CALLAGHANITE, A NEW MINERAL

CARL W. BECK† AND JOHN H. BURNS*
Shell Development Company, Houston, Texas.

ABSTRACT

Studies of small, azure-blue crystals from the working pits of the Gabbs Refractories, Inc., Gabbs, Nevada lead to the description of a new hydrated basic copper, magnesium, calcium carbonate, $Cu_4Mg_4Ca(OH)_{14}(CO_3)_2 \cdot 2H_2O$. The mineral is named callaghanite after Dr. Eugene Callaghan, Director, New Mexico Bureau of Mines and Minerals, in recognition of his geological work on magnesite deposits. The mineral occurs near peridotite dikes intrusive into magnesite and dolomite.

Cleavages are $\{111\}$ and $\{\bar{1}11\}$, perfect; brittle; hardness is 3–3½; transparent; habit, pyramidal. Calculated specific gravity is 2.78; measured, 2.71.

X-ray studies by Weissenberg and precession methods show callaghanite to be monoclinic; space group either C_s^4—Aa or C_{2h}^6—$A2/a$; and cell dimensions $a_0=8.24$Å, $b_0=11.80$Å, $c_0=10.06$Å, $\beta=107°18'$. Elements calculated from *x*-ray data are: $a:b:c=0.6983:1:0.8525$; $p_0:q_0:r_0=1.2209:0.8140:1$; $\mu=72°42'$; $p_0'=1.2788$, $q_0'=0.8525$, $x_0'=0.3115$. The unit cell contains $Cu_8Mg_8Ca_2(OH)_{28}(CO_3)_4 \cdot 4H_2O$.

Crystal forms present are $\{111\}$, $\{\bar{1}11\}$, $\{221\}$, and $\{\bar{2}21\}$. Elements calculated from the goniometric data are: $a:b:c=0.7252:1:0.8504$; $p_0:q_0:r_0=1.2168:0.8092:1$; $\mu=72°5'$; $p_0'=1.2788$, $q_0'=0.8504$, $x_0'=0.3094$.

Optical data are: $\alpha=1.559$, $\beta=1.653$, $\gamma=1.680$; $2V=55°$; optically (−); $Z \wedge c=18°$; pleochroic in blue with absorption $Z>Y>X$; $r>v$, strong.

INTRODUCTION

In the summer of 1952 while the senior writer was doing field geology in Nevada, Mr. Conrad Martin, consulting geologist, Reno, Nevada, called his attention to the occurrence of small azure-blue crystals disseminated through magnesite and dolomite beds near Gabbs, Nevada (Fig. 1). Mr. Martin had noted that the crystals effervesced slowly in dilute HCl and gave qualitative tests for copper and magnesium. With the permission of Basic Refractories, Inc., Gabbs, Nevada, a collection of the blue crystals was made and brought back to the laboratory for identification.

Mr. Martin has supplied most of the following information on the occurrence of this new mineral. The rocks along the west flank of the Paradise Range in the vicinity of Gabbs, Nevada are carbonates of an undetermined thickness. These carbonate rocks are part of the Luning formation of Upper Triassic age, and consist dominantly of dolomite with substantial masses of crystalline magnesite. In the vicinity of Gabbs the carbonate rocks are intruded by diorite and quartz diorite rocks. At the contact between magnesite and diorite, magnesite has been changed to brucite and diorite has become more basic by assimilation of magnesia.

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† Present address: Department of Geology, Indiana University, Bloomington, Indiana.
* Department of Chemistry, Rice Institute, Houston, Texas.

