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CHAMBERSITE, A NEW MINERAL

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ABSTRACT

Chambersite is present in brine returns from a gas storage well on Barber's Hill salt dome, Chambers County, Texas. Crystals are almost colorless to deep purple, paramorphic isometric with the positive tetrahedron as the dominant form. H 7, G 3.49 (meas.), 3.48 (calc.). No cleavage, fracture subconchoidal to uneven. Optically biaxial positive, $\alpha=1.732$, $\beta=1.737$, $\gamma=1.744\pm0.001$, $2V=83°\pm3°$. Orthorhombic crystal aggregates make up paramorphs. Chemical analysis: MnO 41.87, FeO 1.28, MgO 0.05, CaO tr, B_2O_3 49.50, Cl 6.34, remainder−1.39. Total 100.43 minus O=Cl 1.39, corrected total 99.04%. The formula is $Mn_{2.90}Fe_{0.09}Mg_{0.01}B_7O_{13}Cl$. Unit cell of the low temperature dimorph is orthorhombic, $a=8.68$, $b=8.68$, $c=12.26$Å; strongest lines of the x-ray powder pattern are (10) 3.07, (6) 2.74, (6) 2.08, (5) 3.54, (5) 2.17. Differential thermal analysis shows the orthorhombic-isometric inversion at 407° C. and melting at 1065° C.

INTRODUCTION AND OCCURRENCE

Chambersite was first found in 1957 in brine returns from a gas storage well in the Barber's Hill salt dome, Chambers County, Texas. Preliminary data from optical examination and x-ray powder diffraction indicated the mineral to be related to boracite but distinctly different from any published descriptions. This conclusion was confirmed by spectrographic data furnished through the courtesy of C. L. Christ, I. Adler and H. J. Rose of the U. S. Geological Survey. These data indicated the mineral to be a manganese chloroborate isostructural with boracite and are substantiated by other data collected during the present study. The mineral is analogous to ericaite, the ferrous analogue of boracite (Heide, 1955; Kühn and Schaacke, 1955) and is the second chemical analogue of boracite to be found in nature. Synthesis of the Mg, Fe, Mn, Zn, Co, and Ni analogues of boracite is reported by Heide *et al.* (1961). Properties reported for the synthetic manganese analogue are in good agreement with those determined in this study for the natural mineral.

The only observed occurrence of chambersite is from Storage Well No. 1 of the Texas Natural Gasoline Corporation on the northwest flank of Barber's Hill salt dome, Mont Belvieu, Chambers County, Texas. The mineral is present in brine returns from the well, and although accurate information as to the depth of the occurrence is not available, driller's logs indicate an origin in the main salt mass at a depth between 2,320 and 2,720 feet below sea level. Associated minerals include halite, anhydrite

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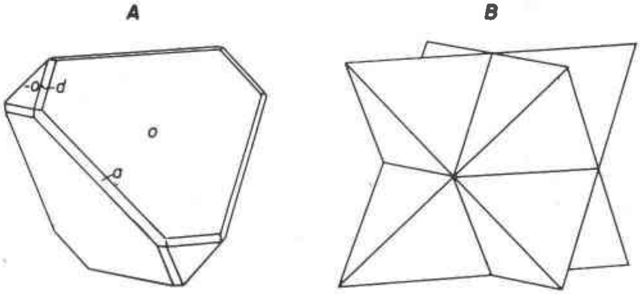

FIG. 1. A. Modified paramorphic isometric crystal of chambersite. Forms: *o*111, −*o*1$\bar{1}$1, *a*001, and *d*011. B. Penetration twin with twinning axis [111] and twin plane (111).

and gypsum. A careful search failed to reveal other borate minerals in the accumulated material from evaporation and settling of brines.

