# A RESTUDY OF BAKERITE, PRICEITE, AND VEATCHITE[*]

HENRY KRAMER, *U. S. Geological Survey, Washington, D. C.*,[†]
AND
ROBERT D. ALLEN, *U. S. Geological Survey, Claremont, California.*

## ABSTRACT

Complete chemical analyses have been made on six specimens to clarify existing uncertainties in the formulas of bakerite, priceite, and veatchite. Previously published formulas are corroborated for all three minerals. Optical measurements clear up several ambiguities in the literature. Tabulated below are formulas (calculated from analyses), optical properties, specific gravities, and spectrographic determinations.

| | *Bakerite* | *Priceite* | *Veatchite* |
|---|---|---|---|
| Chemical formula | $8CaO \cdot 5B_2O_3 \cdot 6SiO_2 \cdot 6H_2O$ | $4CaO \cdot 5B_2O_3 \cdot 7H_2O$ | $3(SrO, CaO) \cdot 8B_2O_3 \cdot 5H_2O$ |
| $\alpha_{Na}$ | $1.626 \pm 0.004$* | $1.573 \pm 0.002$ | $1.550 \pm 0.002$ |
| $\beta_{Na}$ | —— | 1.595 (calc.) | 1.553 (calc.) |
| $\gamma_{Na}$ | $1.655 \pm 0.003$* | $1.597 \pm 0.002$ | $1.621 \pm 0.002$ |
| 2V | —— | $32° \pm 2°$ | $25° \pm 2°$ |
| Optical group | —— | Biaxial negative | Biaxial positive |
| Specific gravity (25° C.) | 2.885* | 2.415* | Not determined |
| Trace elements (<1%) | Al, Mg, Fe, Na, Sr, Cu, Sn, Pb, Ag, Mn | Si, Al, Mg, Fe, Sr, Cu, Na | Ca, Si, Al, Mg, Fe, Ba, Cu, Mn |

* Average value.

*X*-ray data confirm a striking similarity between bakerite and datolite patterns; a possible structural formula for bakerite, which agrees with the chemical analyses is $Ca_8B_8(BO_4)_2(SiO_4)_6(OH)_6 \cdot 3H_2O$.

On the basis of mineralogical and chemical associations it is suggested that (1) priceite is sometimes derived from colemanite, (2) bakerite may be deposited by hydrothermal solutions.

## INTRODUCTION

Bakerite, priceite, and veatchite are three borates whose reported chemical formulas are subject to review; and optical determinations available on these minerals are incomplete or inconsistent. The experimental results of examining California specimens are reported in this paper to help clarify several of these uncertainties. In addition, spectrographic analyses, *x*-ray diffraction data, and density determinations are included. A brief discussion of the origin of bakerite and priceite is based on mineralogical and chemical associations. Descriptions of the six specimens studied are presented below.

---

[*] Publication authorized by the Director, U. S. Geological Survey.

[†] Present address: Pyrotechnics Laboratory, Samuel Feltman Ammunition Laboratories, Picatinny Arsenal, Dover, New Jersey.

| *Specimen number* | *Locality* | *Occurrence* |
|---|---|---|
| Bakerite 1 (Collected by W. T. Schaller) | Corkscrew Canyon, Death Valley area, Inyo County, Calif. (Exact locality not known) | As irregular veins in altered volcanic rock. Pockets among veins are lined with acicular crystals of thomsonite and natrolite |
| Bakerite 2 (Collected by D. H. Kupfer) | Center of sec. 22, T. 26 N., R. 2 E., San Bernardino base and meridian, DeBely Wash, 1000 feet SW. of DeBely Mine, Death Valley area, Inyo County, Calif. | Float. Encrusted and veined by minute crystals of natrolite and thomsonite |
| Priceite 1 (Collected by F. M. Byers) | NW$\frac{1}{4}$ sec. 16, T. 26 N., R 2 E., San Bernardino base and meridian, 1450 feet N. 55° E. from U. S. Mineral Monument 40 (elev. 2191 feet); Monte Blanco area, Death Valley area, Inyo County, Calif. | White veins associated with colemanite in basaltic tuff. (Tuff consists of partly devitrified glass with average index of refraction near 1.50, nondescript anisotropic material, and basalt fragments) |
| Priceite 2 (Collected by J. F. McAllister) | SW$\frac{1}{4}$ sec. 9, T. 26 N., R. 2 E., San Bernardino base and meridian, 3900 feet N. 45° E. from U. S. Mineral Monument 40 (elev. 2191 feet), Corkscrew Wash, Death Valley area, Inyo County, Calif. | White veins in altered basalt |
| Priceite 3 (Collected by D. F. Hewett) | Same as Priceite 2 | Megascopically translucent and pale olive-yellow.* Float presumably derived from veins in altered basalt |
| Veatchite (Collected by S. J. Muessig) | Center NE$\frac{1}{4}$ sec. 32, T. 5 N., R. 14 W., San Bernardino base and meridian, lower dump, Lang Borate district, Tick Canyon, Los Angeles County, Calif. | Silky fibrous crystals encrusting colemanite and clay on massive howlite |

