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THE IDENTITY OF ASCHARITE, CAMSELLITE, AND β -ASCHARITE WITH SZAIBELYITE; AND SOME RELATIONS OF THE MAGNESIUM BORATE MINERALS*

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ABSTRACT

The published values of the indices of refraction of ascharite, $2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$, are shown to be incorrect. The correct values, with new chemical analyses, and x-ray powder photographs, show the identity of szaibelyite, ascharite, camsellite, and β -ascharite. A compilation and discussion of the properties and analyses of these minerals is presented.

The isomorphous series szaibelyite-sussexite is discussed with a compilation of properties and analyses, and the variation curve plotted. A similar treatment is given for the fluorborites. The indices of refraction for the magnesium borate minerals with corrections are compiled.

INTRODUCTION

The only recorded determinations of the indices of refraction of ascharite,¹ a hydrous borate of magnesium, $2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$, from the German potash deposits near Stassfurt, are those given by Larsen² on material from Schmidtmanshall, near Aschersleben, namely $\alpha = 1.53$, β and $\gamma = 1.55$, somewhat variable, negative with small $2V$, and the single value of 1.54 for the mean index given by Boeke³ on ascharite from Neustassfurt.

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¹ Named after Ascharia, an old Latin province. The present locality name is Aschersleben in the province of Saxony, southern Prussia.

² Larsen, E. S., *The Microscopic Determination of the Nonopaque Minerals: U. S. Geol. Survey, Bull.* **679**, 42 (1921).

³ Boeke, H. E., *Ueber die Borate der Kalisalzlagerstätten: Centralbl. Mineral., Geol., Pal.*, 535 (1910).

These consistent values differ considerably from those determined for other named minerals (szaibelyite, camsellite, and β -ascharite) of very similar, if not identical composition, and considerable confusion has resulted in the systematic placing of ascharite and in its relation to these other minerals. It will be shown that the values given by Larsen and Boeke are not the correct indices of refraction of ascharite, that its correct indices are the same as those of the other named minerals, and that all are identical.

PROPERTIES OF ASCHARITE

The obvious procedure to try to reconcile these inconsistencies was to restudy the specimen on which Larsen made his optical determinations. This specimen, formerly in the collection of Col. W. A. Roebing, is now in the U. S. National Museum, and through the courtesy of Dr. W. F. Foshag, it was obtained for such restudy.

The specimen (U. S. Nat. Mus. Cat. No. R 5846) is a small massive piece weighing about 40 grams, of a dull white chalky appearance, and was purchased by Colonel Roebing from Schuchardt in 1890. The label gives the locality as Schmidmannschacht near Aschersleben, Prussia.

A thin section ground in alcohol showed the material to be very finely fibrous in structure with an apparent low birefringence, and homogeneous except for discrete particles of minute size irregularly disseminated. When crushed fragments were examined in immersion oils, the indices of refraction seemed to be close to the values given by Larsen and by Boeke. The writer obtained 1.54 to 1.55, variable, and Miss J. J. Glass found 1.55 to 1.56, variable. Neither result was satisfactory and accurate consistent values could not be obtained.

These determined values, consistently about 1.55 and obtained by four different individuals, lie within the range of the indices of other magnesium borates such as kaliborite (1.51–1.55), sulphoborite (1.53–1.54), lueneburgite (1.52–1.55), and fluoroborite (1.52–1.57), and suggested that Colonel Roebing's specimen might be one of these. Tests showed the absence of P_2O_5 and of F but the presence of both potash and sulphate. Hence it seemed necessary to make a complete analysis of the material in order to determine its identity. Accordingly, about eight grams of selected material were crushed to 100 mesh size, the powder offering no difficulty in sieving, and the sample then analyzed.

The first results obtained were very confusing. The loss on ignition was about 20 per cent (ascharite yields 11 to 12 per cent loss), indicating possibly kaliborite or sulphoborite but determinations of K_2O and of SO_3 gave results of less than one per cent each. The material gave a good yellow color to the blowpipe flame and had a bitter saline taste. Evi-

dently considerable saline material was present in the sample and a determination of material soluble in cold water yielded the unexpected high value of about 20 per cent when air dried, or about 15 per cent when dried at 110°. A ten minute water leach suffices to remove all the water-soluble material.

When the insoluble residue was examined under the microscope, its indices of refraction were seen to be much higher than previously found, with a strong birefringence. Even the minute fibers showed brilliant interference colors. Parallel to the elongation of the fibers the index of refraction was 1.58, and normal to the elongation 1.65, ± 0.01 . On account of the extreme minuteness of the interlocking fibers, the indices could not be determined more accurately. These indices are the same as those determined on the other named minerals of similar composition, as are also the chemical analyses and x-ray powder photographs. Hence the specimen is ascharite thoroughly coated and impregnated with water-soluble saline material. Consequently the indices of refraction (1.53–1.56) measured by Larsen, Boeke, Miss Glass, and the writer, on the material before water leaching represent neither the true indices of ascharite nor the indices of any single mineral, but are a meaningless composite or average value of the indices of ascharite plus those of the enclosing complex saline material.

TABLE 1. ANALYSIS OF ASCHARITE SPECIMEN IMPREGNATED WITH SALINE MATERIAL

	Water-soluble saline material	Water-insoluble magnesium borate	Average
Cl	5.64, 5.85	—	5.75
SO ₃	0.85, 0.82, 0.77	—	0.81
Mg	1.96, 1.97	—	1.97
K ₂ O	0.46, 0.38, 0.43	—	0.42
Na ₂ O	1.18, 1.14, 1.06	—	1.13
CaO	None	—	None
MgO	—	37.73, 37.56	37.65
B ₂ O ₃	—	32.58, 32.21	32.40
Insoluble in HCl	—	0.13, 0.06, 0.08, 0.12	0.10
R ₂ O ₃ ^a	—	0.11, 0.13	0.12
Loss below 110° ^b	—	—	7.26
Loss above 110° ^b	—	—	13.30
			100.91

^a Chiefly iron oxide.

^b Essentially H₂O but the loss above 110° may include a little Cl or chloride which may account for the high summation. Sodium tungstate used as retaining flux.

The analysis of the sample—ascharite plus saline material—is shown in Table 1. The analysis of the ascharite freed from the saline material by water leaching is shown in Table 2. The ratio of MgO to B₂O₃ in the water insoluble portion (Table 1) is 0.934:0.465 or 2:1, the same as that in ascharite, and it is evident that the specimen is composed of about 80 per cent of ascharite impregnated with about 20 per cent of saline material. About half the powdered sample was then leached with water, thoroughly washed with cold water, then with acetone, air dried at room temperature for 48 hours, and analyzed with the results shown in Table 2.

