SEARLESITE FROM THE GREEN RIVER FORMATION OF WYOMING*

JOSEPH J. FAHEY†

WITH *X*-RAY NOTES BY JOSEPH M. AXELROD**

ABSTRACT

The third recorded occurrence of searlesite, hydrous sodium borosilicate, is in the Green River formation of southwestern Wyoming.

It is found in flat anhedral crystals in the oil shale and in subhedral crystals as much as 7 inches long in the trona bed, 10 feet thick, at a depth of 1500 feet.

The optical properties of the searlesite from Wyoming are in close agreement with those previously published. The indices of refraction, measured with sodium light, are: $\alpha=1.516$, $\beta=1.531$, and $\gamma=1.535$ (2V=55°, neg., calculated). *X*-ray diffraction photographs and a chemical analysis confirm the identity of the Wyoming mineral as searlesite.

INTRODUCTION

The Green River formation in southwestern Wyoming affords the third recorded occurrence of searlesite, a hydrous sodium borosilicate. This mineral was first described in 1914 by Larsen and Hicks,[1] from the old Searles deep well at Searles Lake, San Bernardino County, California, and named after Mr. John W. Searles, the pioneer who put down the well. It was found in clay at a depth of 540 feet as white spherulites about a millimeter in diameter. Great difficulty was experienced in preparing a sample for chemical analysis due to the intimate association of tiny grains of calcite, quartz, feldspar, chlorite, and hornblende. The analyzed sample contained about 40% of this extraneous material. Larsen states that the optical properties were measured with difficulty and that his results were only approximate.

The second locality of searlesite is the Silver Peak Range, Esmeralda County, Nevada, described in 1934 by Foshag.[2] The crystallographic and optical constants of searlesite from this location were published by Rogers[3] in 1924. These crystals are prismatic and seldom exceed 3 mm. in length. The sample analyzed by Foshag contained less than one per cent of impurities and his analysis was very close to the theoretical composition, $Na_2O \cdot B_2O_3 \cdot 4SiO_2 \cdot 2H_2O$.

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† U. S. Geological Survey, Washington, D. C.

[1] Larsen, Esper S., and Hicks, W. B., Searlesite, a new mineral: *Am. Jour. Sci.*, **38,** 437–440 (1914)

[2] Foshag, William F., Searlesite from Esmeralda County, Nevada: *Am. Mineral.*, **19,** 268–274 (1934).

[3] Rogers, Austin F., The crystallography of searlesite: *Am. Jour. Sci.*, **7,** 498–502 (1924).

Occurrence and Association

The third recorded occurrence of searlesite is at three places in the Green River formation in Sweetwater County, Wyoming. These places are the locations of the drill core of the John Hay, Jr., Well No. 1, approximately 18 miles west of the town of Green River; the drill core of the Union Pacific Well No. 4 that was put down $2\frac{3}{4}$ miles west of the John Hay, Jr., Well No. 1; and the shaft, and trona bed reached by this shaft of the Westvaco Chemical Corporation, formerly the Westvaco Chlorine Products Company. This shaft is approximately $3\frac{1}{2}$ miles north of the John Hay, Jr., Well No. 1 and $4\frac{1}{4}$ miles northeast of the Union Pacific Well No. 4. The exact location of the shaft is 1650 feet south and 1010 feet west of the north and east boundaries of Sec. 15, T.19 N., R. 110 W., 6 P.M. Wyoming. Drilling was started August 16, 1946, and completed to a total depth of 1552 feet on September 22, 1947.

Searlesite occurs at depths of 1480 feet and 1706 feet respectively, in the John Hay, Jr., Well No. 1 and the Union Pacific Well No. 4. This indicates a dip of the shale to the west of 216 feet in $2\frac{3}{4}$ miles, the elevations at the surface of the wells being 6355 feet and 6365 feet in the order named. In the shaft of the Westvaco Chemical Corporation searlesite was found at a depth of 1300 feet. The elevation at the top of the shaft is 6227 feet. These figures point to a dip of the strata to the north of 52 feet in the $3\frac{1}{2}$ miles between the John Hay, Jr., Well No. 1, and the shaft.

