THE CRYSTALLOGRAPHY AND CHEMICAL COMPOSITION OF CREEDITE.

By William F. Foshag,
Assistant Curator, Division of Mineralogy, United States National Museum.

INTRODUCTION.

The mineral creedite was found by Dr. E. S. Larsen, of the United States Geological Survey, in the fluorite deposits of Wagon Wheel Gap, Creede Quadrangle, Colorado, and was described by Larsen and Wells.[1] Since their description Doctor Larsen has collected a large suite of specimens which has now been deposited in the United States National Museum (Cat. No. 93117, U.S.N.M.). This material is better suited for study than the original and contains a number of specimens showing well-developed and measurable crystals. At Doctor Larsen's suggestion this mineral was further studied and the writer wishes to express his appreciation for the interest taken by that gentleman in this investigation.

OCCURRENCE.

The creedite was found in two modes of association. One type of occurrence is with fluorite, either as crystals in cavities or as embedded radiated masses of crystals in the white, sacharroidal spar. The fluorite itself is banded and shows a weak radiated structure. Very minute crystals of hematite are sometimes found in the cavities in the fluorite masses.

The second type shows loose, doubly terminated crystals embedded in a white, evenly textured clay described by Larsen and Wherry[2] as halloysite. These crystals range up to 1 centimeter in size. Their distribution in the halloysite is very uneven, ranging from a few scattered crystals to masses of almost pure creedite. Rarely small groups of divergent crystals are met with in this clay.

[1] Proceedings of the National Academy of Science, vol. 2, p. 360, 1916.
[2] Journal of the Washington Academy of Sciences, vol. 7, p. 178, 1917.

PHYSICAL PROPERTIES.

Creedite is ordinarily colorless, but many of the radiated masses show broad bands of a beautiful, delicate purple color. The luster is vitreous. The cleavage is pinacoidal, parallel to the 100 face. The mineral is brittle and breaks with a conchoidal fracture. The hardness is 4. The specific gravity, determined by the pycnometer method, is 2.713. (Larsen and Wells give the specific gravity as 2.730.) The common mode of aggregation is in radiated masses.

OPTICAL PROPERTIES.

The optical properties given below are those determined by Larsen. The indices of refraction of the new material were measured and found to agree with those given below. The mineral is optically negative. The optic axial angle as measured is:

$2V_{Li} = 64° 30' \pm 10'$; $2V_{Na} = 64° 22' \pm 10'$; $2V_{Tl} = 64° 20' \pm 10'$.

The dispersion was perceptible only on one axis. Extinction angle $42° 30' \pm 30'$. Optical orientation, $Y = b$.

The indices of refraction are:

$$\alpha = 1.461 \pm 001$$
$$\beta = 1.478 \pm 001$$
$$\gamma = 1.485 \pm 001$$

The axial angle calculated from these indices is 65°, agreeing well with the observed ones.

CRYSTALLOGRAPHY.

There are two main habits of crystals, those of the first type occurring in the fluorite, those of the second in the halloysite. The crystals of type 1 are prismatic with an equal development of the front and rear pyramids. The base on these crystals is sometimes absent but generally well developed and sometimes sufficiently large to reduce the pyramids to narrow faces. The crystals of the second type are also prismatic, are doubly terminated, and with a very prominent development of the front pyramid. The rear pyramid and base are reduced to almost minute size. The figures show some of the various types drawn so as to bring the plane of the clino-pinacoid to the front.

In the calculation of the elements only the faces of the unit pyramid could be used. The orthodome zone, including the base, was in all cases when present considerably etched. The crystals from the clay were brilliant, but the faces were invariably curved and yielded a number of signals. The following are the angles for the unit pyramid as measured and designated as excellent.

ϕ $(111, 1\bar{1}1)$	ρ $(111, 111)$	ϕ $(\bar{1}11, \bar{1}11)$	ρ $(\bar{1}\bar{1}1, \bar{1}11)$
° ′	° ′	° ′	° ′
34 34	54 37	28 48	52 59
34 27	54 37	28 59	52 51
34 23	54 31	28 44	53 08
34 13	54 37	28 49	53 00
34 28	54 37	28 50	52 52
		28 44	52 41
Av.=34 29	54 36	29 10	53 08
		28 50	52 51
		28 57	52 59
		Av.=28 52	52 57

From these $x'=0.7181$, $y'=1.1597$, $e'=0.0786$, $\mu=85°\ 30'$ $\beta=94°\ 30'$. Since these are x' and y' for the unit form, $p'_0=0.7181$, $q'_0=1.1597$. These reduce to the monoclinic elements $p_0=0.7159$, $q_0=1.1562$, $e=0.0785$. Also $a=1.6199$ and $c=1.1597$.

The following forms were observed:

$c=0$ (001). This face varies in size from minute to large. Usually dull and etched.

	ϕ	ρ
Measured.....	89° 15′	4° 42′
Calculated.....	90° 00′	4° 30′

$a=\infty 0$ (100). Sometimes occurs as a very narrow face with faint but distinct signal.