TABLE 2. ANALYSIS OF ASCHARITE FREED FROM SALINE MATERIAL BY LEACHING WITH WATER

		Average
MgO.	47.21, 47.10, 47.05, 47.13	47.12
B ₂ O ₃	40.17	40.17
R ₂ O ₃	0.30, 0.19, 0.39	0.29
Insoluble in HCl	0.11, 0.08, 0.12	0.10
Total H ₂ O	12.03, 11.89, 12.07	12.00
Cl, SO ₃ , Alk.	Traces	Traces
		99.68
The loss of water:		
At 110°	0.31, 0.37	
At 200°	0.13	0.98
At 400°	0.40	
Above 400°	11.05, 10.68	
Average loss of H ₂ O above 400° = 10.90		

Considering only the essential constituents, namely MgO, B₂O₃, and H₂O (ignition loss above 400°), the ratios are:

	Per cent	Molecular ratios
MgO	47.12	1.169 or 2.00
B ₂ O ₃	40.17	0.577 or 0.99
H ₂ O	10.90	0.606 or 1.04

These ratios yield the formula 2MgO·B₂O₃·H₂O.

PROPERTIES AND ANALYSES OF SZAIBELYITE, ASCHARITE, CAMSELLITE, AND β-ASCHARITE

The analyses of the variously named hydrous magnesium borate minerals corresponding to the formula 2MgO·B₂O₃·H₂O are given in Table 3, together with their indices of refraction and specific gravities.

TABLE 3. PROPERTIES AND ANALYSIS OF MINERALS (SZAIBELYITE, ASCHARITE, CAMSELLITE, AND β -ASCHARITE) CORRESPONDING TO THE FORMULA $2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$

	Szaibelyite				Ascharite					Camselite		β -ascharite	$2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$	
	Nevada	Chosen	Hungary		Sweden	Germany				Canada	Calif.	USSR		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
α	1.575	1.576	1.578	1.59	1.575	1.58	—	—	—	—	1.575	1.580	1.575	1.575
β	—	—	—	—	—	—	—	—	—	—	1.649	—	1.642	1.646
γ	1.650	1.650	1.651	1.65	1.650	1.65	—	—	—	—	—	1.651	1.646	1.650
B	.075	.074	.073	.05	.075	.07	—	—	—	—	.078	.071	.071	.075
2V	0°	—	—	—	—	Small	—	—	—	—	Small	—	28°	25°
G	2.76	—	2.7	—	—	2.69	—	—	2.7	2.7	2.60	2.6	2.65	2.65
MgO	46.72	—	52.49	49.44	—	47.12	49.2	47.1	47.0	46.9	45.24	48.84	46.70	47.91
FeO	—	—	—	—	—	—	—	—	—	—	1.28	—	0.02	—
MnO	—	—	—	—	—	—	—	—	—	—	1.09	—	—	—
CaO	1.26	—	—	—	—	—	—	—	—	—	—	—	0.00	—
B ₂ O ₃	31.22	—	36.66	31.60	—	40.17	42.8	41.5	41.5	41.7	40.40	40.49	40.85	41.38
H ₂ O +	9.87	—	6.99	12.37	—	12.00	8.0	11.4	11.3	11.2	10.55	10.67	10.95	10.71
H ₂ O -	1.26	—	—	—	—	—	—	—	—	—	0.26	—	0.32	—
Fe ₂ O ₃	4.21	—	1.66	3.20	—	0.22	—	—	—	—	0.85	—	0.13	—
Al ₂ O ₃	0.63	—	—	—	—	—	—	—	—	—	0.29	—	0.16	—
SiO ₂	4.83	—	0.20	—	—	0.10	—	—	—	—	—	—	0.20	—
Cl	—	—	0.49	0.20	—	—	—	—	—	—	—	—	0.11	—
SO ₃	—	—	—	—	—	—	—	—	—	—	—	—	0.69	—
Alk.	—	—	—	—	—	—	—	—	—	—	0.04	—	0.46	—
	100.00		98.49	99.81		99.63	100.0	100.0	99.8	99.8	100.00	100.00	100.59	100.00

References:

- Gillson, J. L., and Shannon, E. V., Szaibelyite from Lincoln County, Nevada: *Am. Mineral.*, **10**, 137-139 (1925).
- Watanabe, Takeo, Kotoite, ein neues gesteinsbildendes Magnesium-borat: *Mineral. u. Petrogr. Mitteil.*, **50**, 448 (1939).
- Peters, K. F., A. Stromeyer's Analyse des Minerals Szeibelyit: *Sitz. K. Akad. Wissensch. Wien*, **47** (1), 347-354 (1863). Needles. Sample contained much kotoite, the anhydrous magnesium borate, thus accounting for the low percentage of water. See Watanabe (ref. 2), p. 454. Indices of refraction by Watanabe (p. 452).
- Peters, same reference as no. 3. Large grains. Indices of refraction by Loew. *Abst. in Zeits. Krist.*, **54**, 180-181 (1914). Slavik gave $\epsilon(\alpha)=1.575$, $\omega(\gamma)=1.60$, a low value. See *Am. Mineral.*, **13**, 230 (1928), for references.
- Geijer, Per, The paragenesis of ludwigite in Swedish iron ores: *Geol. Fören. Stockholm Förh.*, **61**, 27 (1939).
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- van't Hoff, J. H., *Untersuch. Bildungs. ozean. Salzablagerungen*: 347 (1912).
- Same reference as 7. From Neu-Stassfurt.

10. Same reference as 7. From Schmidtmannshall.

11. Ellsworth, H. V., and Poitevin, Eugene, Camsellite, a new borate mineral from British Columbia, Canada: *Trans. Roy. Soc. Canada*, Sect. IV, Ser. 111, **15**, 1-8 (1921). Recalculated analysis with admixed dolomite and serpentine deducted. The β index given in Table 3 is the γ value of Ellsworth and Poitevin.

12. Eakle, A. S., Camsellite from California: *Am. Mineral.*, **10**, 100-102 (1925). Eakle's γ is probably β . Analysis given with serpentine deducted. See following paragraphs.

13. Godlevsky, M. N., Mineralogical investigation of the Inder borate deposits: *Mém. Soc. Russe Mineral.*, ser. 2, **66**, 315-344 (Russian), 345-368 (English), **1937**. Abstr. in *Min. Abstr.*, **7**, 122-123 (1938). $2V$ from indices. Boky, G. B., Kristallographische Untersuchung der Borate des Indersky-Fundortes: *Bull. Acad. Sci. URSS*, **1937**, 871-881 (Russian), 882-883 (German) gives $\alpha=1.576$, β near γ , $\gamma=1.646$, biaxial, negative.

14. Calculated composition and average indices of refraction for $2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$.