Geological relationships in the vicinity of the Barber's Hill dome are described by Bevier (1925) and Judson *et al.* (1932). The salt mass is known from subsurface data to intrude sediments ranging in age from Pleistocene to Late Cretaceous. The age of the salt in the intrusion is not definitely known but is at least Late Cretaceous and probably Jurassic. The salt mass is capped by porous rock consisting of limestone, gypsum and anhydrite. Open spaces contain varying amounts of crystalline sulfur, pyrite and calcite. Cap rock and some salt form an overhang relative to the main salt core. Thickness of the cap rock varies from approximately 850 feet over the central part of the dome to only a few feet on the outer edges of the overhang.

PHYSICAL PROPERTIES

Chambersite occurs in subhedral to euhedral crystals ranging from less than 1 mm to 1.2 cm on an edge. Crystals are paramorphic isometric, and are composed of aggregates of the low temperature orthorhombic modification of the mineral. The dominant form is the positive tetrahedron (111), which is commonly modified by faces of (001), (110), and (1$\bar{1}$1). Figure 1 illustrates a typical modified crystal, although all combinations of the modifying forms were observed. A single morphologically twinned crystal was found; it consists of interpenetrating tetrahedrons with the twinning axis (111) and twin plane parallel to an octahedral face. Similar twins have been described for tetrahedrite. Inversion of the isometric to the orthorhombic dimorph is accompanied by microscopically observable twinning. Paramorphs are seen on optical examination to consist of an aggregate of crystals with irregular contacts. Both optical and *x*-ray work indicate analogy to boracite dimorphism in which the high temperature

TABLE 1. OPTICAL PROPERTIES OF CHAMBERSITE COMPARED WITH BORACITE AND ERICAITE

	1	2	3
	Chambersite	Boracite	Ericaite
α	1.732±0.001	1.658	
β	1.737±0.001	1.662	*ca.* 1.75
γ	1.744±0.001	1.668	
	Biaxial (+)	Biaxial (+)	?
2V	83°±3°	$82\frac{1}{2}$°	?
Birefringence	0.012	0.010	?

1. Chambersite—present study.
2. Boracite—Guppy, 1944.
3. Ericaite—Kühn and Schaacke, 1955.

form is isometric hextetrahedral whereas the low temperature modification is orthorhombic pyramidal (Ito *et al.* 1951).

The mineral has no cleavage and breaks with a subconchoidal to uneven fracture. The hardness is 7. Crystals vary from almost colorless to deep purple, the intensity of coloration apparently varying with very slight oxidation of manganese, for the color is deepened by continued exposure to sunlight. Synthetic manganese boracite is colorless (Heide *et al.* 1961). Specific gravity, as determined for nine samples with the Berman balance, is 3.49±0.02 (3.48 calculated for pure chambersite). A specific gravity of 3.484 is reported for the synthetic manganese analogue of boracite (Heide *et al.*, 1961).

In transmitted light the orthorhombic dimorph has optical properties as listed in Table 1. As shown in the table, indices of refraction are close to the approximate value determined for the ferrous analogue—ericaite, and considerably higher than for boracite.

CHEMICAL COMPOSITION

Chambersite is a manganese chloroborate—$Mn_3B_7O_{13}Cl$. Quantitative analysis (Table 2) indicates limited substitutional solid solution of Fe^{2+} and Mg^{2+} to give the formula $(Mn_{2.90}Fe_{0.09}Mg_{0.01})B_7O_{13}Cl$. The mineral is thus the manganese analogue of boracite ($Mg_3B_7O_{13}Cl$) and of ericaite (essentially $Fe_3B_7O_{13}Cl$). Manganese is reported in ericaite in amounts up to MnO-2.32% (Kühn and Schaacke, 1955), but has not previously been reported in natural material as the principal cation. Heide *et al.* (1961) report complete solid solution between the synthetic Mg-, Fe-, and Mn-boracite products, and list resulting changes in density and cell-edge.

