

TEEPLEITE, A NEW MINERAL FROM BORAX LAKE, CALIFORNIA

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Borax Lake, in Lake County, California, was the earliest commercial source of borax in the United States. This mineral was first found there by Doctor John A. Veatch in 1857, and for ten years the lake was actively exploited. The mineral occurs as crystals of borax, oftentimes of large size, in a saponaceous mud. A narrow ridge separates Borax Lake from the fresh waters of Clear Lake. Immediately beyond the ridge lies Sulfur Banks, a solfatara which yields highly boraciferous waters. Near the shores of Borax Lake is a small extinct solfatara, known as Little Sulfur Banks, and is probably the original source of the borax. Analysis of water² from Borax Lake showed a high content of sodium carbonate, sodium chloride and sodium borate, but with low sodium bicarbonate content.

During the late summer of 1934, Borax Lake became almost completely dry, due to a prolonged period of unusual dry weather and the lake was reduced to a mud playa, covered by a white efflorescence of salts, a condition not observed since 1861, when the lake was reported to have completely dried. In the pools of brine remaining, crusts of salts were formed, and in the central area, covering as much as an acre or two, a shallow pool remained, beneath which beds of saline minerals of a light buff color were deposited.

ANALYSIS OF BORAX LAKE BRINE

F. H. May, *Analyst*

Na ₂ CO ₃	14.69
Na ₂ B ₄ O ₇	0.87
Na ₂ B ₂ O ₄	4.32
KBr	0.03
KCl	3.40
NaCl	10.60
Na ₂ SO ₄	0.323
S ⁻⁻	tr.
As ₂ O ₃	tr.
P ₂ O ₅	0.133
I	None found
Organic matter	Appreciable
H ₂ O, etc. (by difference)	65.64
pH	11.1
Sp. Gr. (20°C.)	1.332

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² Geology of the quicksilver deposits of the Pacific slope: *Mon.* 13, *U. S. Geol. Surv.*, p. 265, 1888.

In this central portion of the lake bed, immersed and covered by a thick brown viscous brine, were bodies of salts, the largest about sixty feet in length. The viscous liquid upon analysis showed the above composition on the basis of hypothetical combinations in which the components of the reciprocal salt pair $\text{Na}_2\text{CO}_3 - \text{Na}_2\text{B}_4\text{O}_7$ and $\text{NaHCO}_3 - \text{Na}_2\text{B}_2\text{O}_4$ are expressed in terms of the three salts shown.

Recalculating the main constituents on the basis of grams per 100 grams of water, the results shown in column A below were obtained:

MAIN CONSTITUENTS OF BORAX LAKE BRINES

	Grams/100 grams H_2O	
	A	B
Na_2CO_3	22.38	22.4
$\text{Na}_2\text{B}_2\text{O}_4$	6.58	6.7
$\text{Na}_2\text{B}_4\text{O}_7$	1.32	0.3
$\text{NaCl} + \text{KCl}$	21.33	23.1

In column B is given the composition of the liquid phase at the end point of crystallization in the system $\text{NaCl} - \text{Na}_2\text{CO}_3 - \text{NaHCO}_3 - \text{Na}_2\text{B}_4\text{O}_7 - \text{Na}_2\text{B}_2\text{O}_4 - \text{H}_2\text{O}$ at 35°C ., at which halite, trona, $\text{Na}_2\text{B}_2\text{O}_4 \cdot 2\text{NaCl} \cdot 4\text{H}_2\text{O}$ and $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$ are in equilibrium with the solution.³ It is evident from these compositions that the compound $\text{Na}_2\text{B}_2\text{O}_4 \cdot 2\text{NaCl} \cdot 4\text{H}_2\text{O}$ and $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$ (or $\text{Na}_2\text{CO}_3 \cdot 7\text{H}_2\text{O}$, which is in equilibrium with this solution at a somewhat lower temperature) would be expected to be present in the salts found in this central portion of the lake.

A number of specimens of these salts, which when first collected, were thought to be trona pseudomorphous after halite, proved upon further examination to be $\text{Na}_2\text{B}_2\text{O}_4 \cdot 2\text{NaCl} \cdot 4\text{H}_2\text{O}$, which had formed upon and largely replaced halite. Since this compound is new in nature, although well known as an artificial compound, having been first prepared by W. E. Burke at the Searles Lake plant in 1920, it is here proposed to give it the mineralogical name, *teepelite*, for the late Dr. John E. Teeple, in recognition of his contribution to the chemistry of Searles Lake salts.

The salts that formed during the desiccation of the lake consist of buff colored crusts of crystals made up of cubes of halite, blades of trona and crusts of teepelite. Borax is absent in these specimens. The specimens show strong indications that in many cases cubes of halite have reacted with the mother liquor to form teepelite as the composition of the brines changed through crystallization, giving rise to pseudomorphs of teepelite after halite. The sequence of crystallization was (1) halite, (2) trona, (3) teepelite, and (4) $\text{Na}_2\text{CO}_3 \cdot 7\text{H}_2\text{O}$ (?).

³ Teeple, John E.: The Industrial Development of Searles Lake Brines, with Equilibrium Data, 1929, p. 130.

Later in the season, after several rains and cooler weather, teepleite disappeared and halite again crystallized in fresh, glassy cubes.