* Pale olive-yellow 10 Y 7/2, Rock-Color Chart, *Geol. Soc. Am.* (1951).

*X*-ray powder patterns were prepared by Arthur Chodos, Department of Geology, California Institute of Technology. Spectrographic analyses were made by H. W. Johnson, Pacific Spectrochemical Laboratory, Los Angeles, Calif. Datolite specimens were supplied by W. C. Oke of the California Institute of Technology. Borate specimens were collected by members of the U. S. Geological Survey whose names are given above.

The original manuscript was revised in accord with suggestions by W. T. Schaller, C. L. Christ, and members of the Claremont office of the Geological Survey.

## BAKERITE

### *Optical Properties*

Palache, Berman, and Frondel (1951) describe bakerite as "Optically biaxial with moderate birefringence and a mean index of refraction of 1.642; in part spherulitic." The specimens used in the present investigation have permitted measurement of both alpha and gamma. It was not possible, however, to determine either beta or 2V because of its fine-crystalline habit.

TABLE 1. OPTICAL PROPERTIES OF BAKERITE

| | Bakerite 1 | Bakerite 2 | Palache, Berman, and Frondel (1951) |
|---|---|---|---|
| $\alpha_{Na}$ | 1.624±0.002 | 1.628±0.002 | — |
| $\gamma_{Na}$ | 1.654±0.002 | 1.656±0.002 | — |
| Birefringence ($\gamma$–$\alpha$) | 0.030±0.004 | 0.028±0.004 | Moderate |
| Average index | 1.639 | 1.642 | 1.642 |
| $\text{Habit}_{\text{micro}}$ | Cryptocrystalline to submicroscopic; spherulitic extinction | Same as bakerite 1 | In part spherulitic |

### *Chemical Analyses*

From two analyses of bakerite, Giles (1903) derived the following formula: $8CaO \cdot 5B_2O_3 \cdot 6SiO_2 \cdot 6H_2O$. No other published analyses are known to the writers. W. F. Foshag (1954) has obtained two bakerite analyses which are essentially the same as those published by Giles. Contrasting with the above formula is the one proposed by Palache, Berman, and Frondel (1951) "based on the structural resemblance to datolite, herderite, and homilite indicated by *x*-ray powder diffraction study": $Ca_4B_4(BO_4)(SiO_4)_3(OH)_3H_2O$. When the latter formula is recast as oxides and multiplied by two it becomes: $8CaO \cdot 5B_2O_3 \cdot 6SiO_2 \cdot 5H_2O$. Thus, the only difference between the formulas is in the number of molecules of water. Two bakerites have been analyzed to determine the water content as well as the cationic ratios.