TABLE 2. CHEMICAL COMPOSITION OF CHAMBERSITE

	A	B	C	D
MnO	43.97	41.87	.5903	
FeO		1.28	.0178	3.00
MgO		0.05	.0012	
CaO		tr	—	
B_2O_3	50.36	49.50	.7108	3.50
Cl	7.32	6.34	.1788	0.88
Remainder		1.39		
Total	101.65	100.43		
Less O=Cl	1.65	1.39		
	100.00	99.04		

A. Theoretical weight percentages for $Mn_3B_7O_{13}Cl$.
B. Chambersite, Mont Belvieu, Barber's Hill salt dome, Chambers County, Texas. Remainder includes SiO_2 0.32, TiO_2-trace, Al_2O_3 0.12, Na_2O 0.05, K_2O 0.03, H_2O 0.87. Analyst: M. Chiba, Japan Analytical Chemistry Research Institute.
C. Molecular amounts calculated from B.
D. Molecular proportions calculated from B.

Quantitative spectrographic analysis of a separate sample by H. J. Rose of the U. S. Geological Survey (pers. comm. from C. L. Christ, 1958) gave:

Mn	Fe	Mg	Ca	Sr	Ba	B	Si
15	1.7	0.20	0.2	0.0	0.0	10	0.050

Looked for but not found: Cu, Ag, Au, Hg, Pd, Pt, Mo, W, Re, Ge, Sn, Pb, As, Sb, Bi, Zn, Cd, Tl, In, Co, Ni, Cr, V, Ga, Sc, Y, Yb, La, Ce, Nd, Zr, Th, Nb, P. Results are reported to have an overall accuracy of ±15% except near the limits of detection where one digit is reported.

X-RAY STUDY

X-ray unit cell data determined by indexing of the powder diffraction pattern are given in Table 3. Indexing is based on analogy of the powder patterns of chambersite and boracite and on the unit cell data presented in the structure analysis of boracite by Ito *et al.* (1951). The paramorphic isometric crystals available in this study are composed of crystal aggregates of the orthorhombic modification, and single crystal data could not be obtained. Figure 2 shows the correspondence of the powder patterns of boracite and the manganese analogue.

Indexed powder diffraction spacings are given in Table 4 with calculated values of *d* from the unit cell constants cited above. It is worthy of note that the pseudotetragonal nature of the unit cell, combined with a

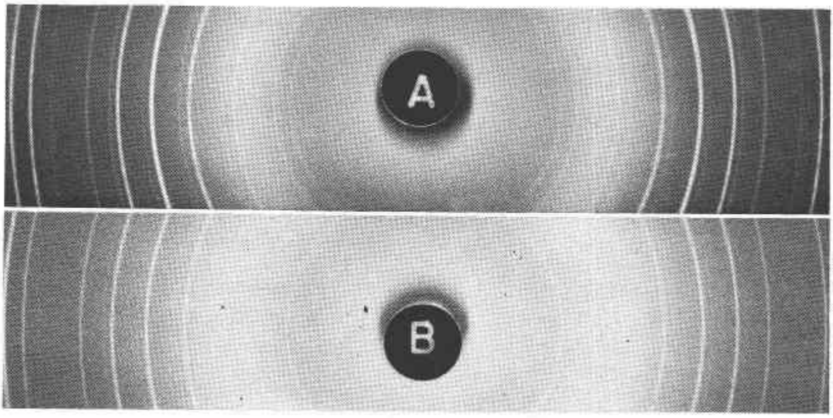

FIG. 2. Photograph comparing x-ray powder diffraction patterns of (A) chambersite and (B) boracite from Luneburg, Germany. Fe radiation, Mn filter. Contact print.

close approximation of the axial ratio c/a of $\sqrt{2}$, allows indexing of the powder pattern for a pseudoisometric cell with the dimension $a\sqrt{2} = 12.27$A. An a of 12.248±0.005A is reported for synthetic manganese boracite (Heide *et al.*, 1961).