A comparison of the figures given in Table 3 leaves little doubt as to the identity of all these minerals. The only discordant value reported in the literature is the large axial angle (about 80°) inferred by Winchell⁴ for camsellite from Canada. Gillson and Shannon described the szaibelyite from Nevada as being uniaxial, as does Loew for the mineral from Hungary, although it is listed as being "Optically biaxial" by Dana. Larsen describes the ascharite from Germany as "with small $2V$."

Ellsworth and Poitevin,⁵ in the description of the optical properties of camsellite state: "The fibres of camsellite are always flattened parallel to the axial plane. The extinction is parallel and suggests that the mineral is orthorhombic. Its elongation is negative while that of the admixed chrysotile is positive. The habit of the mineral does not allow the emergence of an optic axis and for that reason β could not be determined. No attempt was made to measure $2V$ but this angle is probably very large. α and γ were determined by the oil immersion method." The indices of refraction are given as $\alpha=1.575$ and $\gamma=1.649$, ± 0.005 . No reason is given for the statement that $2V$ "is probably very large." It is possible that they observed the emergence of the very large obtuse bisectrix on the broad face of the laths.

The writer⁶ had previously noted the probable identity of camsellite with szaibelyite. This conclusion was questioned by Winchell⁷ as in the original description of camsellite it was stated that the axial angle is probably very large, whereas that of szaibelyite is zero or very small. Winchell states that by turning a capillary glass tube containing a lath-shaped crystal of camsellite, β was measured as $1.620 \pm .005$. "Assuming no error in this determination of N_m , the optic angle ($2V$) must be nearly

⁴ Winchell, A. N., Camsellite and szaibelyite: *Am. Mineral.*, **14**, 49 (1929).

⁵ Ellsworth and Poitevin, *op. cit.*, p. 7.

⁶ Schaller, W. T., The probable identity of camsellite with szaibelyite: *Am. Mineral.*, **13**, 230-232 (1928).

⁷ Winchell, A. N., Camsellite and szaibelyite: *Am. Mineral.*, **14**, 48-49 (1929).

80°," using the values of $\alpha = 1.575$ and $\gamma = 1.649$ given by Ellsworth and Poitevin, and assuming that the axial plane is parallel to the broad lath face with Y normal to the laths. Winchell concludes: "Therefore the two minerals cannot be the same even if there is no chemical difference between them, a condition which is not yet fully proved."

It seems to the writer that direct observation of the optical interference figure with determined optical orientation on camsellite would yield more decisive conclusions than any indirect method, the results of which even Winchell does not seem sure of, as he qualifies his conclusion with the statement: "Assuming no error in this determination." Such direct observations, described in the following paragraphs, do not bear out his statement that the "optic angle ($2V$) must be nearly 80°," in fact, they show that the axial angle of camsellite is small, less than 30°, probably somewhere in the range of 0° to 25°, and hence in accord with the data given for szaibelyite, ascharite, and β -ascharite.

Microscopic examination of a sample of camsellite from Canada (U. S. Nat. Mus. Coll. No. 95584) shows that the mineral forms exceedingly thin laths or flattened fibers, a habit incompatible with any uniaxial mineral; hence camsellite must be biaxial. These laths are so minute that ordinary observation under the microscope with a no. 7 objective fails to reveal the true optical orientation. The laths give the impression of being parallel to the optic axial plane as no interference figure can be seen under ordinary conditions. However, with an optical system especially arranged for the study of minute crystal grains, the true optical orientation can be determined directly, and it is found that Z , the obtuse bisectrix, and not Y , is normal to the broad lath faces, and hence the axial plane is normal to and not parallel to the broad lath faces. X is parallel to the elongation as in all these borates.

The special optical arrangements were suggested and carried out by Dr. Clarence S. Ross, who has had extensive experience in determining the optical orientation of minute fragments and who has arranged a microscope system especially adapted for the study of the optical properties of unusually minute grains. The specially arranged microscopic adaptations were, essentially, very intense illumination, a condensing system with a numerical aperture of 1.40, oil immersion objective, and the sliding stop eyepiece.

An aggregate of camsellite fibers was dispersed in water by means of a small mechanical stirrer and then thoroughly washed with acetone. Bakelite was then added, a little acetone being allowed to remain on the dispersed camsellite to prevent aggregation of the mineral laths and to act as a thinner. A thin smear of the bakelite plus camsellite was then applied to a glass slide, allowed to stand for a few hours for the acetone to evapo-

rate and then cured overnight at a temperature of 80° C. By this means laths of camsellite with a minimum of distortion were fixed in a variety of positions in a rigid medium of suitable index of refraction.

No essential water is lost by any of these magnesium borates or by sussexite at low temperatures, as the following recorded results show.

LOSS OF WATER AT RELATIVELY LOW TEMPERATURES

	Szaibelyite	Ascharite	Camsellite	β -ascharite	Sussexite
110°	1.26	0.34	0.52	0.32	0.34
140°	—	—	0.02	—	—
180°	—	—	0.07	—	—
200°	—	0.13	—	—	—
250°	—	—	—	—	0.56
300°	—	—	0.08	—	—
350°	—	—	0.15	—	—
400°	—	0.40	0.12	—	—
450°	—	—	0.05	—	—
500°	—	—	0.43	—	—

Hence, curing the bakelite in which the camsellite was embedded, at 80°, cannot have had any effect on the composition of the mineral. The water content of all these borates is high-temperature water only.

Flat laths of camsellite lying parallel to the surface of the glass slide were first examined and many of these showed the emergence of a centered obtuse bisectrix with the axial plane parallel to the elongation of the laths. On turning the stage of the microscope the isogyres pass very far outside the field, although the optical system of the microscope is such that for a mineral with $2V$ of 90° or 100°, the isogyres would be only slightly outside of the field. Thus it is evident that the obtuse axial angle in camsellite is extremely large, being much closer to 180° than to 90°, and consequently the acute angle must be small.

The acute bisectrix is parallel to the direction of elongation of the laths and hence would be observable if the laths stand on end. It was not possible to see any laths in this position but those inclined downward at a high angle showed an off-center interference figure adequate for study. A number of laths were seen lying in such an inclined position that the acute bisectrix emerged outside of, but very close to the border of the field.

On rotation of the stage, the visible isogyre for some laths moved across the field of view with seemingly complete parallelism, in other laths a slight curvature was observable in the 45° position. This shows that the axial angle of camsellite is small, not exceeding about 30°, with possibly some variation due to slight distortion of the laths. The optical

character of the acute bisectrix figure is negative, and the slight dispersion is $r > v$.

The distinction between camsellite and the admixed or associated chrysotile is obvious, but for every lath of camsellite on which optical determinations were made, its identity was checked by comparison of its indices of refraction against the enclosing bakelite (determined $n = 1.627$), β of the camsellite being a little higher (estimated 0.02 higher) and α being considerably lower.