The possibility that "$H_2O$ (−)" can be held in bakerite at temperatures in excess of 105° C. has been explored by two methods. (1) A differential

TABLE 2. BAKERITE—CHEMICAL ANALYSES AND CALCULATION OF FORMULA

| | Bakerite 1 (per cent) | | Bakerite 2 (per cent) | | Giles (1903)* (per cent) | | Palache Berman, and Frondel (1951) theoretical per cent) |
|---|---|---|---|---|---|---|---|
| | Orig. | Recalc. | Orig. | Recalc. | Orig. | Recalc. | |
| CaO | 35.14 | 35.42 | 34.47 | 35.24 | 35.05 | 35.38 | 35.97 |
| $B_2O_3$ | 27.58 | 27.79 | 26.57 | 27.17 | 27.30 | 27.56 | 27.92 |
| $SiO_2$ | 27.90 | 28.12 | 28.40 | 29.03 | 28.25 | 28.52 | 28.89 |
| $H_2O$ (+) | 8.60 | 8.67 | 8.37 | 8.56 | 8.46 | 8.54 | 7.22 |
| $H_2O$ (−) | 0.30 | | 0.26 | | | | |
| $R_2O_3$ | 0.65 | | 1.93 | | 0.94 | | |
| Total | 100.17 | | 100.00 | | 100.00 | | |
| Less $H_2O$ (−) and $R_2O_3$ | 0.95 | | 2.19 | | 0.94 | | |
| Total | 99.22 | 100.00 | 97.81 | 100.00 | 99.06 | 100.00 | 100.00 |
| Specific gravity (25° C.) | 2.88 | | 2.89 | | | | 2.88 |

Analyst: Henry Kramer

| | Molecular proportions (Bakerite 1) | Oxygen atoms | Atomic ratios | Atomic ratios on basis of 40 O's |
|---|---|---|---|---|
| CaO | 0.632 | 0.632 | Ca 0.632 | 7.788 |
| $B_2O_3$ | 0.399 | 1.197 | B 0.798 | 9.833 |
| $SiO_2$ | 0.468 | 0.936 | Si 0.468 | 5.767 |
| $H_2O$ | 0.481 | 0.481 | H 0.962 | 11.854 |

Atomic ratios and formula on basis of 41 O's

| | | |
|---|---|---|
| Ca | 7.983 | $Ca_8B_{10}Si_6O_{35} \cdot 6H_2O$ |
| B | 10.080 | |
| Si | 5.911 | or |
| H | 12.151 | $8CaO \cdot 5B_2O_3 \cdot 6SiO_2 \cdot 6H_2O$ |

---

* Average of two analyses.

thermal analysis curve of bakerite 2 was prepared with a portable apparatus, using maximum sensitivity and a heating rate of 30° C. per minute to obtain maximum thermographic response from the instrument. A single endothermic peak was recorded which commenced at an indefinite point between 400 and 500° C. and reached a maximum at 590° C. The sample was not heated above 600° C. (2) Bakerite 1 was heated in a muffle furnace at 200° C. for 30 minutes. Water loss was not appreciably greater than at 105° C. These results would indicate that the usual procedure for determination of "$H_2O$ (−)" is applicable to bakerite.

The assumption of 41 oxygen atoms in the formula fits the analysis of bakerite 1 and verifies Giles' formula for bakerite. Although bakerite 2 was unsuitable for formula calculation because of impurities, its $B_2O_3/H_2O$ ratio, calculated from weight per cents, also substantiates this formula:

| | *Bakerite 1* | *Bakerite 2* |
|---|---|---|
| $B_2O_3/H_2O$ | 3.205 | 3.174 |

## PRICEITE

### *Optical Properties*

Although the indices of refraction of priceite are known with reasonable accuracy (Larsen, 1917; Foshag, 1924), the measured and calculated values of 2V are discordant (Palache, Berman, and Frondel, 1951). In fact, 2V has been previously measured only on priceite from Panderma, Turkey (also known as pandermite).

The direct measurement of beta on grains of priceite is exceptionally difficult because the orientation of the optical indicatrix is uncertain. Beta was determined, therefore, by calculation from alpha, gamma, and 2V measured on the universal stage, as well as by direct measurement.

Cryptocrystalline varieties of priceite (priceite 2 and 3) whose crystal diameter averages less than 5 microns appear to have a lower gamma index, and consequent lower birefringence, than the coarser crystallized type (priceite 1), whose crystal diameter averages more than 20 microns. This effect is probably caused by the nearly submicroscopic particle size rather than by variations in the chemistry of the mineral. Optical data from the coarser material are believed to be superior. The 2V measured on priceite 1 is exactly the same as that reported for priceite from Panderma (Larsen, 1917). Beta calculated is the same as beta measured (on grains "on edge"), limits of error considered.

