MINERALOGY OF TRIPLITE

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Abstract

Triplite, previously treated as a divariant series between Fe″ and Mn″, may also contain relatively large amounts of Mg and lesser amounts of Ca. Variation in Fe and Mg is the primary factor influencing the optical properties, but Mn variation has little effect. Three new analyses of Colorado triplites are presented; two are high in Mg. Apparently the only valid species formed through weathering of triplite are dufrenite, vivianite, and phosphosiderite. Alluaudite and apatite form by reaction with solutions. Nearly 80 triplite localities have been recorded. Triplite occurs in four types of granitic pegmatites and three types of hydrothermal, high temperature veins.

Introduction

Previous to the work of Hurlbut (1936) triplite generally was regarded as consisting of an isomorphous series of two elements, ferrous iron and manganese. Analyses of triplite containing important amounts of magnesium were rare, and usually no consideration was given to the element in attempting to relate physical properties to composition (Henderson, 1928, Otto, 1936, and Richmond, 1940). As a result of a study of the pegmatites of Eight Mile Park, Fremont County, Colorado, the writer described several new triplite discoveries (Heinrich, 1948). Rough crystals of triplite from one of these occurrences were measured by Wolfe and Heinrich (1947). Qualitative tests indicated that the magnesium contents of these triplites might be abnormally large and that complete chemical analyses would be desirable. The writer is indebted to the Faculty Research Fund of the Rackham Graduate School, University of Michigan, for a generous grant defraying the cost of the analyses and other expenses. Thanks are due to Professor Clifford Frondel of the Department of Mineralogy and Petrography, Harvard University, and to Professor Brian Mason of the Department of Geology, Indiana University, for critical examinations of the manuscript and for suggestions toward its improvement. All conclusions are the responsibility of the writer. Dr. George Switzer of the U. S. National Museum kindly furnished several specimens for examination, and Mr. W. G. Griffitts of the U. S. Geological Survey furnished a description of and a specimen from a previously unrecorded occurrence in northern Colorado.

New Analyses

In Table 1 are listed the results of three new analyses of triplite. All samples were taken from unaltered central parts of triplite masses that did not contain any other intergrown minerals. Selected pieces were broken to minus 1/8th-inch particles and handpicked under a binocular microscope. Pieces showing alteration or coatings were rejected, and the remainder was ground in an agate mortar. The powdered sample was examined in oil immersion and was found to be practically free of any impurities. Analyses of three-gram samples were completed at the Laboratory for Rock Analysis, Department of Geology and Mineralogy, University of Minnesota, by Dr. Lee C. Peck, to whom the writer is strongly indebted for painstaking work in difficult analyses.

TABLE 1. NEW ANALYSES OF TRIPLITE

	1.	1*a*	1*b*	2.	2*a*	2*b*	3.	3*a*	3*b*
Fe_2O_3	0.86			1.63			2.30		
TiO_2	0.19			0.08			0.42		
FeO	9.00	.125	4	10.65	.168*	4	11.39	.187*	4
MnO	33.20	.468		44.44	.626		31.46	.443	
MgO	13.62	.337		1.15	.028		9.93	.246	
CaO	2.29	.040		4.59	.082		4.70	.083	
Na_2O	0.03			0.11			0.11		
K_2O	0.01			0.03			0.02		
H_2O+	0.21			0.23			0.35		
H_2O-	0.03			0.06			0.06		
P_2O_5	34.96	.246	1	32.01	.225	1	34.41	.242	1
F	8.52	.448	2	7.66	.403	2	7.63	4.01	2
Total	102.92			102.64			102.78		
Less O for F	3.59			3.25			3.22		
Total	99.33			99.39			99.56		

1. Triplite, Mica Lodge pegmatite, Eight Mile Park, Fremont County, Colorado.
1*a*. Molecular ratios.
1*b*. Molecular proportions.
2. Triplite, School Section pegmatite, Eight Mile Park, Fremont County, Colorado.
2*a*. Molecular ratios.
2*b*. Molecular proportions.
3. Triplite, Turkey Creek, Deadmans Canyon, El Paso County, Colorado.
3*a*. Molecular ratios.
3*b*. Molecular proportions.
Analyst, Lee C. Peck.

* With Fe_2O_3 recalculated to equivalent FeO.

