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June 28, 1911

NEOCOLEMANITE, A VARIETY OF
COLEMANITE, AND HOWLITE FROM
LANG, LOS ANGELES COUNTY,
CALIFORNIA

BY

ARTHUR S. EAKLE

BERKELEY

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NEOCOLEMANITE

Occurrence.—A deposit of calcium borate occurs at the head of a valley about five miles northwest of Lang, a station of the Southern Pacific railway in Los Angeles County, which is owned and now mined by the Sterling Borax Company of Los Angeles. The borate is known as colemanite and in its chemical composition and general physical properties it agrees with the colemanite from the Death Valley and Calico districts, but in its optical and crystallographical properties it is somewhat different, so the name *neocolemanite* is proposed to distinguish it as a variety of colemanite.

The mineral occurs as a stratified deposit, the strata alternating with layers of black carbonaceous shales, and the main seam of the solid mineral is from six to ten feet thick. A northern uplift has tilted the deposit so that the bands of mineral and shale stand almost vertical, the dip being about 80° south. The shales underlying the mineral layers are of considerable thickness, while above the deposit are heavy bedded sandstones. These sandstones show efflorescences of white alkali salts along their seams and bedding planes.

The shafts and mining operations are carried down on the main seam of the mineral and they are now down 250 feet with no apparent change in the dip or width of the bed. The lateral extent of the deposit is not yet determined, but it is evident that an extensive deposit of the pure borate exists. A narrow-gauge road connects the mine with Lang and all of the material is hauled to this station and shipped to Chicago and San Francisco. The poorer grade is separated from the gangue and impurities by calcination at the mine and then shipped in sacks.

Origin of the deposit.—The bedded character of the deposit is evidence that the mineral crystallized from an evaporating solution and that precipitations of both the borate and some of the silt which formed the shales took place. The solution filled a closed basin as a lake or marsh, probably similar to the alkali marshes of the desert regions. It is generally characteristic of such deposits that salts of various kinds, often in alternating

series, especially carbonates and sulphates of lime and soda, make up the deposit, and the well-known Searles Borax Lake in San Bernardino County, with its many associated minerals, is a good illustration of a desert formation. The Lang deposit, however, is an exception, as the neocolemanite is practically unaccompanied by other minerals except howlite, which is a silico-colemanite, and some calcite. Waters emptying into the basin could not have been charged with mixed alkali salts.

It seems probable that the original site of the deposit was a marsh containing marl and calc tufa with mud and considerable organic growth, and that later waters charged with boracic acid flowed into the basin and converted the carbonate of lime into the borate. Some and perhaps the greater part of the argillaceous material which forms the shales was precipitated by the decomposition of the impure limestone, together with organic matter. The carbon dioxide set free may not wholly have escaped, but possibly became occluded in the mud and later converted into carbon. Most of the borate is of a blackish gray color, due to impregnations of carbon along the cleavages and fractures. The conversion of the limestone into the borate in all probability took place before the overlying sandstones were formed. The absence of soda compounds and the presence of abundant plant life indicate that the lake or marsh was fresh into which springs containing boric acid discharged. The deposit later became submerged and the sandstones were laid down.

The origin of the boric acid is presumably volcanic and the springs probably issued from vents in the immediate vicinity of the basin. The deposit is situated in a hilly district and is partly surrounded by high masses of volcanic tuffs and rhyolites. The subsequent tilting of the deposit was not accompanied by heat or pressure sufficient to modify the borate materially, yet the mineral shows lines of strain and columnar partings due to pressure and shrinkage. The fissile shales owe their solidity to this slight pressure, and carbonization to some extent was also the result. The reduction of the occluded carbon dioxide may have been brought about through the decomposition of organic material deposited in the basin. There is, of course, the possi-

bility that all of the carbon in the deposit is from organic matter, the CO_2 of the carbonate escaping, as some of the shales are quite bituminous.

Structure of the mineral.—The neocolemanite is massive crystalline with a very glassy luster and eminent clinopinacoidal cleavage. It has also a distinct basal cleavage, yet does not part readily in this direction. This basal cleavage can be seen as lines on the clinopinacoid and is a very important help in the proper orientation of the crystals, because the angles for the positive faces are quite similar to those for the negative. The clinopinacoidal cleavage is so prominent that practically all of the mineral comes from the mine in cleaved fragments and cleaved masses. Specimens with a divergent columnar structure, the columns curving into fan-like shapes, are frequently found. A peculiar fibrous form of the lime borate with a satin luster occurs in the main shaft, which strongly resembles satin-spar. Crystals are comparatively rare and only a few good specimens were obtainable.