### *Chemical Analyses*

Foshag (1924) gives two possible formulas for priceite: (1) $4CaO \cdot 5B_2O_3 \cdot 7H_2O$ (after Van't Hoff); (2) $5CaO \cdot 6B_2O_3 \cdot 9H_2O$. Either one

TABLE 3. OPTICAL PROPERTIES OF PRICEITE

| | Priceite 1 | Priceite 2 | Priceite 3 | Foshag (1924) |
|---|---|---|---|---|
| $\alpha_{Na}$ | $1.573 \pm 0.002$ | $1.573 \pm 0.003$ | $1.573 \pm 0.003$ | 1.571 |
| $\beta_{Na}$ calc | 1.595 | — | — | — |
| $\beta_{Na}$ meas. | $1.594 \pm 0.002$ | — | — | 1.590 |
| $\gamma_{Na}$ | $1.597 \pm 0.002$ | $1.595 \pm 0.003$ | $1.591 \pm 0.003$ | 1.593 |
| Birefringence ($\gamma - \alpha$) | $0.024 \pm 0.004$ | $0.022 \pm 0.006$ | $0.018 \pm 0.006$ | 0.022 |
| Optic sign | Negative | — | — | Negative |
| $2V_{\text{meas.}}$ | $32° \pm 2°$ | — | — | Medium |
| $\text{Habit}_{\text{micro.}}$ | Tiny "books" of plates with rhombic outline | Cryptocrystalline | Cryptocrystalline | — |
| Orientation | $\alpha$ angle long dimension of "plates on edge" varies between 60° and 70°. $\gamma$ is at an angle with the bisectrix of the obtuse angle of a rhomb of about 5° | — | — | — |

is in approximate agreement with published analyses. In this investigation three extremely pure priceites have been analyzed in an attempt to refine our knowledge of the stoichiometry. All three priceites gave negative tests for $SO_3$ and $CO_2$. Priceites 1 and 2 contained virtually no insoluble material whereas priceite 3 contained a trace of insoluble material, microscopically identified as volcanic glass and clay. Calculations based on analyses of priceites 1 and 2 support the formula $4CaO \cdot 5B_2O_3 \cdot 7H_2O$.

## VEATCHITE

### *Optical Properties*

Published optical measurements on veatchite (Switzer, 1938; Stewart, Chalmers, and Phillips, 1954) present the following inconsistency: 2V (measured?) is reported as $37° \pm 2°$, but 2V calculated from the indices of refraction would be 20.4°.

The indices of refraction found for veatchite are close to those determined by Switzer, but 2V was measured as 25°, which is consistent with these indices. Because of its perfect side pinacoidal cleavage, beta was determined by calculation from alpha, gamma, and measured 2V.

TABLE 4. PRICEITE—CHEMICAL ANALYSES AND CALCULATION OF FORMULA

| | Priceite 1 (per cent) | | Priceite 2 (per cent) | | Priceite 3 (per cent) | | Priceites 1 and 2 Average (per cent) Recalc. |
|---|---|---|---|---|---|---|---|
| | Orig. | Recalc. | Orig. | Recalc. | Orig. | Recalc. | |
| $B_2O_3$ | 49.87 | 49.88 | 49.64 | 49.92 | 48.95 | 49.20 | 49.90 |
| CaO | 32.04 | 32.05 | 31.90 | 32.08 | 32.06 | 32.43 | 32.06 |
| $H_2O$ (+) | 18.07 | 18.07 | 17.90 | 18.00 | 18.28 | 18.37 | 18.04 |
| $H_2O$ (−) | 0.20 | | 0.69 | | 0.41 | | |
| Total | 100.18 | | 100.13 | | 99.70 | | |
| Less $H_2O$ | (−0.20) | | 0.69 | | 0.41 | | |
| Total | 99.98 | 100.00 | 99.44 | 100.00 | 99.29 | 100.00 | 100.00 |
| Specific gravity (25° C.) | 2.41 | | N.D. | | 2.42 | | |

