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GOWERITE, A NEW HYDROUS CALCIUM BORATE, FROM THE DEATH VALLEY REGION, CALIFORNIA*

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ABSTRACT

Gowerite is a new hydrous calcium borate, $CaO \cdot 3B_2O_3 \cdot 5H_2O$, from the Furnace Creek borate deposits of the Death Valley region, California. Globular minute clusters of gowerite form from the weathering of colemanite and priceite veins in some basaltic rocks in the Furnace Creek formation of late Tertiary age. Associated with gowerite are ulexite, meyerhofferite, ginorite, sassolite, hydroboracite, and an undescribed magnesium borate.

Gowerite is monoclinic and is optically biaxial (+), $\alpha = 1.484 \pm 0.002$, $\beta = 1.501 \pm 0.002$, $\gamma = 1.550 \pm 0.002$, $2V = 63°$ (calc.), $r > v$ slight, $Y = b$, $Z \wedge c = 27°$. Hardness 3, specific gravity 2.00 ± 0.01.

Two chemical analyses of the mineral gave: CaO, 15.54, 15.46; SrO, 0.71, 0.71; B_2O_3, 58.14, 58.05; H_2O, 25.75, 25.77; total 100.14, 99.99 per cent.

Synthetic calcium hexaborate pentahydrate is identical with gowerite. The strongest lines of the x-ray powder patterns of both are at 8.2 Å (10), 4.11 Å (5), 3.19 Å (6), and 2.73 Å (5).

The mineral is named in honor of Mr. Harrison P. Gower of the U. S. Borax & Chemical Corporation, Los Angeles, California.

INTRODUCTION

The mineral described in this paper was first noted by McAllister in July 1955 in some samples of efflorescent borates from the Mott open cut in the Furnace Creek area of the Death Valley National Monument, California (Fig. 1). His study of the optical properties of the material indicated that the mineral was distinct from any known borate mineral. This was confirmed by Robert D. Allen‡ who continued the optical study and prepared an x-ray powder pattern. Later Erd refined these data and made the mineralogical studies reported here.

A preliminary qualitative chemical examination by Almond of a very small quantity of the mineral showed it to be a hydrous calcium borate

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with a minor amount of strontium. An adequate amount of material for quantitative analysis was not available, however, until McAllister found a new occurrence of the mineral at the Hard Scramble claim in the Furnace Creek area. The mineral was then found to have the same composition, $CaO \cdot 3B_2O_3 \cdot 5H_2O$, as the calcium hexaborate pentahydrate which was synthesized by H. K. Gode in 1949.

This mineral, $CaO \cdot 3B_2O_3 \cdot 5H_2O$, is named gowerite in honor of Mr. Harrison P. Gower, of the U. S. Borax & Chemical Corporation, who for many years was in charge of the company's mining operations in Death Valley. Mr. Gower has shown many kindnesses to members of the U. S. Geological Survey's borate project and he conducted them to the principal borate deposits in the Furnace Creek area including the Mott colemanite deposit where gowerite was subsequently discovered.

OCCURRENCE

Gowerite has been found at four localities in the Furnace Creek borate deposits of the Death Valley region, California (Fig. 1). They are on patented mining claims of the Pacific Coast Borax Company and in Death Valley National Monument. The new mineral was first found at the Mott open cut, which is on a colemanite prospect three-fourths of a mile in a straight line S. 17° E. of the upper or eastern junction of the Twenty Mule Team Canyon road with California highway 190. The Mott open cut (loc. 1, Fig. 1) is half a mile up a dry stream channel southeast of the side road. Locality 2, where gowerite is more abundant, is on the Hard Scramble claim about 5 miles southeast of the Mott prospect. The Hard Scramble occurrence is on the western slope of low foothills of the Black Mountains 1.9 miles in a straight line N. 72° W. of Ryan and about 1.2 miles up a wash south of the Dantes View road. The third locality, between the other two, is 1.4 miles S. 43° E. of the Mott open cut and 0.6 mile north of the De Bely mine. Locality 4 is 3,000 feet N. 72° W. of Ryan.