Crystal habits.—The crystals occur thickly grown together and firmly attached to the massive mineral. In general they are so attached that either the right or left half of the crystal can be seen. They range from several millimeters to more than a centimeter in width. Three distinct habits occur, each on a distinct type of the massive material. Crystals of Habit 1 are large, white, and translucent, lining the inner surface of a geode. They are the simplest type of the crystals, consisting mainly of the combination of the unit prism (110) and the clinodome (011). This habit is shown in figure 1, plate 30. Habit 2 is more common. The crystals are pale brown and nearly transparent, and possess the largest combination of forms. The predominating forms are the unit prism and clinodome, like in Habit 1, but the ends of the *b*-axis are invariably terminated by a group of small faces, as seen in figure 2. A more general combination of forms on this type is shown in figure 3. Habit 3 is totally dissimilar to the others. The crystals are white or colorless, occurring in small cavities in a white and coarsely granular variety of the mineral. In this habit the unit prism is elongated vertically and terminated

by the two faces of a low negative pyramid ($\bar{2}23$). Other forms are also present on most of the crystals but are much subordinate in size. This habit is shown in figure 4.

Forms.—Crystals of colemanite from Calico and Death Valley have been described by Jackson¹ and also by the writer² and about fifty forms have been determined for that mineral. The neocolemanite has eighteen forms and seven of them have no correspondence on colemanite. These seven forms are represented by excellent faces and most of them are common for the type. Readings were also obtained for other faces from which no satisfactory symbols could be deduced, so they are not included. The forms are arranged in the list below, those not found on colemanite being designated by an asterisk.

Letter	Symbol		Letter	Symbol		Letter	Symbol	
	Gdt.	Miller		Gdt.	Miller		Gdt.	Miller
<i>c</i>	0	001	κ	01	011	o	+ 2*	221
<i>b</i>	0 ∞	010	<i>a</i>	02	021	q	- 6*	$\bar{6}61$
<i>a</i>	$\infty 0$	100	<i>h</i>	-20	$\bar{2}01$	<i>v</i>	- 2	$\bar{2}21$
<i>t</i>	2 ∞	210	<i>W</i>	-30	$\bar{3}01$	tw	- $\frac{2}{3}$ *	$\bar{2}23$
<i>m</i>	∞	110	ϵ	+24*	241	<i>o</i>	-21	$\bar{2}11$
I	$\infty \frac{3}{2}$ *	230	r	+23*	231	b	- $\frac{2}{3}$ 2*	$\bar{2}63$

The base and front pinacoid are very narrow when present, one of the brown crystals only being an exception, where the *b*-axis was elongated and the faces were wide. The natural faces of (010) are small and narrow.

The prism (210) is always a line face. The prism (230) occurs only on the brown crystals and is a common form.

The clinodome (011) is broad and often has a wavy structure. The dome (021) is a common form only on the brown crystals.

Of the two negative orthodomes, ($\bar{3}01$) is fairly common while ($\bar{2}01$) was observed only on crystals of Habit 2.

¹ A. W. Jackson. On the morphology of Colemanite. Bull. Cal. Acad. Sci., vol. 2 (1885), p. 3.

² A. S. Eakle. Colemanite from Southern California. This bulletin, vol. 3, no. 2 (1902).

The form (241) is common to the crystals of all three habits, and the forms ($\bar{2}23$) and ($\bar{2}63$) are common forms on Habits 2 and 3, but were not observed on crystals of Habit 1. The steep negative pyramid ($\bar{6}61$) is represented by one broad face on a brown crystal. The other pyramids are fairly common.

Referring to the gnomonic projection of the forms and zones as shown in plate 31, figure 6, it will be seen that the two zones of pyramids are missing where the values of $p_0 = +1$ and -1 , whereas in colemanite these two zones are well developed. On the other hand, the zone with $p_0 = +2$ occurs on neocolemanite and is missing on colemanite. There is also the additional zone with $p_0 = -\frac{2}{3}$, on these crystals.

Measurements of the crystals.—The two-circle goniometer was used for the measurements, and practically all of the readings were good. It was evident from the first crystal measured that the angles ϕ and ρ for the clinodomes and base were greater than those for colemanite, indicating that the vertical axis was longer and the forms steeper. This variation was constant for all crystals and the lowest values of ϕ and ρ were higher than the greatest values for the corresponding faces on colemanite.

