

TAYLORITE, MASCAGNITE, APHTHITALITE, LECONTITE, AND OXAMMITE FROM GUANO

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ABSTRACT

The original type specimen of taylorite is believed located. It is an ammonian arcanite, belonging to the isomorphous series arcanite—mascagnite, $K_{2-x}(NH_4)_xSO_4$, with x near 0.35, according to a new analysis. $2V = (-)$ small, $N_x = 1.5007$, $N_y = 1.5034$, $N_z = 1.5048$; X-ray powder diffraction data in Tables 1 and 2. Mascagnite and arcanite were not found in the guano studied. Ammonian aphtthitalite predominates in a fossil penguin egg analyzed by Mrs. Setlow. Chemical, optical, and x-ray data in Tables 4 and 5; $N_o = 1.4998$, $N_e = 1.5026$. Lecontite from the type locality, labelled by Taylor, was studied by x-ray methods (Table 6). Refractive indices $1.495 \pm .010$. Oxammite is ammonium oxalate monohydrate (not dihydrate), according to a new analysis (Table 7). This proved similar (Table 8) to oxammite from a specimen that is as nearly identical with Shepard's type specimen as any that probably exists.

INTRODUCTION

During the preparation of a monograph on guano in the Survey of Contemporary Knowledge of Biogeochemistry, Professor G. E. Hutchinson of Yale University wished to have some specimens from guano deposits examined mineralogically. It soon became evident that certain problems needed further study; this report is the result. The minerals taylorite, aphtthitalite, glaserite, mascagnite, arcanite, lecontite, and oxammite have all been reported as occurring in guano, and several of these were found in the specimens studied, but their published descriptions were in some cases inaccurate. A comprehensive study of the guano specimens available was therefore undertaken not only to determine their components but also to characterize or re-describe certain ones.

ACKNOWLEDGMENTS

Professor G. E. Hutchinson's work in assembling suitable specimens actually originated this study. He personally examined guano specimens in the collections of the American Museum of Natural History, of Columbia University, and of the Philadelphia Academy of Natural Sciences, obtaining valuable information and specimens at each institution. These specimens, together with ones from subfossil birds originally presented to the Peabody Museum of Yale University by Shepard (1870) from a boatload of guano that docked in Carolina that year, and several specimens from the Brush Mineral Collection of Yale University, constitute the material here described. The cordial cooperation of the several museums is acknowledged with great appreciation. X-ray and optical tests

were made with equipment provided by the trustees of the George Sheffield fund, and certain other funds of Yale University. Special thanks are due Professor C. Frondel of Harvard University for the pre-publication loan of his 1950 manuscript on certain sulfates. Thanks are due Mr. V. T. Bowen, Mr. T. Sippel, and Mrs. Jane K. Setlow for analyses.

METHODS OF STUDY

Some specimens were identified by chemical analysis, most by x -ray powder diffraction and optical data; in all cases the refractive indices and x -ray powder diffraction data were eventually obtained. Optical studies were carried out mainly by the immersion method at room temperature, with white light. The accuracy of such results is ± 0.005 . Critical specimens were studied by the Emmons double-variation method (1929, p. 415), and accuracy in such cases is probably about ± 0.0004 . The x -ray patterns of the rarer minerals were not found in any available literature; in some cases, such patterns were nevertheless compared with those of chemical reagents. Samples of certain type specimens obtained from various museums were analyzed chemically. In some cases the material was originally identified on the basis of crude chemical, optical, or crystallographic determinations, and proved to be rather poorly characterized.

DESCRIPTIONS OF SPECIMENS

Mascagnite

Artificial $(\text{NH}_4)_2\text{SO}_4$ has $N_x = 1.5209$, $N_y = 1.5230$, $N_z = 1.5394$; $2V = (+) 52^\circ$; $X = c$, $Y = b$, $Z = a$ (Winchell, 1931, p. 216). Reagent ammonium sulfate yields the x -ray data shown in Table 1, column 3 (A.S.T.M. Joint Committee on X -ray Data, 1950).