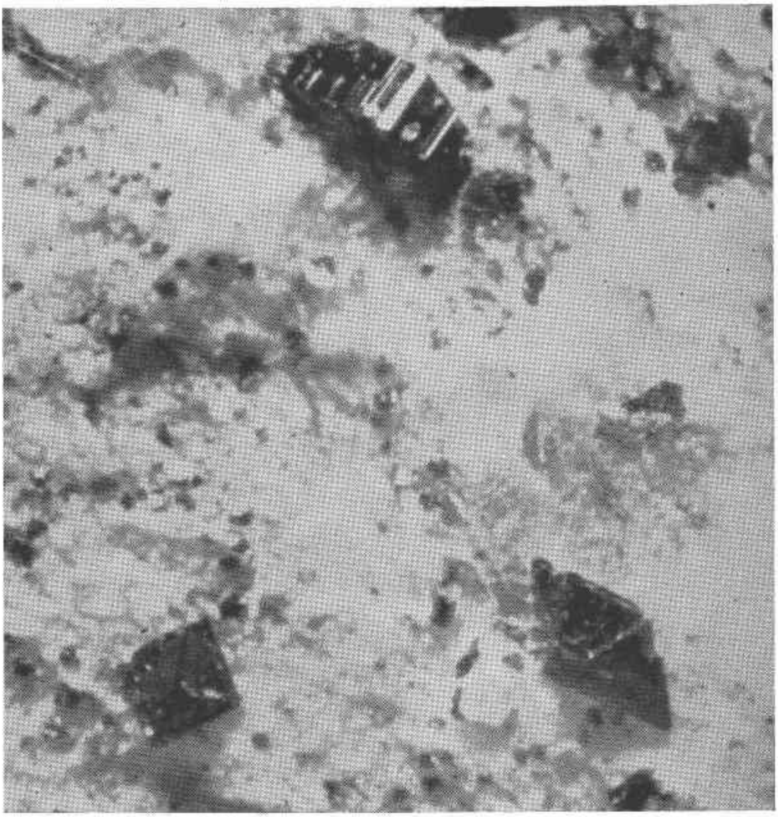

FIG. 1. Callaghanite crystals on dolomite rock. ×34.

Apophyses of diorite within brucite may be changed completely to serpentine. A thin band of forsterite often marks the boundary between the serpentine and brucite. The new mineral generally is found within this serpentine-forsterite-brucite zone where it occurs as tiny disseminated crystals (Fig. 1), as encrustations (Fig. 2), and as veinlets. The field relationship of the mineral suggests that it is hydrothermal in origin. From the chemical composition (below) the writers suggest that the ore-forming solution would normally have precipitated azurite but, in the presence of magnesium and calcium from the surrounding sedimentary rocks, formed a new mineral.

When the mineral could not be identified from a powder *x*-ray picture, a more complete study was made. The writers are indebted to Professor J. Waser, Department of Chemistry, Rice Institute, Houston, Texas, for permission to use his Weissenberg and precession cameras for the single crystal results reported herein, and to Professor S. E. Clabaugh, Department of Geology, University of Texas, Austin, Texas, for the use of a two-circle goniometer.

The new mineral has been named *callaghanite* after Dr. Eugene Callaghan, Director, New Mexico Bureau of Mines and Minerals, Socorro, New Mexico, in recognition of his geological work on magnesite deposits including the Gabbs deposit in which the mineral was found.

PHYSICAL PROPERTIES

The specific gravity of callaghanite was determined by two methods: (1) by means of a microchemical analytical balance, on which the crystals were first weighed in air and then in a mixture of bromoform and n-amyl alcohol with a specific gravity of 1.915; and (2) by suspension in a heavy liquid mixture of bromoform and acetone. These procedures were necessitated by the small size of the crystals, which range from microscopic up to 1.5 mm. in length, and by the fact that the total amount of material for study was small. Three crystals, aggregating 6.06 mg., were used. A specific gravity of 2.71 was obtained by both methods, a reasonable check with the theoretical value of 2.78 (below).

The cleavages of callaghanite are perfect parallel to the unit positive fourth-order prism, $\{111\}$, and unit negative fourth-order prism, $\{\bar{1}11\}$. Hardness is 3–3½; luster, vitreous; fracture, irregular; color, azure-blue; streak, white; diaphaneity, transparent; tenacity, brittle.

STRUCTURAL CRYSTALLOGRAPHY

The tiny crystals of callaghanite were admirably suited for single crystal studies. Rotation, Weissenberg, and precession pictures were taken using CuK_α radiation. The Weissenberg and precession pictures indicated monoclinic symmetry, and the extinctions were characteristic of either the space group C_s^4—Aa or the space group C_{2h}^6—$A2/a$. An experiment to determine pyroelectricity gave negative results; therefore, it is not known whether callaghanite is centrosymmetrical or not. The cell dimensions are: $a_0 = 8.24 \pm .03$ Å, $b_0 = 11.80 \pm .03$ Å, $c_0 = 10.06 \pm .04$ Å, $\beta = 107°18' \pm 30'$. Elements calculated from x-ray data are: $a:b:c = 0.6983:1:0.8525$; $p_0:q_0:r_0 = 1.2209:0.8140:1$; $\mu = 72°42'$; $p_0' = 1.2788$, $q_0' = 0.8525$, $x_0' = 0.3115$.