Ten good crystals were chosen for the measurements and below is a table containing the number of measurements of each form, the averages of the readings, and the calculated values from the axial ratio determined. For comparison the calculated values of ϕ and ρ for colemanite for corresponding forms as determined by the writer³ and by Goldschmidt⁴ from Jackson's measurements, are also included.

³ *Loc. cit.*

⁴ V. Goldschmidt. *Krystallographische Winkeltabellen.*

No. of Mets.	Neocolemanite						Colemanite			
	Gdt.	Miller	Measured		Calculated		Eakle		Goldschmidt	
			ϕ	ρ	ϕ	ρ	ϕ	ρ	ϕ	ρ
9	0	001	90°00'	21°40'	90°00'	21°40'	90°00'	20°07'	90°00'	20°13'
20	0 8	010	0 00	90 00	0 00	90 00	0 00	90 00	0 00	90 00
9	8 0	100	89 58	90 00	90 00	90 00	90 00	90 00	90 00	90 00
31	8 8	110	54 09	90 00	54 10	90 00	53 53	90 00	53 57	90 00
12	2 8	210	70 08	90 00	70 08	90 00	69 58	90 00	70 00	90 00
10	8 1/2 3/8	230	42 41	90 00	42 43	90 00	.....	.....	.....	.....
9	02	021	19 58	49 22	19 53	49 26	18 38	48 54	18 57	48 50
19	01	011	35 53	34 07	35 53	34 08	34 00	33 13	34 13	33 13
4	-30	301	90 00	62 00	90 00	62 02	90 00	61 49	90 00	61 47
1	-20	201	90 00	48 15	90 00	48 20	90 00	48 18	90 00	48 14
15	24	241	41 10	71 09	41 08	71 04	.....	.....	.....	.....
5	23	231	49 20	68 25	49 20	68 25	.....	.....	.....	.....
13	2	221	60 12	65 43	60 12	65 40	.....	.....	.....	.....
1	- 6	661	51 32	79 39	51 39	79 21	.....	.....	.....	.....
7	- 2	221	45 52	57 31	45 40	57 32	45 56	57 22	45 58	57 18
9	- 2/3	223	16 47	20 50	16 42	20 55	.....	.....	.....	.....
9	- 2/3 2	263	5 24	47 47	5 42	47 53	.....	.....	.....	.....
2	-21	211	63 59	51 21	63 57	51 22	64 11	51 16	64 12	51 12

The pole of the crystals is almost midway between the normals to the base and rear dome ($\bar{1}01$), consequently the angles for positive terminal faces are quite similar to those for negative faces. If the neocolemanite is reversed in position so that all of the positive forms become negative and *vice versa*, then the readings would correspond closer to those for forms on colemanite, and only the forms (230), ($\bar{6}61$), ($\bar{2}23$) and ($\bar{2}63$) would be new, they becoming respectively (230), (561), (123), and (163). There would also be more correspondence in the optical orientation. However, the two minerals have a similar basal cleavage and it was by this cleavage that the crystals were oriented.

Determination of the polar elements.—The method of determining the values of e' , μ , β , p'_0 , q'_0 , e , p_0 , and q_0 is fully explained in the author's paper on colemanite, so will not be repeated here. The average of nine direct measurements on the base gave $\rho = 21^\circ 41'$; $e' = \text{tg}\rho = .3973$. Since $e' = \cot\mu$ then $\mu = 68^\circ 20'$ and $\beta = 180 - \mu = 111^\circ 40'$. An average of twenty-eight readings on the clinodomes gave $e' = .3973$, thus agreeing with the direct measurements.

The average of sixty-seven measurements gave $p'_0 = .7606$, and an average of ninety-five measurements gave $q'_0 = .5492$.

The values of these elements are therefore:

$$e' = .3974; \mu = 68^\circ 40'; p'_0 = .7606; q'_0 = .5492.$$

Since the mineral is monoclinic, the polar elements e , p_0 , and q_0 are obtained by multiplying the values e' , p'_0 , and q'_0 by the $\sin \mu$. The polar elements become therefore:

$$e = .3692; p_0 = .7069; q_0 = .5104.$$

Axial ratio.—The length of the axes c and a can be derived from the equations $c = q'_0$ and $a = \frac{q'_0}{p_0}$.

