

FERROTREMOLITE, OXYHORNBLLENDE, AND TOURMALINE

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1. FERROTREMOLITE

The formula of tremolite has recently been established by the x-ray studies of Warren¹ as $H_2Ca_2Mg_5Si_8O_{24}$. It has been the practise of mineralogists for many years to consider that a monoclinic amphibole of this type should be called tremolite if it was nearly or quite colorless, while similar material of a green color has been called actinolite. Expressed in chemical terms this means that such amphiboles with less than about 3 weight percent FeO or 10 molecular percent $H_2Ca_2Fe_5Si_8O_{24}$ are called tremolite, while those with more iron than this are called actinolite. Such a practise was satisfactory as long as iron-rich members of this series were unknown, but at present so-called "actinolites" have been described with 75 and even 95 molecular per cent of the iron molecule.² Therefore a name for this end member of the series is needed. It seems undesirable and unreasonable to give the same name to the pure iron end-member as is given by all to a mineral containing only 15 molecular percentage of that molecule. Accordingly "actinolite" is not satisfactory as a name of this substance. Is it not fitting to call it *ferrotremolite*?

2. OXYHORNBLLENDE

Barnes³ has recently demonstrated quite completely that ordinary hornblende can be changed artificially to a condition similar to that found in so-called "basaltic hornblende" without destruction of the space lattice. He has proved that the change in properties is due to an oxidation of the ferrous iron of the mineral to the ferric state, a change which takes place readily in air at about 800°C; this change can be reversed by heating the mineral to the same temperature in an atmosphere of hydrogen. Nevertheless, this oxidation of ferrous iron is not produced by addition of oxygen from the air, but rather by a loss of hydrogen (not water) and re-

¹ *Zeit. Kryst.*, **LXXII**, 1929, p. 42.

² W. Kunitz, *N. Jahrb. Min., Bl. Bd.*, **LX**, 1930, p. 171; A. N. Winchell, *Am. Mineral.*, **XVI**, 1931, p. 250.

³ *Am. Mineral.*, **XV**, 1930, p. 393.

arrangement of valence bonds of oxygen atoms already in the mineral. Natural "basaltic hornblende" differs from hornblende artificially changed in that the oxidation of the ferrous iron is generally partial rather than complete, but the essential feature is oxidation in both cases. It is well known that dark brown hornblendes are not confined to basalts, but are found in all kinds of volcanic rocks so that the name "basaltic hornblende" is clearly

