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ART. XV.—*On Northupite; Pirssonite, a new mineral; Gaylussite and Hanksite from Borax Lake, San Bernardino County, California;* by J. H. PRATT.

INTRODUCTION.

THE minerals to be described in this paper are from the remarkable locality of Borax Lake, San Bernardino County, California. They were brought to the author's notice, in the fall of 1895, by Mr. Warren M. Foote of Philadelphia, who sent one of them, the northupite, together with some of the associated minerals, to the mineralogical laboratory of the Sheffield Scientific School, for chemical investigation. About the same time Mr. C. H. Northup of San José, Cal., sent some minerals from the same region to Prof. S. L. Penfield. Among them, gaylussite, hanksite and a third mineral, which has proved to be a new species, were identified. These same minerals were also observed among the specimens sent by Mr. Foote. Mr. Northup, in his letter of transmittal, stated that he had carefully saved all of the crystals of the new mineral, having observed that they were different from gaylussite in habit, and that he believed they would prove to be a new and interesting species.

Both Mr. Northup and Mr. Foote have thus most generously furnished material for this investigation, and the former has also supplied valuable information concerning the locality and mode of occurrence of the minerals. The author, therefore, takes great pleasure in expressing his thanks to both of these gentlemen for the services they have rendered.

In addition to the investigation of northupite and the new mineral, some interesting data concerning hanksite and gaylussite have also been obtained.

Occurrence.—The Borax Lake region has already been described by De Groot* and Hanks† and therefore only a brief description is necessary in this article.

This alkali lake, or better alkali marsh, is situated in the northwestern corner of San Bernardino County near the Inyo County line and is 72 miles from Mojave, the shipping point for that district. Borax Lake proper is a small basin about one mile and a half in length by half a mile wide, separated by a narrow ridge from a larger basin, which is about ten miles long and five miles wide, known as "Dry Lake," "Alkali Flat," "Salt Bed" and "Borax Marsh." The appropriateness of these names is very apparent, for the marsh is really a dry

* Report State Min. of Cal. 1890, p. 534.

† This Journal, xxxvii, p. 63, 1899.

lake, partly filled up with salt, borax, alkali, mud and volcanic sand. During the wet seasons a little water accumulates, but it remains only a short time and is never over a foot or two deep, while in most places it is not more than two or three inches. In the smaller basin, however, the water stands considerably longer. The larger basin is somewhat lower than the other, the narrow ridge referred to above preventing the waters of the smaller basin from flowing into it.

At the present time, borax is the only product manufactured from the minerals of the locality, and it is from the smaller basin and the narrow ridge that most of it is obtained. Tincal, or native borax, has been found in crystals to a depth of 450 feet, which is as deep as explorations with drills have penetrated. "Crude borax" is described by Mr. Northup as found on the surface of the higher parts of the lake, in a condition resembling burnt bone. Underlying this is a very hard, uneven deposit of different salts, which is generally not disturbed. The crude borax is collected only to a depth varying from two to eight inches, although the original thickness is much greater. In about four years, the efflorescence of borax forms again, the solution being drawn up by capillary attraction and leaving the bone-like deposit on evaporation. Most of the borax is obtained from this crude material, although some is obtained by the evaporation of the natural solution of borax in the lake water.

The minerals described beyond were found while exploring the underlying formations, and were obtained by Mr. Northup after carefully working over the tailings or debris from the borings.

The minerals associated with the borax at this region are, according to Hanks,* sulphur, gold, cerargyrite, embolite, halite, anhydrite, thenardite, celestite, glauberite, gypsum, calcite, dolomite, trona, gaylussite, natron, hanksite, colemanite, tincal, soda niter and hydrosulphuric acid. To this list sulphohalite, northupite and the new mineral to be described in this paper must be added. Of the foregoing, colemanite,† hanksite,‡ and sulphohalite § were first derived from this locality.

Northupite.

A preliminary description of this mineral has been given by Mr. Warren M. Foote.¶ According to information received

* This Journal, xxxvii, p. 66, 1889.