The axial ratio therefore for neocolemanite becomes:

$$a : b : c = 0.7771 : 1 : 0.5492; \beta = 111^\circ 40'$$

For colemanite the axial ratio is

$$a : b : c = 0.7768 : 1 : 0.5430; \beta = 110^\circ 07' \text{ Eakle.}$$

$$a : b : c = 0.7755 : 1 : 0.5415; \beta = 110^\circ 13' \text{ Goldschmidt.}$$

Optical orientation.—Neocolemanite is optically positive and the plane of the optic axes lies normal to the clinopinacoid as with colemanite, but in neocolemanite the axis of least elasticity makes an angle of about 42° with the vertical axis in the acute angle μ , whereas in colemanite this axis is inclined about 83° from the vertical in the obtuse angle β . The position of the acute bisectrix, determined with sodium light is as follows:

$$\text{Neocolemanite } c \wedge c = -42^\circ 30'$$

$$\text{Colemanite } \begin{cases} c \wedge c = +83^\circ 44' & \text{Hiortdahl.}^5 \\ c \wedge c = +82^\circ 34' & \text{Bodewig and vom Rath.}^6 \end{cases}$$

Indices of refraction.—The indices of refraction were determined with the "Abbe Totalreflectometer," using sodium light.

⁵ Th. Hiortdahl. Colemanit, ein krystallisirtes Kalkborat aus Californien. Zeitschr. für Kryst., 10 (1884), 25.

⁶ C. Bodewig und G. vom Rath. Colemanit aus Californien. *Ibid.*, 179.

They vary somewhat from those obtained by Mülheims⁷ for colemanite.

Neocolemanite $\alpha = 1.58185$; $\beta = 1.58746$; $\gamma = 1.60984$; $\therefore 2V = 54^\circ 36'$
 Colemanite 1.58626 ; 1.59202 ; 1.61398 ; $\therefore 2V = 54^\circ 52'$

The optic angle measured with sodium light gave for neocolemanite

$$2E = 95^\circ 22'; 2V = 55^\circ 32'$$

Chemical composition.—The analysis of the mineral shows that it does not differ from colemanite in composition, so the indicated morphotropy in the vertical direction is not due to a chemical replacement or change. The variety is simply an allotropic modification of colemanite brought about by a possible difference in the mode of crystallization.

In the analysis of the neocolemanite the boric oxide was determined by titration with standard sodium hydrate, using mannite to set free the boron. The calcium was determined both gravimetrically and volumetrically.

Analysis:

B ₂ O ₃	49.45%
CaO	27.76
H ₂ O	22.48
	99.69

Specific gravity = 2.423 at 13° C.

HOWLITE

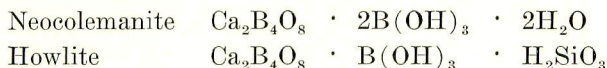
Occurrence.—The silico-borate of lime occurs in considerable quantity in the deposit, as large and small nodular masses embedded in the layers of the lime borate. The mineral is very compact with a fine flaky structure and a snow-white color. Black streaks of carbonaceous matter ramify through much of the compact round masses. The layers of neocolemanite are bent and curved around the knotty lumps of howlite, which appear like "Augen" in the banded borate. The surfaces of some of the nodules have a botryoidal structure, but no crystals have been found.

⁷ A. Mülheims. Colemanit von Californien. Zeitschr. für Kryst., 14 (1888), 230.

The mineral is soft and crushes easily to crystalline flakes and flour with no gritty particles. It is easily fusible, and completely soluble in dilute acid, yielding gelatinous silica on evaporation. Unlike colemanite or neocolemanite, it does not calcine to a white powder and cannot therefore be so readily separated from the gangue and carbonaceous impurities.

Origin of the mineral.—It is evident from the position of these masses of howlite in the deposit that the silico-borate was formed from the same evaporating solution and simultaneously with the crystallization of the neocolemanite. Granted that the original mineral was a siliceous travertine or marl acted upon by boracic acid then some of the silica became dissolved and formed metasilicic acid, which replaced the water of crystallization and boric acid that would otherwise have formed the neocolemanite. These nodular masses of howlite probably represent silico-borate segregations in the solution similar to magmatic segregations in the fused rock mass.

The similarity of the two minerals is more apparent if we express their composition as follows:



It would seem from this that the howlite was formed in the presence of silicic acid which was taken up in the place of water and boric acid, and the resultant silico-borate was precipitated more rapidly as finely crystalline masses.