At the gowerite localities colemanite and priceite veins, generally less than 2 inches thick, occur in altered fragmental olivine basalt. The borate-veined basalt is in the Furnace Creek formation (Noble, 1941, p. 955–956) of late Tertiary age and lies stratigraphically above the main zone of colemanite and ulexite, which is in lake and stream sediments near the base of the formation. The gowerite is restricted to a weathered zone where the colemanite and priceite veins waste away within a few feet of the present surface of the hillsides and leave irregular aggregates of alteration products. The alteration products rarely continue to the surface, but as a rule they end under a thin crust of slope debris.

Among these products of weathering at many localities thus far ex-

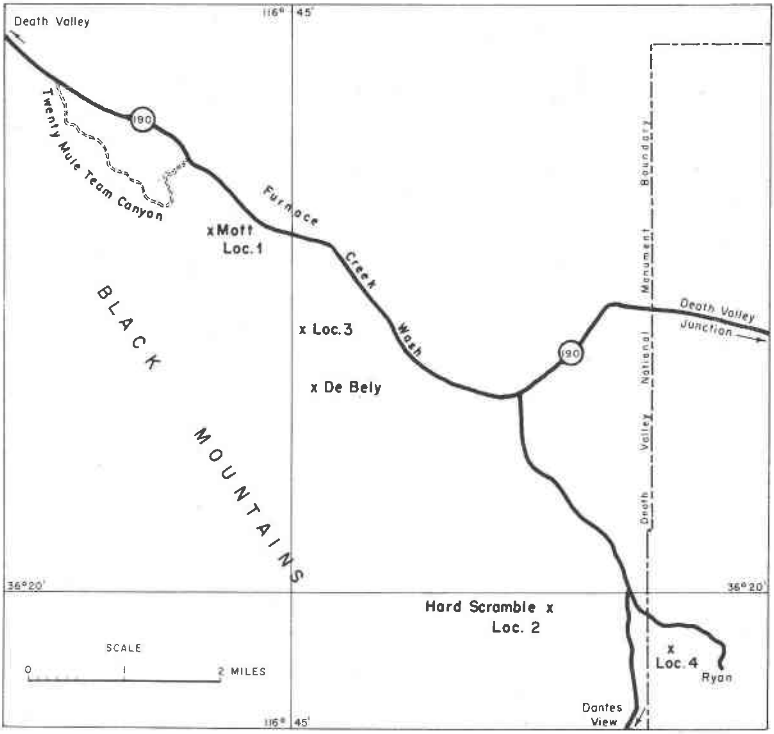

FIG. 1. Index map of a portion of the Death Valley National Monument, showing the localities where gowerite has been found.

amined, gowerite is one of the rarer borates, like sassolite and hydroboracite, in contrast to consistently abundant fluffy ulexite. Others, such as ginorite, meyerhofferite, colemanite, and a magnesium borate of uncertain identity, seem to be intermediate in abundance. Associated minerals commonly include gypsum, thenardite, and some limonite.

In the Mott open cut some of the scarce gowerite is in globular clusters (to ten mm. in diameter) of radiating small blades on remnants of a colemanite vein and is closely associated with crusts and clusters of subhedral crystals of meyerhofferite, some gypsum, and a small quantity of hydroboracite. Some of the gowerite at Mott forms small clusters in the loose aggregate from the weathered basalt, like the much more abundant ginorite associated with sassolite (Allen and Kramer, 1957, p. 56) nearer the surface. Ulexite occurs throughout the weathered zone but is concentrated in the upper part. Ulexite appears to be the only alteration product of colemanite in the calcareous sedimentary rock adjacent to the basaltic rock.

The more abundant gowerite at the Hard Scramble locality is in compact globular clusters, commonly from 1 to 10 mm. in diameter, within loose material weathered from the underlying basaltic rock and on veinlike coherent aggregates of meyerhofferite produced also by the weathering of the same priceite veins. Ulexite, ginorite, and gypsum occur with the gowerite but are more widely distributed in the weathered material above the veins. Unlike those at the Mott locality, the alteration products at the Hard Scramble are derived from priceite, and no sassolite has yet been found among them. The mineralogical observations in this paper were made on material from the Hard Scramble locality. No differences were noted in the properties of gowerite from the other localities.