† Bull. Cal. Acad., No. 2, Jan., 1885, and Zs. Kr. 10, p. 179, 1884.

‡ This Journal, xxx, pp. 133 and 136, 1885, also xxxvii, p. 63, 1889.

§ Ibid., xxxvi, p. 463, 1888.

¶ Proceedings of the Acad. of Nat. Sci. Phil., Sept. 1895, and this Journal, 1, p. 480, 1895.

from Mr. Northup, it has been found in only one boring, known as the "New Well," and was probably formed in a stratum of clay, about 450 feet below the surface. With two exceptions, northupite has been observed only in detached crystals, Mr. Foote having in his possession a single specimen showing two octahedrons of northupite attached to a crystal of the new mineral, pirssonite, to be described beyond, and a similar specimen being in the Brush collection.

Physical properties.—The crystallization is isometric, the octahedron being the only form observed. The crystals vary in size from less than a millimeter to rarely a centimeter in diameter. There is no apparent cleavage, but the crystals, which are extremely brittle, break with a distinct conchoidal fracture. The luster on fractured surfaces is decidedly vitreous. The hardness is between 3.5 and 4. The specific gravity was obtained by floating the crystals in methylene iodide diluted with methyl iodide and was found to be 2.380. The pure material is colorless, but owing to impurities the color of the crystals, as stated by Foote, varies from dirty white, pale yellow and greenish gray to dark brown. The impurities are probably clay or organic matter and Foote has called attention to their arrangement in directions parallel to the axial planes of the isometric system. No decomposition on exposure to the air has been observed.

Optical properties.—Fragments of the mineral, when examined in polarized light, were found to be isotropic. By means of a prism of $79^{\circ} 35'$ the following indices of refraction were determined:

$$n_x = 1.5117 \text{ Li.} \quad n_y = 1.5144 \text{ Na.} \quad n_z = 1.5180 \text{ Tl.}$$

Chemical composition.—A qualitative examination showed the presence of carbonic acid, chlorine, sodium, magnesium and minute traces of sulphuric acid and water. Potassium was very carefully tested for, but not even a trace of it could be detected.

The results of the analyses are as follows:

	I.	II.	Average.	Ratio.	
CO ₂	35.21	35.02	35.12	.798	2.01
Cl.....	14.10		14.10	.397	1.00
SO ₂.....	.08	.08	.08		
MgO.....	15.96	16.20	16.08	.402	1.01
Na ₂ O.....	36.99		36.99	.597	1.50
H ₂ O.....	.72		.72	.040	
Insol. ....	.25	.19	.22		

103.31

O equivalent to Cl,

3.16

100.15

The ratio of the $\text{CO}_2 : \text{Cl} : \text{MgO} : \text{Na}_2\text{O}$ is almost exactly 2:1:1:1.5. Two-thirds of the sodium, if taken to form a molecule of Na_2CO_3 , would leave just enough to form with the chlorine a molecule of NaCl . This would then give as the formula, $\text{MgCO}_3, \text{Na}_2\text{CO}_3, \text{NaCl}$.

The percentage composition required by this formula is given below, together with the results of the analysis recalculated to 100 per cent, after deducting the slight amounts of water and insoluble material and converting a sufficient amount of the soda into metallic sodium to unite with the chlorine and form NaCl .

	Found.	Calculated for $\text{MgCO}_3, \text{Na}_2\text{CO}_3, \text{NaCl}$.
CO_2	35.43	35.41
MgO	16.22	16.09
Na_2O	24.90	24.96
Cl	14.23	14.28
Na	9.22	9.26
	100.00	100.00

Pyrognostics.—Before the blowpipe, the mineral fuses at 1, with frothing, due to escaping carbon dioxide, and yields a white or grayish white mass, which reacts alkaline with moistened turmeric paper. The flame is colored intensely yellow. In the closed tube, the mineral decrepitates violently, sometimes giving off a trace of water, derived probably from impurities held mechanically in the crystals. The crystals are easily soluble in cold dilute hydrochloric and nitric acids with effervescence. Cold water acts slowly on the mineral, but hot water decomposes it very rapidly with separation of magnesium carbonate.

