

THE AMERICAN MINERALOGIST, VOL. 46, MAY-JUNE, 1961

## GEDRITE FROM OXFORD COUNTY, MAINE\*

DANIEL J. MILTON AND JUN ITO, *Harvard University, Cambridge, Mass.*

## OCCURRENCE

Gedrite (aluminian anthophyllite) occurs in the metamorphosed Ammonoosuc volcanics at several localities in Grafton, Oxford County, Maine. The material chosen for study is from an elevation of about 1730 feet in the tributary entering Black Brook at about elevation 1650 near the west edge of the Old Speck Mountain 15' quadrangle.

The estimated mode of the rock is:

40%	quartz
45%	albite
7%	gedrite
5%	garnet
1%	biotite
1%	chlorite
1%	magnetite.

The pre-metamorphic nature of the rock is not definitely known, but it was probably a felsic tuff, perhaps considerably modified by sedimentary processes.

The gedrite forms dark green needles or platy prisms about one centimeter long, with some tendency to sheaf-like aggregation. It is partially altered to a brownish-yellow mineral of low birefringence that may be a serpentine or a chlorite.

## SEPARATION

The rock was crushed and the 50 to 200 mesh fraction was used for separation. Gedrite was concentrated by means of heavy liquids and a Frantz isodynamic separator and remaining impurities were picked out by hand. Most of the altered gedrite was removed by floating in fresh methylene iodide. The product used for analysis is estimated to have contained less than 0.5% of the alteration product and less than 0.1% of other impurities.

## CHEMICAL COMPOSITION

Table 1 gives the chemical composition and the atomic ratios calculated on the basis of 24 oxygen atoms, corresponding to the amphibole formula  $AM_2M_5(Si,Al)_8O_{22}(OH)_2$ . The assumption that there are 24

\* Contribution from the Department of Mineralogy and Petrography, Harvard University.

oxygen atoms to the formula, or 96 to the unit cell, leads to a calculated density only 1% less than the measured density, well within the probable error of the various determinations. Six out of the seven anthophyllites studied by Rabbitt, however, also have higher measured than calculated densities. This suggests that the conclusion drawn by Francis (1956) for a particular anthophyllite, that there are more than 96 oxygen (plus fluorine) atoms per unit cell, may be frequently valid.

The amount of aluminum in the tetrahedral positions is the highest

TABLE 1. COMPOSITION OF GEDRITE

SiO <sub>2</sub>	40.71	Si	5.99	}8.00
TiO <sub>2</sub>	0.29	Al <sup>iv</sup>	2.01	
Al <sub>2</sub> O <sub>3</sub>	18.73	Al <sup>vi</sup>	1.23	}
Fe <sub>2</sub> O <sub>3</sub>	0.90	Mg	2.34	
FeO	24.39	Fe <sup>''</sup>	3.00	}7.20
MnO	0.14	Fe <sup>'''</sup>	.10	
MgO	10.66	Mn	.02	}
CaO	0.05	Ti	.03	
Na <sub>2</sub> O	1.59	Ca	.01	}
K <sub>2</sub> O	0.06	Na	.46	
H <sub>2</sub> O <sup>+</sup>	2.75	K	.01	}
H <sub>2</sub> O <sup>-</sup>	0.15	OH	2.70	
F	tr.			
Total	100.42			

## Spectrographic determinations

V 0.0x

Ga 0.0x

Zn 0.0x

Co, Ag, Cu very weak

Jun Ito, analyst.

reported for any anthophyllite, within the limits of error equal to the two out of eight positions usually considered as the limit on the gedrite side of the anthophyllite series. The Fe/Mg ratio is higher than in any anthophyllite listed by Rabbitt, but recently Seki and Yamasaki (1957) have found an anthophyllite very near the ferrogedrite Fe<sub>5</sub>Al<sub>2</sub>Si<sub>6</sub>Al<sub>2</sub>O<sub>22</sub>(OH)<sub>2</sub> end member. The sodium content is the highest reported for any anthophyllite. Calcium is even lower than usual, as might be expected from the association with albite. Potassium is, as usual, very low.