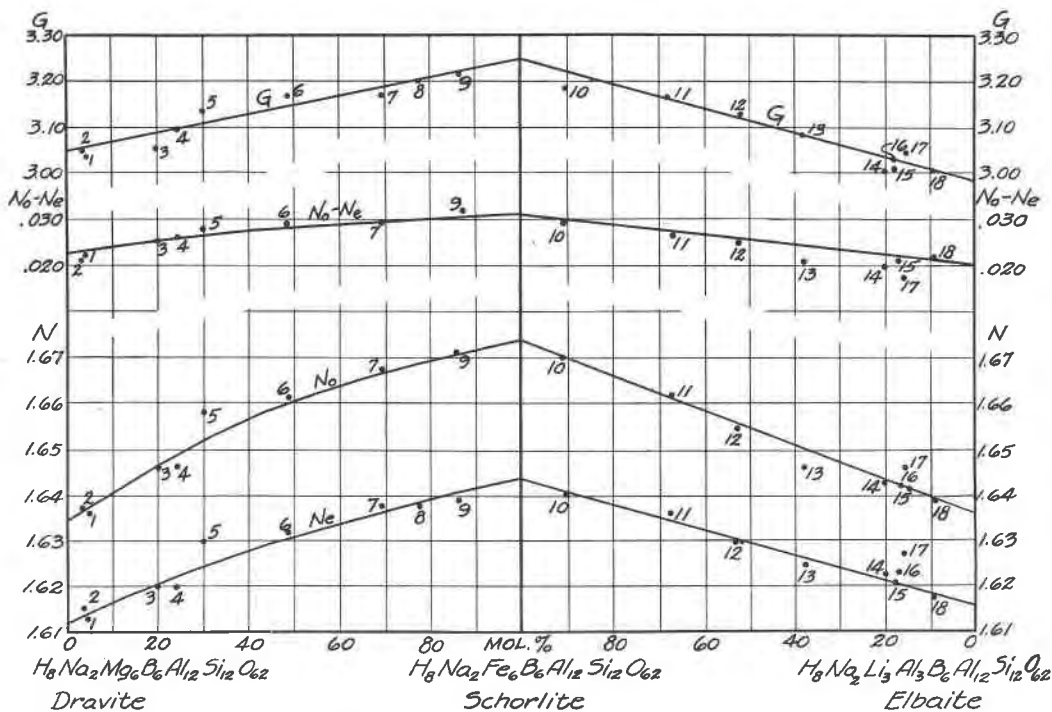


FIG. 1. Relations between composition and properties in the dravite-schorlite and schorlite-elbaite series.

not well chosen. The writer would suggest that such amphiboles may well be called *oxyhornblendes*. Some rare dark brown hornblendes contain very little ferric iron, but, like the others, they contain very little hydrogen and therefore have valence bonds of oxygen (in other cases united with hydrogen) available for other elements. Apparently such a condition permits the presence of considerable titanium, as found in *kaersutite*.

3. TOURMALINE

Kunitz⁴ has recently published an important study of the chemical composition and optic properties of tourmaline. From a study of twenty new analyses (and some old ones) he derived a complex formula which may be generalized as follows:— $H_8Na_2R_6Al_{12}B_6Si_{12}O_{62}$. Nearly at the same time Machatschki⁵ published the results of an *x*-ray study of tourmaline which led to a formula as follows: $H_xNa_2(R'' + R''')_{18}B_6Si_{12}O_{62}$. These two formulas, obtained quite independently by entirely different methods, are so

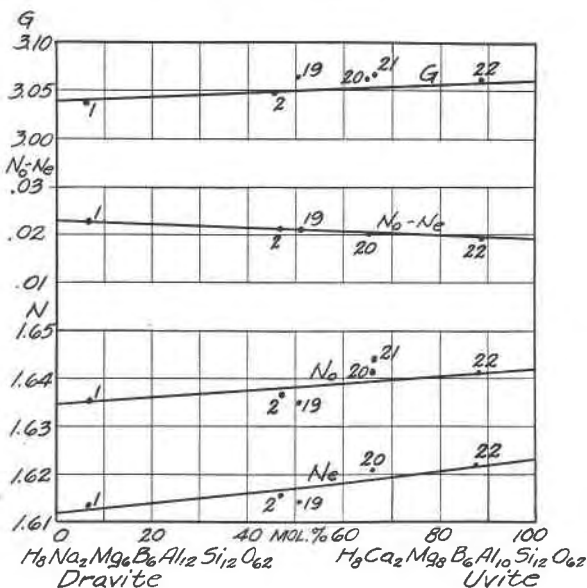


FIG. 2. Relations between composition and properties in the dravite-uvite series.

nearly alike that it is very probable that they both represent a very close approximation to the truth.

Kunitz also prepared graphs showing the relation between optic properties and chemical composition in certain binary series of the tourmaline system, but the writer has found some difficulties in attempting to correlate these graphs with the analyses. Therefore new graphs have been prepared with the assistance of Mr. L. G. Trowbridge, and they are shown in Fig. 1. The magnesium, iron,

⁴ *Chem. Erde*, IV, 1929, p. 208.

⁵ *Zeit. Kryst.*, LXX, 1929, p. 211; Ca included with Na.

and lithium types (dravite, schorlite, and elbaite) might be shown in one triangular diagram, but actual examples of the dravite-elbaite series as well as examples well within the triangle are not now known; accordingly, the binary diagrams are better adapted to show present data.

The sodium-calcium variation in tourmaline is entirely independent of the magnesium-iron-lithium variation, its effects on the optic properties of magnesium-rich tourmalines are shown in Fig. 2. Its effects on other tourmalines can be shown conveniently in a

