

in the meantime with epsomite. Some large lumps of this mineral from Basque Siding, Ashcroft, B. C., have been on exhibition for several years in a large glass container. The material is as bright as when first collected. A large reserve specimen wrapped in paper has become chalky and friable.

In discussion, Dr. A. C. Lane called attention to the fact that minasragite which had been stored in a possibly damp basement during the summer was represented by a green spot in the tray.

Dr. G. F. Kunz pointed out that silver and lead, as well as almost any mineral, would be better preserved by dipping them in a solution of alcohol (95%) and collodion (5%). The collodion can be removed again by alcohol if it is desirable to use the material for investigation.

Mr. G. L. English stated that specimens of native lead from Sweden at Ward's Natural Science Establishment had remained bright and unaltered.

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#### DOUBTFUL MINERAL SPECIES AS ILLUSTRATED BY "FAROELITE"\*

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"Faroelite" is a mineral name of so little importance that any printed discussion of it may seem unwarranted, but it is believed that some parts of such a discussion may be made of so general a character as to warrant its presentation.

That the great majority of common silicate minerals vary considerably in composition is now so well established and generally recognized that the obvious application of this fact to concrete cases may fairly be expected; yet articles still appear which seem to ignore it completely. Before the development of our knowledge of isomorphous variations in mineral systems this was more or less excusable; but at the present day it is surely not going too far to hold that *two samples of silicate minerals, which are closely similar (but not identical) chemically and also crystallographically, probably belong to an isomorphous series or system, and names implying the existence of two different independent species should not be used for such cases unless accompanied by unquestionable evidence that the substances are not isomorphous.*

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As a corollary it may be mentioned that, unless the laws of isomorphous replacement are correctly understood and applied, it is obvious that no simple formula should be expected to result from recalculations of analyses of examples of such isomorphous systems. For example, it is not possible, and should not be possible, to derive simple ratios between any two oxides composing plagioclase of composition  $Ab_{47}An_{53}$ , nor of any other composition, unless the ratio between Ab and An *happens* to be simple. In spite of this fact many writers on mineralogy are so accustomed to the idea that every analysis, if made accurately on pure material, must correspond to some simple formula that they use all sorts of devices to derive such a formula. Thus, in a recent excellent discussion of a silicate the authors state that five analyses are "decidedly similar" and "consistent" although they show the following variations:<sup>1</sup>

OMITTED		RANGE		RANGE
21.14	SiO <sub>2</sub>	35.43 to 42.05	} SiO <sub>2</sub> +TiO <sub>2</sub>	35.43 to 42.05
0.03	TiO <sub>2</sub>	0.00 to 0.27		
2.28	Al <sub>2</sub> O <sub>3</sub>	0.00 to 4.53	} Al <sub>2</sub> O <sub>3</sub> +Fe <sub>2</sub> O <sub>3</sub>	32.81 to 34.71
57.43	Fe <sub>2</sub> O <sub>3</sub>	29.70 to 34.09		
0.62	FeO	0.00 to trace		
1.51	CaO	1.76 to 3.06	} CaO+MgO	7.24 to 13.63
2.47	MgO	4.91 to 10.42		
9.91	H <sub>2</sub> O+	5.19 to 9.73	} Total H <sub>2</sub> O	13.29 to 17.51
4.59	H <sub>2</sub> O-	6.81 to 8.51		

Even this degree of "similarity" is only obtained by arbitrarily omitting from consideration one analysis which the authors describe as representing the "most homogeneous" material at their disposal, which they use to establish the chief physical characters of the mineral.

This silicate always occurs in a finely granular state in complex rocks so that it is exceedingly difficult to obtain pure material for analyses; and the authors deserve high praise for the successful performance of such a difficult task. They report that they obtained "clean crystalline" material from six different localities, and used this for their analyses.

This tendency to write a formula for nearly every mineral analysis disregards the fact that nearly all minerals are isomor-

<sup>1</sup> The figures are purposely quoted incorrectly, but they are in all cases of the right order of magnitude.

phous systems and, unless the isomorphism happens to be confined to elements of the same valence, the usual methods of deriving formulas are incorrect and misleading. It is now well established that isomorphism involving elements of unlike valence is the usual condition, especially in aluminum silicates, as illustrated in the plagioclase series, the orthoclase-celsian series, the scapolite series, the pyroxene system, the amphibole system, the mica system, the chlorite system, and probably in the zeolites.

Many other illustrations of this tendency to write unwarranted formulas could be cited, including some from excellent articles in the latest numbers of *THE AMERICAN MINERALOGIST*; it is because the tendency is so wide spread and well nigh universal that the error involved in it is important. This should make it clear that this criticism is directed against the present practice of many mineralogists and not especially against the authors of the particular study quoted.