The formulae are:

1. $Mn_{0.95}Fe_{0.25}Mg_{0.7}Ca_{0.1}PO_4F$
2. $Mn_{1.4}Fe_{0.4}Mg_{0.05}Ca_{0.15}PO_4F$
3. $Mn_{0.95}Fe_{0.4}Mg_{0.5}Ca_{0.15}PO_4F$

Triplite from the Mica Lode (Anal. No. 1) has one of the highest MgO contents reported for the mineral, being exceeded only in the material from Punau, Marienbad, Moravia (Anal. No. 27, Table 2) and "talc-triplite" from Horrsjöberg, Sweden (Anal. No. 30, Table 2.) Both of these older analyses (1910 and 1883, respectively) are of poorer quality.

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4. Branchville, Conn. Dana, 1892, p. 777, Anal.—Penfield.
5. Haddam Neck, Conn. Shannon, 1920. Anal.—Shannon. Rem. is insol.
6. Rapid City, South Dakota. Eakins, 1891. Anal.—Eakins. Rem. is SiO_2 0.43, Al_2O_3 8.74, K_2O tr, Na_2O 5.25, Li_2O 0.13, Cl 0.25, CO_2 0.26. "In reality it probably represents a mixture . . ."
7. Reagan Mining District, Aurum, White Pine County, Nevada. Hess and Hunt, 1913. Anal.—Hunt.
8. 7U7 Ranch, near Hillside, Arizona. Hurlbut, 1936. Anal.—Gonyer. Rem. is Na_2O.
9. Mt. Loma, 7 miles from locality of No. 8, near Hillside, Arizona. Hurlbut, 1936. Anal.—Gonyer.
10. San Luis, Sierrá de Córdoba, Argentina. Stelzner, 1873. Anal.—Siewart. Rem. is SiO_2.
11. San Luis, Sierrá de Córdoba, Argentina. Stelzner, 1873. Anal.—Siewart. Rem. is SiO_2.
12. Salado, La Rioja, Argentina. Henderson, 1933. Anal.—Henderson. Rem. is Na_2O 0.27, K_2O 0.33, insol. 0.28, Cl tr.
13. Mangualde, Portugal. de Jesus, 1933. Anal.—de Jesus. Rem. is Na_2O 0.38, K_2O 0.27, $-H_2O$ 0.07, insol. 0.24.
14. Mangualde, Portugal. de Jesus, 1933. Anal.—de Jesus. Rem. is Na_2O 0.82, K_2O 1.18, $-H_2O$ 2.50, insol. 0.20, Mn_2O_3 4.74. Called metatriplite.
15. Chanteloube, Limoges, France. Otto, 1936. Anal.—Otto. Fluorine not determined. Two older analyses of triplite from France are not included in the table; both are of material from Limoges (Vauquelin, 1802 and Berzelius, 1819.) Vauquelin presented the original description of triplite, under the name, "phosphate native de fer mélange de manganèse." The name, triplite, was applied by Hausmann in 1813.
16. Zwiesel, Bavaria. Fuchs, 1839. Anal.—Fuchs. Rem. is SiO_2 0.68, Fe 4.76.
17. Zwiesel, Bavaria. Otto, 1936. Anal.—Otto.
18. Schönfeld, Germany, Otto, 1936. Anal.—Otto.
19. Wildenau-Plössberg, Germany, Laubman and Steinmetz, 1920. Anal.—authors. Note low P_2O_5. Rem. is insol.
20. Pleystein, Germany. Laubman and Steinmetz, 1920. Anal.—authors. Rem. is insol.
21. Hagendorf, Germany. Laubman and Steinmetz, 1920. Anal.—authors. Rem. is insol.
22. Schlaggenwald, Bohemia. von Kobell, 1864. Anal.—von Kobell.
23. Vienna, Gross-Meseritsch, Moravia. von John, 1900. Anal.—von John. Rem. is Na_2O 0.52, K_2O 0.72.
24. Vienna, Gross-Meseritsch, Moravia. Kovar and Slavik, 1900. Anal.—Kovar. Rem. is SiO_2. Altered, may be triploidite.
25. Königswart, Marienbad, Moravia. Sellner, 1924. Anal.—Stanczak. Rem. is Na_2O 0.22, K_2O 0.06, insol. 0.36.
26. Königswart, Marienbad, Moravia. Sellner, 1924. Anal.—Stanczak. Rem. is Na_2O 0.30, K_2O 0.12.
27. Punau, Marienbad, Moravia. Sellner, 1924. Anal.—Stanczak. Rem. is Na_2O 0.36, K_2O 0.45, insol. 8.10. Probably impure, note high insol. " . . . gangformig Triplit mit Granat." According to Lazaravic (1910) also intergrown with fluorite.
28. Peilau, Reichenberg, Silesia. Bergemann, 1860. Anal.—Bergemann. Rem. is SiO_2 0.23, Na_2O 0.41, ignition loss 1.28. Fluorine not determined.
29. Varuträsk, Sweden, Mason, 1941B. Anal.—Berggren. Rem. is Na_2O 0.39, K_2O 0.33, Li_2O 0.10, $-H_2O$ 0.27, Insol. 6.22.
30. Horrsjöberg, Sweden. Igelström, 1882. Anal.—Igelström. Fluorine not determined. Very likely a mixture, for Igelström (1883) states, " . . . je n'avais alors que peu d'echantillons assez impurs."
31. Skrumpetorpsee, Östergötland, Sweden, Hamberg, 1904. Anal.—Sahlbohm. Rem. is SiO_2 0.11, Al_2O_3 2.16, Na_2O 0.98, K_2O 0.33.
32. Lilla Elysjö, Krockek, Linköping, Sweden. Nordenskjöld, 1902. Anal.—Nordenskjöld. Rem. is SiO_2 0.18, Al_2O_3 0.37, Na_2O 0.31.
33. Lemnäs, Kimito, Southwest Finland. Pehrman, 1939, Anal.—Pehrman. Rem. is Na_2O 0.22, K_2O tr, $-H_2O$ 0.07.
34. Mattkärr, Kimito, Finland. Otto, 1936. Anal.—Otto.
35. Serro Branco, Picuhy, Parahybla, Brazil. Fornaseri, 1943. Anal.—Fornaseri. Rem. is Na_2O 0.10, K_2O tr, $-H_2O$ 0.20. Called "alluaudite."