Chemical composition.—The mineral was dissolved in dilute hydrochloric acid, the boron expelled by evaporation with methyl alcohol, and the silica and calcium determined gravimetrically. The boric oxide was obtained in the same way as in neocolemanite. The average analysis showed

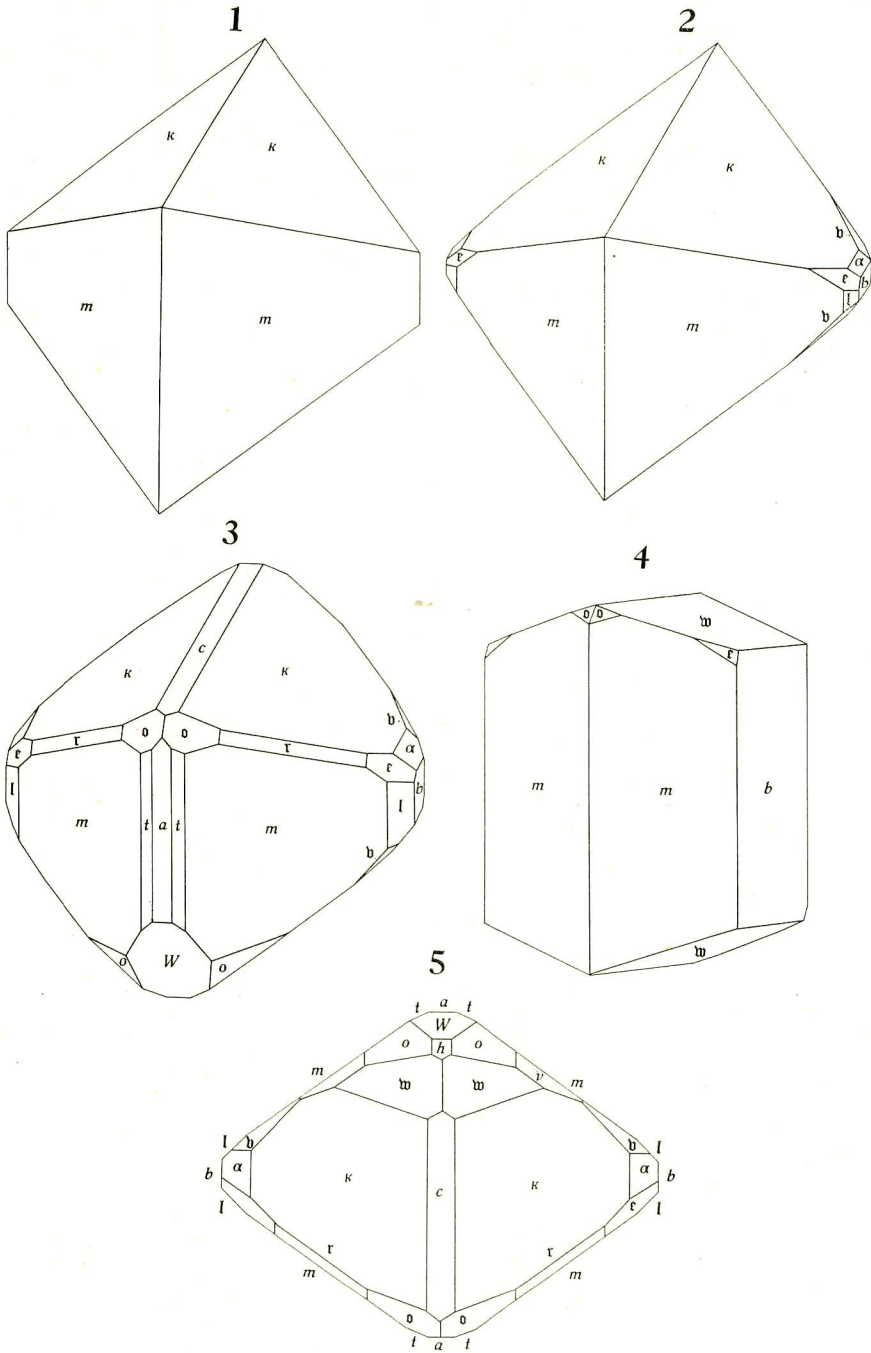
B_2O_3	45.56%
CaO	28.26
SiO_2	14.81
H_2O	11.37
	100.38

Specific gravity at 13° C = 2.531.