Hence camsellite is definitely biaxial with a small optic angle which is estimated to be not far from 25° , and may be considerably smaller. The value 1.649 ± 0.005 , given by Ellsworth and Poitevin for γ , in reality is β , and γ must be slightly higher. These results agree with those given for β -ascharite, whose identity with camsellite has been shown by x-ray powder photographs by Agafonova and Isküll,⁸ and which Godlevsky describes as forming "separate plates" as well as fibers. His figure 18, a photomicrograph of β -ascharite, would pass just as readily for a photomicrograph of camsellite. Sussexite, the manganese analogue of szaibelyite, also occurs as laths, rather than fibers. Slawson states: "The fibers are flattened so that most of them yield α and β ," as do the laths of camsellite.

Camsellite,	β -ascharite,
$\alpha = 1.575$,	1.575^a 1.576^b
$\beta = 1.649$	1.642
	} 1.646
$\gamma = \text{---}$	1.646
$2V$ 20° — 30°	28°

^a Godlevsky

^b Boky

The values listed for γ in Table 3 for the various samples of szaibelyite from different localities may be either β or γ , or an intermediate value. The true value for γ may be slightly greater than 1.650, but the actual difference between β and γ is very small and comparable in magnitude with the errors of measurement on such fibrous material.

If it be assumed that for camsellite $\alpha = 1.575$ and β (usually given as γ) = 1.649, then with an assumed $2V$ of 25° , γ would become about 1.653. There is no conclusive evidence that there is a marked difference in $2V$ for the two end members of the szaibelyite-sussexite series. Sussexite no. 9 (Table 5) gives $\gamma - \beta = 0.008$, yielding a $2V$ angle of 37° but sussexite no. 8 has $\gamma - \beta$ only 0.003, and sussexite no. 10 has $\gamma - \beta$ not greater than 0.005.

⁸ Agafonova, T. N., and Isküll, E. W., Identity of the Inder ascharite and camsellite: *C. R., Acad. Sci., URSS*, **22**, 325-326 (1939).

Evidently, the mineral szaibelyite (= ascharite, camsellite, β -ascharite) is orthorhombic, biaxial, with a small axial angle which has been taken by some observers to be uniaxial. It is possible that some varieties are almost uniaxial as it is common for nearly uniaxial minerals to show a slight variation in the size of the optic angle.

As the name szaibelyite has priority, the names ascharite, camsellite, and β -ascharite are to be discarded as needless synonyms. The ascharite from Germany should not be referred to as α -ascharite, in distinction to β -ascharite, as suggested by the describers of β -ascharite, based on the incorrect assumption that the indices of refraction of the ascharite from USSR were different from those of ascharite from Germany. The name magnesiosussexite also should be discarded as the mineral is a manganoan szaibelyite.

Eakle considered the silica present in the analysis of camsellite from California as an essential constituent. "It is not a case of admixed silica or silicate, but rather a definite replacement of one molecule of B_2O_3 , by SiO_2" He also stated: "No dolomite or chrysotile occurs with it and by lightly scraping the coatings pure material was obtained." Regarding its insolubility in acid he said: "The silica may act like an opal in the fibers preventing them from ready attack by the acid and dehydration changes this condition of the silica."

The ratios of Eakle's analysis give: $(Mg,Fe)O:B_2O_3+SiO_2:H_2O = 1.98:1.00:1.02$, apparently supporting his claim that the silica is an inherent constituent of the camsellite. However, as his indices of refraction and specific gravity are practically identical with those for other occurrences of the mineral, it is believed that his conclusion is not correct. If seven per cent of SiO_2 actually replaced the equivalent quantity of B_2O_3 , the replacement should be reflected in a material change in the indices of refraction.

A microscopic examination of a specimen of camsellite, from near Stinson Beach, Marin County, California (U. S. Nat. Museum Coll. no. 95183), indicates that it would be impossible to prepare a sample of this borate mineral free from serpentine. While it is true as Eakle states that "No dolomite or chrysotile occurs with it," careful examination shows that minute particles of massive serpentine (not chrysotile as in the camsellite from Canada) are scattered throughout the fibers of the borate mineral and the SiO_2 reported in Eakle's analysis probably represents admixed serpentine.

Twelve samples from different parts of the specimen were removed, and after picking out the visible fragments of serpentine were examined in immersion oils of the proper index. By spreading out the preparation into a very thin layer under the cover glass and using high magnification

(Leitz objective no. 7), abundant fragments of serpentine (massive, very low birefringence, mean index about 1.55) can be seen. Some of the serpentine is nearly colorless, other fragments are pale yellow, and still others are dark olive colored. Minute black specks are also present. In some pieces, the camsellite is replacing the serpentine and where abundantly developed, an apparent solid group of fibers of camsellite can be seen largely replacing but still retaining much of the serpentine as a matrix for the fibers which then cannot be broken down into single loose fibers.

Ascribing the SiO_2 in Eakle's analysis to serpentine and deducting it (with the corresponding amounts of MgO and H_2O , as required by the formula $3\text{MgO} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$) from the molecular ratios of the analysis, the remaining ratios come out very close to 2:1:1, as required by the formula $2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$, as shown in Table 4.

TABLE 4. RATIOS OF EAKLE'S ANALYSIS OF CAMSELLITE FROM CALIFORNIA, DEDUCTING SiO_2 AND CORRESPONDING AMOUNTS OF MgO AND H_2O , AS SERPENTINE

Ratios of Eakle's analysis		Ratios of serpentine	Ratios of silica-free borate
$\text{MgO} + \text{FeO}$	1.1768	.1788	.9980 or 2.03
B_2O_3	.4787	—	.4787 or 0.97
SiO_2	.1192	.1192	—
H_2O	.6072	.1192	.4880 or 0.99

Treatment of the sample with cold 1:1 HCl readily yields a yellowish solution, and probably most of the iron in the sample is in the serpentine rather than in the camsellite. If all the FeO in the analysis is assigned to the included serpentine, Eakle's analysis may be recalculated as follows:

TABLE 5. RECALCULATION OF EAKLE'S ANALYSIS, DEDUCTING SERPENTINE, $3(\text{Mg}, \text{Fe})\text{O} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$

Analysis		Admixed serpentine		Remaining camsellite		$2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$
		$3\text{MgO} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$	$3\text{FeO} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$			
MgO	46.07	5.85	—	40.22	48.84	47.91
FeO	2.46	—	2.46	—	—	—
B_2O_3	33.34	—	—	33.34	40.49	41.38
SiO_2	7.16	5.80	1.36	—	—	—
H_2O	10.94	1.74	0.41	8.79	10.67	10.71
	99.97	13.39	4.23	82.35	100.00	100.00

These values for the serpentine-free camsellite are much closer to those required by the formula $2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$, than those previously calculated by the writer⁹ on the basis of deducting only SiO_2 , and are those given in column 12 of Table 3.