TABLE 2. OTHER ANALYSES OF TRIPLITE

No.	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FeO	7.69	4.95	1.97	1.68	11.68	6.68	18.30	15.88	23.54	20.34	—	27.61	35.44	41.96	25.80	41.60
Fe_2O_3	—	—	2.36	—	—	0.40	—	2.22	—	2.50	24.20	—	—	—	—	—
MnO	54.14	52.40	29.13	57.63	34.55	53.77	37.84	37.74	34.84	36.52	29.90	33.44	20.34	18.40	28.48	31.03
MgO	—	0.58	tr.	1.21	11.87	0.31	tr.	tr.	tr.	0.91	0.17	—	—	0.80	7.20	—
CaO	1.80	3.18	6.72	2.86	2.48	2.17	4.46	5.92	3.48	2.86	2.18	1.70	—	1.69	1.80	—
H_2O+	0.36	0.35	3.67	—	0.75	—	—	—	1.58	0.13	4.70	—	—	—	—	—
P_2O_5	32.17	32.81	39.68	31.84	33.32	32.20	35.65	31.13	31.50	32.15	26.67	32.02	35.60	32.85	31.98	19.73
F	7.53	9.09	2.35	7.77	8.02	7.58	4.94	7.78	6.41	7.35	5.02	n.d.	3.18	7.21	7.64	6.28
Rem.	—	1.17	15.06	—	0.52	—	0.13	1.17	0.88	0.96	9.44	—	5.44	—	—	1.03
Total	103.69	104.53	100.94	102.99	103.19	103.11	101.32	101.84	102.23	103.72	102.28	94.77	100.00	102.91	102.90	99.67
O=F	3.16	3.83	1.05	3.27	3.38	3.19	2.07	3.27	2.69	3.09	2.11	—	1.37	3.02	3.21	2.64
Sum	100.53	100.70	99.89	99.72	99.81	99.92	99.25	98.57	99.54	100.63	100.17	94.77	98.63	99.89	99.69	97.03