Name.—The name, *northupite*, was given to this mineral by Mr. Foote as a compliment to Mr. Northup, whose very careful search has brought to light a number of interesting minerals from this locality.

Pirssonite, a New Mineral.

As stated in the introduction, a new mineral was first observed by Mr. Northup among some crystals of gay-lussite, which it somewhat resembles. It has been found very sparingly in only one boring, "New Well," which also furnished the northupite crystals. With the two exceptions mentioned under northupite, only detached crystals have been observed, and they were probably formed in the same part of the deposit which yielded the northupite. Unfortunately, pirssonite must be classed among the rare minerals; but it is hoped

that, as explorations are carried on, it will be found in other parts of the deposit.

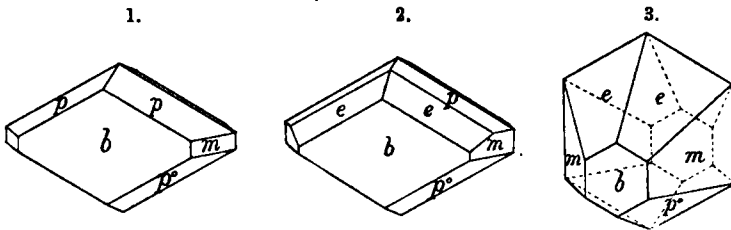
Crystalline form.—The mineral crystallizes in the orthorhombic system and is hemimorphic in its development. The hemimorphic axis has been taken as the vertical one, and the forms which have been observed are as follows :

b , 010	p , 111	e , 131
m , 110	p° , 11 $\bar{1}$	α , 311

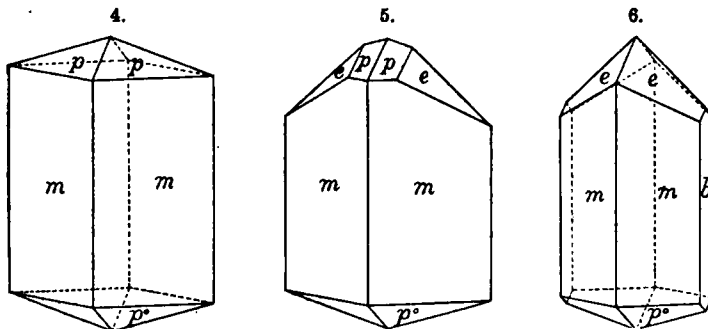
The axial ratio, derived from the measurements marked by an asterisk in the table beyond, is as follows :

$$a : b : c = 56615 : 1 : 3019.$$

Although the forms are not numerous the crystals show a



considerable variety in habit. Figs. 1 and 2, drawn with 010 in front, in order to show the shape better, represent the prevailing types. The pyramid e is developed at one extremity of the vertical axis only, and varies much in size. Often e alone terminates the upper end of the crystals, figs. 3 and 6. The pinacoid b is sometimes wanting as represented by figs. 4 and 5. The pyramid α was observed on only a single fragmentary crystal and is not represented in the figures. The



crystals vary much in size; the smaller ones, averaging about 5^{mm} in greatest diameter, usually have the habit represented by figs. 1 and 2; while the larger ones, sometimes 15^{mm} in length, are usually developed like figs. 4 and 5. The larger

prismatic crystals are often only well terminated at that end where the e faces occur.

The following table includes a list of the measured and calculated angles.

As the reflections were not always very perfect, the extremes of two or more independent measurements are given.

