

## KRAUSITE, A NEW SULFATE FROM CALIFORNIA

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### INTRODUCTION

During a field study of the boron deposits of California and Nevada in 1929 there was found in the colemanite district of Borate, in the Calico Hills, San Bernardino County, California, a small deposit of sulfates of iron. This deposit was found to contain a fair abundance of a new sulfate of iron and potash not previously described. Earlier, in 1926, there was collected from the dumps of the Santa Maria mine, at Velardena, Durango, Mexico, a small amount of similar material which proves to be the same mineral. For this new mineral species the writer proposes the name *krausite*, in honor of Doctor Edward Henry Kraus, professor of crystallography and mineralogy and director of the Mineralogical Laboratory, University of Michigan.

### LOCALITY AND OCCURRENCE

The borax camp of Borate is situated six miles from the town of Yermo from which it is readily accessible by road. The camp has long since been abandoned and is now largely fallen into ruin. The road from Yermo follows the main Los Angeles-Salt Lake City Highway for a short distance, circles the eastern end of the Calico Hills and approaches Borate by way of a dry and sandy wash. The old road to Borate continued up this wash to a small side canyon from the southwest that led directly to the old camp but this is now washed out and the newer road swings south to an old railroad grade which it uses to the camp. At the point where the old road leaves the main wash is a prominent outcrop of dark banded cherts at the southern exposure of which is a small prospect hole containing the sulfate minerals. This body of salts was known to the borax miners and was generally referred to as the "sulfur" prospect, a fair abundance of yellow copiapite being mistaken for sulfur.

The rocks in the immediate vicinity of Borate are sedimentary, sandstones, shales, marls, fresh water algal limestones and related rocks resting upon a basement of rhyolite and capped unconformably by andesite tuffs, the "calico rock" of the old silver miners of the silver camp of Calico, a few miles to the west. Near the upper part of the exposed portion of the sedimentary beds is found the

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colemanite that produced the borax ore mined some years ago. The sulfate bearing cherts are several hundred feet stratigraphically below this but have no apparent connection with the borate deposits.

The sulfate body is a lenticular mass of mixed salts, probably not over 10 feet in thickness and the minerals contained therein, in the order of their relative abundance are: alunite, coquimbite, roemerite, voltaite, jarosite, halotrichite, krausite, metavoltite, fibroferrite, sulfur, gypsum, anhydrite and a few others that occur sparingly and are not yet fully determined. The salts are roughly zoned; the alunite occupies the foot wall and grades into sugary white coquimbite, while the center of the deposit and the hanging wall is made up of a complex aggregate of mixed salts. Krausite is found in small part in the alunite and coquimbite but more largely and in better specimens in the transition zone between the coquimbite and the mixed salts.

Krausite occurs in several different forms. That found in the alunite forms comparatively large but rough crystals, lacks transparency and often has a pale mauve color superimposed on the yellow of the purer mineral. It occupies nests and irregular cavities in the fine clay-like alunite or coquimbite. The krausite of the transition zone is in lemon yellow crystals, often clear and with brilliant luster. These crystals, rarely exceeding two or three millimeters, line cracks and are associated with colorless or purple coquimbite, brown crystals of roemerite, black cubes of voltaite and chestnut

ANALYSIS OF KRAUSITE FROM BORATE, CALIFORNIA  
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	1.	2.	3.
Insoluble	0.92		
CaO	0.12	.0021	
FeO	0.24	.0033	
Fe <sub>2</sub> O <sub>3</sub>	24.94	.1562	26.2
K <sub>2</sub> O	14.71	.1562	15.4
Na <sub>2</sub> O	0.64	.0103	
SO <sub>3</sub>	51.05	.6381	52.3
SiO <sub>2</sub>	2.19		
H <sub>2</sub> O	5.59	.3158	5.9
	100.40		
Sp. Gr. 2.840			

flakes of metavoltite. Rarely radiated blades of a dull yellow color are seen.