No.	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
FeO	33.51	35.50	26.98	31.03	26.10	24.84	26.50	14.87	31.72	19.96	16.12	20.48	18.43	21.90	38.52	29.40
Fe_2O_3	—	—	—	—	2.80	0.17	1.43	—	1.55	0.78	—	3.40	2.38	—	—	0.10
MnO	25.42	28.66	30.00	31.05	29.17	31.96	33.40	20.75	30.83	32.07	14.86	32.60	35.23	37.35	24.20	25.97
MgO	—	—	3.05	tr.	4.58	tr.	tr.	14.05	0.32	tr.	17.42	1.33	4.46	—	—	1.60
CaO	—	—	2.20	1.42	0.49	6.89	4.90	7.84	1.19	4.68	14.91	0.80	2.10	2.65	0.50	8.10
H_2O+	—	—	—	—	4.16	—	—	—	—	0.48	—	1.25	0.10	0.38	0.62	1.02
P_2O_5	33.14	31.89	33.85	31.29	31.67	31.87	30.44	29.08	32.76	30.63	32.82	32.33	32.05	33.09	32.65	31.96
F	6.77	7.29	8.10	8.17	1.11	3.29	3.34	5.15	n.d.	6.72	n.d.	6.96	8.72	7.83	6.02	5.50
Rem.	0.46	0.83	—	1.24	0.84	0.64	0.42	8.91	1.92	7.31	—	3.58	0.86	0.29	—	0.30
Total	99.30	104.17	104.18	104.20	100.92	99.66	100.43	100.65	100.29	102.63	96.13	102.73	104.33	103.49	102.51	102.95
O=F	2.84	3.06	3.40	3.43	0.47	1.39	1.40	2.16	—	2.83	—	2.84	3.66	3.29	2.57	2.31
Sum	96.46	101.11	100.78	100.77	100.45	98.27	99.03	98.49	100.29	99.80	96.13	99.89	100.67	100.20	99.94	100.64

See opposite page for notes.

OTHER ANALYSES

Table 2 lists analyses of triplite from the literature. Those in which fluorine was not determined are of questionable value, and those that list a high percentage of insoluble material were undoubtedly performed on impure samples. Large percentages of Fe_2O_3, Mn_2O_3, and $H_2O(-)$ and subnormal percentages of P_2O_5 and F indicate alteration of the specimen.

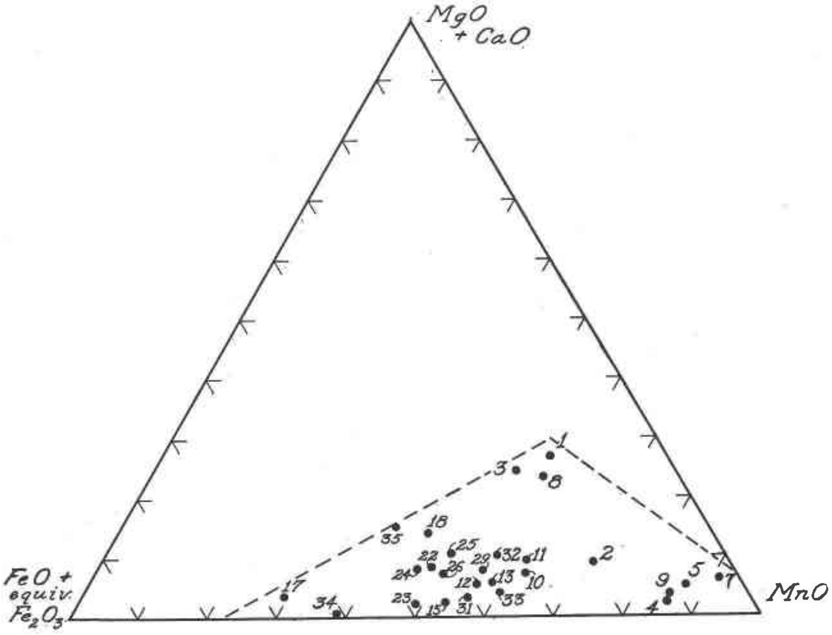


FIG. 1. Compositional field of triplite in terms of FeO+equivalent Fe_2O_3, MnO, and MgO+CaO.