The apparent discrepancy in the recorded statements as to the acid solubility of various samples of this mineral is more apparent than real. As far as available material permitted tests to be made, the mineral is soluble in cold 1:1 HCl, but only very slowly. It takes several days for it to dissolve completely in cold 1:1 HCl, but digestion on the steam bath with hot 1:1 HCl completely dissolves it in a few hours, as shown by tests made on ascharite from Germany and camsellite from Canada and from California. Both samples of camsellite yielded silica skeletons from the admixed serpentine. Eakle's statement that the camsellite from California "is so slowly attacked that boiling for hours fails to decompose it" could not be verified. However, he does not state that he tested the filtered solution for magnesium or for boric acid, and either the insoluble silica skeletons of admixed serpentine or possibly some of the remaining coarser camsellite may have led him to conclude that the mineral was insoluble.

Similar errors, resulting from not testing the filtrate for dissolved matter, have occurred before. For example J. W. Daly, in describing the sepiolite from Crestmore, California (*Am. Mineral.*, **20**, 652, 1935), states that: "It is unattacked by HCl." This statement is not correct for a sample of this mineral kindly furnished by Mr. Daly was attacked by cold 1:1 HCl after several days, the filtrate containing abundant magnesium, but the residual insoluble silica skeleton of the sepiolite *looked* exactly like the untreated sepiolite when first introduced into the acid.

X-RAY POWDER PHOTOGRAPHS

No single investigation on all occurrences of all these minerals has been carried out on the basis of x-ray photographs. However, such pictures have been made on small groups of all these minerals.

Watanabe¹⁰ reports the identity of szaibelyite from Hungary, ascharite from Leopoldshall, Germany, and camsellite from California; Dr. W. E. Richmond of the Geological Survey has compared photographs of ascharite from Aschersleben, Germany (the water-leached sample, analysis in Table 2), camsellite from Canada (U. S. Nat. Mus. Cat. No. 95584), and sussexite from New Jersey (U. S. Nat. Mus. Cat. No. C4459), and reports

⁹ Schaller, W. T., The probable identity of camsellite with szaibelyite: *Am. Mineral.*, **13**, 232 (1928), column 6.

¹⁰ Watanabe, Takeo, Kotoit, ein neues gesteinsbildendes Magnesiumborat: *Mineral. u. Pet. Mitteil.*, **50**, 454 (1939).

them identical with no difference between ascharite and camsellite and only a spacing difference for sussexite. Agafonova and Isküll¹¹ state that β -ascharite from the Inder region and camsellite from Canada are identical; and Gruner shows the identity of camsellite from Canada, magnesio-sussexite from Michigan, and sussexite from New Jersey, with only a spacing difference.

The observed identities may be expressed schematically as follows:

TABLE 6. IDENTITY OF α -RAY POWDER PHOTOGRAPHS OF SZAIBELYITE, ASCHARITE, CAMSELLITE, β -ASCHARITE, AND SUSSEXITE

	Szai-belyite	Ascharite	Camsellite		β -ascharite	Magnesio-sussexite	Sussexite
	Hungary	Germany	Canada	Calif.	USSR	Michigan	New Jersey
Watanabe	X	X	—	X	—	—	—
Richmond	—	X	X	—	—	—	X
Agafonova and Isküll	—	—	X	—	X	—	—
Gruner	—	—	X	—	—	X	X

GEOLOGIC OCCURRENCES OF SZAIBELYITE

Four distinct types of occurrence of szaibelyite are recorded in the literature.

(1) Contact metamorphic deposits in limestone and dolomite. Hungary, Nevada, Chosen, and Sweden.

(2) Saline deposits (ascharite and β -ascharite). Germany and USSR. The Inder (USSR) borates occur near the Inder salt lake, 150 km. north of the Caspian Sea in western Kazakstan, with clays and residual anhydrite in the gypsum capping of a large Lower Permian salt dome, in the underlying halite and sylvite, and in the Quaternary surface deposits (Taken from *Min. Abstr.*, **7**, 122, 1938).

(3) With serpentine (camsellite). Canada and California.

(4) A manganese-bearing variety (magnesiosussexite) in iron ore. Michigan.

SZAIBELYITE-SUSSEXITE SERIES

Szai-belyite, $2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$, and sussexite, $2(\text{Mn,Mg})\text{O} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$, form an isomorphous series ranging from the manganese-free magnesium borate to a sussexite (No. 10, Table 7) of composition 80 per cent $2\text{MnO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$ and 20 per cent $2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$. The isomorphous

¹¹ Agafonova, T. N., and Isküll, E. W., Identity of the Inder ascharite and camsellite: *C. R., Acad. Sci., URSS*, **22**, 325-326 (1939).