	ϕ	ρ
Measured.....	90° 00′	90° 00′
Calculated.....	90° 00′	90° 00′

$m=\infty$ (110). This is the only prism observed. It is usually bright and gives sharp signals. On the second type of crystals it is somewhat curved and gives a multiple signal.

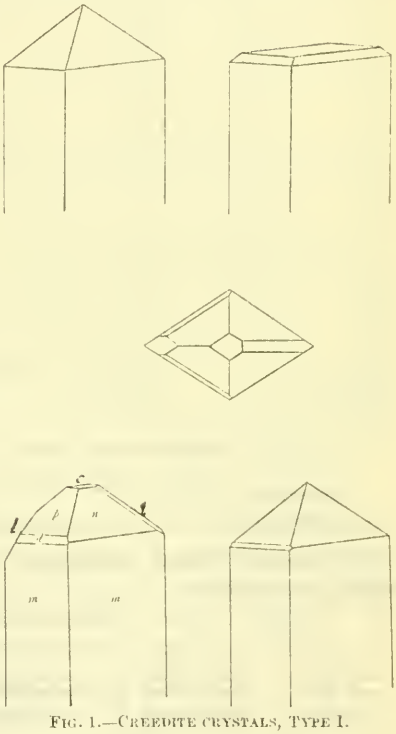

FIG. 1.—CREEDITE CRYSTALS, TYPE I.

	ϕ	ρ
Measured.....	31° 45′	90° 00′
Calculated.....	31° 45′	90° 00′

$l=+20$ (201). Occurs occasionally as dull faces yielding no reflections and measured by the position of maximum illumination. The face is generally of good size.

	ϕ	ρ
Measured.....	89° 00′	56° 15′
Calculated.....	90° 00′	56° 25′

$i = -10$ ($\bar{1}01$). Observed in several cases as a dull face yielding no signal but measured by the position of maximum illumination.

	ϕ	ρ
Measured	90° 00′	32° 10′
Calculated	90° 00′	32° 35′

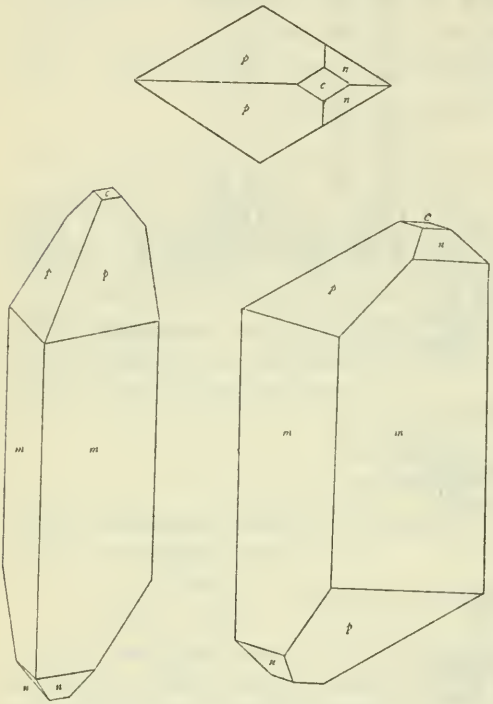

FIG. 2.—CREEDITE CRYSTAL. TYPE II.

$d = +2$ (221). Often present as narrow to line faces on both types of crystals.

	ϕ	ρ
Measured..	33° 15′	70° 08′
Calculated.	33° 09′	70° 09′

$p = +1$ (111). This is the most prominent pyramid face and is generally bright, yielding excellent reflections. In the second type of crystal it reduces the negative pyramid to small faces.

	ϕ	ρ
Measured..	34° 29′	54° 36′
Calculated.	34° 30′	54° 36′

$n = -1$ ($\bar{1}11$). This face is the same size as p in the first type of crystal, but is small on the second. It is bright and yields excellent reflection.

	ϕ	ρ
Measured	28° 52′	52° 57′
Calculated	28° 52′	52° 56′

The elements and calculated angles are brought together in the table given below.

Creedite.—Monoclinic.

$a = 1.6199$ $c = 1.1597$ $\mu = 85° 30'$	$lg\ a = 0.209501$ $lg\ c = 0.064345$ $lg\ h = 9.998659$	$lg\ a_0 = 0.145156$ $lg\ b_0 = 9.935655$ $lg\ c = 8.894643$	$lg\ p_0 = 9.854844$ $lg\ q_0 = 0.063004$ $lg\ \frac{p_0}{q_0} = 0.791840$	$a_0 = 1.3969$ $b_0 = .8623$ $h = .9969$	$p_0 = 0.7159$ $q_0 = 1.1562$ $\epsilon = .0785$

	Gdt.	Miller.	ϕ	ρ	ξ_0	η_0	ξ	η	x' prisms x; y.	y'	$d' = \tan \rho$.
			° ′	° ′	° ′	° ′	° ′	° ′			
c	0	001	90 00	4 30	4 30	0	4 30	0	0.0785	0	0.0785
a	∞ 0	100	90 00	90 00	90 00	0	90 00	0	∞	0	∞
m	∞	110	31 46	90 00	90 00	90 00	31 46	58 18	0.6192	∞	∞
l	+20	201	90 00	56 25	56 25	0	56 25	0	1.5061	0	1.5061
i	−10	$\bar{1}01$	90 00	32 35	32 35	0	32 35	0	.6387	0	.6387
d	+ 2	221	33 09	70 09	56 34	66 40	30 57	51 57	1.5147	2.3195	2.7760
p	+ 1	111	34 30	54 36	38 33	49 14	27 29	42 13	.7969	1.1596	1.4071
n	− 1	$\bar{1}11$	28 52	52 56	32 36	49 14	22 39	44 20	.6394	1.1596	1.3238

CHEMICAL COMPOSITION.