The sum of the cations in the formula (other than hydrogen and the silicon and aluminum required to fill the tetrahedral positions) is 7.20. The mean value for the complete analyses (with alkali determinations)

listed by Rabbitt is 7.13, significantly greater than the 7.00 indicated by the usual anthophyllite formula  $M_7(\text{Si},\text{Al})_8\text{O}_{22}(\text{OH})_2$ . The excess cations are presumably housed in the mostly vacant A position, as was suggested for calcium by Whittaker (1960). The sum of the calcium, sodium, and potassium atoms in Rabbitt's analyses shows a small but definite positive correlation with the total number of non-tetrahedral cations. This suggests that there is a tendency for the larger minor cations to enter the A position, but that they are not restricted to it. In some anthophyllites the cation sum is less than 7.00, so that some of the M positions must be vacant, especially so if some of the A positions are occupied.

The  $\text{H}_2\text{O}$  content is high, but within the known range for anthophyllite. Francis has discussed an unusually hydrous anthophyllite, concluding that water molecules are present in the A or M positions or, less likely, that  $\text{SiO}_4$  tetrahedra are replaced by  $(\text{OH})_4$  tetrahedra. For a number of anthophyllites listed by Rabbitt the sum of the silicon and aluminum atoms is less than 8, and in these the average  $\text{H}_2\text{O}$  content is significantly higher than in the others, suggesting that replacement of silicon tetrahedra by hydroxyl tetrahedra does occur.

#### NOMENCLATURE

The anthophyllite series may be considered an incomplete solution between four end members: magnesioanthophyllite  $\text{Mg}_7\text{Si}_8\text{O}_{22}(\text{OH})_2$ , fer-

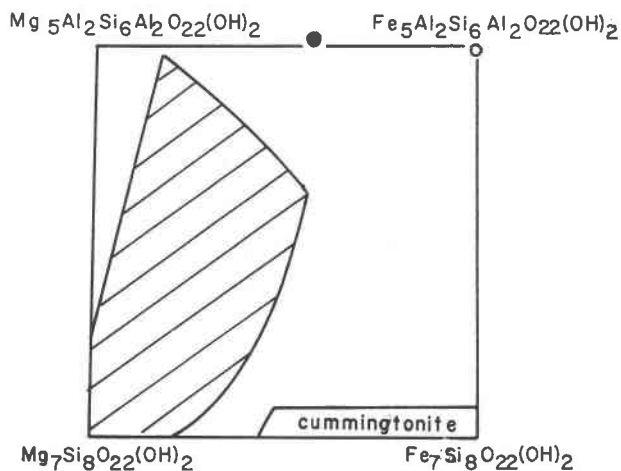


FIG. 1. Compositional field of anthophyllite. Closed circle is gedrite of this paper. Open circle is analyzed ferrogdrite of Seki and Yamasaki (1957). Hatched field encloses anthophyllite analyses compiled by Rabbitt (1948).

roanthophyllite  $\text{Fe}_7\text{Si}_8\text{O}_{22}(\text{OH})_2$ , magnesiogedrite  $\text{Mg}_5\text{Al}_2\text{Si}_6\text{Al}_2\text{O}_{22}(\text{OH})_2$ , and ferrogedrite  $\text{Fe}_5\text{Al}_2\text{Si}_6\text{Al}_2\text{O}_{22}(\text{OH})_2$  (Fig. 1). Seki and Yamasaki, who found a naturally occurring mineral very close to the last end member, preferred to call it aluminian ferroanthophyllite, since the ratio of tetrahedral aluminum to the silicon which it replaces is less than unity. Although there is no obvious reason why this replacement should be limited to two out of eight atoms, the known compositions suggest that this is a natural limit. The name gedrite is entrenched and, unlike most varietal names, is associated with a meaningful ideal formula. It would seem a proper name for the mineral here described.

#### DENSITY

The density, as determined by suspension in Clerici solution, with the density of the liquid in turn determined by pycnometer, is 3.37. Calculation from the composition and the unit cell dimensions yields a density of  $3.33_4$ .

#### OPTICAL PROPERTIES

The optical properties are:

$\alpha = 1.671 \pm 0.002$	$X = a$	yellowish gray
$\beta = 1.681 \pm 0.002$	$Y = b$	greenish gray
$\gamma = 1.690 \pm 0.002$	$Z = c$	greenish gray
$(-)\ 2V_{\text{meas}} \sim 75^\circ$		abs. $Z > Y > X$

Indices were determined by means of a spindle stage (Wilcox 1960) with the oils checked at the time of use by a Leitz-Jelley microrefractometer. The axial angle was determined by the method of Kamb (1958). Extinction positions were carefully observed in monochromatic light of various wave lengths, in an attempt to find dispersion of the bisectrices. None was found.