Mascagnite was not found with the fossil birds or eggs. The following museum materials are labelled mascagnite: (1) Brush Collection (Yale) No. 1693, mascagnite from Geysers, Sonoma [County, California], whose optical properties agree closely with those quoted above, gives the x -ray powder diffraction data recorded in Table 1, column 1. (2) Peabody Collection (Yale) No. 8971, mascagnite from Naples, Italy, whose optical properties also agree closely with those of reagent material, gives the x -ray powder data recorded in Table 1, column 2. (3) A Vaux Collection (Philadelphia Acad. Nat. Sci.) No. 15339, "mascagnite" from Etna, Italy, proved to be a mixture of sulfur and salammoniac. (4) Vaux Collection (Philadelphia Acad. Nat. Sci.) No. 5574, "mascagnite" from Chincha Islands is considered to be the material which Taylor (1859, p. 309) described as "? glaserite" and which Dana (1892, p. 895) called

taylorite and accepted as a new species. This material is treated under *taylorite*.

TABLE 1. X-RAY POWDER DATA FOR MASCAGNITE

1		2		3	
<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>
5.44	1	5.16	2	5.2	2
4.96	9	4.27	10	4.36	10
4.65	3	3.87	5	3.91	2
4.31	4	3.08	8	3.12	4
3.74	8	3.00	8	3.03	4
3.36	10	2.62	1	2.67	0.7
3.04	1	2.495	1	2.51	0.7
2.90	7	2.298	4	2.32	2
2.68	1	2.161	4	2.18	2
2.475	3	1.937	1	2.05	0.1
2.321	1			1.97	0.4
2.196	2			1.93	0.2
1.884	1			1.77	0.2
				1.73	0.2
				1.70	0.2
				1.63	0.5
				1.56	0.2
				1.52	0.2
				1.49	0.5

1. Brush Collection (Yale) No. 1693 mascagnite, Sonoma County, California.
2. Peabody Museum (Yale) No. 8971 mascagnite, Naples, Italy.
3. A.S.T.M. card file, ammonium sulfate.

Arcanite

Artificial K_2SO_4 is orthorhombic with $N_x=1.4935$, $N_y=1.4947$, $N_z=1.4973$; $2V=(+)$ $67^\circ 20'$; $X=b$, $Y=a$, $Z=c$ (Winchell, 1931, p. 217). Although this material has reportedly been found among guano materials, none was found in the specimens studied. An x -ray pattern of artificial K_2SO_4 from the reagent shelf was made for reference purposes; its measurements agree satisfactorily with published data (A.S.T.M. Joint Committee on X -ray Data, 1950). The refractive indices of reagent K_2SO_4 quoted above were confirmed within an experimental error of $\pm .0010$.

Taylorite and the arcanite-mascagnite series

Dana proposed the name *taylorite* for material from the Chincha Islands described by Taylor (1859, p. 309) as “?glaserite.” Taylor ana-

lyzed the material and computed the formula $(K,NH_4)_2SO_4$. Taylor's analysis (Taylor, 1859, p. 309; Dana, 1892, p. 895; molecular proportions based upon modern atomic weights) follows:

			Formula
SO ₃	48.40%	.604 mol.	K ₅ NH ₄ (SO ₄) ₃ ; more exactly, K _{2-x} (NH ₄) _x SO ₄ , with x=0.42
(NH ₄) ₂ O	5.37	.127	
K ₂ O	43.45}	.491	
Na ₂ O	1.68}		
	<hr/> 98.90		

Taylor described the specimens as occurring in "lumps or concretions about the size and shape of a hickory nut, of a white or creamy color." Some specimens in the Vaux Collection of the Philadelphia Academy of Natural Sciences (Vaux No. 5574), labelled "Mascagnite, Chincha Islands," fit this description perfectly. This material gives an x-ray powder pattern (Table 2, column 1) different from that of mascagnite (Table 1), but agreeing with those of two correctly labelled taylorite specimens from Guanapé. Its optical properties differ from those of mascagnite. No other specimens of guano materials in the Vaux Collection have this habit. The probability seems very good that the specimens, Vaux No. 5574, are actually the type material for taylorite. A new chemical analysis yielded the following results:

Taylorite: Vaux Collection, No. 5574, "Mascagnite, Chincha Is."