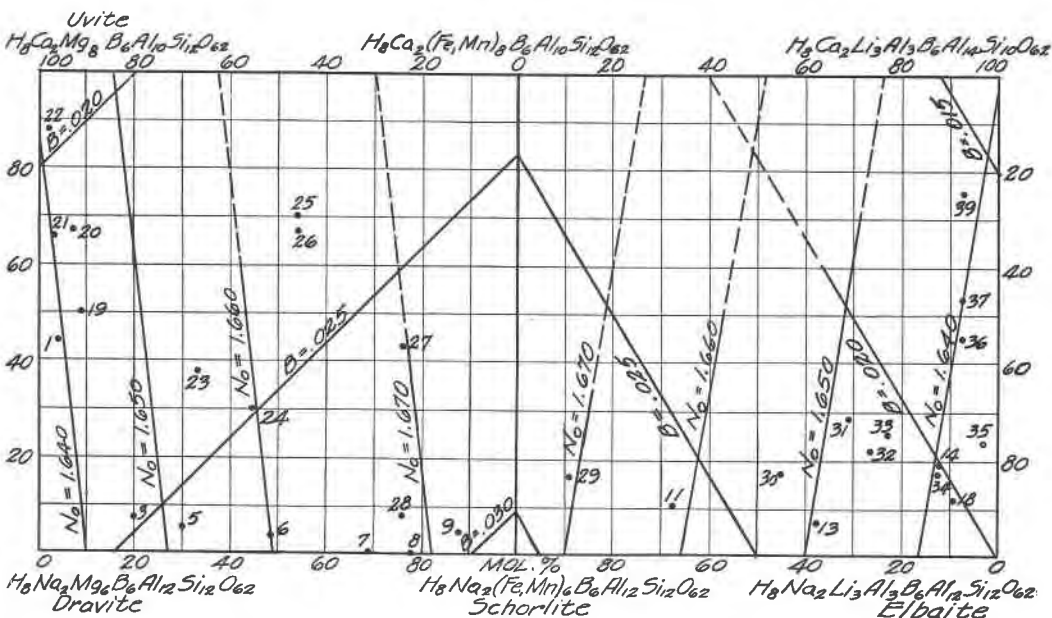


FIG. 3. Relations between composition and optic properties in some tourmalines.

diagram having chemical variations of two kinds on two coordinates, as illustrated in Fig. 3. In this diagram some analyses are used which can be calculated into the molecules used only by assuming some replacement of MgSi by AlAl,⁶ and some others are used which seem to require the presence of more Li₂O than reported in the chemical analyses. Also, manganese, ferric iron, and titanium atoms are considered as equivalent to ferrous iron atoms. Some difficulties in the interpretation of tourmaline analyses may be due

⁶ This change seems to have very little effect on the optic properties.

to changes in the composition of tourmaline after formation, a process the occurrence of which is indicated by the recent work of Ward.⁷

A series is now known from the lithium tourmaline (elbaite) to about 50 molecular per cent of the manganese tourmaline, which has been named *tsilaisite*. Unfortunately this series can not be distinguished at present from the lithium-iron tourmalines by its indices of refraction. The magnesium-iron tourmalines (the dravite-schorlite series) vary from light brown at the magnesium end to dark brown, dark green, or dark blue, to black with 25 to 100 molecular percent of the iron molecule.

It seems almost superfluous to add that no claims of high accuracy are made for these diagrams, though they represent present data fairly well. However, they assume that the optical effects of ferric iron, manganese and titanium atoms are the same as those of ferrous iron atoms, which is only approximately true, and they disregard entirely some other variations in composition, especially, substitution of AlAl for MgSi, and of F for OH, which unquestionably produce some effects upon the optical properties.