The writer does not pretend to be able to give the correct interpretation of the analyses cited, but he can see no justification for averaging them together and claiming that the simplest numbers thus obtained represent the composition of the mineral. One might just as well expect to obtain the correct chemical formula for plagioclase by averaging all analyses of that mineral. Even if the analyses happened to be distributed uniformly through the plagioclase series the result obtained would not give a correct idea of the composition of the mineral; on the contrary, the formula deduced would be  $\text{NaCaAl}_3\text{Si}_5\text{O}_{16}$ . Any simple ratios obtained by such a process must be regarded as purely accidental. Any formula derived in such a way would hide entirely the presence of an isomorphous series, and would require fixed physical properties. The authors of the new study state that the formula they have obtained for it "may be confidently quoted as that of the normal" mineral. And yet their own account of the physical properties of the mineral plainly requires wide variations in its composition,<sup>2</sup> since the optic angle measured about X varies from 25° to 120°, the birefringence varies from 0.035 to 0.047, and the index of refraction ( $N_m$ ) varies from 1.65 to 1.75, even if one disregards

<sup>2</sup> The authors recognize variations in composition in that  $\text{MgO}$  is supposed to be "replaced" by  $\text{CaO}$ , and  $\text{Fe}_2\text{O}_3$  by  $\text{Al}_2\text{O}_3$ , to some extent, but these variations are distinctly less than the variations disregarded by the formula and are clearly inadequate to explain the variations in optic properties, especially since increase of iron corresponds with decrease of mean refractive index, a condition contrary to that in other isomorphous systems.

the sample which the authors state "shows the physical properties in greatest perfection." If this sample be included, the variations in index and birefringence are nearly doubled, and the variations in composition are much increased.

In the writer's opinion the same condition, though in less degree, exists in regard to the mineral known as thomsonite. It has long been regarded as having the formula  $(\text{Ca}, \text{Na}_2) \text{Al}_2\text{Si}_2\text{O}_8 \cdot 2\frac{1}{2} \text{H}_2\text{O}$ . Wherry<sup>3</sup> has recently argued that so-called thomsonite really includes two distinct minerals, each of fixed composition, one being the true thomsonite, assumed to have the fixed formula  $\text{NaCa}_2\text{Al}_5\text{Si}_5\text{O}_{20} \cdot 6\text{H}_2\text{O}$ , and the other being "faroelite," supposed to be also of fixed formula. However, it is so difficult to determine from the analyses the precise character of this fixed formula of "faroelite" that Wherry himself in two discussions<sup>4</sup> of the matter gives it in two ways which differ from each other by an amount more than one third as great as the difference between one of them and Wherry's fixed formula for true thomsonite.

A mere inspection of the diagram prepared by Wherry shows that there is no break or discontinuity in chemical variability of minerals known as thomsonite, provided the analyses can be trusted. Wherry would explain this condition by assuming that nearly all of the samples analyzed consisted of mixtures of two or more zeolites; and in support of this assumption he cites the fact that Bøggild has observed intergrowths of thomsonite with mesolite, natrolite, etc., and the further fact that he finds optical evidence (consisting of differences in birefringence and refringence) of the presence of two (or more) zeolites in more than four out of five of some 25 samples examined.

Under these circumstances it seems necessary to call attention to the fact that the presence of two substances optically (and chemically) somewhat unlike in a given mass is not proof that the substances are not isomorphous; if it were, it would be easy to prove from many examples in igneous rocks that various members of the plagioclase series<sup>5</sup> are not isomorphous since one type is commonly formed as phenocrysts with another type in the ground-

<sup>3</sup> *Am. Mineral.*, 8, 121, (1923).

<sup>4</sup> *Am. Mineral.*, 8, 121, (1923); and 10, 342, (1925).

<sup>5</sup> Wherry considers the previous reference to the plagioclase series unjustified because in it there is optical evidence of isomorphism; however, at the time Fouqué wrote (1894) there was a considerably greater gap in measured refractive indices between anorthite and labradorite in that series than now exists between admitted thomsonite and "faroelite."

mass of the same rock. Proof that two types occurring together are not isomorphous would be supplied if it could be shown that they were formed simultaneously from the same solution.

It may be worth while to compare the physical properties of Wherry's special type of thomsonite and his "faroelite." They are both orthorhombic, of long fibrous habit, with one perfect and one distinct longitudinal cleavage, the distinct cleavage (which may be taken as 100) being normal to the perfect cleavage (which may be taken as 010); both are commonly colorless and transparent or translucent, with vitreous to pearly luster; both fuse very easily to a transparent globule; both gelatinize with hydrochloric acid. According to Des Cloizeaux,<sup>6</sup> "faroelite" is a (siliceous) variety of thomsonite, and, like it, has parallel extinction with the optic plane normal to the elongation and an optic angle (2E) of about 90° about the positive acute bisectrix, which is normal to the best cleavage.