THERMAL BEHAVIOR

Differential thermal analysis curves were prepared, using a Deltatherm DTA unit, of chambersite ground to minus 100 mesh. The curves have a sharp endothermic reaction at 407° C. and the beginning of a broad endothermic trough at 1065° C. The low temperature reaction results from inversion of the low temperature orthorhombic dimorph to the high temperature isometric modification and indicates a higher temperature for

TABLE 3. UNIT CELL CONSTANTS FOR CHAMBERSITE COMPARED WITH THOSE OF BORACITE. SPACE GROUP BASED ON ANALOGY TO LOW BORACITE AND NOT DETERMINED IN PRESENT STUDY

	1	2
	Chambersite	Boracite
a	8.68+0.01A	8.54A
b	8.68+0.01A	8.54
c	12.26+0.01A	12.07
Space Group	*Pca*	*Pca*
Z	$4(Mn_3B_7O_{13}Cl)$	$4(Mg_3B_7O_{13}Cl)$

1. Determined in present study.
2. Ito *et al.* (1951).

Table 4. X-Ray Powder Diffraction Pattern of Chambersite from Barber's Hill Salt Dome, Mont Belvieu, Chambers County, Texas. Space Group Pca; $a=8.68$A, $b=8.68$, $c=12.26$; Fe Radiation, Mn Filter, Wavelength 1.9373 Å. Corrected for Film Shrinkage

d (meas.)	I	*hkl*	d (calc.)	d (meas.)	I	*hkl*	d (calc.)	d (meas.)	I	*hkl*	d (calc.)
6.15	1	110	6.15	2.17	5	224	2.17	1.641	1	152	1.642
		002	6.12			400	2.17			512	1.642
5.46	1	111	5.49			040	2.17			136	1.641
4.33	2	112	4.34	2.08	6	125	2.08			316	1.641
		200	4.32			215	2.08			244	1.640
		020	4.32			141	2.08			424	1.640
4.08	½	201	4.09			411	2.08	1.598	1	127	1.599
3.91	½	120	3.89			233	2.08			217	1.599
		210	3.89			323	2.08			145	1.598
3.54	5	202	3.54	2.05	1	402	2.06			415	1.598
		022	3.54			042	2.06	1.571	1	153	1.572
3.40	1	113	3.41			006	2.05			513	1.572
3.07	10	004	3.07			134	2.05	1.534	1	440	1.534
		220	3.07			314	2.05			008	1.533
2.98	½	221	2.97			330	2.05	1.488	2	118	1.488
		203	2.97	2.02	1	016	1.992			350	1.488
2.74	6	114	2.74			142	1.989			530	1.488
		130	2.74			412	1.989			406	1.488
		310	2.74	1.941	1	116	1.941			046	1.488
		222	2.74	1.916	½	225	1.918	1.477	½	137	1.478
2.67	1	131	2.68			241	1.917			317	1.478
		311	2.68			421	1.917	1.446	1	208	1.447
2.50	3	204	2.51			403	1.917			028	1.447
		024	2.51	1.851	5	206	1.851			600	1.446
		132	2.51			026	1.851			060	1.446
		312	2.51	1.830	1	135	1.830	1.417	½	237	1.417
2.39	½	124	2.41			315	1.830			327	1.417
		214	2.41	1.771	3	404	1.772			161	1.417
230		230	2.41			044	1.772			611	1.417
		320	2.41	1.753	½	243	1.754	1.410	½	246	1.408
2.28	1	115	2.28			423	1.754			426	1.408
		133	2.28	1.701	2	226	1.698	1.398	½	155	1.391
		313	2.28	1.685	½	117	1.686			515	1.391
						151	1.686	1.372	2	260	1.372
						511	1.686			620	1.372

the orthorhombic-isometric inversion than for either boracite (265° C.) or ericaite (310–315° C.). The endothermic trough starting at 1065° C. marks the beginning of melting. The observed inversion temperature of 407° C. corresponds precisely to that reported for synthetic manganese boracite by Heide *et al.* (1961).

Cooling curves have a broader exothermic reaction at approximately 400° C. with slight maxima at 405° C. and 395° C. separated by a shallow trough. The significance of doubling of the low temperature maximum on cooling has not been investigated, but probably results from better resolution during the slower cooling process showing both the breakdown of the isometric modification and crystallization of the orthorhombic form. A rapid inversion is indicated by the close correspondence of temperatures on both heating and cooling curves.

Name

The name is in allusion to the locality in Chambers County, Texas.

Acknowledgments

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