REFERENCES FOR THE TOURMALINE DIAGRAMS

1. Dravite, Dobrowa. W. Kunitz: *Chem. Erde*, **IV**, 1929, p. 214, No. 1; p. 217, No. 1.
2. Uvite, Gouverneur, N. Y. W. Kunitz: *op. cit.*, p. 214, No. 5; p. 217, No. 9.
3. Tourmaline, Posten Sonjo, E. Africa. E. A. Wülfing and K. Becht: *Sitz. Akad. Wiss. Abh.*, **20**; *Zeit. Kryst.*, **LVII**, 1922, p. 332.
4. Tourmaline (black), Spessart. W. Kunitz: *op. cit.*, p. 214, No. 2; p. 217, No. 2.
5. Tourmaline (black), Bamle. W. Kunitz: *op. cit.*, p. 214, No. 3., p. 217, No. 3.
6. Tourmaline (black), Pedretto. W. Kunitz: *op. cit.*, p. 214, No. 8; p. 217, No. 4.
7. Schorlite, Hörilberg. W. Kunitz: *op. cit.*, p. 214, No. 6; p. 217, No. 6.
8. Schorlite, Chursdorf. W. Kunitz: *op. cit.*, p. 214, No. 7; p. 217, No. 7.
9. Schorlite, Epprechtstein. W. Kunitz: *op. cit.*, p. 214, No. 9; p. 217, No. 8.
10. Schorlite, Eibenstock. W. Kunitz: *op. cit.*, p. 215, No. 5; p. 222, No. 7.
11. Indigolite, Ural. W. Kunitz: *op. cit.*, p. 215, No. 3; p. 222, No. 5.
12. Tsilaisite, Nertschinsk. W. Kunitz: *op. cit.*, p. 215, No. 9; p. 222, No. 11.
13. Indigolite, Germ. S. W. Africa. W. Kunitz: *Op. cit.*, p. 215, No. 10; p. 222, No. 3.
14. Rubellite, Antsongambato, Madagascar. Duparc, Wunder and Sabot: *Arch. Sc. phys. nat. Genève*, **XXIX**, 1910, pp. 381-387, No. 3.
15. Rubellite, Nertschinsk. W. Kunitz: *op. cit.*, p. 215, No. 8; p. 222, No. 9.
16. Rubellite, Penig. W. Kunitz: *op. cit.*, p. 215, No. 7; p. 222, No. 1.
17. Tourmaline (pale green), Mesa Grande, Calif. W. T. Schaller: *Zeit. Kryst.*, **LI**, 1912, p. 321.
18. Rubellite, Mursinsk. W. Kunitz: *op. cit.*, p. 215, No. 1, p. 222, No. 8.

⁷ *Am. Mineral.*, **XVI**, 1931, p. 145.

19. Tourmaline, Macomb. E. A. Wülfing and K. Becht: *op. cit.*
20. Tourmaline, Mosalahy, Madagascar. A. Lacroix: *Mineral. Madagascar*, I, 1922, p. 411.
21. Tourmaline (aver. brown), Ceylon. E. A. Wülfing and K. Becht: *op. cit.*
22. Tourmaline (pale brown), Ceylon. E. A. Wülfing and K. Becht: *op. cit.*
23. Tourmaline (black), Drummerstown, Vt. G. W. Ward: *Am. Mineral.*, XVI, 1931, p. 145, No. 38.
24. Tourmaline (black), Wickes, Mont. G. W. Ward: *op. cit.*, No. 23. This is the tourmaline described by H. V. Winchell and A. N. Winchell: *Econ. Geol.*, VII, 1912, p. 287.
25. Tourmaline (black), St. Lawrence Co., N. Y. G. W. Ward: *op. cit.*, No. 70.
26. Tourmaline (dark brown), Ceylon. E. A. Wülfing and K. Becht: *op. cit.*
27. Tourmaline (black), Moriah, Essex Co., N. Y. G. W. Ward: *op. cit.*, No. 179.
28. Tourmaline (black), Custer, S. Dak. G. W. Ward: *op. cit.*, No. 79.
29. Tourmaline (black), Thousand Islands, G. W. Ward: *op. cit.*, No. 158.
30. Tourmaline (black), Tsilaisina, Madagascar. Duparc, Wunder and Sabot: *op. cit.*, pp. 389-395, No. 14.
31. Tourmaline (greenish brown), Tsilaisina, Madagascar. Duparc, Wunder and Sabot: *op. cit.*, pp. 389-396, No. 11.
32. Tourmaline (pale yellow), Tsilaisina, Madagascar. Duparc, Wunder and Sabot: *op. cit.*, pp. 389-396, No. 8.
33. Tourmaline (pale green), Haddam, Conn. W. T. Schaller: *op. cit.*
34. Rubellite (clear red), Antsongombato, Madagascar: Duparc, Wunder and Sabot: *op. cit.*, pp. 381-387, No. 4.
35. Tourmaline (red), Himalaya mine, Calif. W. T. Schaller: *op. cit.*
36. Tourmaline (pink), Tsilaisina, Madagascar. Duparc, Wunder and Sabot: *op. cit.*, pp. 389-396, No. 7.
37. Tourmaline (dark red), Anjanbonoina, Madagascar. A. Lacroix: *op. cit.*
38. Rubellite (pink), Maroando, Madagascar. Duparc, Wunder and Sabot: *op. cit.*, pp. 388-389, No. 5.
39. Tourmaline (red), Antaboko, Madagascar. Duparc, Wunder and Sabot: *op. cit.*, pp. 397-398, No. 15.