The following measurements of optical properties of thomsonite and "faroelite" have been made by Wherry, or accepted as satisfactory by him:

LOCALITY	$N_g$	$N_m$	$N_p$	OBSERVER	REFERENCE
Peekskill, N. Y.	1.543	1.531	1.527	Phillips	<i>Am. Mineral.</i> , 9, 240.
Franklin, N. J.	1.542	1.532	1.530	Gordon	<i>Am. Mineral.</i> , 8, 125.
Kilpatrick,	1.540	1.525	1.520	Wherry	<i>Am. Mineral.</i> , 8, 124.
WHERRY'S "faroelite"					
Table Mt., Colo.	1.518	1.513	1.512	Wherry	<i>Am. Mineral.</i> , 8, 124.

According to this table the gap in observed indices of refraction is considerable, and Wherry emphasizes this point and makes use of it to distinguish between thomsonite and "faroelite" by using a liquid with  $N = 1.518$ , in which all the indices of thomsonite are said to be higher, while all those of "faroelite" are said to be lower. Wherry<sup>7</sup> states definitely that all three indices of "faroelite" are "lower than the lowest of thomsonite." However, in another place<sup>8</sup> he gives the indices of "faroelite" as:  $N_g = 1.518$ ,  $N_m = 1.513$ ,  $N_p = 1.512$ , all  $\pm 0.005$ ; therefore the upper limits of the indices attributed to "faroelite" are:  $N_g = 1.523$ ,  $N_m = 1.518$ ,  $N_p = 1.517$ . Moreover, the indices of refraction of thomsonite have been measured by other observers with results as follows:

<sup>6</sup> MANUEL DE MINÉRALOGIE, 1, 374-378, (1862).

<sup>7</sup> *Am. Mineral.*, 10, 345.

<sup>8</sup> *Am. Mineral.*, 10, 346.

LOCALITY	$N_g$	$N_m$	$N_p$	OBSERVER	REFERENCE
Jakuben, Bohemia	1.534	1.523	1.521	Scheit	<i>T. Min. Pet. Mit.</i> 31, 495.
Faroe Islands	1.530	1.520	1.517	Gordon	<i>Am. Mineral.</i> , 8, 125.
Fritz Isl., Pa.	1.527	.....	1.516	Gordon	<i>Am. Mineral.</i> , 8, 125.

Therefore, on the basis of published data there is little, if any, gap in the series of values of indices of refraction in the thomsonite—"faroelite" series.

In view of all the facts, the writer believes that it is much more reasonable to consider that these mineral samples belong to a single isomorphous series rather than to assert that one of them represents a new and independent species.

However, the question can be tested in various ways. The writer had at his disposal only a few samples of thomsonite so that search for material which would come in the supposed gap seemed futile at first. Nevertheless, measurements were made by two methods, with interesting results.

Dr. T. B. Williams used the ordinary method with immersion liquids and daylight and obtained the following data:

LOCALITY	$N_g$	$N_m$	$N_p$	SOURCE OF MATERIAL
Kilpatrick	1.540+	1.528±	1.526+	<i>Phila. Acad. Sci.</i> , No. 18724
Table Mt., Colo.	1.528±	1.520+	$\left\{ \begin{array}{l} <1.515 \\ >1.510 \end{array} \right.$	<i>Univ. Wis.</i> , No. 1640
Table Mt., Colo.	1.526+	1.520-		
Faroe Isl.	$\left\{ \begin{array}{l} <1.530 \\ >1.526 \end{array} \right.$	1.520±	$\left\{ \begin{array}{l} <1.515 \\ >1.511 \end{array} \right.$	<i>Phila. Acad. Sci.</i> , No. 13903
Table Mt., Colo.		1.526-		

Dr. R. C. Emmons used the much more accurate dispersion method with a monochromator, a refractometer, and careful temperature control. In order to obtain results rapidly he measured only the intermediate index of refraction because that is easily found on any prismatic crystal or elongated cleavage fragment. He obtained the following values for sodium light:

LOCALITY	$N_m$	TEMPERATURES	SOURCE OF MATERIAL
Table Mt., Colo.	1.513	35°C	<i>U. S. Nat. Mus.</i> , No. 83260
Table Mt., Colo.	1.516-1.520	34°C	<i>U. S. Nat. Mus.</i> , No. 83260
Faroe Islands	1.512, 1.517, 1.520	32°C	<i>Phila. Acad. Sci.</i> , No. 13903
Faroe Islands	1.521	26°C	<i>Phila. Acad. Sci.</i> , No. 13903

In summary the measured values of  $N_m$  in thomsonite show the following series: 1.513, 1.516, 1.520, 1.523, 1.525, 1.530, 1.532. Therefore the supposed gap in the optic properties does not exist, if the evidence furnished by the measurements of Scheit, Gordon, Williams, and Emmons can be trusted.