PHYSICAL PROPERTIES

Gowerite has distinct cleavage parallel to the terminating face (001?) and imperfect cleavage parallel to {100?}. The mineral is brittle and has an uneven fracture. The hardness is 3. Its specific gravity, (D_4^{20}) determined by sink-float in a mixture of bromoform and carbon tetrachloride is 2.00 ± 0.01. The color of aggregates is white; individual crystals are colorless, transparent, and have a vitreous luster. The streak is white.

Gowerite displays no fluorescence with short or long wave ultraviolet radiation and is not sensibly thermoluminescent.

OPTICAL PROPERTIES

Gowerite is colorless and non-pleochroic in transmitted light. It is biaxial (+) and has the following optical properties:

	n	
α	1.484 ± 0.002	$2V = 63°$ (calc.)
β	1.501 ± 0.002	$r > v$ slight
γ	1.550 ± 0.002	

It has positive elongation. The optic orientation is $Y = b$, $Z \wedge c = 27°$. Viewed on {100?} many of the crystals show an apparent slight inclined extinction. This is probably due to the difficulty of obtaining correctly oriented individuals and to poorly formed crystals.

CRYSTALLOGRAPHY

Morphology

Crystals of gowerite are long prismatic [001] to needlelike and are grouped in radiating globular clusters. The dimensions of an average single crystal are 0.8 mm. in length by 0.06 mm. and 0.02 mm. in width and breadth. The largest crystal observed was 1.5 mm. long.

Prismatic faces are striated parallel to [001]. The terminating form

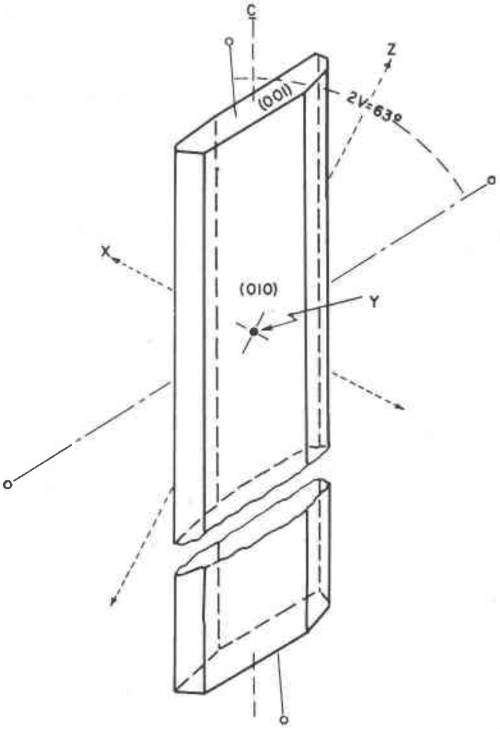

FIG. 2. Optical orientation and approximate habit of gowerite.

{001?} and the cleavage plane parallel to it make an angle of approximately 60° to [001] in sections parallel to {010}.

A sketch of a typical gowerite crystal is shown in Fig. 2. This is intended only to give an approximate idea of the habit and optical orientation, and inter-edge and interfacial angles shown should not be taken seriously as to value or as an indication of symmetry. Study of the crystals by *x*-ray single crystal techniques points to monoclinic symmetry (Joan R. Clark, private communication). Goniometric measurements and *x*-ray crystallographic and structural data are being obtained by Joan R. Clark and Charles L. Christ.

X-ray powder data

Powder diffraction data for gowerite and synthetic calcium hexaborate pentahydrate, shown in Table 1, were obtained with a Norelco diffractometer over the range $2\theta = 2° - 150°$ using unfiltered iron radiation. Powder photographs using iron radiation with a manganese filter were taken as a check on the diffractometer data.