#### CHEMICAL PROPERTIES

For analysis clear crystals or groups of crystals were selected. A small amount of coquimbite, metavoltite, clay and an unknown hexagonal mineral contaminated the sample but in amounts aggregating less than one or two percent. The analysis and ratios derived therefrom are given above.

From these results it is quite evident that the insoluble matter, lime, ferrous oxide, silica and perhaps the soda should be deducted as extraneous matter; the remaining constituents giving, in a very satisfactory manner, the ratios:  $K_2O:Fe_2O_3:SO_3:H_2O = 1:1:4:2$ . The mineral is therefore a normal sulfate of iron and potash of the composition  $K_2SO_4 \cdot Fe_2(SO_4)_3 \cdot 2H_2O$ , the theoretical composition of which is given in Column 3.

Krausite is insoluble in water and is only slowly decomposed; crystals left for several days in water show only a superficial film of iron hydroxide. It is slowly but completely soluble in hydrochloric acid. Before the blowpipe the mineral decrepitates strongly coloring the flame violet. The mineral first becomes opaque, then assumes a red crust and finally is reduced to a black scoriaceous mass. In the closed tube it decrepitates in part, turns first ochreous yellow, then chestnut brown and finally fuses to a dull vesicular mass. Water that is strongly acid in character is given off.

#### CRYSTALLOGRAPHIC PROPERTIES

Krausite is found only as crystals or aggregates of crystals and abundant satisfactory material was available for measurement. The crystals seldom reach 5 millimeters in size and these are rough and deeply striated crystals from the alunite zone. The smaller crystals are often completely developed and are bright and often flawless. Numerous crystals were examined, a large number provisionally mounted on the goniometer and 16 were finally measured. These measurements show the crystals to be monoclinic in form but of several different habits. The recognized faces are:  $c(001)$ ,  $m(110)$ ,  $l(210)$ ,  $a(100)$ ,  $f(\bar{1}02)$ ,  $d(\bar{1}01)$ ,  $r(211)$  and  $s(\bar{1}12)$ . Not all these faces gave reflections suitable for crystallographic calculations although three,  $m$ ,  $c$  and  $d$  gave good to excellent signals. The measurements of these faces, used in the calculations are given in the following tables.

<i>m</i> (110)	<i>c</i> (001)	<i>d</i> (101)
33°19' (1)	12°24'	-43°00'
30 (1)	42	19
31 (2)	44	24
36 (3)	49	32
39 (1)	51	36
40 (2)	54	
43 (2)		Average -43°22'
45 (2)	Average 12°44'	
53 (1)		
59 (1)		
Average 33°39'		

From these measurements the following crystallographic elements have been calculated.

Linear elements	Polar elements
<i>a</i> = 1.5401	<i>p</i> <sub>0</sub> = 1.1419
<i>c</i> = 1.7584	<i>q</i> <sub>0</sub> = 1.7101
<i>β</i> = 102°44'	<i>e</i> = 0.2204
	<i>μ</i> = 77°16'

The measured and calculated angles for all the forms are as follows:

MEASURED AND CALCULATED ANGLES OF KRAUSITE

	Measured		Calculated	
	° φ ,	° ρ ,	° φ ,	° ρ ,
<i>c</i> (001)	90 00	12 44	90 00	12 44
<i>a</i> (100)	90 00	90 00	90 00	90 00
<i>l</i> (210)	52 59	90 00	53 50	90 00
<i>m</i> (110)	33 39	90 00	33 39	90 00
<i>d</i> (101)	90 00	-43 22	90 00	-43 21
<i>f</i> (102)	90 00	-19 45	90 00	-19 45
<i>r</i> (211)	-50 5	-69 43	-50 21	-69 49
<i>s</i> (112)	-24 20	-43 46	-22 18	-43 24

FORMS AND HABITS

The prism *m*(110) is often the largest form on the crystals but in some habits is considerably reduced in size although it is always present. It is always sharp and bright but often slightly rounded so that it gives a multiple signal.

