NOTE ON GRÜNERITE FROM THE LAKE SUPERIOR REGION

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A recent publication contained certain statements on grünerite from the Lake Superior Region which should not be passed without comment. Sundius[1] describes as grünerite a specimen of amphibole labeled, "Bijiki Schist, Michigamme." Others would prefer to call such a mineral, containing 12 per cent MgO, cummingtonite. In any case, it is quite a different amphibole from the grünerite examined by the writer which came from Mount Humboldt, Michigan, and was found at other places in the Marquette district; likewise on the Mesabi Range in Minnesota. It has uniform optical properties, the highest refractive index being 1.700 or a little higher and the double refraction is 0.034, thus differing considerably from the cummingtonite mentioned by Sundius which has a gamma index of 1.686 and a birefringence of 0.031. Nevertheless, his description is of interest as it illustrates the fact that there are other varieties of iron-rich amphiboles in the "Iron Formations" of the Lake Superior Region, as was pointed out by the writer of this note at the Toronto Meeting of the Mineralogical Society of America, in December, 1930.

However, the mineral described by Sundius is by no means the common amphibole at Michigamme. The writer was permitted to examine a specimen of typical grünerite kept in the petrographic laboratory of the University of Chicago, which is labeled: "Grünerite Schist, Bijiki Schist, just south of western end of Michigamme Mine." Moreover, my friend Mr. Afuhs collected other specimens for me of the Bijiki Schist from the same mine. The grünerite in all of these samples is of especial interest, because the optical properties are intermediate between Mount Humboldt grünerite and that of Collobrières, France. The indices are: $\alpha=1.677$, $\beta=1.697$, $\gamma=1.714$. A chemical analysis would be very desirable, but it would be a difficult task to separate the very minute blades of grünerite from the magnetite dust which is everywhere present. Also garnet, biotite, chlorite, blue-green amphibole and quartz are intimately interwoven with the grünerite. One would be justified in inferring

[1] N. Sundius, The optical properties of manganese-poor grünerite and cummingtonite compared with those of the manganiferous members: *Am. J. Sci.*, **21,** 330, 1931.

from the higher indices of refraction a higher percentage of iron in this grünerite than in that of Mount Humboldt.

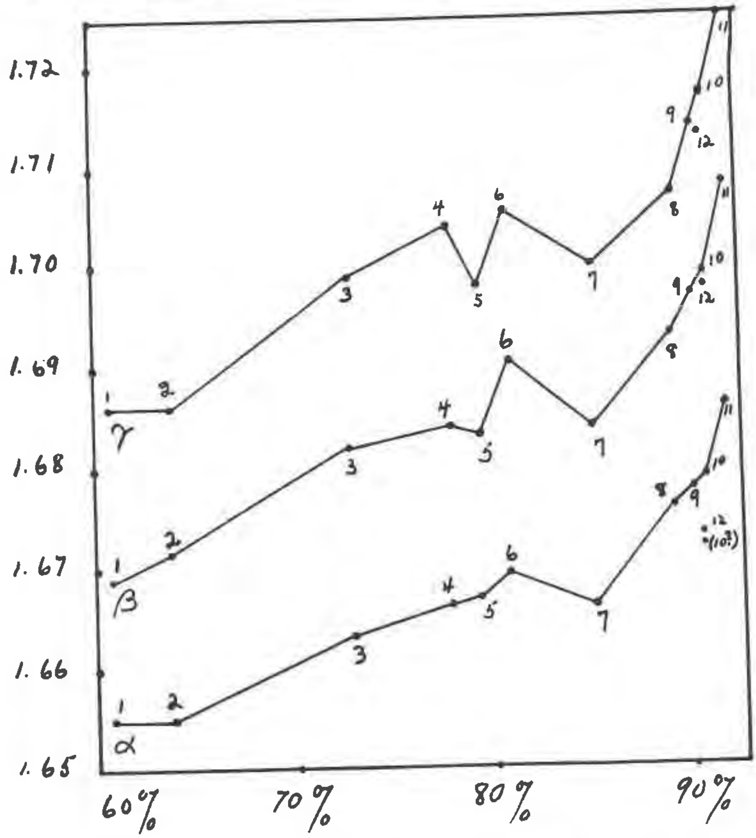
In the course of his paper, Sundius questions the accuracy of my analysis made on pure grünerite from Mount Humboldt. He regards as unusual the 1.25 per cent of alkalies. The alkali determinations were made in the laboratory of the U. S. National Museum by Mr. Earl V. Shannon and their accuracy cannot be questioned. In the meantime Harry V. Warren analyzed grünerite from the Pyrenees.[2] He finds 1.35% of alkalies (average of two analyses), i.e., 0.1% more than in the Mount Humboldt grünerite. At the same time these analyses show that my MgO determination is by no means too low, as Sundius suggests. Warren's average is 3.05%, while the Collobrières grünerite, according to Kreutz, contained 2.61% MgO. Comparing the gamma indices of the three grünerites from Mount Humboldt, Pyrenees, Collobrières, the 4.06% MgO in the first specimen would seem rather too high than too low. I was aware nevertheless that there was a defect in my analysis as the sum total was too low. A recent redetermination of silica resulted in a higher recovery than formerly, 49.90%, which brings up the total to 100.25%. The original error was due to insufficient evaporation in porcelain dishes. In the redetermination platinum was used and the recovery was then complete and uncontaminated. As a consequence, there is no opportunity for more than 4% MgO; nor did several direct determinations result in a larger amount of this oxide.