		Measured.		Mean.	Calculated.
$p \wedge p''$	111 \wedge 111	62°57'	—63° 3'	*63° 0'	
$m \wedge m'''$	110 \wedge 110	59°	—59° 4'30"	*59° 2'	
$p \wedge b$	111 \wedge 010	74°51'30"	—75° 7'	75° 1'33"	75° 5'
$p \wedge m$	111 \wedge 110	58°32'	—58°47'	58°38'15"	58°30'
$p \wedge p'$	111 \wedge 111	53°57'	—54° 5'	53°59'36"	54° 6'
$p \wedge p'''$	111 \wedge 111	29°54'	—29°59'30"	29°57'30"	29°50'
$b \wedge e$	010 \wedge 131	51°14'	—51°43'	51°26'50"	51°22'
$e \wedge e'''$	131 \wedge 131	76°56'	—77°12'	77° 4'	77°16'
$x \wedge x''$	311 \wedge 311	18°12'48"		18°12'48"	18°10'30"
$x \wedge m$	311 \wedge 110	36°44'	—36°45'	36°44'30"	36°15'20"
$x \wedge m'''$	311 \wedge 110	49°26'	—49°23'	49°24'30"	49°24'

Physical properties.—The crystals are extremely brittle, breaking with a conchoidal fracture, but with no apparent cleavage. The luster is vitreous. They vary from colorless to white, but are often darkened by impurities. The hardness is between 3 and 3.5. The specific gravity, taken by means of the heavy solution, was found to be 2.352.

The crystals exhibit the phenomena of pyroelectricity in a marked degree. While cooling, after being gently heated, the extremity upon which the acute pyramid e , 131, is developed, became negatively electrified. This was shown by dusting with a mixture of red oxide of lead and sulphur, as recommended by Kundt.*

Optical properties.—The plane of the optic axes is the base, and the axis b is the acute bisectrix. The optical orientation is $a = a$, $b = c$ and $c = b$. The double refraction is positive and strong. The dispersion is slight $\rho < v$.

For the determination of the indices of refraction the method of total reflection was employed, making use of a crystal upon which a large pinacoid face, b , 010, was developed. The plate was measured in a monobromnaphthalene, whose index of refraction for yellow, Na, was found to be 1.6588 at 23° C. The values obtained were:

$$\begin{aligned} \text{For yellow, Na, } \alpha &= 1.5043 \\ \beta &= 1.5095 \\ \gamma &= 1.5751 \end{aligned}$$

By means of the three indices of refraction the value of $V_{a,y}$ was calculated and found to be 16° 24'.

* Ann. d. Phys. u. Chem, xx, p. 592, 1883.

With a prism of $56^{\circ} 41'$, whose faces were approximately parallel to 110 and $\bar{1}\bar{1}0$, the values of β and γ for red, Li; yellow, Na; and green, Tl, were also obtained.

	β	γ
Red	1.5058	1.5710
Yellow	1.5084	1.5747
Green	1.5115	1.5789

The value of β for yellow is probably not as accurate as that obtained by means of total reflection.

The divergence of the optical axes, $2E$, was measured on a plate parallel to 010. The values that were obtained are as follows:

	Red, Li.	Yellow, Na.	Green, Tl.
$2E$ at $25^{\circ}C.$ =	$47^{\circ}45'$	$48^{\circ}14'$	$48^{\circ}22'$
Hence $2V$ =	$31^{\circ}11\frac{1}{2}'$	$31^{\circ}26'$	$31^{\circ}27'$

The value of $V_{\alpha, \gamma}$ is $15^{\circ} 43'$ and agrees favorably with the value $16^{\circ} 24'$ obtained by calculation from the three indices of refraction.

It was observed that the angle $2E$ varied somewhat, and to determine to what extent this was dependent upon the temperature the following measurements were made:

Temperature	$20^{\circ}C.$	30°	40°	50°	60°	70°	90°
$2E,$	$= 48^{\circ}16'$	$48^{\circ}10'$	$48^{\circ}4'$	$47^{\circ}55'$	$47^{\circ}50'$	$47^{\circ}45'$	$47^{\circ}38'$

Chemical composition.—Suitable material for analysis was readily obtained and the results are as follows:

	I	Found.	Average.	Ratio.	
CO_2	36.23	35.91	36.07	.819	= 2.00
CaO	23.28	23.48	23.38	.417	= 1.02
Na_2O	25.69	25.71	25.70	.414	} .416 = 1.02
K_2O .....	.17	.13	.15	.002	
H_2O	14.74	14.73	14.73	.818	= 2.00
Al_2O_3 , etc. ..		.13	.13		
SiO_2 .....	.36	.22	.29		

100.45

The ratio for $CO_2:CaO:Na_2O:H_2O$ is very close to 2:1:1:2, which gives the formula $CaCO_3.Na_2CO_3.2H_2O$. The theoretical composition is given below, together with the analysis, after deducting impurities, substituting for K_2O its equivalent of Na_2O and recalculating to 100 per cent.

