 \cdot \text{Cl}_4 \cdot 4\text{H}_2\text{O}]$.

A new mineral, hilgardite, found in the Choctaw Salt Dome, Iberville Parish, Louisiana, was described recently by Hurlbut and Taylor (1937). Hilgardite was found in isolated monoclinic crystals of the domatic class, all of which presented a characteristic triangular appearance. More recently additional material from the same salt dome was sent the writer by Mr. Taylor. In this material a few single crystals were found, but



FIGS. 1 AND 2. The characteristic appearance of hilgardite-parahilgardite intergrowths. Figure 1 shows the positive end and Fig. 2 the negative end of the intergrowth.

more abundant than these were hilgardite crystals with growths at one end giving the intergrowths the appearance of twins. In endeavoring to work out the twin law, it was discovered that the optical orientation with respect to the cleavages was different in the different individuals. The supposed twin was thus found to be a parallel growth of two minerals. The name *parahilgardite* has been given to this new mineral because of its close relation to the associated hilgardite.

Parahilgardite was not found as unattached crystals, and all of it appears to have formed by growing on the earlier hilgardite. The crystals range from 0.3 mm. to 8.0 mm. in maximum dimension and are usually smaller than but proportional to the size of the attached hilgardite. An occasional crystal is found where parahilgardite has relatively large dimensions and dwarfs the associated hilgardite individual.

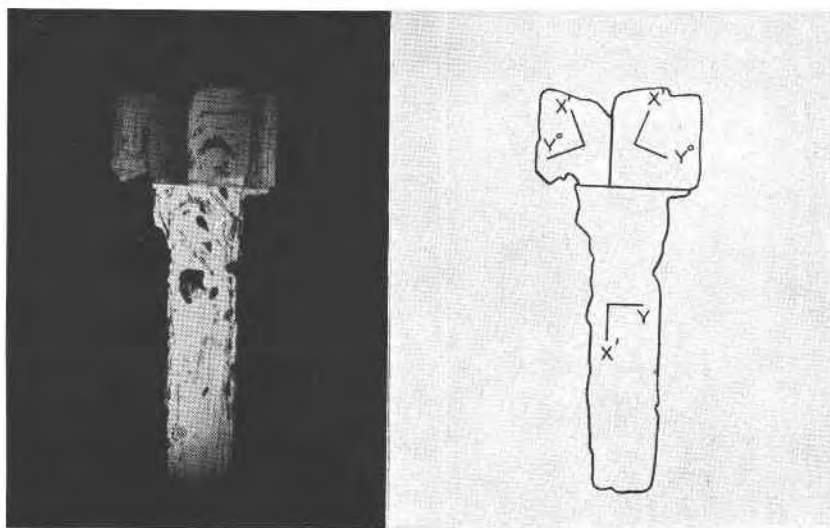


FIG. 3. Photograph of thin section cut normal to the c crystallographic axis showing the right and left hand parahilgardite individuals joined to the hilgardite. Crossed nicols. $\times 8$.

FIG. 4. The optical orientation of the three individuals shown in Fig. 3. Y^0 in the parahilgardite indicates the direction of Z' very close to Y .

Almost without exception parahilgardite is made up of two individuals joined to the $(\bar{1}00)$ plane of hilgardite (Figs. 2 and 3). These two individuals appear to be in twin position to one another as shown in Fig. 4. They usually are not in contact, and their orientation, therefore, is not controlled by their mutual relationship, but rather by their relation to hilgardite. The parahilgardite individuals are arranged in such a manner

that the complete intergrowth has monoclinic symmetry, thus giving further confirmation of the conclusion that hilgardite itself is monoclinic. The presence of parahilgardite always at the negative end of the *a*-axis of hilgardite indicates the polar nature of that axis and confirms the domatic class for hilgardite.

MORPHOLOGY

Parahilgardite is triclinic-pedial, but very closely related structurally and morphologically to hilgardite. It has been chemically attacked and the faces are universally etched, even more than those of hilgardite. Only four crystals were found whose faces would give reflections, and these were so poor that only an approximation of their position could be obtained.

Two excellent cleavages, *b*{010} and *a*{100} in the parahilgardite, permitted an accurate orientation of the crystals. The zone axis [001] determined by these cleavages is parallel to the corresponding zone axis in hilgardite and was set vertical for crystal measurements. The two-circle measurements given in Table 1 are for the left-hand individual of parahilgardite, the one in normal position. The elements and angles in Table 2 are also for the left-hand crystal, and were calculated by using the elements derived from the *x*-ray measurements, since it is believed they were determined with greater accuracy than the best of the morphological measurements. The writer is greatly indebted to Mr. C. W. Wolfe for the calculation of the angles in Table 2.