TABLE 1. *X*-RAY POWDER DATA FOR GOWERITE AND SYNTHETIC $CaO \cdot 3B_2O_3 \cdot 5H_2O$
Unfiltered iron radiation
(Only lines due to FeK_α radiation, $\lambda = 1.9373$ Å, are reported)

Gowerite		$CaO \cdot 3B_2O_3 \cdot 5H_2O$		Gowerite		$CaO \cdot 3B_2O_3 \cdot 5H_2O$	
d_{hkl}	I	d_{hkl}	I	d_{hkl}	I	d_{hkl}	I
9.18	2	9.15	3	2.05		2.05	
8.23	10	8.21	10	2.00		2.01	
6.61	*	6.59	*	1.995		1.995	
5.64		5.63				1.970	
5.52		5.52		1.946		1.943	
5.40	1	5.39	1	1.924		1.924	
5.15	1	5.13	1	1.896		1.897	
4.91	1	4.90	1	1.868		1.868	
4.11	5	4.11	6	1.865			
4.07	2	4.07	3	1.797	1	1.795	1
3.95				1.755		1.755	
3.92	1	3.92	1	1.730	1	1.728	1
3.88	1	3.88	1	1.590	1	1.586	1
3.85	2	3.84	3	1.562		1.561	
3.74		3.74		1.530		1.529	
3.36	1	3.35	2	1.476		1.477	
3.32		3.33		1.465		1.465	
3.23	1	3.23		1.438		1.438	
3.19	6	3.19	5	1.419		1.419	
3.15	2	3.14	3	1.401		1.402	
3.06	1	3.05	1	1.379		1.380	
3.01		3.01		1.369		1.369	
2.97	1	2.96	1	1.357		1.357	
2.96				1.302		1.305	
2.93	1	2.93	1	1.290		1.291	
2.82	1	2.82	2	1.228		1.229	
2.77	1	2.77		1.219		1.220	
2.73	4	2.73	5	1.212		1.212	
2.65	2	2.65	3	1.203		1.203	
2.54	1	2.53	1	1.194		1.194	
2.50				1.178		1.178	
2.46		2.46				1.152	
2.29	1	2.29	2	1.120		1.120	
2.17	1	2.17	1	1.097		1.098	
2.13	1	2.13		1.082		1.082	
2.11		2.11		1.070		1.070	
2.08		2.07		1.062		1.062	
2.06	1	2.06	1	1.050		1.051	

* Blank spaces indicate intensities of less than 1.

The intensities of the set of spacings at 8.23, 4.11, 2.73, and 2.06 Å in the diffractometer charts were greatly increased by aligning uncrushed fibers of gowerite on a glass slide either parallel to or perpendicular to the incident *x*-ray beam. This preferred orientation was minimized by grinding to −400 mesh. For the same reason the sphere mount technique of Hildebrand (1953) was employed in obtaining the powder photographs.

CHEMICAL PROPERTIES

Analysis

Two samples of the purified mineral from the Hard Scramble locality were carefully prepared by different persons. Of these a 0.1 g. sample and a 0.2 g. sample respectively were used for the borate, calcium, and strontium determinations. Separate fractions of the original material were used for the water determination. The mineral was dissolved in dilute hydrochloric acid and diluted to 100 ml. Aliquots were taken for calcium and borate determinations. Borate was determined by titration with standard sodium hydroxide after addition of mannite to the neutralized borate solution (Scott, 1939). Calcium was determined by titration with the disodium salt of ethylenediaminetetraacetic acid, commonly known as EDTA, as outlined by Shapiro and Brannock (1956). A standard series of solutions containing the analyzed amounts of calcium and borate were prepared with different amounts of strontium. The amount of strontium in gowerite was determined, using a Beckman D. U. flame photometer and photomultiplier attachment, by bracketing the unknown strontium between two known values and then interpolating. Inasmuch as strontium reacts with EDTA, a correction was made for the calcium determination to compensate for the EDTA used by the strontium.

Water was determined by heating a weighed sample to 550° C. in a thermostatically controlled electric furnace, then determining loss of weight of the sample. It was found that at high temperatures—700° C.—large losses of B_2O_3 resulted from heating.