Creedite is easily and completely soluble in hydrochloric and sulphuric acids. For the analysis clear, colorless crystals were selected, crushed, and examined under the microscope. The material so selected was homogeneous and without a trace of foreign matter. The mineral was dissolved in sulphuric acid and evaporated to dense fumes to expel the fluorine, and the lime and alumina determined in this portion by the ordinary methods. Sulphate was determined in a separate portion dissolved in hydrochloric acid by precipitation as barium sulphate. Fluorine was determined by Penfield's method, volatilizing as silicon fluoride and absorbing in a 50 per cent alcoholic solution of potassium chloride and titrating this solution with

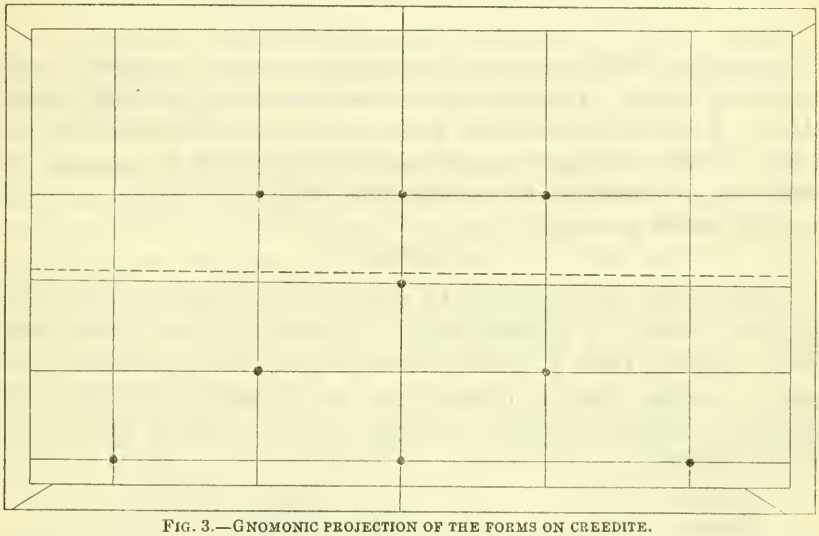

FIG. 3.—GNOMONIC PROJECTION OF THE FORMS ON CREEDITE.

standard sodium hydroxide. Preliminary tests of this method with the apparatus employed gave somewhat high results, due, perhaps, to the imperfect condensation of the sulphur trioxide fumes. Water was determined by Penfield's method. The results together with the ratios derived therefrom are given in the following table:

Analysis and ratios of creedite.

Constituent.	Per cent.	Ratios.		
H_2O	10.72	H_2O	0.610	3.0
SO_4	19.10	SO_4	.199	1.0
F	30.30	F	1.595	8.1
Al_2O_3	21.42	Al	.435	2.2
CaO	35.18	Ca	.595	3.0
	116.72			
$-O=F$	17.28			
	99.44			

These figures compare well with those of Wells's as given below, recalculated to conform with method of statement used by Wells.

Analyses of creedite.

	New analysis.	Wells'sanalysis.
Al	11.74	11.58
Ca	23.72	23.98
SO_4	19.10	18.32
H_2O-	.06	.72
H_2O+	10.72	11.08
O	4.36	3.97
F	30.30	30.35
	100.00	100.00

Larsen and Wells write the formula for creedite as $CaSO_4$. $2CaF_2$ $2Al(OH)_3$. $2H_2O$. It may also be written $3CaF_2$. $Al(OH,F)_2SO_4$. $2H_2O$. A determination of the water at various temperatures showed a loss of only 0.08 per cent at 250°. However, if we consider the water as all constitutional it becomes difficult to assign a simple formula to the mineral.

RELATIONS.

Creedite does not appear to be very closely related to any known mineral. Since it is predominately a fluoride it is best classed with them. Among these it stands closest to pachnolite with two molecules of sodium fluoride replaced by one of calcium sulphate. Its apparent relationship can be brought out by doubling the formula for pachnolite:

Pachnolite.....$2CaF_2$, $2AlF_3$, $2H_2O$, $2NaF$.
Creedite.....$2CaF_2$, $2Al(OH,F)_3$, $2H_2O$, $CaSO_4$.

Creedite can then be grouped with pachnolite in a systematic classification until some closer relations can be shown.