BURKEITE, A NEW MINERAL SPECIES FROM SEARLES LAKE, CALIFORNIA

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INTRODUCTION

Among the new compounds found in the laboratories of the American Potash and Chemical Corporation, in a study of the equilibria relationships of the salts of the Searles Lake brines, was one first prepared by Mr. W. E. Burke[2] in 1919. This new compound is a double sulfate and carbonate of sodium, $2Na_2SO_4 \cdot Na_2CO_3$ and the name burkeite has been given to it. "Although its native occurrence has not hitherto been reported, and although it does not seem to be a constituent of the Searles Lake salt body, we fully expect to hear of it from Owens Lake, or some of the other alkaline lakes, now that attention has been called to its existence. For this reason, and also as a matter of convenience in referring to a material formed in the plant at the rate of some thousands of tons a week, we have given it a name, burkeite."[3]

In studying the samples of the well G-75 drilled by the U. S. Geological Survey during its search for potash, attention was attracted to small x-shaped crystals sparingly present in the sample from the lower portions of the salt crust. These same samples yielded the new mineral schairerite.[4] The new mineral seems to be confined to samples from a depth of 115–130 feet, the lowest sample taken. These x-shaped crystals and others, together with some masses of solid salt prove to have the chemical composition and optical properties of burkeite as produced artificially at Searles Lake.

Because of the recommendation of John E. Teeple cited above and particularly in view of W. E. Burke's valuable and difficult researches on equilibria in Searles Lake minerals, I think it is desirable to retain the name *burkeite* for this new mineral species. I am indebted to Mr. W. A. Gale, Director of Research, American Potash and Chemical Corporation, for samples of artificial burkeite made in their laboratories and for interesting and valuable infor-

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[2] *Jour. Ind. Eng. Chem.*, vol. **13**, p. 249, 1921.
[3] Teeple, John E., Industrial Development of Searles Lake Brines, p. 32, 1929.
[4] *Am. Mineral.*, vol. **16**, pp. 133–139, 1931.

mation on the equilibria relationships of burkeite and its possible occurrence in the salt crust of Searles Lake.

OCCURRENCE

Burkeite occurs sparingly in the samples from a depth of 115–130 feet in well G-75. Undoubtedly more is present in these samples than an examination would indicate for only those grains or crystals showing certain peculiar markings can be readily distinguished from many of the accompanying salt grains. Crystals and groups of crystals seldom exceed 4 millimeters in maximum dimension, but some of the broken fragments of the massive mineral are much larger. In the sample from a depth of 115–125 feet the burkeite occurs in flat, cushion-shaped crystals, groups of small irregular crystals and fragments of massive mineral. This latter form presumably represents thin beds or massive lumps broken in the course of drilling. The salts of this sample are clean and contain trona, in clear laths; halite in cleavages and fragments; pirssonite in flat diamond-shaped crystals, also hemimorphic crystals; borax in lumps; northupite in small rough octahedrons; clear, sharp gay-lussite crystals; sulfohalite in clear cubo-octahedrons; and rarely small hanksite crystals. The burkeite is rather intimately associated with the trona or has been embedded in a very fine grained gay-lussite sand.

The lowest portion of the well, from 125–130 feet, would be classed as a more "clayey" sample but the clay is, for the most part, very finely crystalline gay-lussite. This formed the matrix for many of the other minerals, including the burkeite. The burkeite is more abundant in this sample than in the first and occurs as thin, cushion-shaped crystals, x-shaped twins, and round masses with a mulberry-like surface. All these forms were apparently scattered singly through the gay-lussite "clay." Associated minerals are clear, sharp gay-lussite crystals; pirssonite in relatively large crystals; northupite in pale yellow to gray rounded octahedrons; thenardite in rough blades without distinct crystal form; tychite in minute sharp, clear octahedrons; schairerite in sharp, steep rhombohedrons; minute ivory colored crystals of calcite, and very rarely small crystals of hanksite.

CHEMICAL COMPOSITION

It was very difficult to obtain a reasonably pure quantity of crystals for analytical investigation, so the massive lumps were

used for analysis. Fortunately these lumps were satisfactorily pure, better, in fact than could have been obtained by attempting to select crystals. The mineral is easily soluble in water and standard analytical procedures were used. The results of the analysis is given in the table below:

ANALYSIS OF BURKEITE

	Searles Lake	Theoretical Composition
Insoluble	0.04	
Na_2O	47.89	47.69
K_2O	None	
SO_3	39.96	41.02
CO_2	11.72	11.29
Cl	0.09	
H_2O	0.04	
	99.74	

The analysis gives satisfactorily the formula, $2Na_2SO_4 \cdot Na_2CO_3$.