			Formula
SO ₃	45.18%, 45.55%	.570	K _{2-x} (NH ₄) _x SO ₄ , with x=about 0.35, depending upon assumptions as to the low summation.
(NH ₄) ₂ O	5.14 ± .02	.099}	
K ₂ O	47.50	.501}	
Na ₂ O	.0001	.600	
	<hr/> 97.87		

The SO₄ determination was by precipitation as the sulfate, done twice by Benoit; ammonia was determined by Nessler's colorimetric method by T. Sippel; K₂O and Na₂O were determined spectrographically by V. T. Bowen.

New determinations of the optical properties by Emmons' double-variation method (1929) gave the results shown in the second column of Table 3. A specimen labelled taylorite from Guanapé, Peru, obtained by Professor Hutchinson from the American Museum of Natural History, gave the data shown in the third column. Data of Larsen (1921, p. 142) are probably in error; although Larsen's data were obtained from a sample labelled taylorite, Frondel* states that they were clearly obtained from some other mineral. The apparent discrepancy in optic

* Frondel, C., Private communication, May 8, 1950; Frondel, 1950, p. 597.

TABLE 2. X-RAY POWDER DATA FOR TAYLORITE

1		2		3	
<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>
4.21	8	4.19	8	4.20	7
3.77	1	3.79	2	3.77	1
3.40	2	3.39	1	3.42	2
3.04	7	3.03	9	3.04	9B
2.92	10	2.90	10	2.91	10
2.51	2	2.53	4	2.51	4
2.45	2	2.46	3	2.44	3
2.39	2	2.40	2	2.40	1
2.24	3B	2.23	3B	2.23	4
2.11	6	2.10	5	2.11	6
2.02	1	2.04	1	2.03	1
1.95	1	1.95	1	1.91	4
1.90	2	1.90	2	1.78	2
1.79	1	1.69	1B	1.69	3B
1.70	1	1.59	1	1.58	3
1.67	1	1.455	2	1.450	5
1.59	2	1.359	1B	1.394	1
1.453	2	1.308	1B	1.361	3
1.363	2			1.307	2
				1.256	2B
				1.226	1
				1.187	2
				1.156	2
				1.098	2
				1.054	2
				1.025	1

1. Vaux Collection (Phil. Acad. Nat. Sci.) No. 5574 labelled "Mascagnite Chincha Islands," probably type taylorite.

2. Vaux Collection No. 17879 taylorite Guanapé, Peru.

3. Amer. Mus. Nat. Hist. taylorite Guanapé, Peru, No. 16211.

sign and the variability of $2V$ are explained when it is noted that the material is apparently uniaxial at two compositions (near $\text{Ar}_{50}\text{Ms}_{50}$ and $\text{Ar}_{85}\text{Ms}_{15}$), and changes optic sign twice in the series. Note the orientations shown for the end members in Table 3, the crystal axis c becoming successively the vibration direction of X, of Y, and of Z, while a is the vibration direction of Z for most of the series, becoming Y when Nc exceeds Na ; b is the vibration direction Y, becoming X when Nc exceeds Nb .

If a series be postulated between mascagnite and arcanite, the new optical data from Taylor's presumed type specimen from the Vaux Col-

lection fit the values interpolated from the end members of the series (Table 3).