	Found.	Calculated for.
CO_2	36.08	$CaCO_3.Na_2CO_3.2H_2O.$ 36.36
CaO	23.39	23.14
Na_2O	25.80	25.62
H_2O	14.73	14.88
	<hr/> 100.00	<hr/> 100.00

The chemical composition of this mineral differs from gaylussite, $\text{CaCO}_3 \cdot \text{Na}_2\text{CO}_3 \cdot 5\text{H}_2\text{O}$, in having only two instead of five molecules of water of crystallization. Experiments that were made to determine at what temperature the water is driven off from the air-dry powder are as follows:

	Loss.
Six hours at 100°	Nothing
Ten hours at 150°	13·85
Three hours at 200° .....	.37
Six hours at 250°	·36
Below faint redness	·16
<hr/>	
Total	14·74

As practically all of the water is expelled below 150°, it must be regarded as water of crystallization.

In analysis I the water was weighed directly by the method described by Penfield,* and in II it was determined by loss on gentle ignition.

Pyrognostics.—The mineral decrepitates, when heated before the blowpipe, and fuses about 2—2·5, coloring the flame intensely yellow. It reacts alkaline after heating. In the closed tube it decrepitates and gives off water at a low temperature. It is soluble in cold dilute hydrochloric and nitric acids with effervescence.

Name.—The author takes pleasure in naming this mineral *pirssonite*, in honor of his friend and associate, Prof. L. V. Pirsson, of the Sheffield Scientific School.

Gaylussite.

The only reference that the author has been able to find to gaylussite from this region is in an article by Hanks,† who mentions the mineral as occurring in crystalline masses, but not in distinct crystals. There must have been some mistake in identification, however, for as pointed out by Pirsson,‡ the reactions which are ascribed to the mineral are impossible ones for a compound with the chemical composition of gaylussite.

According to information received from Mr. Northup, the gaylussite occurs abundantly at this locality. It is found in many parts of the deposit and at varying depths. All of the specimens that have been supplied by Mr. Northup have, moreover, been distinct crystals.

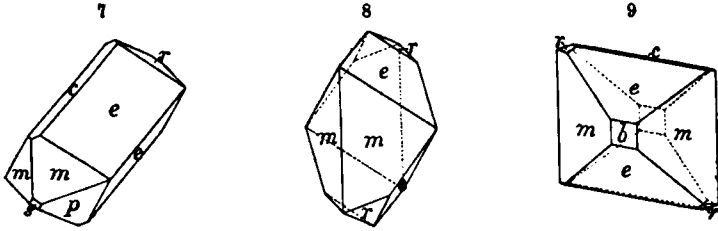
Crystallization.—The forms that have been observed are as follows:

<i>b</i> , 010	<i>m</i> , 110	<i>e</i> , 011
<i>c</i> , 001	<i>s</i> , 101	<i>r</i> , 112

* This Journal, xlviii, p. 31, 1894.

† Mining and Scientific Press, Mar. 26, 1892.

‡ Zs. Kr., xxiii, p. 504, 1894.



Three types of crystals have been observed, represented in figs. 7, 8 and 9. The largest crystals, sometimes 20^{mm} in greatest diameter, are developed like fig. 7, but the faces are generally rough. Crystals, with the habit shown in fig. 8, are seldom over 10^{mm} in diameter. Only a few crystals of the third type, fig. 9, were observed, and in order to show the development of the faces to better advantage, the figure has been drawn with the pinacoid, $b\ 010$, in front. It is only on crystals of the latter type that the pinacoid b , which is apparently an unusual form on gaylussite, is developed. Although many of the crystals are colorless and transparent, many are cloudy, owing to impurities.