In the two drill cores and in the shaft searlesite is found in oil shale with shortite and tiny crystals of pyrite. At the bottom of the shaft at a depth of 1500 feet searlesite is found in association with trona.

The saline mineral assemblage of the Green River formation is unique. Two species, shortite and bradleyite, heretofore reported in no other location, are found associated with trona, pirssonite, gaylussite, and the rare mineral northupite. Shortite is ubiquitous through a vertical distance of more than 600 feet. Trona and northupite, though restricted to definite horizons, are found in great abundance.

Chemical Composition and Physical Properties

A crystal from the trona bed (depth 1500 ft.) of the Westvaco Mine was carefully crushed so that a minimum of fines was formed, then sieved, and the portion passing 80 and retained on 100 mesh was allowed to remain in distilled water, changed daily, for $1\frac{1}{2}$ months. This was done in order to remove the small percentage of sodium carbonate known to be present. Searlesite is not affected by such treatment; a sample so treated for 6 months showed no change of the indices of refraction.

The usual methods of chemical analysis were employed; B_2O_3 was titrated on a sample that had been decomposed by HCl, using mannitol and methyl red and phenolphthalein indicators. Na_2O was determined by the J. Lawrence Smith procedure, and the H_2O determined as the loss in weight on heating the sample to 800° C. for one hour. No B_2O_3 is lost at this temperature. The results of the analysis are recorded in Table 1.

TABLE 1. CHEMICAL ANALYSIS OF SEARLESITE FROM THE GREEN RIVER FORMATION, SWEETWATER CO., WYOMING

J. J. FAHEY, *Analyst*

Composition		Ratios
SiO_2	58.88%	3.992
B_2O_3	16.95	0.991
Na_2O	15.31	1.005
K_2O	none	
H_2O −110° C.	none	
H_2O +110° C.	8.90	2.013
Al_2O_3	0.04	
Fe_2O_3	0.04	
CaO	none	
MgO	0.03	
Total	100.15	
G.=2.460		
Formula: $Na_2O \cdot B_2O_3 \cdot 4SiO_2 \cdot 2H_2O$		

When treated with (1+2) HCl, either cold or hot, searlesite behaves similarly to biotite mica under these circumstances. Silica remains quantitatively as a skeleton that retains the shape of the original grain, and can be filtered off without difficulty. The index of refraction of this siliceous skeleton is between 1.455 and 1.460.

The specific gravity of searlesite is 2.460 determined with an Adams-Johnston pycnometer of 5 cm. capacity, made of fused silica. This is in good agreement with the determination by Rogers[4] (2.45) obtained by suspension in a solution of methylene iodide and benzol.

Searlesite fuses readily to a glass that has an index of refraction of 1.515.

CRYSTALLOGRAPHY

In both the core of the John Hay, Jr., Well No. 1 and that of the Union Pacific Well No. 4, the searlesite is found as segments about 3 mm. thick of flat anhedral crystals that lie parallel to the bedding of the oil shale. These crystals are so oriented that the perfect cleavage parallel

[4] *Op. cit.*, p. 501.

to the front pinacoid is always parallel to the bedding of the oil shale. Also this condition obtains in the shaft of the Westvaco Chemical Corporation at the 1300-foot level. However, in the stratum of trona 10 feet thick that is reached by the shaft at a depth of 1500 feet, subhedral crystals of searlesite up to 7 inches long, 4 inches wide, and one inch thick are not uncommon. The largest crystals heretofore reported (Esmeralda County, Nevada) are approximately 3 mm. long. Due to the presence of minute quantities of organic matter, they are light brown in color. These crystals are randomly oriented in the trona bed and commonly have the front pinacoid (100) and the prisms (110) and ($\bar{1}10$) developed.

