ART. IX.—*Kempite, a New Manganese Mineral from California;* by AUSTIN F. ROGERS.

The new mineral described in this article was found by the writer in the so-called Alum Rock meteorite, a huge bowlder of manganese ore situated on the bank of Penitencia Creek in Alum Rock Park, which is about five miles east of the city of San José, Santa Clara County, California. During the autumn of 1918 when restricted shipping facilities created an urgent demand for domestic manganese ore, the bowlder or so-called meteorite was broken up and several hundred tons of high-grade manganese ore (averaging about 52 per cent metallic manganese) was obtained from it.

The minerals of this bowlder include tephroite, hausmannite, rhodochrosite, barite, pyrochroite, psilomelane, ganophyllite, and indefinite alteration products of tephroite. Recently a small amount of alabandite has been found here.

As has been shown by the writer,[1] this bowlder is not a meteorite, but simply a huge block of manganese ore which has rolled down from the surrounding hills in some past and probably remote period.

The kempite was first noted as minute euhedral crystals in cavities associated with pyrochroite crystals. Later it was found in small patches sporadically distributed through impure hausmannite. It is exceedingly rare and irregularly distributed.

Geometrical Crystallography.

The euhedral crystals of kempite are very small (1 to 2 mm. in longest dimension), singly terminated, and prismatic in habit. The crystal system is orthorhombic, presumably rhombic bipyramidal in symmetry. The forms present are five in number: *m*(110), *d*(011), *t*(121), *a*(100), and *b*(010). The dominant form always is *m*; *t*, though narrow, is characteristic, while *a* and *b* are usually absent and inconspicuous when present. A typical crystal is represented by fig. 1.

The best measurements were made upon a small crystal about 1.5 mm. long. They are as follows:

[1] This Journal, vol. 48, pp. 443-449, 1919.

Angle	Limits	No. Meas.	Average	Calc. Value
$d(011):d'(0\bar{1}1)=$	73°31′—73°35′	5	73°33′	———
$d(011):t(121)=$	36 18—36 41	10	36 30	———
$d(011):t'(\bar{1}21)=$	36 29	1	36 29	36 30
$d(011):m'(\bar{1}10)=$	70 36	1	70 36	70 23½

FIG. 1.

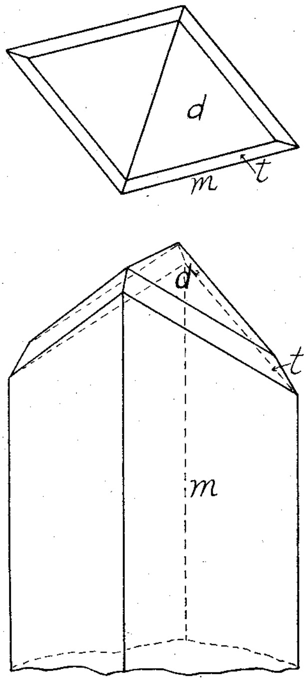

FIG. 1.—Typical kempite crystal; *m*(110), *d*(011), *t*(121).

The *m* faces were for the most part covered with an opaque brownish red coating and reflections could be obtained from only one of them.

From the two measured angles $(011:0\bar{1}1)=73°33'$ and $(011:121)=36°30'$, the following axial ratio was calculated: $a:b:c=0.677:1:0.747$. This was checked by a graphic determination made on a gnomonic projection which gave $a:b:c=0.67:1:0.75$.

The calculation of the axial ratio was a little out of the ordinary in that the unit value for the *a*-axis had to be obtained indirectly. The problem may be explained by referring to the stereographic projection of fig. 2. It was necessary to determine the symbol of *t* graphically. Since *t* is in the zone [*d*(011) :*m*(110)] a probable symbol for it is (121). This was confirmed, for the small circle *ctx*, the locus of all points 36°30′ distant from *d*,

FIG. 2.

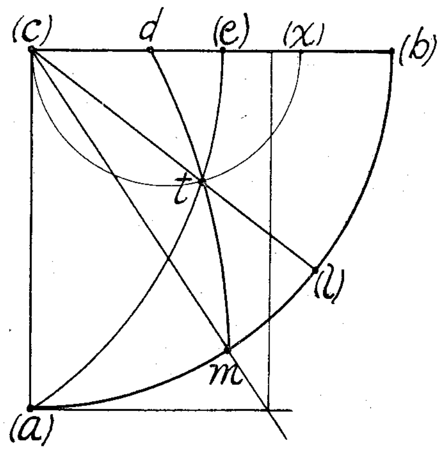

FIG. 2.—Stereographic projection of part of a kempite crystal; *m*(110), *l*(120), *e*(021), *d*(011), *c*(001), *t*(121), *a*(100).

intersected the arc of the great circle *ae* (*e* being the projection of 021) in the point *t* and the symbol of *l*, the *hk*0 face corresponding to *t* is 120. In the right-angled spherical angle *dte*, given the sides *de*(*ce*-*cd*) (*ce*, determined by the tangent formula) and *dt* (measured on the crystal), the side *te* is solved by Napier's rules. Next we have the right-angled spherical triangle *cte* in which the sides *ce* and *te* are known. By Napier's rules the angle *ect* may be calculated. This angle is the same as the angle *bl*(010:120), from which the unit on the *a*-axis may be calculated by the equation: $a=\frac{1}{2}\cot bl$.

The unit value for the *c*-axis was obtained directly from half the measured angle (011:0$\bar{1}$1).