The forms were identified by the following measurements, the calculated angles being derived from the axial ratio established by Phillips: *

$$a : \bar{b} : c = 1.4897 : 1 : 1.4442; \beta = 78^\circ 26\frac{1}{2}' = 001 \wedge 100.$$

		Measured.	Calculated.
$m \wedge m''$	$110 \wedge 1\bar{1}0$	$111^\circ 8'$	$111^\circ 10'$
$m \wedge e$	$110 \wedge 011$	$42^\circ 5\frac{1}{2}'$	$42^\circ 21'$
$e \wedge e$	$011 \wedge 0\bar{1}1$	$109^\circ 34\frac{1}{2}'$	$109^\circ 30'$
$e \wedge r$	$011 \wedge \bar{1}12$	$27^\circ 7'$	$27^\circ 44'$
$r \wedge r$	$\bar{1}12 \wedge \bar{1}\bar{1}2$	$69^\circ 33'$	$69^\circ 29'$
$r \wedge s$	$1\bar{1}2 \wedge 101$	$39^\circ 49'$	$40^\circ 21'$

The measurements could not be made very accurately, as the small crystals did not give very good reflections of the signal on the goniometer, while the larger ones could only be measured with the contact goniometer.

The specific gravity of some of the purest crystals, obtained by means of the heavy solution, is 1.992. This is somewhat higher than is usually given for this mineral. Phillips,† however, gives practically the same value, 1.990, for a remarkably brilliant crystal upon which he made his crystallographic determinations.

Optical properties.—The principal work on the optical properties of this mineral is that by Des Cloizeaux‡ who determined the angle of extinction on the pinacoid $b\ 010$, the apparent

* Philos. Mag. i, p. 263, 1827.

† Ibid., p. 265, 1827.

‡ Ann. d. Mines, V, xiv, p. 400, 1858.

axial angle $2E$, and the character of the double refraction and dispersion. The exceptional purity of the material at hand rendered it possible to make more complete determinations. From a plate cut parallel to 010 the extinction $c \wedge c$ or Bx , was measured in yellow light and found to be about $14^\circ 52'$ from the vertical axis, in the acute angle β . For red the angle was about one degree greater.

These values cannot be regarded as very exact, as the specimens, which were best adapted for optical work, did not show very perfect crystal outline. They differ, however, only slightly from the values given by Des Cloizeaux,* $c \wedge c$ or Bx , for red = $14^\circ 48'$ and for blue = $13^\circ 8'$.

The acute bisectrix is normal to 010 and the following values of the apparent axial angle were obtained :

Red, Li.	Yellow, Na.	Green, Tl.
$2E$ at $26^\circ C = 51^\circ 26'$	$52^\circ 7\frac{3}{4}'$	$52^\circ 47\frac{3}{4}'$

These values agree closely with those obtained by Arzruni,† which are as follows :

Red, Li.	Yellow, Na.	Green, Tl.
$2E = 51^\circ 25'$	$52^\circ 19'$	$52^\circ 58'$

Des Cloizeaux gives : $2E = 51^\circ 38'$ for red and $52^\circ 53'$ for blue.

Crossed dispersion could be distinctly observed and the character was $\rho < v$. The double refraction is negative and strong. By means of total reflection the following values of the indices of refraction, for yellow light, Na, were obtained.

$$\alpha = 1.4435 \text{ Na.} \quad \beta = 1.5156 \text{ Na.} \quad \gamma = 1.5233 \text{ Na.}$$

From the foregoing values V_y was calculated and found to be $17^\circ 32'$, while $16^\circ 53'$ was obtained from the values of $2E_y$ and β .