Analyst: Henry Kramer

| | Molecular proportions | Oxygen atoms | Atomic ratios | | Atomic ratios and formula on basis of 26 O's | |
|---|---|---|---|---|---|---|
| $B_2O_3$ | 0.713 | 2.139 | B | 1.426 | 9.988 | $Ca_4B_{10}O_{19}\cdot 7H_2O$ |
| CaO | 0.572 | 0.572 | Ca | 0.572 | 4.006 | or |
| $H_2O$ | 1.001 | 1.001 | H | 2.002 | 14.022 | $4CaO\cdot 5B_2O_3\cdot 7H_2O$ |

TABLE 5. OPTICAL PROPERTIES OF VEATCHITE

| | Allen | Switzer (1938) | Stewart, Chalmers, and Phillips (1954) |
|---|---|---|---|
| $\alpha_{Na}$ | 1.550±0.002 | 1.551 | 1.551 |
| $\beta_{Na}$ | 1.553 (calc.) | 1.553 | 1.553 |
| $\gamma_{Na}$ | 1.621±0.002 | 1.621 | 1.621 |
| Birefringence ($\gamma$–$\alpha$) | 0.071±0.004 | 0.070 | 0.070 |
| Optic sign | Positive | Positive | Positive |
| $2V_{meas.}$ | 25°±2° | 37°±2° | 37° |
| Habit$_{micro}$ | Platy cleavage fragments (parallel to 010) | — | — |
| Orientation | Angle between $\gamma$ and "$c$" is about 30° | Angle between $\gamma$ and "$c$" is −38° | Angle between $\gamma$ and "$c$" is −30° |

### *Chemical Analyses*

An average of three analyses of veatchite from the Lang district indicates the formula $3SrO \cdot 8B_2O_3 \cdot 5H_2O$ (Switzer and Brannock, 1950). A microchemical analysis of veatchite from Aislaby, Yorkshire, gives the formula $SrO \cdot 3B_2O_3 \cdot 2H_2O$ (Stewart, Chalmers, and Phillips, 1954).

The present veatchite analysis is essentially in agreement with the average analysis of Switzer and Brannock (1950), and agrees approximately with the formula they proposed. Unfortunately, our veatchite specimen, which contained less than one per cent clay, was not sufficient for a second analysis or specific gravity measurement.

TABLE 6. VEATCHITE—CHEMICAL ANALYSES AND CALCULATION OF FORMULA

| | Veatchite (per cent) | | Switzer and Brannock (1950) (average of three recalculated analyses (per cent) | Stewart, Chalmers and Phillips (1954) (per cent) | |
|---|---|---|---|---|---|
| | Orig. | Recalc. | | Orig. | Recalc. |
| SrO | 30.50 | 30.72 | 30.0 | 30.0* | 29.8* |
| CaO | 1.68 | 1.69 | 1.6 | | |
| $B_2O_3$ | 57.56 | 57.96 | 58.5 | 60.3 | 59.8 |
| $H_2O$ (+) | 9.56 | 9.63 | 9.6 | 10.5 | 10.4 |
| $H_2O$ (−) | 0.30 | | | | |
| $CO_2$ | nil | | | | |
| $SO_3$ | nil | | | | |
| Insoluble | N.D. | | | | |
| Total | 99.69 | | | | |
| Less $H_2O$ (−) | 0.39 | | | | |
| Total | 99.30 | 100.00 | 99.7 | 100.8 | 100.0 |

Analyst Henry Kramer

| | Molecular proportions | Oxygen atoms | | Atomic ratios | Atomic ratios and formula on basis of 32 O'S |
|---|---|---|---|---|---|
| SrO | 0.296 | 0.296 | Sr | 0.296 | 2.821 } 3.107 |
| CaO | 0.030 | 0.030 | Ca | 0.030 | 0.286 |
| $B_2O_3$ | 0.832 | 2.496 | B | 1.664 | 15.861 |
| $H_2O$ | 0.535 | 0.535 | H | 1.070 | 10.199 |
| | | | | | $(Sr, Ca)_3B_{16}O_{27} \cdot 5H_2O$ |
| | | | | | or |
| | | | | | $3(SrO, CaO) \cdot 8B_2O_3 \cdot 5H_2O$ |

* Includes SrO and CaO.