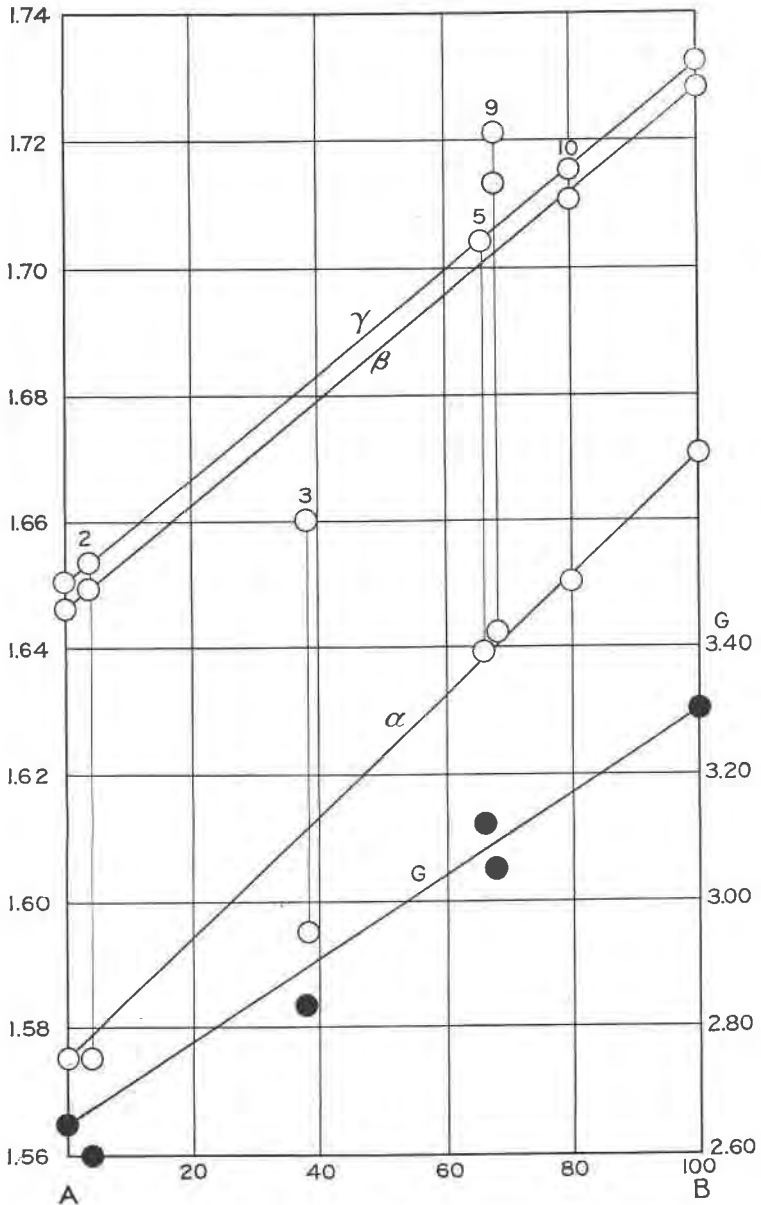


FIG. 1. Diagram showing relations between indices of refraction, specific gravity (G), and component composition (weight percentage) for the szaibelyite-sussexite series: A = szaibelyite, $2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$. B = magnesium-free sussexite, $2\text{MnO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$.

relationship between camsellite (=szaibelyite), magnesiosussexite, and sussexite has already been shown by Gruner.¹² Two other isomorphous series are known among the magnesium borates, the ludwigite-vonsenite series, $4(\text{Mg, Fe})\text{O} \cdot \text{Fe}_2\text{O}_3 \cdot \text{B}_2\text{O}_3$, and the fluoborites $3\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot 3\text{Mg}(\text{F, OH})_2$.

The variations in the properties with changing chemical composition for the szaibelyite-sussexite series are shown in Fig. 1, the series including such minerals described under the names of szaibelyite, ascharite, camsellite, β -ascharite, magnesiosussexite, and sussexite. The chemical composition is expressed as weight percentage of the two end members. The plotted data are those shown in Table 7. The recorded indices of refraction of magnesiosussexite are considerably lower than they should be for a mineral of the composition given by the analysis, indicating that the material is probably variable in composition.

The calculated value of β for the pure magnesium component is 1.646, if the measured β of 1.649 (= γ of Ellsworth and Poitevin) is for the analyzed camsellite with 4 per cent of the manganese plus iron component.

The only example of the pure magnesium component for which all three indices of refraction were measured is the β -ascharite for which β is given as 1.642 and γ as 1.646. These two values are slightly lower than the other measurements.

A careful consideration of all the determined values, with allowance for the 4 per cent of the manganese and iron component in camsellite, indicates that the indices of the pure magnesium component are probably very close to $\alpha = 1.575$, $\beta = 1.646$, $\gamma = 1.650$, with $B = .075$ and $2V = 25^\circ$. These are the values given in column 14 of Table 3 and in column 1 of Table 7, and are the values used in Fig. 1. The extrapolated values for the pure manganese component ($2\text{MnO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$) are: $\alpha = 1.670$, $\beta = 1.728$, $\gamma = 1.732$. $G = 3.30$.

¹² Gruner, J. W., Magnesiosussexite, a new mineral from a Michigan iron mine, isomorphous with sussexite and camsellite: *Am. Mineral.*, **17**, 509-513 (1932).

TABLE 7. PROPERTIES AND ANALYSES OF MEMBERS OF THE SZAIBELYITE
($2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$)-SUSSEXITE ($2\text{MnO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$) SERIES

	1	2	3	4	5	6	7	8	9	10	11
Mg comp.	100	96	62	36	34	33	—	—	32	20	0
Mn comp.	0	4	38	64	66	67	—	—	68	80	100
α	1.575	1.575	1.595	—	1.639	—	1.639	1.630	1.642	1.65	1.670
β	1.646	1.649	—	—	—	—	1.70†	1.709	1.713	1.71	1.728
γ	1.650	1.653	1.660	—	1.704	—	1.712	1.712	1.721	1.715	1.732
B	.075	.078	.065	—	.065	—	.073	.082	.079	.065	.062
2V	25°	Small	—	—	—	—	Small	22°	37°	Small	30°
G	2.65	2.60	2.83	3.42?	3.12	3.12	—	—	3.05	—	3.30
MgO	47.91	45.24	29.32	17.03	16.29	15.92	—	—	14.57	9.56	—
MnO	—	1.09	23.48	40.10	37.58	38.08	—	—	40.42	49.40	61.81
FeO	—	1.28	—	—	—	—	—	—	—	0.16	—
ZnO	—	—	0.00	—	3.87	3.24	—	—	—	—	—
CaO	—	—	0.05	—	0.10	—	—	—	0.35	2.03	—
B ₂ O ₃	41.38	40.40	36.18	31.89	33.16	33.31	—	—	33.24	30.52	30.34
H ₂ O†	10.71	10.55	10.18	9.59	7.80	9.43	—	—	8.91	8.33	7.85
H ₂ O—	—	0.26	0.22	—	0.10	—	—	—	—	—	—
SiO ₂	—	—	0.43	—	0.50	—	—	—	0.89	—	—
Insol.	—	—	—	—	—	—	—	—	0.69	—	—
Fe ₂ O ₃	—	0.85	} 1.34	—	0.60	—	—	—	} 0.29	—	—
Al ₂ O ₃	—	0.29		—	—	—	—	—		—	—
Alk.	—	0.04	—	—	—	—	—	—	—	—	—
	100.00	100.00	100.20	98.61	100.00	99.98			99.36	100.00	100.00

References:

1. Calculated composition of szaibelyite, $2\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$. Indices of refraction given are average of those given in Table 3 for szaibelyite, camsellite, and β -ascharite.
2. Camsellite from Canada. Ellsworth and Poitevin. The 4 per cent of the Mn component includes the analogous Fe component. The camsellite from California may contain several per cent of the analogous Fe component. Eakle reports no manganese present. The position of the camsellite from California is nearly the same as that from Canada and hence is not shown in figure 1.
3. Magnesiosussexite. Gruner, J. W., Magnesiosussexite, a new mineral from a Michigan iron mine, isomorphous with sussexite and camsellite: *Am. Mineral.*, **17**, 509–513 (1932).
4. Sussexite. Brush, G. J., On sussexite, a new borate from Mine Hill, Franklin Furnace, Sussex County, New Jersey: *Am. Jour. Sci.*, 2d ser., **46**, 240–243 (1868). Brush already noted that: "In some of its physical and chemical characters sussexite resembles the mineral szaibelyite from southern Hungary."
5. Sussexite. Poitevin, Eugene, and Ellsworth, H. V., New optical data for analyzed sussexite: *Am. Mineral.*, **9**, 188–190 (1924).
6. Sussexite. Penfield, S. L., and Sperry, E. S., Mineralogical Notes; 4. Sussexite from Mine Hill, Franklin, N. J.: *Am. Jour. Sci.*, 3d ser., **36**, 323 (1888). As in szaibelyite, only a little water is given off at low temperatures. Loss at $100^\circ = 0.34$, additional loss at $250^\circ = 0.56$.
7. Sussexite. Winchell.
8. Sussexite. Larsen. 2V calculated.
9. Sussexite. Slawson, C. B., Sussexite from Iron County, Michigan: *Am. Mineral.*, **19**, 575–578 (1934). 2V calculated.