Burkeite is easily and completely soluble in water, the solution giving the usual reactions for sulfates and carbonates. Before the blow-pipe it fuses easily and quietly to a clear bead, when hot; white and crystalline when cold; and colors the flame an intense yellow. The mineral is alkaline to tumeric paper.

CRYSTALLOGRAPHICAL PROPERTIES

Crystals of burkeite are common in the material available but are not suitable for crystallographic measurements. A narrow face, considered here the side pinacoid, is usually present on the crystals and is sometimes sufficiently smooth to give fair reflections. The
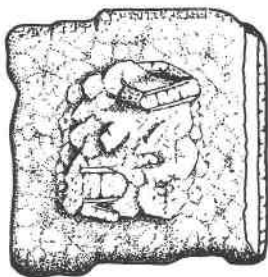

FIG. 1   FIG. 2

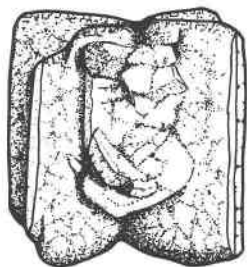FIG. 1. Simple crystal of natural burkeite, showing broad front pinacoid, prism and side pinacoid.

FIG. 2. X-shaped twin crystal of natural burkeite.

front pinacoid is broad and rough with a shagreened surface and yields no reflections. Between the two pinacoids is often a narrow prism, distinct, but mat. The third pinacoidal position is occupied by numerous minute terminations, apparently in parallel position but giving this part of the crystal a rough appearance. Figure 1 is a drawing of one of these simple crystals.

The twin crystals are made up of individuals of the same habit as the simple crystals intergrown to form an x-shaped twin. Their appearance varies somewhat, depending on the relative thickness of the individual crystals. Where these crystals are thin the twin is decidedly x-shaped; where the crystals are thick the twin may resemble hexagonal prisms with two pairs of plane faces (the side pinacoids), each pair separated by a rough median line; and two rough re-entrant faces. Complex aggregates suggest that there is also a transverse twinning but this could not be definitely established on the material available. The re-entrant angles of the twins are partially filled with rough crystals in apparently random position (Figure 2). The only angular measurements obtainable were those between the side pinacoid faces of the twinned crystals. These measurements, while not good, were fairly satisfactory and average 59°42′ and 120°12′. If we assume that the twinning plane is $m(110)$, the prismatic angle 59°42′ would yield an axial ratio of: $a:b=0.574:1$. Certain prismatic markings in some grains observed under the microscope gave a measured angle of 56° when rolled to as near a normal position to the axis as possible. Unfortunately no direct measurements could be made on the prism itself.

Often a large number of crystals are intergrown to form reticulating aggregates of plates. Another form commonly met with is small pea-shaped nodules, their surface being composed of relatively bright faces of the side pinacoid, giving some suggestion of a facetted grain. There are also irregular warty masses resembling mulberries.

Optical and Physical Properties

The color of burkeite is white to pale buff or slightly grayish. The luster is cryolitic, but usually glassy on the side pinacoid.

Under the microscope the mineral is strongly birefracting with low indices of refraction. The mineral is biaxial, negative, with medium small axial angle. 2V = 34°. Dispersion distinct, $r>v$. The indices of refraction, by the oil immersion method, were determined to be as follows:

	α	β	γ	Determined by
Natural mineral	1.448	1.489	1.493	W. F. Foshag
Natural mineral	1.449	1.488	1.491	Jewell Glass
Artificial salt	1.450	1.490	1.492	W. F. Foshag

The plane of the optic axes is parallel to the front pinacoid. The orientation is: $X = c$; $Y = a$; $Z = b$. Figure 3 is a camera lucida sketch of a thin cross section of a twinned crystal showing the optical orientation as well as the twinning habit.
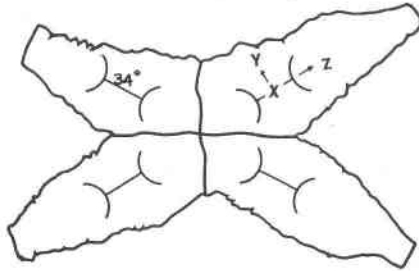

Fig. 3. Camera lucida sketch of thin cross section of natural burkeite crystal showing twinning and optical orientation.

The specific gravity, measured by floating in a heavy solution, was found to be 2.57. The actual density is probably slightly higher, since grains free from minute inclusions were unobtainable. Burkeite readily scratches calcite but does not scratch fluorite. Its hardness is, therefore, $3\frac{1}{2}$. It is very brittle, breaking with a rough conchoidal fracture and shows no evidence of cleavage.