Several other crystals were measured with the following results:

Angle		No.	Meas.	Calc.
Crystal 2	$d(011) : d'(0\bar{1}1)$	1	73°36′	73°33′
" 3	$d(011) : d'(0\bar{1}1)$	1	73 34	73 33
" 4	$m(110) : m'''(1\bar{1}0)$	1	68 29	68 12
" 4	$a(100) : m(110)$	1	34 12	34 6

Optical Properties.

The principal indices of refraction of kempite are: n_α=1.684±.001; n_β=1.695±.001; n_γ=1.698±.001; $n_\gamma - n_\alpha$=0.014±.002. These values were determined by the indirect immersion method; the first is the lowest of

FIG. 3.

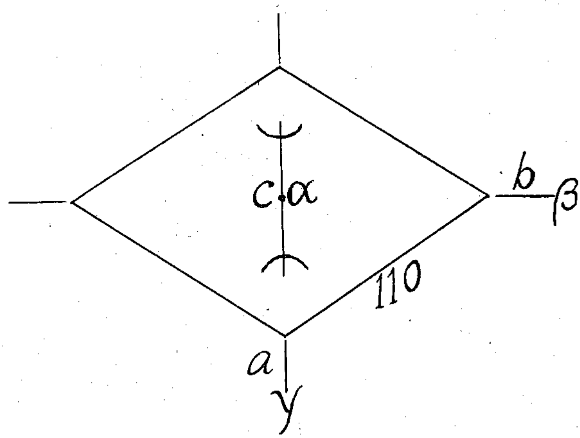

FIG. 3.—Optical orientation of kempite.

all the values obtained, the third, the highest, while the second or intermediate value is based upon the fact that it ($n\beta$) always lies between the two values n_1 and n_2 (or in rare cases coincides with one of them) obtained for any fragment. A Wratten orange filter E-No. 22 was used in lieu of monochromatic light for these determinations. Since the intermediate value is closer to the maximum value than it is to the minimum value, the mineral must be optically negative (this was later confirmed).

The optical orientation[2] of kempite is $a=\gamma$; $b=\beta$; $c=\alpha$; axial plane parallel to (010) as shown in fig. 3.

The orientation was obtained with some difficulty. A minute prismatic crystal in two positions gave elongation parallel to the faster ray when tested with the mica plate, so that the c-axis is α. Various methods to determine the position of β and γ were made without any degree of success until finally a rough section normal to the c-axis of a minute prismatic crystal was cut by a knife blade. For this rhombic section (fig. 3) the short diagonal proved to be the slower ray so that $a=\gamma$; hence $b=\beta$.

This same rhombic section gave a negative biaxial interference figure with its axial plane parallel to (010), which checks the above determination.

Physical Properties.

The color of kempite is emerald green. The hardness is about 3½. The specific gravity is about 2.94. This is an approximate value determined by the behavior of fragments in heavy liquids in comparison with minerals of known specific gavity.

Chemical Composition.

The kempite gives blowpipe tests for manganese and chlorine. In the closed tube it furnishes water which gives an acid reaction to litmus paper and turns black.

It is soluble in dilute nitric acid without any visible phenomenon. The solution gives a good test for chlorides with silver nitrate solution. Tests for other acid radicals all gave negative results.

It is soluble in dilute hydrochloric acid with the evolution of chlorine.

After the qualitative and optical tests were made, a very small amount of the mineral was available for quantitative determinations. The manganese and chlorine determinations were kindly undertaken for me by Crook. The water determination was made by the

[2] The symbols α, β, and γ are optical directions; n_α, n_β, and n_γ are the indices of refraction for these directions.

writer, the Penfield tube method being used. The results are shown in the following tabulation:

Analyses of Kempite by Welton J. Crook.

	I	II	III	IV		Theory for
	0.0296g.	0.0495g.	0.0181g.	Recalc.	Ratios	$Mn_4Cl_2O_6.3H_2O$
Mn	47.58	——	——	50.59	.928=4 x .232	49.86
Cl	——	15.59	——	16.41	.463=2 x .231	16.09
H_2O	——	——	11.60	11.60	.644=3 x .215	12.25
O*	——	——	——	(21.40)	1.337=6 x .223	21.80
Insol.	5.23	2.79		Total=100.00		Total=100.00

* By difference.

The results of the analyses lead to the empirical formula, $Mn_4Cl_2O_6.3H_2O$, which may also be written: $MnCl_2.3MnO_2.3H_2O$ or $MnCl_2.3H_2MnO_3$. Considering the small amounts used in the analysis the results check as well as could be expected. There is not much doubt as to the correctness of the empirical formula, but the constitution of the mineral is in doubt. There may be interpretations other than those indicated above.

Kempite is the only known manganese oxychloride; there are only four other minerals which contain manganese and chlorine as essential constituents: scacchite, chloromanganokalite, friedelite, and pyrosmalite. Of these, only the last two give water in the closed tube.

Origin of Kempite.—Kempite is closely associated with pyrochroite, hausmannite, and rhodochrosite. Rhodochrosite often surrounds kempite and is apparently an alteration product of it. The kempite also alters to an opaque brownish red substance which is probably not a distinctive mineral.

It would seem that kempite is about the same age as the pyrochroite; whether it is a product of hydrothermal activity or a product of deep-seated oxidation is uncertain.

The name *kempite* is given in honor of Professor James Furman Kemp, Professor of Geology at Columbia University.

Stanford University,
March, 1924.