10. Sussexite. Palache, Charles. Mineralogical Notes on Franklin and Sterling Hill, New Jersey: *Am. Mineral.*, 13, 323 (1928). $2V$ about 25° , assuming $\beta=1.712$.

11. Theoretically pure sussexite, $2\text{MnO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$. Values for the indices of refraction and for specific gravity by extrapolation from FIG. 1. Indices probably correct within 0.005. Assuming $\beta=1.728$, then $2V$ will be about 30° .

FLUOBORITE

The properties and analyses of the fluoborites have been compiled (Table 8) in a similar manner so that the properties of the two end members, $3\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot 3\text{MgF}_2$ and $3\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot 3\text{Mg}(\text{OH})_2$, may be obtained by extrapolation for inclusion in the table (Table 9) of indices of refraction of the magnesium borate minerals. The data in Table 8 are plotted in

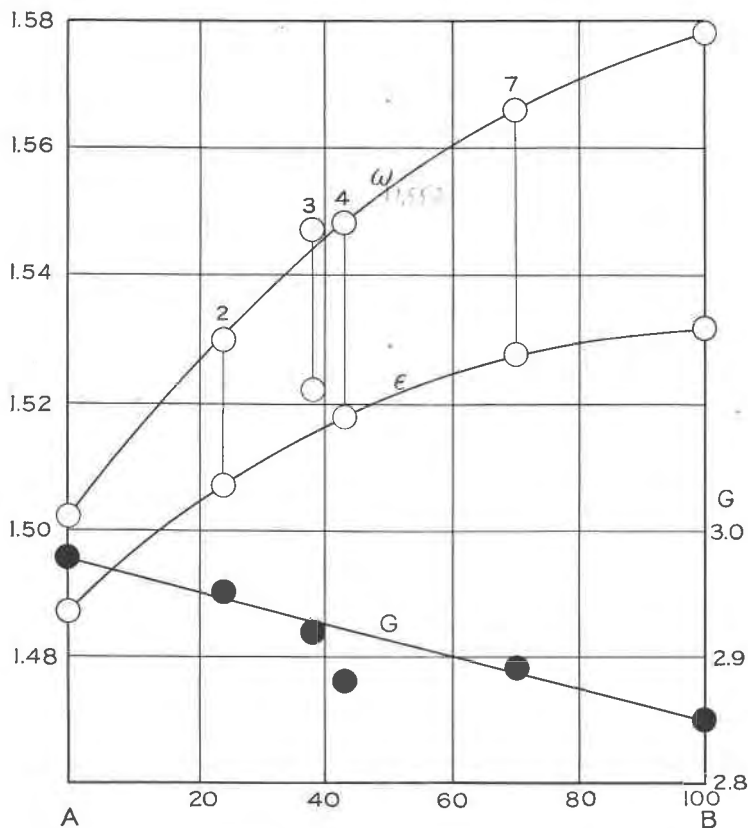


FIG. 2. Diagram showing relations between indices of refraction, specific gravity (G), and component composition (weight percentage) for the fluoborites. A = $3\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot 3\text{MgF}_2$ and B = $3\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot 3\text{Mg}(\text{OH})_2$.

Fig. 2. By plotting the birefringence against percentage composition, the fluorine end member, *A* in Fig. 2, is seen to have a birefringence of about 0.015, and the hydroxyl end member, *B* in Fig. 2, a birefringence of about 0.047. The values of the indices of refraction given in columns 1 and 8 of Table 8, for the end members, are of course only approximate.

TABLE 8. PROPERTIES AND ANALYSES OF MEMBERS OF THE FLUOBORITE SERIES

	3MgO· B ₂ O ₃ · 3MgF ₂	Malaya	New Jersey		Chosen	Nevada	Nor- berg	3MgO· B ₂ O ₃ · 3Mg(OH) ₂
	1	2	3	4	5	6	7	8
F comp.	100	76	62	57	—	—	30	0
OH comp.	0	24	38	43	—	—	70	100
ω	1.502	1.530	1.547	1.548	1.550	1.561	1.566	1.579
ϵ	1.487	1.507	1.522	1.518	1.522	1.527	1.528	1.532
B	.015	.023	.025	.030	.028	.034	.038	.047
G	2.98	2.95	2.92	2.88	—	—	2.89	2.85
MgO	64.07	62.02	60.07	62.07	—	—	61.65	66.17
FeO	—	1.16	—	—	—	—	—	—
MnO	—	—	1.93	2.09	—	—	0.05	—
ZnO	—	—	2.41	2.05	—	—	—	—
CaO	—	0.56	1.19	—	—	—	—	—
B ₂ O ₃	18.44	17.67	17.25	18.68	—	—	17.90	19.05
F	30.20	20.94	17.60	17.14	—	—	9.30	—
H ₂ O	—	3.23	5.22	1.29	—	—	10.78	14.78
SiO ₂	—	0.88	—	—	—	—	0.45	—
Al ₂ O ₃	—	0.92	—	—	—	—	0.90	—
Fe ₂ O ₃	—	0.36	—	—	—	—	0.81	—
CO ₂	—	—	1.23	—	—	—	1.36	—
O = F ₂	112.71	107.74	106.90	103.32	—	—	103.20	100.00
	12.71	8.82	7.41	7.22	—	—	3.92	—
	100.00	98.92	99.49	96.10	—	—	99.28	—

References:

1. The fluorine end member. Indices of refraction and specific gravity by extrapolation.
2. JOHNSTON, R. W., AND TILLEY, C. E., On fluoborite from Selibin, Malaya: *Geol. Mag.*, **77**, 141-144 (1940).
- 3 & 4. Palache, Charles, The minerals of Franklin and Sterling Hill, Sussex County, New Jersey: *U. S. Geol. Survey, Prof. Paper* **180**, 127-128 (1935). No. 3: "Material associated with zincite." No. 4: "Material associated with mooreite." In No. 4, the percentage of H₂O is much too low, as stated. Based on the percentage of F, the percentage of H₂O should be about 6.