Associated calcite.—Specimens containing veins of crystallized calcite were recently collected from the main shaft by R. M. Wilke and kindly sent me. The mineral is both yellow and colorless, and the crystals exhibit three types of combinations. Most of the crystals are slender prisms terminated by rhombohedral faces. One type consists simply of the prism $(10\bar{1}0)$ and striated faces of the low rhombohedron $(01\bar{1}2)$. A second type shows the prism capped by large striated faces of the steep negative rhombohedron $(09\bar{9}5)$, narrow faces of $(01\bar{1}2)$, very narrow faces of the unit rhombohedron $(10\bar{1}1)$, and a small triangular base (0001) . The third type shows the prism capped by perfect faces of the unit rhombohedron $(10\bar{1}1)$ and striated faces of the negative rhombohedron $(02\bar{2}1)$, the two being in about equal development.

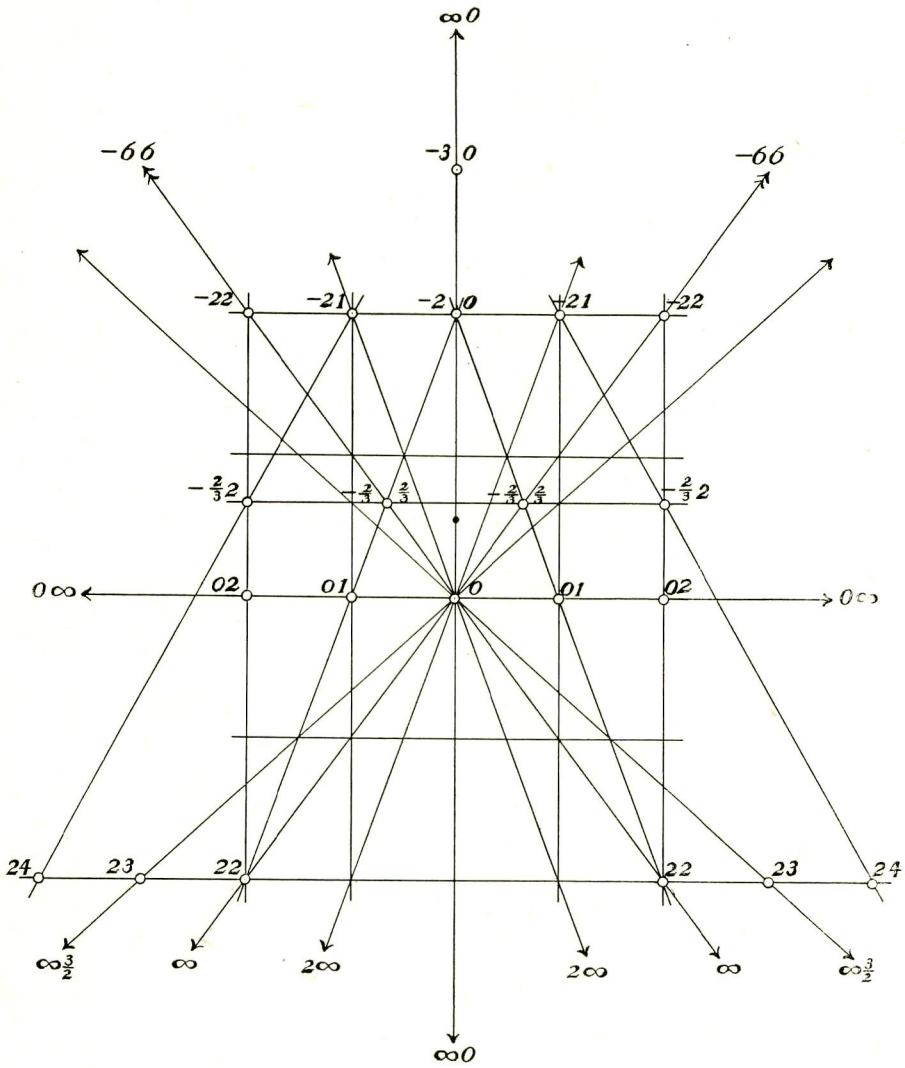
*Mineralogical Laboratory,
University of California.*

Transmitted March 9, 1911.



NEOCOLEMANITE FROM LANG, CALIFORNIA.

6



GNOMONIC PROJECTION OF NEOCOLEMANITE.

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