TABLE 3. OPTICAL CONSTANTS OF THE ARCANITE-MASCAGNITE SERIES

Name Composition Locality	Arcanite K ₂ SO ₄ Artificial ¹	Taylorite Ar+Ms		Mascagnite (NH ₄) ₂ SO ₄ Artificial ¹
		Chincha Is. ²	Guanapé ³	
N_x	$N_b=1.4935$	1.5008	1.5007	$N_c=1.5209$
N_y	$N_a=1.4947$	1.5037	1.5034	$N_b=1.5320$
N_z	$N_c=1.4973$	1.5062	1.5048	$N_c=1.5394$
2V	(+) 67°	lg	(-) sm., var.	(+) 52°

¹ Winchell, 1931.

² Vaux Collection No. 5574.

³ Amer. Mus. Nat. Hist. No. 16211.

Aphthitalite

Fron del (1950) states that the proper formula for aphthitalite is (K,Na)₃Na(SO₄)₂. Winchell (1933, p. 96) indicates that the material is uniaxial positive, $N_o=1.487-1.491$, $N_e=1.492-1.499$. Bellanca (1943) worked out the crystal structure and determined the following physical data for material from Vesuvius: $N_o=1.4882$, $N_e=1.499$, spec. gr. 2.697, axial ratio $c/a=1.290$. Fron del (1950) noted ammonian aphthitalite in guano from Guanapé.

Material from a fossil egg of *Pelecanoides garnoti* from Peruvian guano was analyzed by Mrs. Jane K. Setlow (Hutchinson, 1950, p. 94, anal. XI), with the result shown in Table 4, column 1. Optical and x-ray data for this specimen are given in Tables 4 and 5, as also for an aphthitalite from Searles Lake. The fossilized egg is an ammonian variety quite similar to that described by Fron del (1950), which is included in Table 4, column 2, for comparison. The Searles Lake aphthitalite (column 3) is without ammonia.

Druzinin (1938) investigated the system K₂SO₄-Na₂SO₄-H₂O, and reported that the compound K₃Na(SO₄)₂ permits substitution of Na for K within the range K/Na=2.44 to 3.00. Specific gravity and goniometric data are given for the solid solutions. If K and NH₄ are written together the ratio of these to sodium according to analysis 1, Table 4 (46/17=2.71), is within the limits given by Druzinin. NH₄ and K have similar ionic radii (Goldschmidt, 1945) and should be expected to substitute for each other rather freely. The *P. garnoti* fossilized egg is therefore an ammonian aphthitalite similar to that found by Fron del in guano from Guanapé.

X-ray powder data for the materials from the fossil egg and for the Vesuvius and the Searles Lake specimens already cited with optical data are listed in Table 6. Aphthitalite from Vesuvius was analyzed by Bianchini (1937), but there is no reason to correlate his analysis with the physical properties reported here.

TABLE 4. CHEMISTRY AND OPTICS OF APHTHITALITE

	1		2		3		4	
	Fossil egg, Peru ¹		Guanapé ²		Searles Lake, Calif. ³		Vesuvius ⁵	
(NH ₄) ₂ O	5.72%	.11 mol.	6.58					
K ₂ O	32.88	.35	33.87		39.1			
Na ₂ O	10.42	.17	9.65		8.0			
SO ₃	47.46	.60	48.62		43.6			
P ₂ O ₅	1.33		0.70					
NaCl					7.9			
Oxalate (C ₂ O ₃)	0.35							
Insol.	0.60							
H ₂ O			0.21		0.1			
Sum	98.76		98.73		98.7			
N _o	1.4998 ± .0004		1.498 ± .002		1.490 ± .003 ⁴		1.498 ± .004	
N _e	1.5026 ± .0004		1.503 ± .002		1.496 ± .003		1.505 ± .004	

¹ Aphthitalite. Fossil egg of *Pelecanooides garnoti* (Hutchinson, 1950, p. 94, anal. XI). Optics by H. Winchell. Analyst, Setlow.

² Ammonian aphthitalite, Guanapé (Fron del, 1950). Optics by Fron del. Analyst, Gonyer.