Furthermore, the agreement, with the formula as proposed for such amphiboles by Schaller, and since confirmed by Kunitz and B. E. Warren, may be regarded as an indirect confirmation of the accuracy of the analysis. According to the method advised by the latter, it was found that the sum of Si and Al amounts to 8.15, that of the metal-atoms 7.01, and of the H-atoms 1.82; indeed a very close approximation to the theoretical formula, closer than in most amphiboles. The grünerite of Collobrières, calculated in the same way, gave 7.86:7.16:2.44.

If Sundius prefers two old analyses of grünerite schists with their unknown impurities, to an analysis of the pure mineral, he should not be surprised if his calculations are to be regarded as quite doubtful. Sundius does not mention in his recalculated analyses any

[2] Harry V. Warren, An occurrence of grünerite at Pierrefitte, Hautes-Pyrénées, France: *Min. Mag.*, **22**, 477, 1931.

water, which is evidently essential to an amphibole. Nor does he take into account the "loss" of 0.67 and 1.40% respectively, as given in the analyses referred to (U. S. Geol. Survey, Monograph 28, p. 338). Such a loss is highly puzzling. Grünerite ignited does not lose weight, but gains. I found a net gain of 1.73% after igniting



$H_2 (Fe, Mn)_7 Si_8 O_{24}$

the Mount Humboldt material, although 1.71% of water was driven off. Nearly all FeO was changed to Fe_2O_3. A loss would be possible in the second analysis on account of the presence of CO_2, but not in the third although for this one the highest loss is recorded. Thus these old analyses are of very doubtful value. Dr. Schaller writes concerning them as follows: "It has been my considerable experience that it does not pay to try to interpret these old analytical data, especially if the figures, finally given, have been corrected by plus and minus items due to other constituents. One never knows whether the final result means anything. Personally, I would not use Melville's figures, simply because the 'loss' is too indefinite." For the somewhat higher amount of magnesia in these analyses, a blue-green amphibole may be responsible which frequently was seen in grünerite schists.

Many attempts have been made to find a simple relationship between the optical properties of amphiboles and their chemical compositions. For the majority of the iron-rich amphiboles this relationship is well established. However, it cannot be denied that there are still a few points which prevent us from representing the optical properties as simple functions of the chemical compositions. In the accompanying diagram these relations in twelve amphiboles, of rather high iron-manganese content, are illustrated. Following Kunitz, the percentage of $H_2(Fe, Mn)_7Si_8O_{24}$ to $H_2Mg_7Si_8O_{24}$ was calculated and the former used as abscissa. Instead of drawing straight lines, the points indicating the refractive indices are connected with zigzag lines, which bring out clearly minor deviations.

For the grünerites in the strict sense of this term, with which the writer is especially concerned, the relationships sought can be represented by almost a smooth curve, if we take into account some new determinations. In a previous paper (this Journal, vol. **12**, p. 353, 1927), the writer stated the opinion that the Collobrières grünerites might represent varying compositions and optical properties. The latter has been partly confirmed. In a specimen preserved in the U. S. National Museum the refractive indices were found by the writer to be higher than those determined by Kreutz. To make sure of this fact, Dr. Clarence S. Ross of the U. S. Geological Survey was asked to check these indices. The values found were: $\alpha=1.686$, $\beta=1.708$, $\gamma=1.725$, all ± 0.002. In the specimen examined the grünerite is associated with magnetite, garnet and fayalite. The color is greenish-brown and the pleochroism quite noticeable. The grünerite described by Kreutz from La Mallière near Collobrières, fragments of which are in my possession, is less highly colored and is associated with only magnetite and garnet.

By plotting the indices of grünerite from Mount Humboldt, the Pyrenees and the French grünerite, the alpha index of the La Mallière specimen, as given by Kreutz falls considerably below the line connecting the values of the other specimens. However, a redetermination of these indices on the original material convinced me that the alpha index is undoubtedly higher than 1.672. In several instances I found that alpha does not go below 1.679. Also beta is a trifle higher than 1.697. Thus the indices fit well in the curve connecting all known grünerites.