The orthopinacoid *a*(100) is rarely present and then only as a narrow face; a prominent cleavage in this direction often gives small reflecting surfaces.

The base  $c(001)$  is always a prominent face on the crystals, sometimes occupying the entire crystal termination and usually it is the most prominent terminal face. It is always sharp giving good reflections although it is sometimes curved.

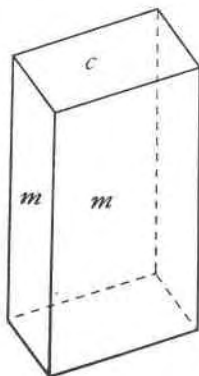


FIG. 1. Simple crystal of kausite with  $c(001)$  and  $m(110)$ .

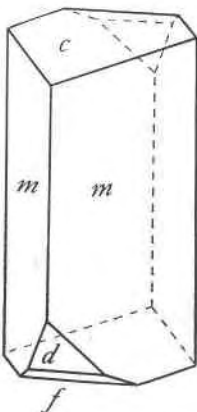


FIG. 2. Crystal of kausite with  $c(001)$ ,  $m(110)$ ,  $d(\bar{1}01)$ , and  $f(\bar{1}02)$ .

The two orthodomes  $d(\bar{1}01)$  and  $f(\bar{1}02)$  are often present but quite variable in size. The face  $d$  rarely exceeds  $c$  in size and is usually much smaller, while  $f$  is usually a small to medium sized face.

The prism  $l(210)$  is rare and found only as narrow faces.

The pyramids  $r(\bar{2}11)$  and  $s(\bar{1}12)$  are occasionally encountered but are always much rounded, yielding poor signals. The face  $s$  is often large. Both forms appear to be solution forms.

The habit of the crystals vary from long needle-like prisms to thin, flat wedges and there are all gradations between these two extremes. The commonest habit is a medium prismatic one, terminated by the base  $c$  (Fig. 1), the base  $c$  and the orthodome  $f$ , or the base  $c$ , orthodomes  $d$  and  $f$  (Fig. 2). By a reduction in the length of

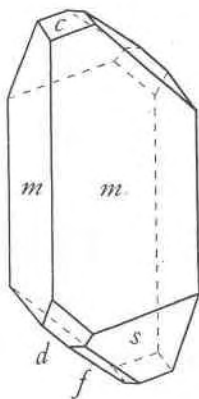


FIG. 3. Crystal of krausite with  $c(001)$ ,  $m(110)$ ,  $d(\bar{1}01)$ ,  $f(\bar{1}02)$  and  $s(\bar{1}12)$ .

the prism the crystals become more nearly equidimensional and sometimes assume a rhombic aspect. A still further reduction in the length of the prism gives a habit with a pyramidal development (Fig. 5), particularly if only  $c$  and  $f$  are the terminal faces and the prism is reduced to a point where these three faces join. The final



FIG. 4. Tabular crystal of krausite.

habit, brought about by the reduction of the prism is a thin wedge-shaped crystal (Fig. 4). The presence of large pyramidal faces gives a habit unrelated to the usual one. The base and orthodomes are reduced to small size, the crystal being usually terminated by large but curved faces of  $s(\bar{1}12)$  (Fig. 3).

A gnomonic projection of the crystal forms is shown in fig. 6.

## PHYSICAL AND OPTICAL PROPERTIES

The color of krausite is a pale yellowish green. The crystals are nearly pale turtle green (Ridgway) while the aggregated crystals are somewhat more gray, approaching lichens green. The luster is a bright vitreous one. Crystals are transparent and often flawless. Streak white. There are two good cleavages, the basal one being

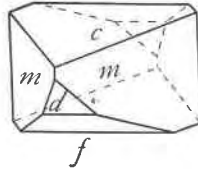


FIG. 5. Pseudo-pyramidal crystal of krausite.

perfect and the mineral readily splits along this direction into thin plates. A second cleavage parallel to  $a(100)$  is good; the combination of these two cleavages causes the mineral to be easily broken into rods and shreds. The hardness is 2.5. The specific gravity, determined by floating clear crystals in a mixture of methylene iodide and carbon tetrachloride was found to be 2.840.