TABLE 1. TWO-CIRCLE MEASUREMENTS ON FOUR CRYSTALS

Forms	No. of Faces	Measured Range		Measured Mean	
		φ	ρ	φ	ρ
\bar{b} 010	8	180°00'	90°00'	180°00'	90°00'
<i>a</i> 100	3	88°47'–88°49'	90 00	88 48	90 00
\bar{a} 100	4	–91 10 –91 14	90 00	– 91 12	90 00
<i>j</i> 160	1	–17°55'	90 00	–17 55	90 00
<i>k</i> 120	1	–45 14	90 00	–45 14	90 00
<i>l</i> 120	1	–134 22	90 00	–134 22	90 00
<i>n</i> 160	1	–161 34	90 00	–161 34	90 00
<i>p</i> 121	5	–134°15'–133°49'	142°11'–141°32'	–134 02	141 50
<i>r</i> 161	1	–18°42'	119°30'	– 18 42	119 30
<i>s</i> 342	1	–123°22'	134°05'	–123 22	134 05
<i>t</i> 321	3	–106°46'–106°22'	62°51'–64°53'	–106 34	63 52

TABLE 2. PARAHILGARDITE. TRICLINIC; PEDIAL—1

		$a:b:c=0.5045:1:0.2783$		$\alpha=90^{\circ}00', \beta=90^{\circ}00', \gamma=91^{\circ}12'$		
		$p_0:q_0:r_0=0.5518:0.2781:1$		$\lambda=90^{\circ}00', \mu=90^{\circ}00', \nu=88^{\circ}48'$		
		$p_0'=0.5518, q_0'=0.2784; x_0'=0.00, y_0'=0.00$				
Forms		φ	ρ	A	B	C
\bar{b}	010	180°00'	90°00'	91°12'	180°00'	90°00'
a	100	88 48	90 00	0 00	88 48	90 00
\bar{a}	$\bar{1}00$	- 91 12	90 00	180 00	91 12	90 00
j	$\bar{1}60$	- 18 23½	90 00	107 11½	18 23½	90 00
k	$\bar{1}20$	- 45 20	90 00	134 08	45 20	90 00
l	$\bar{1}20$	-135 51	90 00	135 21	135 51	90 00
n	$\bar{1}\bar{6}0$	-161 50½	90 00	109 21½	161 50½	90 00
p	$\bar{1}2\bar{1}$	-135 51	141 37	116 12½	116 27½	141 37
r	$\bar{1}6\bar{1}$	- 18 23½	119 46	104 52	34 33	119 46
s	$\bar{3}4\bar{2}$	-124 41½	134 49	126 16	113 48½	134 49
t	$\bar{3}2\bar{1}$	-109 40	60 21½	145 31½	107 00½	60 21½

The forms common to all the crystals and those best developed on most of them are: $b\{010\}$, $p\{121\}$, and $t\{321\}$ as shown in Fig. 2. Although these forms can always be seen, it is unusual to find a crystal on which they have not been etched. Many crystals showed the presence of faces in the prism zone, but only one was of sufficient quality to be measured.

EVIDENCE FOR THE PEDIAL CLASS OF PARAHILGARDITE

Since the pyroelectric properties of axinite were described by Haüy (1822), it has stood alone among minerals as an example of triclinic-pedial symmetry. Due probably to the holohedral appearance of axinite, the pedial symmetry has not been accepted by some of the present-day workers. Since parahilgardite is the second mineral to be described as belonging to the pedial class, it seems best to present the evidence on which the determination was made.

The orientation of parahilgardite has been determined by the attached hilgardite; the positive end of $[100]$ of the former joins the negative end of $[100]$ of the latter. This may in part account for the fact that most of the forms listed above are at the back of the crystal and are negative, and that there was little chance for the development of positive faces. On some crystals, however, as on that shown in Figs. 1 and 2, the $a(100)$ face can be seen joining the $b(010)$ face directly with no prism or pyramid present though these faces may exist at the back of the crystal. In Fig. 3,

the right-hand parahilgardite individual shows zones of growth parallel to \bar{a} , b , and either a negative prism or pyramid, but apparently no positive pyramid or prism ever existed. This lack of parallel opposite faces suggests that parahilgardite belongs to the pedial class. The only symmetry element of hilgardite is a reflection plane which is wanting in parahilgardite; a fact that further supports the idea that parahilgardite may be pedial, lacking all symmetry elements.

In order to find more definite evidence of the pedial class, a test to determine whether or not parahilgardite is piezoelectric was made by Prof. G. W. Pierce of Harvard University. By using an apparatus for acoustic research recently described by Noyes and Pierce (1938), he positively determined the presence of piezoelectricity, with a strong electric axis parallel to or nearly parallel to the a crystallographic axis. This fact, taken with the other evidence, proves the absence of a center of symmetry and that parahilgardite is, indeed, pedial. A test was also made on hilgardite which showed a similar electric axis parallel to the a crystallographic axis and, hence, nearly parallel to that of parahilgardite.