³ Aphthitalite, Searles Lake, California. Recalculated from Foshag (1920).

⁴ Brush No. 4436, Aphthitalite from Searles Lake, gives N_o=1.4905, N_e=1.4979, both ±.0004.

⁵ Aphthitalite, Vesuvius. Vaux Collection No. 19480. Optics by H. Winchell.

Lecontite

Taylor (1858) described a mineral from bat guano from a cave near Comayagua, Honduras, and on the basis of his analysis concluded it was a new species for which he proposed the name lecontite. Taylor's analysis is given below, with molecular proportions based on modern atomic weights:

(NH ₄) ₂ O	12.94%	.248 mol.	} .277
K ₂ O	2.76	.029	
Na ₂ O	17.56	.283	
SO ₃	44.97	.562	
H ₂ O	19.45	1.080	
Organic residue	2.30		
Inorganic residues	.11		
Phosphoric acid	tr.		

100.09

TABLE 5. X-RAY POWDER DATA FOR APHTHITALITE

1		2		3	
d Å	I	d Å	I	d Å	I
4.04	7	4.98	4	4.98	3
3.66	4	4.11	6	4.10	6
2.92	8	3.66	5	3.69	5
2.81	10	2.94	8	2.97	9
2.42	1	2.82	10	2.85	10
2.32	2	2.46	5	2.46	6
2.02	9	2.31	3	2.34	4
1.81	1	2.24	1	2.19	×
1.63	3	2.18	1	2.09	9
1.52	1	2.05	9	1.852	1B
1.406	2	1.84	2	1.725	×
		1.74	1	1.656	3
		1.65	6B	1.603	×B
		1.60	1	1.544	1
		1.54	4	1.471	2
		1.469	3	1.425	3B
		1.423	5	1.310	×
		1.366	1	1.287	1
		1.331	1	1.266	×
		1.313	1	1.229	×B
		1.284	2		
		1.268	1		
		1.236	2		
		1.196	1B		
		1.169	1		
		1.155	1		
		1.123	1		
		1.098	1		
		1.079	2		

1. Aphthitalite, Vesuvius, Vaux No. 19480.
2. Egg of *Pelecainoides garnoti*, Am. Mus. Nat. Hist.
3. Aphthitalite, Searles Lake, Brush No. 4436.

Winchell (1933, p. 97) gives the formula $\text{NaNH}_4\text{SO}_4 \cdot 2\text{H}_2\text{O}$, and the following optical properties: $X=a$, $Y=c$, $Z=b$; $N_x=1.440$, $N_y=1.452$, $N_z=1.453$; $2V=(-)$ 43° with dispersion $r > v$. A calculation based on modern atomic weights indicates a formula $(\text{NH}_4, \text{K})\text{NaSO}_4 \cdot 2\text{H}_2\text{O}$ with NH_4/K about 8.5.

Using the law of Gladstone and Dale, and specific refractive energies furnished by Larsen (1934, p. 31), with the analytical and optical data now available it is possible to estimate the specific gravity of lecontite as about 2.5. This estimate differs from the known specific gravity (2.68) of thenardite by about 0.2, which is probably significant. Suitable material for a good determination apparently has never been studied. There are also differences in the x-ray powder patterns of lecontite and thenardite, as shown in Table 6.

Vaux Collection specimen No. 15337 Lecontite, Comayagua, Honduras, appears to be Taylor's type material for this species because the sample fits Taylor's physical description even including the bat hairs. The material is so fine grained that only an average index of refraction could be obtained. $N_y = 1.495 \pm .010$. Table 6 shows the x-ray data for this lecontite and for a similar specimen in the Brush Collection (Yale), No. 1696, received directly from Taylor, and also including the bat hairs. The pattern of reagent sodium sulfate (thenardite), in the same table is somewhat similar, but differs significantly from that of lecontite.