RELATION TO OTHER SALT MINERALS

The equilibrium relationship of burkeite to the other saline minerals of Searles Lake has been worked out by W. E. Burke and his co-workers and the equilibrium diagrams have been published in John E. Teeple's "The Industrial development of Searles Lake Brines." A study of the system, sodium chloride- potassium chloride- sodium sulfate- potassium sulfate- sodium carbonate-potassium carbonate-water, suggests that simple evaporation of normal Searles Lake brine will not yield burkeite in stable equilibrium with the other salts. On this point W. A. Gale[5] has the following to say:

[5] Personal communication.

In the case of Searles Lake, the brine from the lower portions of the main salt body is a considerable distance from the end point of crystallization of the preceding eight component systems ($K-Na-H-SO_4-CO_3-Cl-B_2O_4-PO_4-H_2O$). The relative proportions of the sulfate, carbonate and potassium ions indicate that the point representing this brine falls on the boundary between the hanksite and glaserite fields of the phase rule diagram. It is also saturated with halite, borax and trona, thus being trivariant. Thenardite and burkeite are not stable phases in contact with this lower brine at lake temperatures (about 22.5°C.), although only a slight change in liquid phase composition is necessary in order to reach the divariant point in metastable equilibrium with thenardite, burkeite, glaserite, halite, borax and trona. A considerable change is necessary, however, before burkeite could be a stable solid phase.

On the other hand the marginal and surface brines vary greatly in composition, and we have found considerable thenardite in marginal portions of the deposit near the surface. Therefore, there seems no reason why burkeite should not also occur in certain parts of the deposit in equilibrium with local brines.

We have obtained artificial crystals of hanksite in the laboratory, but they are very slow in growing. Starting at the above mentioned metastable point, months, or even years, may be required to reach equilibrium even after hanksite seeds appear or are intentionally added. Therefore, in the original deposition of the salt strata of the lake, we think it possible that burkeite was first precipitated along with thenardite, glaserite, etc., and that eventually hanksite appeared and crystallized slowly at the expense of these other sulfate phases. Large quantities of glaserite remain, but burkeite and thenardite are now absent from this portion of the deposit except possibly as inclusions within other crystals or within dense aggregates of other salts.

The mineral assemblage found in the samples—thenardite, burkeite, trona and halite—and the absence of glaserite and the very rare occurrence of hanksite suggests that the brines from which these salts crystallized were simpler in composition than the normal Searles Lake brines, being deficient in potash salts, corresponding more nearly to the system: $NaHCO_3-Na_2CO_3-Na_2SO_4-NaCl-H_2O$.[6] This variation from the normal brine may be due to the vagaries of underground drainage, or, as already suggested by W. A. Gale, may represent an ancient stage in the evaporation of these brines. Gale states:

We note that the association of natural burkeite from well G-75, includes borax, trona, halite, thenardite and some hanksite, but an absence of glaserite. The original mother liquor in contact with these solid phases would, therefore, correspond to the liquid phase represented by point 288, Diagram 17, shown on page 103 of Teeple's book, except for the addition of borax, trona and the less soluble minerals. These latter, however, would not be expected to greatly affect the solubility relations of the other salts at ordinary temperatures. In other words, the solution from which

[6] System XXIV, Diagram 50, *Industrial Development of Searles Lake Brines.*

the natural burkeite crystallized must have been at the opposite side of the hanksite field from that of normal Searles Lake brine as found in the main salt body today.

In this connection it is interesting to note that the relative proportions of the principal salts in Owens Lake brine prior to the start of crystallization in 1921 were such as to place the brine within the stable portion of the burkeite field, about midway between points 288 and 4 (Teeple's Diagram 17), upon reaching saturation with a sulfate phase.

Since the Searles Lake salt deposit resulted from the evaporation of saline waters which had originally overflowed from Owens Lake, it is quite conceivable that some of the early stages of crystallization should take place from brines having compositions falling along the boundary between the burkeite and thenardite fields and approaching saturation with hanksite at point 288 as the concentration of potassium increased.

In a crystallographical and optical study of an artificial salt submitted to him as $2Na_2SO_4 \cdot Na_2CO_3$, Austin F. Rogers[7] obtained the following optical properties:

$$\alpha = 1.463, \qquad \beta = 1.469, \qquad \gamma = 1.480.$$

These values are those of an optically positive mineral with small axial angles and do not correspond to the values obtained on either the natural mineral or the artificial burkeite as produced at Searles Lake. The crystallography of Rogers' salt suggests that it may be, in part, thenardite as both the crystal habit and the angular measurements suggest that mineral.

[7] *Am. Jour. Sci.*, vol. **11,** pp. 473–476, 1926.