The analytic results are given in Table 2 in which the formula of gowerite is shown to be $CaO \cdot 3B_2O_3 \cdot 5H_2O$ (or $CaB_6O_{10} \cdot 5H_2O$).

Synthesis

Calcium hexaborate pentahydrate, $CaO \cdot 3B_2O_3 \cdot 5H_2O$, was first synthesized by H. K. Gode (1949). His paper was not available to us but, by a slight modification of his synthesis as described in *Chemical Abstracts*, Erd was able to prepare a compound which has an *x*-ray powder pattern nearly identical with that of gowerite (Table 1). This synthetic gowerite was obtained from a mixture of 20 g $Ca(C_2H_3O_2) \cdot H_2O$ and 40 g H_3BO_3 in

100 ml. of water that was held at a temperature of 35° C. and stirred continuously for 24 hours. The pH of the solution at the beginning and end of the reaction was approximately 5. The product was an extremely fine-grained precipitate of nearly pure synthetic gowerite. Larger crystals, with the same habit and radiating structure of natural gowerite, were grown at room temperature in a mixture of the same composition in a period of 18 days (without stirring).

The density of 2.12 reported by Gode for his synthetic material agrees reasonably well with the value of 2.00 which we obtained for natural and synthetic gowerite.

Solubility data

Gowerite is soluble with difficulty in cold water; moderately soluble in hot water. Gode (1949) obtained a figure of 6.03 g/liter at 20° C. for the synthetic material. Gowerite is readily soluble in cold dilute acids and alkalis and is slowly dissolved by cold 30 per cent hydrogen peroxide. It reacts with sulfuric acid to give gypsum and sassolite. The mineral is apparently insoluble, or only slightly soluble, in methyl alcohol.

Differential thermal analysis

Differential thermal analysis curves of natural and synthetic gowerite (prepared by Erd) were obtained with a portable unit following the procedure described by Allen (1957). Both curves show three endothermic reactions whose initial and trough temperatures are:

	Initial temperature (° C)	Trough temperature (° C)
Gowerite	150	190
	210	270
	440	460
$CaO \cdot 3B_2O_3 \cdot 5H_2O$ (Synthetic)	140	170
	210	250
	440	460

These reactions represent loss of water and agree fairly well with Gode's thermal analysis of the synthetic material. He found that his synthetically prepared $CaO \cdot 3B_2O_3 \cdot 5H_2O$ loses the first mole of water at 85°, the second between 85° and 110°, the third and fourth at 230°, and the last at 480° C. A glass ($\eta = 1.558$) is formed when gowerite is heated to about 500° C. and the runs were stopped at 550° C. to prevent fusion in the sample block.

TABLE 2. CHEMICAL ANALYSES OF GOWERITE

	Weight per cent*			Ratios	Calculated composition for $CaO \cdot 3B_2O_3 \cdot 5H_2O$
	Sample 1	Sample 2	Average		
CaO	15.54	15.46	15.50	1.00 or 1 (1×1.00)	15.79
SrO	0.71	0.71	0.71		
B_2O_3	58.14	58.05	58.10	2.95 or 3 (3×0.98)	58.84
H_2O	25.75	25.77	25.76	5.05 or 5 (5×1.01)	25.37
	100.14	99.99	100.07		100.00

* Hy Almond, U. S. Geological Survey, *Analyst*, 1957.

Pyrognostics

Upon heating in a closed tube, gowerite decrepitates, loses water, and turns white and translucent to opaque. Before the blowpipe, gowerite decrepitates, then fuses to an opaque enamel bead.

Although gowerite becomes a glass at a temperature of 500°–550° C., the sharp outlines of the crystals are preserved. The glass begins to soften at about 600° C. and is completely melted by 660° C. to yield two immiscible liquids. With prolonged heating, during which B_2O_3 is driven off, only a clear liquid remains from which $CaO \cdot B_2O_3$ crystallizes in transparent prismatic crystals. The melting point of 900° reported for the synthetic material by Gode seems unaccountably high.

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