X-RAY POWDER PATTERN

The x-ray powder pattern of callaghanite is shown in Fig. 3. The estimated intensities and the measured θ and d values are given in Table 1. The pattern has been indexed as far as $\theta = 27.17°$, and the measured values agree with one or more theoretical values.

FIG. 2. Encrustation of callaghanite on serpentine rock. ×2.

TABLE 1. CALLAGHANITE: X-RAY POWDER PATTERN

Monoclinic, C_s^4—Aa or C_{2h}^6—$A2/a$; $a_0=8.24$ Å, $b_0=11.80$ Å, $c_0=10.06$ Å, $\beta=107°18'$

I	θ (Cu)	d (meas.)	(hkl)	d (calc.)	I	θ (Cu)	d (meas.)	(hkl)	d (calc.)
10	5.95°	7.45 Å	(011)	7.45 Å	2	20.32°	2.22 Å	$(\bar{2}24)$	2.21 Å
10	7.17	6.17	$(\bar{1}11)$	6.17	1	20.92	2.16	(151)	2.16
6	9.25	4.80	(002)	4.80	2	22.10	2.05	(313)	2.05
9	11.50	3.87	(200)	3.93				$(\bar{3}33)$	2.05
6	11.95	3.72	(022)	3.72				(402)	2.05
9	14.02	3.18	$(\bar{2}22)$	3.08				$(\bar{2}51)$	2.04
			$(\bar{1}13)$	3.20	2	23.15	1.96	(400)	1.96
2	15.12	2.95	(040)	2.95				(340)	1.96
2	16.20	2.76	(140)	2.76				(060)	1.97
			(041)	2.76	1	23.45	1.94	(224)	1.95
			(113)	2.74	1	23.72	1.91	(160)	1.91
6	16.75	2.67	$(\bar{3}11)$	2.67				(251)	1.92
2	17.65	2.54	(231)	2.53	1	24.47	1.86	(044)	1.86
			$(\bar{1}42)$	2.51				(420)	1.86
			(042)	2.51	5	25.20	1.81	$(\bar{1}62)$	1.81
			(033)	2.48				(062)	1.82
4	18.75	2.40	(004)	2.40				(204)	1.82
			(320)	2.42	2	26.00	1.76	$(\bar{1}15)$	1.76
			$(\bar{2}04)$	2.39				$(\bar{2}15)$	1.76
4	19.02	2.36	(240)	2.36				(053)	1.75
7	19.55	2.30	(051)	2.29	2	26.50	1.73	(162)	1.73
			(142)	2.29				$(\bar{2}62)$	1.73
2	20.32	2.22	(024)	2.23	1	27.17	1.69	(026)	1.67

I	θ (Cu)	d (meas.)	I	θ (Cu)	d (meas.)	I	θ (Cu)	d (meas.)
1	27.72	1.66	½	32.85	1.42	2	39.00	1.23
4	28.80	1.60	½	33.15	1.41	3	39.50	1.21
1	29.20	1.58	2	33.90	1.38	2	40.70	1.18
1	29.90	1.55	2	34.97	1.34	½	40.90	1.18
2	30.45	1.52	1	35.35	1.33	2	41.80	1.16
2	30.80	1.51	½	35.80	1.32	½	42.30	1.15
1	31.55	1.47	2	36.65	1.29	1	43.35	1.12
2	32.17	1.45	2	37.45	1.27	½	43.85	1.11
5	32.42	1.44	2	37.75	1.26	½	44.65	1.10

MORPHOLOGICAL CRYSTALLOGRAPHY

Five separate crystals of callaghanite were used for the measurement of interfacial angles on a two-circle goniometer. Three of these crystals were mounted with the c-axis parallel to the axis of the goniometer head; two with the b-axis parallel to the axis of the goniometer head. Four of the crystals showed only $\{111\}$ and $\{\bar{1}11\}$ forms, equally developed, but

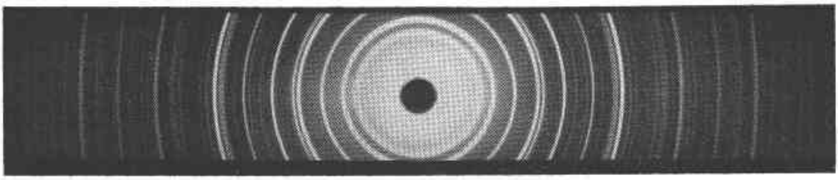

FIG. 3. X-ray powder pattern of callaghanite.