CHEMICAL PROPERTIES

Material for analysis was selected from the groups of teepleite crystals grown upon halite and trona. Their surfaces were scraped to remove adhering salts but the sample contained inclosed blades of trona. Attempts to separate the teepleite from the trona by heavy solutions discolored the teepleite, due to reaction with the organic heavy liquids, so that the best possible sample was prepared by hand picking. Microscopic examination showed the prepared sample carried trona and a little halite, but no other contaminant. The results of the analysis is given in the table below:

ANALYSIS OF TEEPLEITE, BORAX LAKE, CALIFORNIA

William F. Foshag, *Analyst*

	Percentages	Ratios	Theory for $\text{Na}_2\text{B}_2\text{O}_4 \cdot 2\text{NaCl} \cdot 4\text{H}_2\text{O}$
Na	28.93	1.2565	28.70
K	None	—	
Ca	0.08	.0021	
Cl	18.72	.5279	22.15
B_2O_4	22.05	.2574	26.70
CO_3	9.42	.1519	
SO_4	None	—	
H_2O	20.48	1.1366	22.45
Insol.	0.15		
	99.83		100.00

After deducting the calcium as CaCO_3 and the remaining CO_3 as trona ($\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\frac{1}{2}\text{H}_2\text{O}$), the remaining ratios, attributable to teepleite ($\text{Na}_2\text{B}_2\text{O}_4 \cdot 2\text{NaCl} \cdot 4\text{H}_2\text{O}$) are as follows:

	Ratios	
Na	1.0318	4×2579
B_2O_4	.2574	1×2574
Cl	.5279	2×2639
H_2O	.9494	4×2376

These ratios except for the low water value, which may be explained, in part at least, by the dehydrated appearance of some of the teepleite, indicate satisfactorily the composition $\text{Na}_4\text{B}_2\text{Cl}_2\text{O}_4 \cdot 4\text{H}_2\text{O}$ or, written as a double salt, $\text{Na}_2\text{B}_2\text{O}_4 \cdot 2\text{NaCl} \cdot 4\text{H}_2\text{O}$.

Teepleite is easily soluble in water to an alkaline solution and gives the usual reactions for chloride and borates. Before the blowpipe, or on a platinum wire, it fuses easily to a white enamel-like crystalline bead, coloring the flame strongly yellow with a momentary flash of green.

CRYSTALLOGRAPHY

Teepleite occurs in crystals but measurable individuals on the material collected are rare. The crystals are flat, beveled plates, usually rounded into flat cushion shape or even lens-shaped individuals. The crystals are usually aggregated into small nubbins, giving a botryoidal effect. Sometimes they are grouped into "roses." Two natural crystals suitable for measurement were found, the measurements of which yielded the data upon which the crystallographic properties were determined. A number of artificial crystals were prepared but did not yield any more satisfactory data.

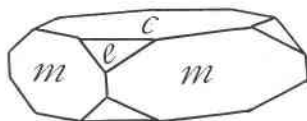
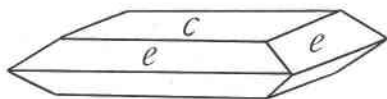


FIG. 1. Teepleite, Borax Lake, Lake County, California.

FIG. 2. Artificial teepleite.

Teepleite is tetragonal, of simple crystal habit. Only the base $c\{001\}$ and the pyramid $e\{101\}$ were found. The base is large, the pyramids relatively narrow, so that the crystals are flat, tabular to the base (Fig. 1). The artificial crystals showed, in addition to the two above forms faces of $m\{110\}$, (Fig. 2).

On crystal No. 1, three good readings for the face $e\{101\}$ gave $\rho = 33^\circ 49'$, while 3 fair readings on crystal No. 2 gave $\rho = 33^\circ 43'$, $33^\circ 40'$ and $33^\circ 42'$. The weighted average for ρ for $e(101) = 33^\circ 47'$. From this the axial ratio was calculated $a:c = 1:0.6690$. Seven measurements for e , on artificial crystals, gave $\rho = 33^\circ 42'$ (average), the individual values ranging from $33^\circ 39'$ to $33^\circ 54'$.

To Mr. George Switzer we are indebted for the determination of x -ray measurements on teepleite. The unit cell dimensions of the simple tetragonal lattice are: $a = 7.27 \text{ \AA}$; $c = 4.84 \text{ \AA}$, with $c/a = 0.666$, which agrees well with the morphological ratio: $c/a = 0.6690$. Since the morphology indicates the holohedral crystal class $4/m2/m2/m$, the space group $P4/nmm$ (D_{4h}^7) is fixed by the following observed reflections: hkl all orders present, $hk0$ present only when $h+k$ is even, $0kl$ all orders present and hhl all orders present. These observations and measurements were made

upon artificial crystals since the natural crystals available were not suitable.

PHYSICAL AND OPTICAL PROPERTIES

The color of the natural teepelite is white to pale buff. This latter color is induced in the mineral by the organic matter in the brines, which in the final state of desiccation of Borax Lake colored the waters molasses brown. Artificial crystals are clear and transparent to white. The luster of the natural mineral is glassy to somewhat greasy, becoming duller upon exposure. The mineral is uniaxial, negative. Indices of refraction on both the natural and the artificial crystals are:

	Natural	Artificial
$\epsilon =$	1.503	1.503
$\omega =$	1.519	1.521

The mineral has a hardness of 3–3.5 and is very brittle. Its fracture is irregular to semi-conchoidal. The specific gravity, determined upon a selected fresh fragment by floating in heavy solution, is 2.076.

SUMMARY

Teepelite is a sodium borate chloride, $\text{Na}_2\text{B}_2\text{O}_4 \cdot 2\text{NaCl} \cdot 4\text{H}_2\text{O}$. Tetragonal. $c = 0.6690$. Uniaxial, negative. $\epsilon = 1.503$, $\omega = 1.519$. $H = 3\text{--}3.5$. $G. = 2.076$. Occurs with halite and trona on specimens from Borax Lake, Lake County, California.