Des Cloizeaux has shown that the axial angle varies considerably with the temperature, and a series of experiments has been made to illustrate this, the results of which are shown in the following table :

Temperature.	Apparent Angle. $2E_y$. Na.	Temperature.	Apparent Angle. $2E_y$. Na.
$22^\circ C$	$52^\circ 6'$	$60^\circ C$	$54^\circ 7'$
30°	$52^\circ 32'$	70°	$54^\circ 43'$
40°	$52^\circ 54'$	80°	$55^\circ 13'$
50°	$53^\circ 26'$	90°	$55^\circ 48'$

The maximum variation from 22° to $90^\circ C$. is therefore $3^\circ 42'$.

* Ann. d. Mines, V, xiv, p. 400, 1858.

† Zs. Kr., vi, p. 24, 1882.

For red, Des Cloizeaux measured $51^{\circ} 50'$ at 21.5°C. and $53^{\circ} 32'$ at 71.5° , a variation of $1^{\circ} 42'$.

Hanksite.

This mineral was first identified in 1885 by Mr. W. E. Hidden,* who observed some crystals with hexagonal habit marked thenardite, in the mineral exhibit from California, at the World's Industrial and Cotton Centennial Exposition, held in New Orleans. Upon examination these crystals proved to be a new mineral, to which the name, *hanksite*, was given in honor of Mr. H. G. Hanks, formerly State Mineralogist of California.

The mineral occurs at Borax Lake in many places. According to information received from Mr. Northup, short crystals with prominent basal planes are found near the surface, either attached to the under side of the crust, already referred to on page 124 of this article, or in the mud directly beneath this. The habit of these crystals is illustrated by figures in the articles by Hidden and Hanks.† Beneath the crust, for a distance of about 50 feet, hanksite crystals are rare, but at this depth a stratum of mud was encountered, containing a few crystals with a habit somewhat resembling quartz, shown in fig. 10. The crystals were etched to such an extent that they could not be measured with the reflection goniometer, but by means of the contact goniometer the forms were identified as the prism m , $10\bar{1}0$, and the unit pyramid o , $10\bar{1}1$.

Optical properties.—As the indices of refraction of hanksite had not been determined, a basal section was prepared from a tabular crystal, and by means of total reflection the following values were obtained:

For yellow, Na, $\omega = 1.4807$. $\epsilon = 1.4614$.

The section showed a normal uniaxial interference figure and a strong negative double refraction.

Chemical composition.—Our knowledge concerning the chemical composition of hanksite is confined to two analyses. One by Mackintosh, quoted by Hidden,‡ from which the formula, $4\text{Na}_2\text{SO}_4 + \text{Na}_2\text{CO}_3 + \frac{1}{2}\text{NaCl}$ was derived. Sodium chloride, however, was regarded as non-essential and $4\text{Na}_2\text{SO}_4 + \text{Na}_2\text{CO}_3$ was suggested as the probable formula. It should be pointed out, however, that a mistake in the calculation of the analysis was made, for while the ratio of $\text{Na}_2\text{SO}_4 : \text{Na}_2\text{CO}_3 : \text{NaCl}$ is given as $3.95 : 1.46$ or $4 : 1 : \frac{1}{2}$, it should have been

* This Journal, xxx, p. 33, 1885.

† Ibid., xxxvii, p. 66, 1889.

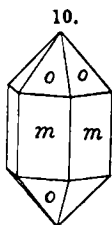
‡ Ibid., xxx, p. 134, 1885.

4.6 : 1 : .53. The analysis is also incomplete since the bases are calculated wholly as soda.

An analysis has also been made by Penfield * on material from a large crystal presented to the Brush collection by the late Prof. J. S. Newberry. It was quite impure, apparently owing to included clay, the analysis giving 4.41 per cent. of insoluble material and 1.32 per cent. loss on ignition. In addition to sodium, 2.33 per cent. of potassium was determined, which is just sufficient to unite with the 2.13 per cent. of chlorine to form potassium chloride. An examination of a section of this crystal by Prof. E. S. Dana † showed numerous rectangular inclusions, supposed to be either sodium or potassium chloride. The material was regarded as too impure to warrant the establishment of a complicated formula, and the results of the analysis, after deducting the insoluble material, loss on ignition and KCl, approximated to the formula $4\text{Na}_2\text{SO}_4 + \text{Na}_2\text{CO}_3$, suggested by Mackintosh.