## SPECTROGRAPHIC ANALYSES

Spectrographic analyses for minor elements in bakerite, priceite, and veatchite are presented in Table 7.

TABLE 7. SPECTROGRAPHIC ANALYSES

| Concentration range (per cent) | Bakerite | | Priceite | | | Veatchite |
|---|---|---|---|---|---|---|
| | 1 | 2 | 1 | 2 | 3 | |
| 0.X | Mg<br>Al<br>Fe | Mg<br>Na | Si | Si<br>Mg<br>Sr | Si<br>Mg<br>Al<br>Fe<br>Na | Si<br>Mg<br>Ca |
| 0.0X | Sr<br>Cu<br>Pb<br>Na | Al<br>Fe<br>Pb | Mg<br>Al<br>Fe<br>Sr | Al<br>Fe | — | Al<br>Fe<br>Ba |
| 0.00X | Ag<br>Mn | Cu<br>Sn | Cu | Cu | Cu | — |
| 0.000X | — | — | — | — | — | Cu<br>Mn |

## *X*-RAY DIFFRACTION DATA

*X*-ray powder patterns were prepared for all three minerals with nickel-filtered copper radiation over the range $2\theta = 0°$ to $90°$, the spectrum being scanned with a Geiger counter spectrometer at 1° per minute.

The similarity between powder patterns of bakerite and datolite has been noted by Palache, Berman, and Frondel (1951). In Table 8 the bakerite pattern is compared with patterns prepared from (1) finely crystalline datolite from Keweenaw Peninsula, Michigan (datolite 1), and (2) coarsely crystalline datolite from Hampden Quarry, Springfield, Maine (datolite 2). With respect to spacing, the patterns nearly coincide for all major peaks and for many minor peaks. The bakerite pattern, however, apparently represents a slight contraction of either datolite pattern. If the bakerite structure can be derived from that of datolite by partial substitution of B for Si, contraction would be expected. Undoubtedly, bakerite and datolite structures are nearly identical, but a structural formula must account for the bakerite composition. If the formula proposed by Palache, Berman, and Frondel (1951) were modified

TABLE 8. *X*-RAY DATA: INTERPLANER SPACINGS AND RELATIVE INTENSITIES
Nickel-filtered copper radiation