5. Watanabe, *op. cit.*, p. 448. The indices indicate about 50 per cent of the hydroxyl end member.
6. Gilson and Shannon, *op. cit.*, p. 138. Schaller, *op. cit.*, p. 230, footnote No. 5. The indices indicate about 65 per cent of the hydroxyl end member.
7. GEIJER, PER, Some mineral associations from the Norberg district: *Sver. Geol. Unders. Årsbok*, 20 (1926), 27, 1927.
8. The hydroxyl end member. Indices of refraction and specific gravity by extrapolation.

INDICES OF REFRACTION OF MAGNESIUM BORATE MINERALS

In a preliminary tabulation of the optical properties of the magnesium borates, prepared originally in an attempt to place the (incorrect) published indices of ascharite, it was noted that the indices of paternoite, as given by Barth and Berman,¹³ were almost identical with those of kaliborite. As given these are:

Paternoite, $\alpha=1.509$, $\beta=1.528$, $\gamma=1.548$, positive, monoclinic.

Kaliborite, $\alpha=1.508$, $\beta=1.526$, $\gamma=1.550$, positive, monoclinic.

At first, it was thought that this closeness in values of the indices might be accidental as the indices of sulfoborite and lueneburgite, likewise, are very similar. As however in the original description of paternoite Millosevich¹⁴ gives the mean index as much lower, namely about 1.475 (n given as 1.47 to 1.48), a statement not considered by Barth and Berman, it seemed advisable to check the identity of the specimen, even though the authors state that it "ist sicherlich authentisch." Accordingly, through the courtesy of Dr. Berman, the sample (Harvard collection No. 89270) on which Barth and Berman made their determinations was loaned for restudy. A comparative qualitative test for potash made by R. K. Bailey of the Geological Survey Chemical Laboratory, indicated the presence of from 5 to 10 per cent K_2O , a quantity similar to that found for known kaliborite. Hence the supposed paternoite described by Barth and Berman is kaliborite and the optical properties given by them are to be transferred to kaliborite.¹⁵

The values given in the following table for the fluorine end member, $3MgO \cdot B_2O_3 \cdot 3MgF_2$, and for the hydroxyl end member, $3MgO \cdot B_2O_3 \cdot 3Mg(OH)_2$, of the fluoborite series, $3MgO \cdot B_2O_3 \cdot 3Mg(F,OH)_2$, are derived by extrapolation, as shown in Fig. 2, and are subject to correction

¹³ Barth, Tom., and Berman, Harry, Neue optische Daten wenig bekannter Minerale: *Chemie der Erde*, 5, 29 (1930).

¹⁴ Millosevich, F., Paternoite: un nuovo minerale del giacimento salifero di Monte Sambuco in territorio di Calascibetta (Sicilia): *Rend. R. Accad. Lincei*, ser. 5, 29, sem. 2, 286-289 (1920).

¹⁵ Apparently, the small vials containing samples of supposed paternoite distributed by Palumbo (in Rome) are all kaliborite as the U. S. Nat. Museum has an identical sample, labeled paternoite, but actually kaliborite.

when more fluorborites are described. For the purpose of practical use, both values for the theoretical end members are listed in the table as well as both the lowest and the highest of the determined values for fluorborite.

Similarly, for the sussexites, the values for the pure manganese end member, derived by extrapolation as shown in Fig. 1, are listed as well as the lowest (Gruner's magnesiosussexite) and the highest values for sussexite. The magnesium end member of the sussexites is szaibelyite.

In the compilation shown in Table 9, the magnesium borate minerals are listed in the order of increasing value of β .

TABLE 9. INDICES OF REFRACTION OF MAGNESIUM BORATE MINERALS

		α	β	γ	B	$2V$
Paternoite	MgO · 4B ₂ O ₃ · 4H ₂ O	—	n1.475	—	—	—
Inderite	2MgO · 3B ₂ O ₃ · 15H ₂ O	—	1.488	1.504	—	—, Large
Fluorborite, F-end member	3MgO · B ₂ O ₃ · 3MgF ₂	ε1.487	ω1.502	ω1.502	.015	—, 0°
Kurnakovite	2MgO · 3B ₂ O ₃ · 13H ₂ O	1.489	1.510	1.525	.036	—, 80°
Kaliborite	4MgO · K ₂ O · 11B ₂ O ₃ · 18H ₂ O	1.508	1.526	1.550	.042	+, 81°
Fluorborite	3MgO · B ₂ O ₃ · 3Mg(F, OH) ₂	ε1.507	ω1.530	ω1.530	.023	—, 0°
Hydroboracite	MgO · CaO · 3B ₂ O ₃ · 6H ₂ O	1.523	1.534	1.570	.047	+, 60°
Sulfoborite	6MgO · 2SO ₃ · 2B ₂ O ₃ · 9H ₂ O	1.527	1.540	1.544	.017	—, 70°
Lueneburgite	3MgO · P ₂ O ₅ · B ₂ O ₃ · 8H ₂ O	1.520	1.541	1.545	.025	—, 48°
Pinnite	MgO · B ₂ O ₃ · 3H ₂ O	ω1.565	ω1.565	ε1.575	.010	+, 0°
Fluorborite	3MgO · B ₂ O ₃ · 3Mg(OH, F) ₂	ε1.528	ω1.566	ω1.566	.038	—, 0°
Fluorborite, (OH)-end member	3MgO · B ₂ O ₃ · 3Mg(OH) ₂	ε1.532	ω1.579	ω1.579	.047	—, 0°
Szaibelyite	2MgO · B ₂ O ₃ · H ₂ O	1.575	1.646	1.650	.075	—, 25°
Kotoite	3MgO · B ₂ O ₃	1.652	1.653	1.673	.021	+, 21°
Sussexite	2(Mg, Mn)O · B ₂ O ₃ · H ₂ O	1.595	—	1.660	.065	—, Small
Boracite	5MgO · MgCl ₂ · 7B ₂ O ₃	1.662	1.667	1.673	.011	+
Sussexite	2(Mn, Mg)O · B ₂ O ₃ · H ₂ O	1.65	1.71	1.715	.065	—, Small
Sussexite, Mn-end member	2MnO · B ₂ O ₃ · H ₂ O	1.670	1.728	1.732	.062	—, 30°
Warwickite	3(Mg, Fe)O · TiO ₂ · B ₂ O ₃	1.808	1.810	1.830	.022	+, 59°
Ludwigite	4(Mg, Fe)O · Fe ₂ O ₃ · B ₂ O ₃	1.85	1.85+	2.02	.17	+, Small
Pinakiolite	4(Mg, Mn)O · Mn ₂ O ₃ · B ₂ O ₃	1.91	2.05	2.065	.155	—, 32°
Vonsenite	4(Fe, Mg)O · Fe ₂ O ₃ · B ₂ O ₃	—	—	—	—	—