TABLE 6. X-RAY POWDER DATA FOR LECONTITE AND THENARDITE

1		2		3	
d Å	I	d Å	I	d Å	I
5.54	1	5.61	4	4.63	8
5.07	10	5.01	10	3.82	2
4.65	9	4.62	8	3.17	4
4.37	8	3.90	3B	3.07	4
3.87	6B	3.39	3B	2.78	10
3.43	1	3.04	9	2.64	8
3.30	1	2.86	1B	2.33	6
3.19	1	2.68	8	2.20	1
3.02	7	2.161	2	1.92	0.5
2.84	1	1.981	3	1.86	8
2.77	6	1.873	3	1.80	1
2.63	6			1.67	4
2.475	1			1.60	1
2.411	1			1.55	3
2.327	4			1.50	2
2.151	1				
2.049	1				etc.
1.965	1				
1.855	5				
1.670	1				
1.605	1				
1.551	1				

1. Vaux Collection No. 15337 lecontite, Comayagua, Honduras
2. Brush Collection No. 1696 lecontite from cave of Las Piedras, Comayagua, Honduras, received from Taylor.
3. Thenardite. Reagent sodium sulfate.

The only other recorded lecontite is mentioned by Lacroix (1912) whose account is as follows (R. J. B., *Transl.*): "Embedded in the guano one finds nodules about the size of a walnut consisting of a water soluble salt, efflorescent in air. On ashing the material loses 59% of its weight;

this part consisting of water and $(\text{NH}_4)_2\text{SO}_4$; the residue is essentially K_2SO_4 . A necessarily summary analysis because of the small quantity available was done by M. Arsandaux and indicated a composition of approximately

45.7%	K_2SO_4
28.1%	$(\text{NH}_4)_2\text{SO}_4$
25.0%	H_2O

“The mineral is colorless, does not seem to possess a good cleavage, and is biaxial positive; the angle of the optic axes seems small [faible]. The only known substance which corresponds to this composition is lecontite $\text{SO}_4(\text{NH}_4, \text{Na}, \text{K})_2 \cdot 2\text{H}_2\text{O}$ which occurs under similar conditions (in caves) at Las Piedras in Central America. The latter is optically negative. The mineral we are dealing with is probably an analogue rich in potassium.”

Oxammite

“ $(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$.” Orthorhombic $2V = (-) 62^\circ$; $N_x = 1.438$; $N_y = 1.547$; $N_z = 1.595$; $X = c$, $Y = a$, $Z = b$ (Winchell, 1933, p. 89). From guano of the Guanapé Is., Peru.

Shepard (1870) described “oxalate of ammonia in very delicate but perfect crystals, which, as it has not been described as a natural substance, may receive the name oxammite.” Shepard did not indicate that the material was a hydrate. (Cf. the section below on material from the mummified birds.)

Shepard (1870) described a material for which he proposed the name guanapite. His analysis of the material is given below:

Sulfate of potash	67.75%
Sulfate of ammonia	29.20%
Oxalate of ammonia	3.75%

In the same article he described a substance

Sulfate of potash	40.20%
Oxalate of ammonia	29.27%
Water	30.46%

and proposed the name guanoxalite. Whether or not the two substances are simply mixtures of substances like taylorite and oxammite could not, of course, be demonstrated unless Shepard's type material were available. There is no available evidence for their homogeneity. Whether true sulfoxalates exist has not, so far as we are aware, been determined; an investigation of the system $(\text{NH}_4)\text{K}_2\text{SO}_4 - (\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$ should settle the question of the existence of guanoxalite.

A fossil penguin egg from the Columbia University Collection was analyzed with the result shown in Table 7 (Hutchinson, 1950, p. 94,

anal. XII). The analysis indicates a formula $(\text{NH}_4)_2\text{O} \cdot \text{C}_2\text{O}_3 \cdot \text{H}_2\text{O}$, that is, a monohydrate. Optical study of the material yielded $N_x = 1.440$; $N_y = 1.470$; $N_z = 1.580$ which agree with the published data for oxammite. Table 8 shows the x-ray data for fossil egg material, for material from Shepard's mummified birds, and for reagent ammonium oxalate monohydrate.