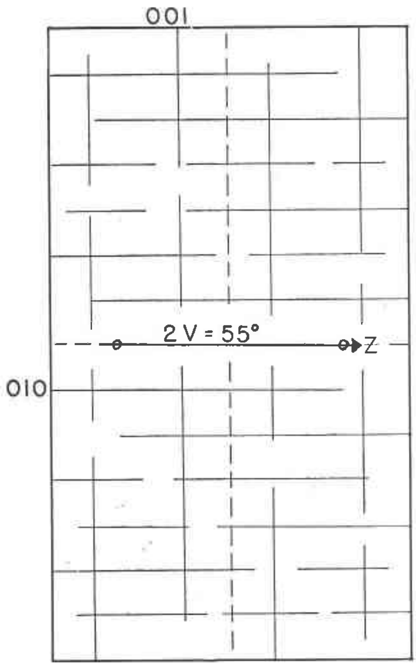

Fig. 1. Orthopinacoidal section showing traces of the (010) and ($\bar{1}02$) cleavages and the emergence of the optic axes.

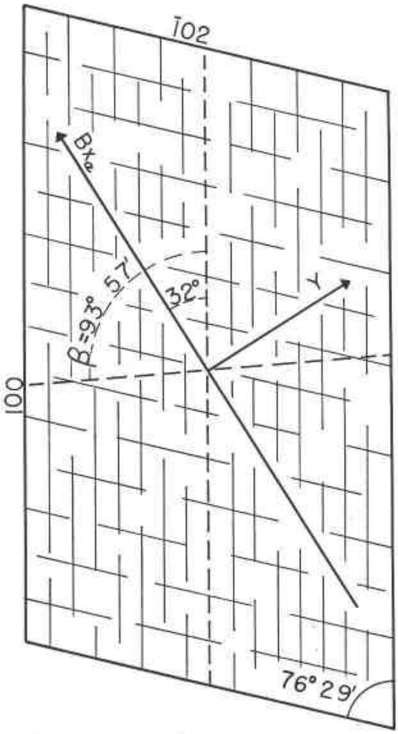

Fig. 2. Clinopinacoidal section showing traces of the perfect cleavage (100) and the poor cleavage ($\bar{1}02$). The optic axial plane is normal to the section.

Two cleavages heretofore unreported are found as traces on the perfect cleavage (100), parallel to the front pinacoid shown in Fig. 1. These are the ($\bar{1}02$) cleavage and the clinopinacoidal cleavage (010). Both are imperfect but unmistakably present. A thin section cut parallel to the clinopinacoid (Fig. 2) shows the traces of the perfect cleavage parallel to the front pinacoid and the imperfect ($\bar{1}02$) cleavage, parallel to the rear dome that Rogers and Foshag, not having x-ray data, mistook for the base. The inclination of the optic axial plane to the c axis is 32° and β is equal to 93° 57′, the latter figure determined by the x-ray study, the form (001) not being present.

The indices of refraction measured with sodium light are: $\alpha = 1.516$, $\beta = 1.531$, and $\gamma = 1.535$. These values check well with those of Rogers[5] and Foshag.[6]

TABLE 2. X-RAY POWDER DIFFRACTION DATA FOR SEARLESITE FROM WYOMING (Fe/Mn radiation, $\lambda = 1.9373$ Å)

d(obs.)	I	hkl	d	I	d	I
8.01	10	100	1.825	2	1.131	½
5.32	1	110	1.765	2	1.110	2
4.31	3	$10\bar{1}$	1.746	1	1.079	½
4.06	5	101	1.690	½		
3.98	2	200	1.647	½		
3.70	1	$11\bar{1}$	1.632	½		
3.54	3	111	1.616	½		
3.48	4	210	1.605	½		
3.24	4	120	1.592	½		
3.21	3	$20\bar{1}$	1.554	2		
2.99	2	201	1.473	½		
2.92	3	$21\bar{1}$	1.451	½		
2.76	2	211	1.431	½		
2.66	3	121	1.406	½		
2.49	1	310	1.334	½		
2.45	2	002	1.320	1		
2.41	1	$30\bar{1}$	1.304	1		
2.39	1	$10\bar{2}$	1.292	½		
2.28	1	102	1.282	½		
2.16	½	311	1.260	½		
2.12	1	320	1.239	1		
2.06	1	$13\bar{1}$	1.224	½		
2.02	½	230, 202, 022	1.215	½		
1.992	1		1.200	½		
1.978	1		1.182	1		
1.945	½		1.161	½		
1.916	1		1.153	½		
1.896	1		1.140	½		

[5] *Op. cit.*, p. 501.
[6] *Op. cit.*, p. 272.