the other crystal showed not only $\{111\}$ and $\{\bar{1}11\}$ forms but also $\{221\}$ and $\{\bar{2}21\}$ forms. Hand lens inspection of twenty other crystals showed no development of either $\{221\}$ or $\{\bar{2}21\}$. The faces were megascopically excellent, but gave fair to poor reflections. Figure 4 illustrates an idealized crystal of callaghanite drawn from goniometric data. Table 2 summarizes the goniometric data. The average of the measured angles agrees closely with the calculated angles. Elements calculated from goniometric data are: $a:b:c=0.7252:1:0.8504$; $\beta=107°55'$; $p_0:q_0:r_0=1.2168:0.8092:1$; $\mu=72°5'$; $r_2:p_2:q_2=1.2358:1.5038:1$; $p_0'=1.2788$, $q_0'=0.8504$, $x_0'=0.3094$. The elements calculated from the goniometric measurements are in agreement with the elements calculated from the x-ray data.

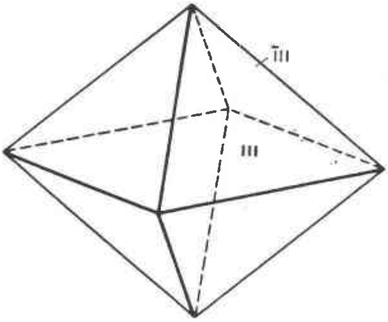

FIG. 4. Callaghanite, clinographic projection showing the forms $\{111\}$ and $\{\bar{1}11\}$.

TABLE 2. CALLAGHANITE: CRYSTAL MEASUREMENTS, FIVE CRYSTALS—MONOCLINIC

Form	Number of Faces	Quality	Average Measured		Range		Calculated	
			Phi	Rho	Phi	Rho	Phi	Rho
$\{111\}$	10	Fair to poor	61°50′	60°58′	61°33′–61°58′	60°46′–61°07′	61°48′	61°00′
$\{\bar{1}11\}$	9	Fair to poor	48 46	52 12	48 39 –48 53	52 05 –52 15	48 46	52 12
$\{221\}$	2	Fair	55 26	70 23	55 14 –55 38	70 12 –70 34	55 27	70 24
$\{\bar{2}21\}$	2	Fair	45 12	63 15	44 58 –45 26	63 06 –63 15	45 10	63 13

COMPOSITION AND CELL CONTENT

A microchemical analysis of callaghanite is given in Table 3. Carbon dioxide and water were determined by igniting 10 mg. of sample and selectively absorbing the two constituents. CuO, MgO, and CaO were determined by fusing 25 mg. of sample with an acid flux. Copper was plated out on platinum electrodes. The remainder of the fusion product consisted of MgO and CaO, and the ratio of these constituents was determined spectrochemically. This chemical analysis gives the empirical formula, $Cu_4Mg_4Ca(OH)_{24}(CO_3)_2 \cdot 2H_2O$. The main discrepancy between the analysis and the empirical formula is that the former is slightly low in CuO and slightly high in combined MgO and CaO. The microchemical analysis combined with the cell dimensions (Table 1) and the measured specific gravity (2.71) gives the number of molecules in the unit cell, namely, two. From this the probable structural formula for callaghanite is written:

$$Cu_8Mg_8Ca_2(OH)_{28}(CO_3)_4 \cdot 4\,H_2O = 2[Cu_4Mg_4Ca(OH)_{14}(CO_3)_2 \cdot 2\,H_2O].$$

The calculated specific gravity for this structural formula is 2.78.

TABLE 3. CALLAGHANITE: COMPOSITION AND CELL CONTENT

Constituent	Per Cent	Molecular Proportion	Molecular Ratio	Empirical Formula	Ideal Cell Content
CuO	38.27	.4811	3.70=4	$Cu_4Mg_4Ca(OH)_{14}(CO_3)_2 \cdot 2H_2O$	2
MgO	20.86	.5174	3.98=4		
CaO	8.89	.1585	1.22=1		
H_2O	20.51	1.1395	8.76=9		
CO_2	11.46	.2604	2.00=2		
	99.99				

Clark Microanalytical Laboratory, analyst.
104½ West Main St., Urbana, Illinois.

OPTICAL PROPERTIES

The optical properties of callaghanite, as determined by the immersion method, are: $\alpha=1.559$, $\beta=1.653$, $\gamma=1.680$; $2V=55°$; optically (−); $Z \wedge c=18°$; pleochroic in blue with absorption $Z>Y>X$; $r>v$, strong.

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