PHYSICAL AND OPTICAL PROPERTIES

Parahilgardite has two perfect cleavages parallel to $\{010\}$ and $\{100\}$. The $\{100\}$ cleavage is parallel to the $\{100\}$ cleavage of hilgardite, while the $\{010\}$ cleavage is at an angle of $1^{\circ}12'$ to the $\{010\}$ cleavage of hilgardite. The hardness (5) and specific gravity (2.71) are the same as in hilgardite within the limits of measurement. The optical properties of parahilgardite are as follows:

	Orientation		$n(\text{Na})$	
	φ	ρ		
X	156°	84°	1.630	positive
Y	66	89	1.636	$2V=35^{\circ}$
Z	0	5	1.664	$r > v$

With the exception of orientation, the above optical properties are the same as those of hilgardite. The only way to distinguish easily between hilgardite and parahilgardite is by observing the extinction angle in the (001) plane (Fig. 4). Z is nearly parallel to c in both minerals. Hilgardite gives parallel extinction, while in parahilgardite the effect is as though the optical indicatrix has been rotated about Z to give an extinction angle of about 20° .

X-RAY MEASUREMENTS

A rotation photograph and Weissenberg photographs of the zero- and first-layer lines were taken with $c[001]$ the rotation axis. The dimensions

of the unit cell calculated from these photographs are given below with those of hilgardite for comparison.

Parahilgardite:	$a_0=11.24\text{\AA}$, $b_0=22.28\text{\AA}$, $c_0=6.20\text{\AA}$
Hilgardite:	$a_0=11.35\text{\AA}$, $b_0=11.12\text{\AA}$, $c_0=6.20\text{\AA}$

From the above it will be seen that the only real difference in the dimensions of the two unit cells is that b_0 of parahilgardite is twice b_0 of hilgardite. The ratio of the cell edges of parahilgardite, $a_0:b_0:c_0=0.5045:1:0.2782$, is that used in the calculation of the angles and elements given in Table 2.

COMPOSITION

A sample of parahilgardite was prepared for analysis by breaking the small crystals from the attached hilgardite. The identity of the physical properties of the two minerals prohibited the separation of uncertain material. Nine-tenths of a gram of parahilgardite was prepared by using a large proportion of the available crystals. The analysis is given in Table 3 with that of hilgardite for comparison.

TABLE 3. ANALYSIS OF PARAHILGARDITE AND CONTENT OF UNIT CELL.

	1	2	3	4	5
B ₂ O ₃	49.18	48.97	50.26	0.7229	B 36.8
CaO	34.41	34.23	35.13	0.6275	Ca 16.0
H ₂ O	6.31	6.07	6.23	0.3462	H ₂ 8.8
Cl	10.37	10.51	10.82	0.3054	Cl 7.8
Insol.	1.89	2.21			
	102.16	101.99			
Less 0	2.34	2.37	2.44		
	99.82	99.62	100.00		

1. Analysis of hilgardite by F. A. Gonyer given in Hurlbut and Taylor (1937).
2. Analysis of parahilgardite by F. A. Gonyer.
3. Insolubles deducted and recalculated to 100%.
4. Molecular ratio.
5. Atomic content of unit cell calculated by using the molecular weight of the unit cell, $M_0=2544$.

The two analyses given in Table 3 agree within the limits of error, and the composition for both minerals may be expressed similarly; hilgardite as $\text{Ca}_8\text{B}_{18}\text{O}_{33}\text{Cl}_4 \cdot 4\text{H}_2\text{O}$ and parahilgardite with twice the content of the hilgardite unit cell as $2(\text{Ca}_8\text{B}_{18}\text{O}_{33}\text{Cl}_4 \cdot 4\text{H}_2\text{O})$. A comparison of the chemi-

cal formulae below shows the relation that parahilgardite bears to the other hydrous calcium borates.

Veatchite	$\text{Ca}_2\text{B}_6\text{O}_{11} \cdot 2\text{H}_2\text{O}$
Parahilgardite	$2[\text{Ca}_8(\text{B}_6\text{O}_{11})_3 \cdot \text{Cl}_4 \cdot 4\text{H}_2\text{O}]$
Colemanite	$\text{Ca}_2\text{B}_6\text{O}_{11} \cdot 5\text{H}_2\text{O}$
Meyerhofferite	$\text{Ca}_2\text{B}_6\text{O}_{11} \cdot 7\text{H}_2\text{O}$
Inyoite	$\text{Ca}_2\text{B}_6\text{O}_{11} \cdot 13\text{H}_2\text{O}$

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