| Priceite 1 | | Priceite 2 | | Bakerite 1 | | Datolite 2 | | Datolite 2 | | Veatchite | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *d*(Å) | *I* | *d*(Å) | *I* | *d*(Å) | *I* | *d*(Å) | *I* | *d*(Å) | *I* | *d*(Å) | *I* |
| 10.92 | 10 | 10.85 | 10 | 6.01 | 1 | 5.99 | 2 | — | | 10.53 | 10 |
| 5.99 | 2 | 6.01 | 3 | 4.82 | 2 | 4.83 | 2 | 4.85 | 1 | 8.27 | 1 |
| 5.46 | 8 | 5.47 | 3 | 3.74 | 5 | 3.75 | 4 | 3.76 | 10 | 6.94 | 1 |
| 4.49 | 1 | 4.51 | 2 | 3.38 | 3 | 3.40 | 4 | 3.41 | 3 | 5.63 | 1 |
| 4.29 | 4 | 4.30 | 3 | 3.10 | 9 | 3.12 | 10 | 3.11 | 10 | 5.22 | 3 |
| 3.63 | 10 | 3.63 | 10 | 3.04 | 1 | — | | — | | 4.20 | 1 |
| 3.49 | 7 | 3.49 | 9 | 2.98 | 3 | 2.98 | 5 | 3.00 | 5 | 3.93 | 1 |
| 3.39 | 1 | 3.40 | 1 | 2.84 | 10 | 2.86 | 6 | 2.86 | 5 | 3.69 | 1 |
| 3.33 | 1 | — | | 2.50 | 3 | 2.52 | 5 | 2.53 | 1 | 3.47 | 10 |
| 3.30 | 1 | 3.30 | 1 | 2.45 | 1 | — | | — | | 3.32 | 2 |
| 3.07 | 1 | — | | 2.39 | 1 | 2.41 | 3 | 2.42 | 1 | 2.88 | 3 |
| 2.98 | 1 | 2.98 | 2 | 2.28 | 1 | 2.30 | 2 | 2.30 | 1 | 2.79 | 1 |
| 2.88 | 2 | 2.89 | 2 | 2.23 | 6 | 2.25 | 5 | 2.24 | 3 | 2.76 | 1 |
| 2.79 | 1 | 2.79 | 2 | 2.18 | 5 | 2.19 | 5 | 2.19 | 3 | 2.67 | 1 |
| 2.72 | 6 | 2.72 | 3 | 2.15 | 2 | 2.16 | 2 | 2.16 | 2 | 2.61 | 10 |
| 2.67 | 1 | 2.67 | 1 | 2.07 | 1 | 2.08 | 2 | 2.08 | 1 | 2.40 | 1 |
| 2.59 | 1 | 2.59 | 1 | 2.03 | 1 | 2.04 | 1 | 2.04 | 1 | 2.21 | 1 |
| 2.52 | 1 | 2.51 | 1 | 1.983 | 3 | 1.996 | 2 | 1.998 | 2 | 2.17 | 1 |
| 2.47 | 1 | 2.46 | 2 | 1.895 | 1 | — | | 1.903 | 2 | 2.16 | 1 |
| 2.42 | 1 | 2.42 | 1 | 1.828 | 2 | 1.873 | 3 | 1.872 | 3 | 2.08 | 9 |
| 2.39 | 1 | 2.39 | 1 | 1.760 | 1 | 1.771 | 2 | 1.774 | 1 | 1.924 | 1 |
| 2.33 | 2 | 2.33 | 2 | 1.735 | 1 | 1.746 | 2 | 1.749 | 1 | 1.833 | 1 |
| 2.31 | 1 | 2.32 | 2 | 1.704 | 2 | 1.720 | 3 | 1.722 | 2 | 1.735 | 2 |
| 2.28 | 1 | — | | — | | 1.664 | 2 | 1.664 | 1 | 1.488 | 2 |
| 2.23 | 1 | 2.23 | 1 | 1.634 | 3 | 1.645 | 3 | 1.647 | 1 | 1.406 | 1 |
| 2.18 | 5 | 2.18 | 5 | 1.603 | 1 | 1.621 | 1 | 1.622 | 1 | 1.301 | 2 |
| 2.16 | 2 | — | | 1.551 | 1 | — | | — | | 1.156 | 1 |
| 2.14 | 1 | 2.14 | 1 | 1.512 | 1 | 1.526 | 2 | 1.528 | 1 | | |
| 2.08 | 1 | — | | — | | — | | 1.499 | 1 | | |
| 2.06 | 1 | 2.06 | 1 | — | | 1.481 | 2 | 1.481 | 1 | | |
| 2.03 | 1 | 2.03 | 1 | — | | — | | 1.429 | 1 | | |
| 1.977 | 1 | 1.977 | 1 | 1.315 | 1 | 1.323 | 1 | — | | | |
| 1.953 | 1 | — | | — | | 1.305 | 1 | — | | | |
| 1.939 | 2 | 1.941 | 2 | — | | 1.228 | 1 | 1.229 | 1 | | |
| 1.852 | 1 | 1.852 | 1 | 1.107 | 1 | 1.191 | 1 | — | | | |
| 1.836 | 1 | — | | — | | — | | 1.122 | 1 | | |
| 1.815 | 2 | 1.814 | 2 | — | | — | | 1.097 | 5 | | |
| 1.801 | 1 | 1.797 | 2 | | | | | | | | |
| 1.757 | 1 | 1.755 | 1 | | | | | | | | |
| 1.731 | 1 | 1.729 | 1 | | | | | | | | |
| 1.695 | 1 | — | | | | | | | | | |
| 1.658 | 1 | 1.656 | 1 | | | | | | | | |
| 1.629 | 1 | 1.629 | 1 | | | | | | | | |
| 1.576 | 1 | 1.576 | 1 | | | | | | | | |
| 1.556 | 1 | 1.556 | 1 | | | | | | | | |
| 1.540 | 1 | — | | | | | | | | | |
| 1.453 | 1 | — | | | | | | | | | |
| 1.375 | 1 | 1.375 | 1 | | | | | | | | |
| 1.352 | 1 | 1.352 | 1 | | | | | | | | |
| 1.308 | 1 | — | | | | | | | | | |
| 1.269 | 1 | 1.270 | 1 | | | | | | | | |
| 1.109 | 1 | 1.109 | 1 | | | | | | | | |