The regression equations of Hey yield indices for this composition of  $\alpha = 1.6704 \pm 0.025$ ,  $\beta = 1.6789 \pm 0.015$ ,  $\gamma = 1.6911 \pm 0.0012$  which are satisfactorily close. Seki and Yamasaki's diagram gives  $\alpha = 1.669$  and  $\gamma = 1.696$ , which are a somewhat poorer match.

#### X-RAY DIFFRACTION DATA

Measurements of a powder photograph taken in Fe radiation are given in Table 2. Indexing of most reflections follows Johansson (1930) and Seki and Yamasaki (1957). The cell dimensions as calculated from the back reflections are:

$$a_0 \quad 18.59_4 \text{ \AA} \quad b_0 \quad 17.89_0 \text{ \AA} \quad c_0 \quad 5.30_4 \text{ \AA}$$

All reflections are consistent with the accepted space group  $Pnma$ .

Hey (1956) presented regression equations relating chemical composition and physical properties for the anthophyllite series. His equation indicates a  $b_0$  of  $18.005 \pm 0.04 \text{ \AA}$ , so the measured value lies outside his probable range.

## ASSOCIATION

From several optical tests the associated plagioclase is an albite with less than 5% an. The garnet has a refractive index of 1.806, a cell edge of

TABLE 2. X-RAY POWDER DATA FOR GEDRITE  
Fe/Mn radiation

I	$d_{\text{obs}}$	$d_{\text{calc}}$	$hkl$	I	$d_{\text{obs}}$	$d_{\text{calc}}$	$hkl$
5	8.97 Å	8.49 Å	020	3	1.997	1.991	661
8	8.27	8.25	210	2	1.976	1.979	751
2	5.06	5.02	230			1.972	602
2	4.93	4.91	111	2	1.876	1.877	702
2	4.66	4.65	400	2b	1.83	1.832	931
4	4.48	4.47	040	1	1.787		
3	4.14	4.13	420	1	1.774		
3	3.88	3.88	131	2b	1.745		
4	3.65	3.65	231	1b	1.667		
4	3.35		$\beta$ 610	1	1.629		
7	3.23	3.21	440	2	1.617		
10	3.06	3.05	610	2	1.601		
1	3.00			1b	1.579		
1	2.90	2.88	521	2	1.550	1.550	12·00
3	2.85	2.84	260	1	1.541		
3	2.82	2.83	251	3	1.511	1.512	10·61
3	2.75	2.75	630	1	1.500		
1	2.71			2	1.491	1.491	0·12·0
3	2.67	2.68	351	2	1.439		
2	2.57	2.57	161	1	1.425		
3	2.55	2.55	202	2	1.416		
4	2.50	2.50	451	2b	1.324		
3	2.44	2.44	302	2b	1.285	1.287	2·12·2
2	2.34	2.34	650	1	1.124		
3	2.32	2.32	551	2	1.028	1.031	16·80
2	2.23			1	1.015		
3	2.16	2.16	502	1	1.006		
3	2.13	2.13	561	1	0.999		
2	2.07			1	0.992		
2	2.015						

Camera radius 114.59 mm.

Corrected for film shrinkage

Low angle cutoff  $\geq 15 \text{ \AA}$

Intensities by visual estimate

b=line broadening.

11.521 Å, a density of 4.20, and a MnO content of 0.82. This fits a composition of about  $al_{77}py_{18}gr_{3}sp_2$ , according to the charts of Sriramadas (1957). The  $\gamma$  indices of the biotite and chlorite are 1.637 and 1.620, respectively. Assuming the usual degree of aluminum substitution (one third of the tetrahedral positions) these indicate Fe/Fe+Mg ratios of about 0.58 for the biotite and 0.43 for the chlorite.

The four ferromagnesian minerals are plotted on an AFM diagram in Fig. 2. The points are, within the limits of accuracy, collinear, with the gedrite and biotite having close to the same Fe/Mg ratio, intermediate between the more siderophile garnet and the more magnesiophile chlorite.