X-Ray Analysis

The x-ray powder pattern of the searlesite from the shaft of the Westvaco Chemical Corporation is identical with that of the searlesite from Nevada described by Rogers and Foshag. Measurements of the stronger lines of the pattern and the Miller indices, obtained from Weissenberg studies, are given in Table 2.

For the single crystal investigation, a small crystal of the searlesite from Nevada was chosen. Weissenberg photograph (with Cu/Ni radiation) taken about the b and c axes and a rotation photograph taken about the a axis combined with positive results of piezoelectric tests made by Dr. Paul Smith of the Naval Research Laboratory show the crystal to be monoclinic with the space group $P2_1$-(C_2^2). The unit cell has the following dimensions:

$$a_0=7.972\pm0.010\text{ Å}$$
$$b_0=7.052\pm0.010\text{ Å}$$
$$c_0=4.900\pm0.010\text{ Å}$$
$$\beta=93°\ 57'\pm10'$$

(The error figures are estimates)

Specific gravity:

Calculated (x-ray)	2.46_4
Foshag	2.44
Rogers	2.45
Fahey (this paper)	2.460

The axial ratio is $a:b:c=1.130:1:0.695$ and the cell content is $2(NaBSi_2O_6\cdot H_2O)$.

These axial ratios and the value for beta are different from those of Rogers and Foshag and are related to them through the following transformations:

$$a=-1/2\,A\ -1/6\,C \qquad A=\ -2a-c$$
$$b=-1/2\,B \qquad B=-2b$$
$$c=\ \ 1/3\,C \qquad C=3c$$

Lower case letters refer to the x-ray description.

Figure 3 shows, on the clinopinacoid, the relationship of the unit cell to the dome faces and to the axial directions derived by Rogers.

The axial ratios found by Rogers and Foshag from goniometric measurements were recalculated to conform to the unit cell found by using x-rays. Interfacial angles were then calculated from the x-ray data. The values derived from the x-ray measurements and from the morphological measurements are compared in Table 3. The dominance of the $(\bar{2}01)$ face caused Rogers to select a different a axis from that found by x-ray measurements, but when the data are recalculated to a common basis, the agreement is very good.

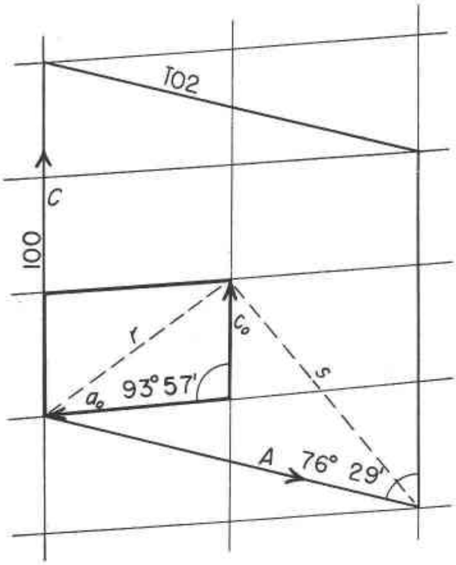

FIG. 3. Projection on the clinopinacoid of the x-ray unit cell, the crystal axes derived by Rogers, and the dome faces.

TABLE 3. COMPARISON OF CRYSTAL CONSTANTS DETERMINED FROM MORPHOLOGY AND FROM X-RAY MEASUREMENTS

	X-ray	Rogers	Foshag
$a:b:c$	1.130:1:0.695	1.119:1:0.689	1.121:1:0.691
β	93°57′	93°58′*	93°56′*
a	(100)	(100)	(100)
b	(010)	(010)	(010)
m	(110)	(110)	(110)
r	($\bar{2}$01)	(101)	(101)
s	(101)	($\bar{1}$01)	($\bar{1}$01)
$m\wedge b$	41°35′	41°50′	41°49′ (range=51′)
$r\wedge a$	40°41′	40°37′	40°35′ (range=38′)
$s\wedge a$	55°35′	55°30′	55°32′ (range=28′)

* Recalculated from Rogers' and Foshag's data to correspond to x-ray orientation.

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