At the suggestion of Mr. S. G. Gordon the matter was next tested by X-ray methods. The X-ray pattern of a sample of natrolite from Bergen Hill, N. J., is compared with the pattern given by thomsonite from the Harz Mts. in the upper half of Fig. 1. It is evident that the two space-lattices are much alike, but, nevertheless, show sharply defined differences such as could

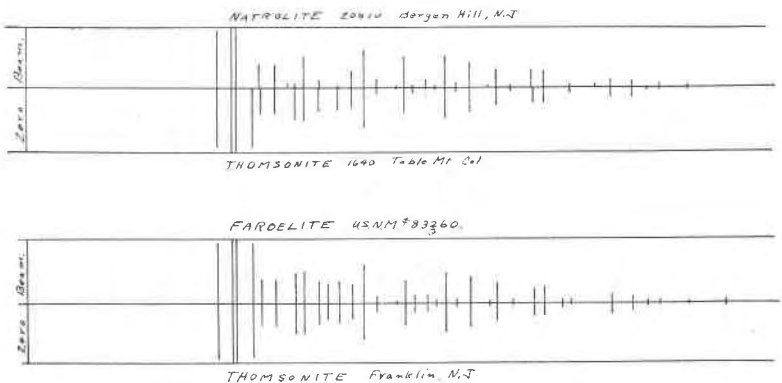


Fig. 1. X-ray patterns from natrolite, thomsonite and "faroelite." Lengths of lines are proportional to their intensity. X-ray tests and drawing thereof made by C. H. Stockwell.

not exist in two substances belonging to an isomorphous series. This is quite in harmony with the fact that both are orthorhombic with axial ratios not extremely different, and that Scheit<sup>9</sup> found thomsonite growing on natrolite so as to completely surround it, the vertical axes being parallel and the vertical pinacoids of thomsonite being as nearly as possible parallel with the prism faces of natrolite. That is, the space-lattices are so similar that one kind controls the orientation of the other kind (when growing upon it), but does not cause completely parallel orientation nor gradation from one to the other. Therefore there can be no doubt that thomsonite and natrolite are not strictly isomorphous.

<sup>9</sup> *Tsch. Min. Pet. Mit.*, 31, 495, (1912)..

In order to test the matter further a sample of thomsonite from Franklin Furnace, N. J. (type material of Wherry's thomsonite) was obtained through the kindness of Mr. S. G. Gordon and Mr. George Vaux, Jr., and a sample of the type material of Wherry's "faroelite" from Table Mountain, Colorado, was obtained from the U. S. National Museum through the courtesy of Dr. W. F. Foshag. The X-ray patterns from these two samples are shown side by side in the lower half of Fig. 1. It is clear that they are substantially identical.

This is not of itself conclusive proof that the two belong to a single isomorphous series since rare cases seem to exist in which non-isomorphous substances give substantially identical patterns. It does show that thomsonite and "faroelite" are more closely alike than thomsonite and natrolite, and, indeed, have substantially identical space lattices.

In summary, it has been shown that: (1) An isomorphous series should be expected in a silicate mineral showing variations in composition. (2) According to the chemical analyses such a series seems to exist in thomsonite (including "faroelite"). (3) The X-ray patterns support the view that an isomorphous series exists in thomsonite which includes the so-called "faroelite." (4) There is no gap in the variations in optic properties in thomsonite. (5) The variations in optic properties therefore prove the existence of an isomorphous series.<sup>10</sup>

<sup>10</sup> As Dr. Wherry's work on thomsonite-faroelite is brought into question by the above article he has stated (private communication) that while he does not agree with several conclusions therein reached, he does not propose to discuss the matter further without additional evidence. It is hoped to have new analyses made on optically controlled "high silica thomsonite", but he has been unable to locate any such material which proves optically homogenous. If any reader of this journal has a specimen which he believes will answer this description, Dr. Wherry would appreciate it greatly if he would furnish him with a gram or two for such study. The silica should exceed 38% and any one refractive index should be constant throughout the specimen to  $\pm 0.003$ . Localities where high silica material has been reported may be found in Dana or Doelter. Editor.