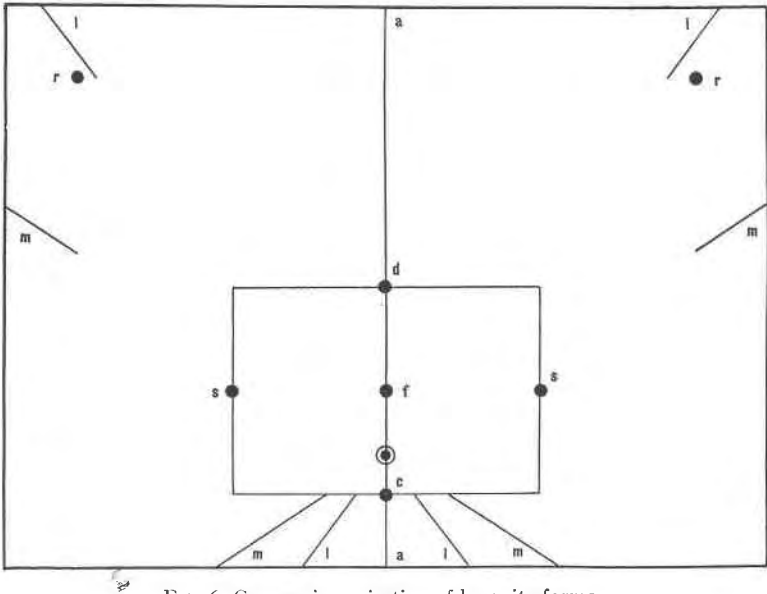


FIG. 6. Gnomonic projection of krausite forms.

Optically krasite is biaxial, positive, with a very large optic axial angle. The indices of refraction were found to be:  $\alpha=1.588$ ,  $\beta=1.650$ ,  $\gamma=1.722$ . The birefringence is high and the crushed fragments show numerous bands of color. The plane of the optic axes is normal to the plane of symmetry and the optical orientation is:  $Z=b$ ,  $X \wedge c=35^\circ$ . The optical orientation is shown in fig. 7. The pleochroism is weak but distinct in the thicker grains:  $X$  = colorless;  $Y$  and  $Z$  = pale yellow. Basal cleavage sections show no appreciable pleochroism and no distinct optical figure. The crystals

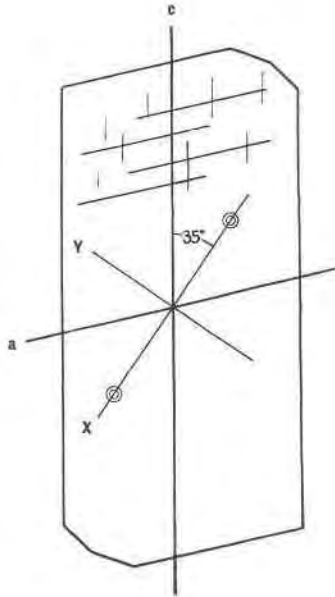


FIG. 7. Optical orientation and cleavage of krasite.

lying on the prism show the emergence of an optic axis just at the edge of the field, while the crystals lying on the clinopinacoid edge show the maximum extinction and an optical figure with a wide separation of the optic axes.

Due to paucity of material and unsatisfactory character of the mineral from Velardena, it was not studied in detail. Krasite from here is found as fine, drusy crusts of crystals of a pale greenish yellow color on blocks and in cracks in limestone, associated with voltaite, halotrichite and other iron minerals. The mineral has resulted from the oxidation of a considerable quantity of pyrite



thrown on the dump many years ago. This pyrite has given rise to a series of iron sulfates, of which copiapite is the most common. The krausite is confined to the material in close association with the fragments and blocks of limestone. The crystals are too small for crystallographic determination but the general appearance of the mineral, the approximate determination of its optical properties, its insolubility in water and its other chemical characters identify it quite satisfactorily as krausite.