Some irregularities appear in the central part of the diagram. It is especially apparent in the V. Silvberg amphibole (6), containing 14.67% of $H_2Mn_7Si_8O_{24}$, which has surprisingly high indices when compared with the preceding Krivoi Rog amphibole (5), in which manganese is absent, and with the Mount Humboldt grünerite (7), which has a small amount of this oxide. Dannemorite (12) and the grünerite from La Mallière (10), in which the sums of the iron and manganese silicates are almost equal, agree fairly well, although in the former much of the iron is replaced by manganese. The writer does not attempt any explanation of these peculiarities; the diagram merely records the facts. Apparently, there are still certain factors influencing the refractive indices which are, at present, not clearly understood.

From theoretical considerations Sundius infers that the graphical relationships of chemical composition and optical properties ought to be represented by straight lines. The deviation therefrom in the Mount Humboldt grünerite he explains by "some abnormal composition of the analyzed specimen" or by "some inexactitude in the analysis" (p. 339). Neither supposition is warranted. The grünerite schists at Mount Humboldt extend over the whole hill, covering an area of about one square mile. Thus I was fortunate in having for analysis abundant material and much of it of unusual purity. Furthermore, the agreement of the optical properties of this analyzed grünerite with the grünerite from various other outcrops, scattered all over the hill, is sufficient proof that the grünerite of Mount Humboldt is of uniform composition. The same agreement was found with grünerites in the eastern part of the Marquette district and likewise with those in the eastern part of the Mesabi district, Minnesota. On the other hand, in the extreme western part of the Marquette district, at Michigamme, grünerite is found with considerably higher indices (9), the values approaching closely to those of the La Mallière material studied by Kreutz. The grünerite at Champion, between Michigamme and Mount Humboldt, has also high indices. The only solution is to arrange the indices in curves which rise rapidly with the increase of iron. The new grünerite from the Pyrenees fits well in such a curve, while there is no place for it in the straight line diagram of Sundius.

Since the above was written the author had another opportunity to study grünerite in the vincinity of Michigamme. At the abandoned Michigamme Mine the mineral occurs abundantly and is of the type showing high refractive indices. Material was also collected at the abandoned Spurr Mine and at the Imperial Mine. In the localities just mentioned it was noted that the indices varied, even in specimens from the same locality. They were, however, always lower than the values obtained from the Michigamme Mine: $\alpha=1.659-1.665$; $\beta=1.676-1.682$; $\gamma=1.690-1.697$. A determination of ferrous iron and manganese, in a specimen with low indices, gave approximately 32% FeO and 2.2% MnO.

Sundius gives at the value of $2v_\alpha=93°$, while the writer found for varieties showing low indices, $2v_\alpha=60°$. Hence it is apparent that grünerite displays a considerable variation in its optical properties and that it is not safe to draw conclusions from a single specimen.

Cummingtonite—Grünerite—Dannemorite Series

The percentage after the author's name gives the proportion of the ferromanganese silicate to the magnesium silicate. If a considerable amount of manganese is present, the manganese silicate is added in parentheses.

	α	β	γ
1) Bijiki schist, Michigamme, (Sundius) 60.67%	1.655,	1.669,	1.686
2) Uttersvik (Sundius) 63.81% (14.35)	1.656,	1.672,	1.686
3) Strömshult (Sundius) 72.59% (11.66)	1.663,	1.682,	1.699
4) Cummington (Sundius) 77.71%	1.666,	1.684,	1.704
5) Krivoi (Kunitz) 79.30%	1.667,	(1.683)	1.698
6) V. Silvberg (Sundius) 80.68% (14.67)	1.670,	1.690,	1.706
7) Mount Humboldt (Richarz) 84.97%	1.666,	1.684,	1.700
8) Pierrefitte, Pyrenees (Warren) 89.08%	1.676,	1.693,	1.707
9) Bijiki schist, Michigamme (This note) 90% (?)	1.677,	1.697,	1.714
10) La Mallière (Kreutz and this note) 90.54%	1.679,	1.679,	1.717
11) Collobrières (U.S.N.M., this note) 91.5% (?)	1.686,	1.708,	1.725
12) Dannemora (Sundius) 90.42% (20.62)	1.673,	1.698,	1.713

The reference to W. Kunitz is contained in: "Die Isomorphieverhältnisse der Hornblendegruppe," *N. Jahrb. f. Min.*, etc., Beilageband **LX**, Abtlg. A, p. 189, 1929. The compositions of 9 and 11 are hypothetical, computed from the indices.