In making the optical examination of the hanksite it was observed by the author that although the sections, when examined with the microscope, showed trifling impurities, nothing of an isometric character could be detected. Moreover, on testing numerous crystals for chlorine, it was found to be invariably present, and since the results by Penfield and Mackintosh have shown that the mineral contains an amount of chlorine corresponding to over 4 per cent. of sodium or potassium chloride, it is not possible that either of these latter compounds could be present to such an extent, as an impurity, without being detected with the microscope. It was suggested, therefore, by Prof. Penfield, that new analyses, made on the exceptionally pure material now at hand, might indicate that chlorine is an essential constituent of the mineral.

Some flat tabular crystals were, therefore, selected, and in order to free them as far as possible from any impurities they might contain, they were crushed and sifted to a uniform grain and separated by means of methylene iodide. Most of the material varied in specific gravity between the narrow limits 2.567 and 2.553, and this was used for the analysis.



The prismatic crystals, fig. 10, derived from the stratum of mud fifty feet below the surface, appeared even purer than the above, and, fortunately, enough of these had been supplied by Mr. Northup for an analysis. The specific gravity was found to be 2.545.

The results of the analyses of the two samples are as follows :

* This Journal, xxx, p. 137, 1885.

† Loc. cit.

	Tabular Crystals.		Average Ratio.		Prismatic Crystals.	
	I.	II.			III.	Ratio.
SO ₃	45.89	45.98	45.93	.574 = 9'	45.78	.572 = 9'
CO ₂		5.65	5.65	.128 = 2.01	5.63	.128 = 2.01
Na ₂ O	43.27	43.43	43.35	.699 = 10.95	43.61	.703 = 11.07
Cl		2.21	2.21	.062 = .97	2.28	.064 = 1.01
K	2.40	2.55	2.48	.063 = .98	2.39	.061 = .96
Insol.	.22	.16	.19		.12	

The analyses are almost identical, indicating that chlorine and potassium are not accidental constituents. The ratios of SO₃:CO₂:Na₂O:Cl:K are very close to 9:2:11:1:1 corresponding to the formula 9 Na₂SO₄ + 2 Na₂CO₃ + KCl.

Of the previous analyses, that of Mackintosh yields the ratio of SO₃:CO₂:Cl = 9:1.93:1.04, fully supporting the above formula, but no further comparison can be made, as the bases were calculated wholly as soda. The analysis of Penfield gives the ratio SO₃:CO₂:Na₂O:Cl:K = 9:2.03:10.89: .99: .99, which is fully in accordance with the above formula.

Further, in order to show the close agreement between the analytical results and the theoretical composition, the analyses with the exception of that of Mackintosh are given below, after deducting impurities and recalculating to 100 per cent.

	Tabular Crystals.	Prismatic Crystals.	Penfield's.	Theory.
SO ₃	46.11	45.92	46.21	46.02
CO ₂	5.66	5.65	5.74	5.62
Na ₂ O	43.53	43.74	43.32	43.59
Cl	2.215	2.29	2.26	2.26
K	2.485	2.40	2.47	2.49
	100.00	100.00	100.00	100.00

With the close agreement of these three complete analyses, together with the partial one of Mackintosh, made on entirely different samples, on crystals collected at different times and from different parts of the deposit, there can be no doubt that both potassium and chlorine are essential constituents of the compound and the somewhat complicated formula, 9Na₂SO₄. 2Na₂CO₃. KCl is the correct one. It is scarcely possible that potassium and sodium are isomorphous in this mineral, for potassium seems always to be present in quantity just sufficient to form KCl with the chlorine. The compound furnishes a very interesting example of the exceptionally rare occurrence of three acid radicals in a mineral.

In conclusion, the author wishes to express his indebtedness to Prof. S. L. Penfield for his valuable advice and assistance, and also for his very kind interest in the work, throughout the entire investigation.