TABLE 7. CHEMISTRY OF OXAMMITE

			Deduct Na_3PO_4	Deduct Arcanite	Remainder Oxammite
SO_3	8.22%	.103 mol.		.103	
$(\text{NH}_4)_2\text{O}$	29.09	.562		.037	.525
K_2O	5.91	.066		.066	
Na_2O	5.87	.095	.087		(.088)
Oxalate (as C_2O_3)	37.39	.519			.519
P_2O_5	4.14	.029	.029		
H_2O (by diff.)	8.85	.491			.491
Insol.	0.53				

ANALYST, Mrs. J. K. Setlow.

TABLE 8. X-RAY POWDER DATA FOR OXAMMITE

1		2		3	
d	I	d	I	d	I
6.33	7	6.37	10	6.46	8
3.79	6	3.83	7	3.83	7
3.23	4	3.45	x	3.49	x
3.05	5	3.28	6	3.29	6
2.88	5	3.08	7	3.07	6
2.67	10	2.88	8	2.88	6
2.60	10	2.68	8	2.68	10B
2.45	4	2.60	8	2.62	10B
2.39	4	2.47	6	2.47	6B
2.15	1	2.39	6	2.40	6B
		2.16	4	2.16	5
		2.07	3B	2.02	3
		2.02	3B	1.89	4B
		1.86	2B	1.84	4B
		1.76	2B	1.75	2
		1.69	1	1.69	1

1. Oxammite from fossil egg of a penguin (*Spheniscus humboldti*) from the Roebling collection of Columbia University (Hutchinson, 1950, p. 94).
2. Oxammite from Shepard's mummified birds, Peabody Museum (Yale).
3. Reagent $(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$.

An analysis by Tanner, quoted by Dana (1892, p. 994) gives the composition of an ammonium oxalate from Guanapé, Peru, which is very close to $(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$, and which appears to be the only analysis of the material, and the only evidence that a dihydrate exists as a natural substance.

Professor J. H. Yoe of the University of Virginia, where Tanner's original type specimen should be located, stated* that the material was probably lost in a fire which destroyed the chemistry laboratory in 1916.

By a fortunate coincidence the Peabody Museum at Yale contains some mummified birds which were from the boatload of guano that Shepard examined. This material is thus as close an approach to type oxammite as now can be obtained. Four specimens of crystalline material were picked off the skin of these sub-fossils and all four had diffraction patterns (Table 8, col. 2) identical with that of reagent ammonium oxalate monohydrate.

The ordinary laboratory salt is the monohydrate. Winchell (1943, p. 25) gives the indices in Na light for artificial monohydrate as $N_x = 1.4383$; $N_y = 1.5475$; $N_z = 1.5950$; $2V = (-) 61^\circ 44'$; $X = c$; $Y = a$; $Z = b$.

The analysis of the material from the fossil egg agrees with $(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$. This material and material from Shepard's mummified birds agree with reagent monohydrate in x -ray diffraction pattern and indices of refraction. Evidently Shepard had a monohydrate and the name oxammite should be reserved for naturally occurring ammonium oxalate monohydrate.

SUMMARY

Taylorite is essentially ammonian arcanite. It has been found in guano of both the Chincha and Guanapé Islands. Taylor's original type specimen is believed to be in the Vaux Collection, and labelled mascagnite. A small sample from this specimen has been analyzed, establishing the mineral as an ammonian arcanite. Ammonian apthitalite occurs as a guano mineral in Peru. Oxammite from the same cargo as Shepard's type material gives an x -ray diffraction pattern identical with that of ammonium oxalate monohydrate, which was also found replacing a penguin egg. X -ray and optical data are given for these minerals. Lecontite appears to be a valid species.

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