as follows it would satisfy the water requirements indicated by oxide analysis: $Ca_8B_8(BO_4)_2(SiO_4)_6(OH)_6 \cdot 3H_2O$.

The pattern for priceite 1 is apparently more completely developed than the pattern for priceite 2, probably because the former is more coarsely crystallized.

The veatchite pattern agrees fairly well with a pattern reported by Stewart, Chalmers, and Phillips (1954), especially with respect to diffraction maxima of strong and moderate intensity.

## ORIGIN OF BAKERITE AND PRICEITE

Mineralogic and chemical evidence suggests that bakerite is deposited by hydrothermal or late-magmatic solutions: (1) bakerite is veined and encrusted with the zeolites natrolite and thomsonite; (2) bakerite contains trace quantities of such typically hydrothermal elements as Pb, Sn, Ag, and Mn, all of which are generally absent from borates.

Mineralogic and petrographic evidence suggests that priceite is derived from colemanite. A white translucent coating sometimes found on "cauliflower" colemanite in Gower Gulch, Death Valley, is characterized by an average index of refraction near 1.585 and moderate birefringence; this material is believed to be priceite, probably an alteration of the colemanite. White pisolitic nodules from the Thompson mine which is located 2.55 miles N. 83° W. of U. S. Mineral Monument 47, Death Valley, consist of comparatively fresh colemanite mingled with finely crystalline transulcent alteration material with fibrous habit and indices of refraction intermediate between those of colemanite and priceite; if the alteration process had reached completion the end-product might have been priceite. Thin sections of priceite from the Monte Blanco area, Death Valley, show corroded euhedral inclusions of colemanite surrounded by fine-crystalline priceite.

Colemanite and priceite from the Death Valley area contain the same trace elements: Si, Al, Fe, Mg, Sr, Ma, and Cu. Principal differences in concentration are shown by Si and Cu as follows:

| Per cent | 0.X | 0.0X | 0.00X | 0.000X |
|---|---|---|---|---|
| Colemanite | | Si | | Cu |
| Priceite | Si | | Cu | |

If priceite is derived from colemanite, the process might bring about enrichment in these elements.

## REFERENCES

FOSHAG, W. F. (1924), Priceite from Furnace Creek, Inyo County, California: *Am Mineral.*, **9**, 11–13.

FOSHAG, W. F. (1954), Personal communication.

GILES, W. B. (1903), Bakerite (a new borosilicate of calcium) and howlite from California: *Mineral. Mag.*, **13**, 353–355.

LARSEN, E. S. (1917), Proof that priceite is a distinct mineral species: *Am. Mineral.*, **2**, 1–3.

PALACHE, C., BERMAN, H., AND FRONDEL, C. (1951), Dana's System of Mineralogy, 7th ed., vol. 2, pp. 341–343, 348–349, 363.

STEWART, F. H., CHALMERS, R. A., AND PHILLIPS, R. B. (1954), Veatchite from the Permian evaporites of Yorkshire: *Mineral. Mag.*, **30**, 389–392.

SWITZER, G. (1938), Veatchite, a new calcium borate from Lang, California: *Am. Mineral.*, **23**, 409–413.

SWITZER, G., AND BRANNOCK, W. W. (1950), Composition of veatchite: *Am. Mineral.*, **35**, 90–92.

*Manuscript received Dec. 8, 1955.*