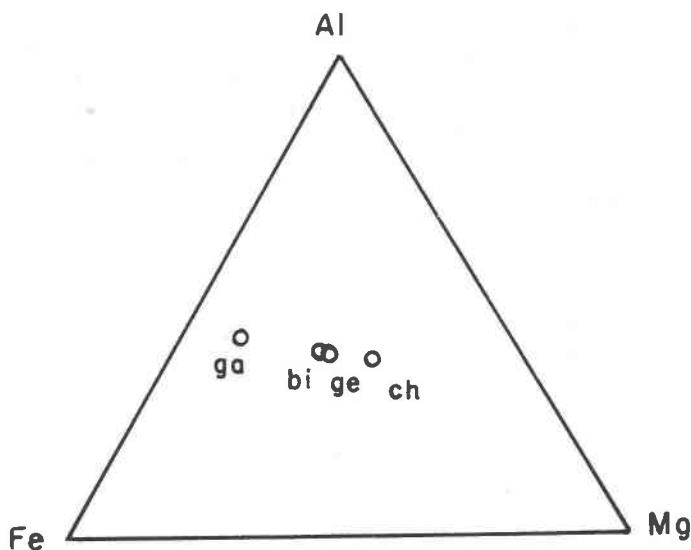


FIG. 2. Compositional relations of gedrite and associated garnet, biotite, and chlorite.

Biotite is, strictly speaking, projected onto the plane of the diagram from the K corner of a KAFM tetrahedron, so that the closeness of the biotite and gedrite points is not irregular. Gedrite, garnet, and chlorite, on the other hand, have all major, and presumably determining, components in common. A collinearity of these points would indicate less than the two degrees of freedom required by the mineralogical phase rule. Probably, were the compositions more accurately determined, there would be a narrow triangle between these three points. As less aluminous anthophyllite would be expected to be stable under the same physical conditions, the gedrite apex is most likely the bottom apex of the triangle, perhaps by virtue of the chlorite being more aluminous than was assumed.

## ACKNOWLEDGMENTS

Thanks are due to Professor C. S. Hurlbut, Jr. for a critical reading of this paper. Work was performed during the tenure of a National Science Foundation pre-doctoral fellowship by the senior author.

## REFERENCES

- FRANCIS, G. H., 1955, Gedrite from Glen Urquhart, Inverness-shire: *Mineral. Mag.*, **30**, 709-716.
- HEY, M., 1956, On the correlation of physical properties with chemical composition in multivariate systems: *Mineral. Mag.*, **31**, 69-95.
- JOHANSSON, K., 1930, Vergleichende Untersuchungen an Anthophyllit, Grammatit und Cumingtonit: *Zeits. Krist.*, **73**, 31-51.
- KAMB, W. B., 1958, Isogyres in interference figures: *Am. Mineral.*, **43**, 1029-1067.
- RABBITT, J. C., 1948, A new study of the anthophyllite series: *Am. Mineral.*, **33**, 263-323.
- SEKI, Y. AND YAMASAKI, M., 1957, Aluminian ferroanthophyllite from the Kitakami Mountainland, Northeastern Japan: *Am. Mineral.*, **42**, 506-520.
- SRIRAMADAS, A., 1957, Diagrams for the correlation of unit cell edges and refractive indices with the chemical compositions of garnets: *Am. Mineral.*, **42**, 294-299.
- WHITTAKER, E. J. W., 1960, The crystal chemistry of the amphiboles: *Acta Cryst.*, **13**, 291-298.
- WILCOX, R. E., 1959, Use of the spindle stage for determining refractive indices of crystal fragments: *Am. Mineral.*, **44**, 1272-1293.

THE AMERICAN MINERALOGIST, VOL. 46, MAY-JUNE, 1961

## LAMELLAR STRUCTURE IN A TYPE I DIAMOND\*

R. M. DENNING, *Department of Mineralogy, University of Michigan*

A lamellar structure parallel to octahedron planes is not unusual in diamonds. Such structure becomes visible between crossed polars when the diamond is observed along a [110] direction.

A very pale-yellow diamond crystal, apparently free of birefringence, was selected for stress-optical study. A rectangular parallelepiped was cut in such a way as to be bounded by two dodecahedral planes and one cube plane. The excellence of the natural octahedral faces was such that the optical goniometer could be used to determine the orientation. The largest orientation error of any of the planes is 6 minutes of arc. The dimensions of the diamond sample are 2.6×3.6×4.6 mm. After the diamond was cut, it was found to show very low double refraction.

Figure 1 shows three views of the crystal between crossed polars. In each view, the vibration directions of the polars are parallel to the edges of the crystal. The interference colors are all first order gray. The birefringence of the lamellae is about  $2 \times 10^{-5}$ . A central nucleus shows a

\* Contribution No. 239 Dept. of Mineralogy, University of Michigan.