Analyses of good quality, i.e., those with low Fe_2O_3, low H_2O+, high P_2O_5, and low insoluble material, are plotted on the triangular diagram of Fig. 1, whose corners are MnO, FeO+equivalent Fe_2O_3, and MgO+CaO, recalculated to 100%. The dashed lines define the compositional field of triplite. The maximum iron recorded is 41.96% FeO (Otto, 1936) in triplite from Zwiesel, Bavaria (Anal. 17). The MnO maximum is 57.63% in material from Nevada (Hess and Hunt, 1913, Anal. 7). The highest MgO, 13.62%, in a modern analysis is from the Mica Lode triplite (Anal. 1). Analyses 27 and 30 show higher MgO contents, but both are of doubtful quality. This last analysis also has an abnormal CaO content above that of Anal. 35, which is apparently a good-quality analysis of triplite from Brazil and which contains 8.10% CaO.

Triplite does not form an isomorphous series with wagnerite. Intermediate compounds are unknown, and b_0 of wagnerite is approximately twice that of triplite. Neither does triplite form an isomorphous series with triploidite, which was recognized by Frondel (1949). Most triplites with less than about 7% F also show some oxidation of the iron.

RELATION OF PHYSICAL PROPERTIES TO COMPOSITION

Indices of refraction

Indices of refraction have been measured on only 14 analyzed specimens (Table 3).

TABLE 3. INDICES OF REFRACTION OF ANALYZED TRIPLITES

Anal No.	1	2	3	5	7	8	9
α	1.643	1.671	1.648	1.665	1.650	1.651	1.662
β	1.647	1.681	1.652	1.673	1.660	1.653	1.673
γ	1.668	1.686	1.672	1.682	1.672	1.665	1.684

Anal No.	12	15	17	18	29	33	34
α	1.675	1.680	1.696	1.664	1.673	1.677	1.684
β	1.683	1.686	1.704	1.674	1.681	1.685	1.693
γ	1.692	1.695	1.713	1.680	1.691	1.695	1.703

Otto (1936) treated triplite as a two-variable series between Fe″ and Mn″ and failed to consider the modifying influence of Mg and Ca on the indices of refraction. His graph (p. 95) shows a straight line relation between % FeO and the three indices.

With those analyses of Fig. 1 for which indices are available, it is possible to contour the triangular diagram for values of the refractive indices. This has been done for α (Fig. 2) and γ (Fig. 3). The few discrepancies that appear probably are attributable to some inaccuracies in index determination. For example, in Fig. 2, α of Anal. 9 appears to be too low and in Fig. 3, γ of Anal. 8 is apparently low.

The contour patterns clearly reveal: (1) that the indices increase with increasing FeO; (2) that the indices decrease with increasing MgO+CaO; (3) that the rate of increase per unit of FeO is much greater than the rate of decrease per unit of MgO+CaO; (4) that variations in the MnO

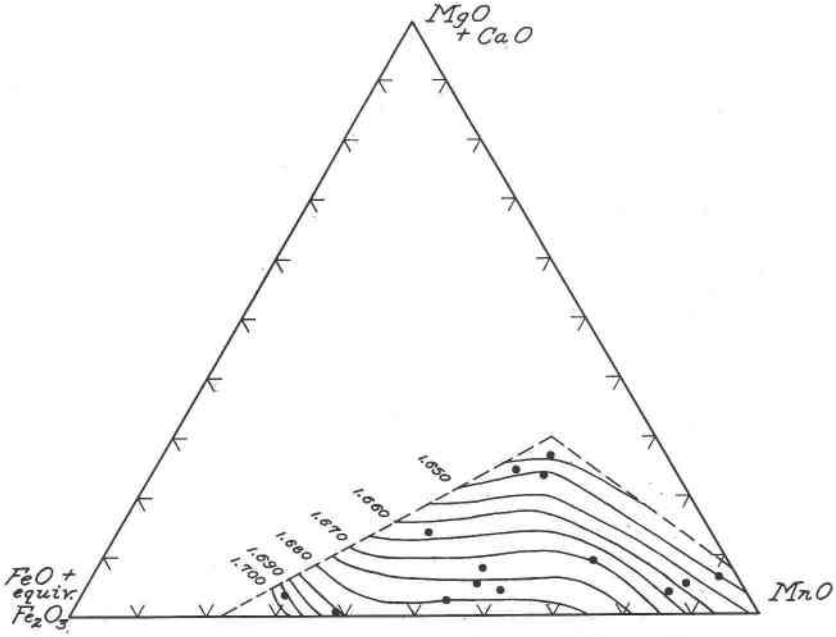


FIG. 2. Relationship between composition and α index of triplite.

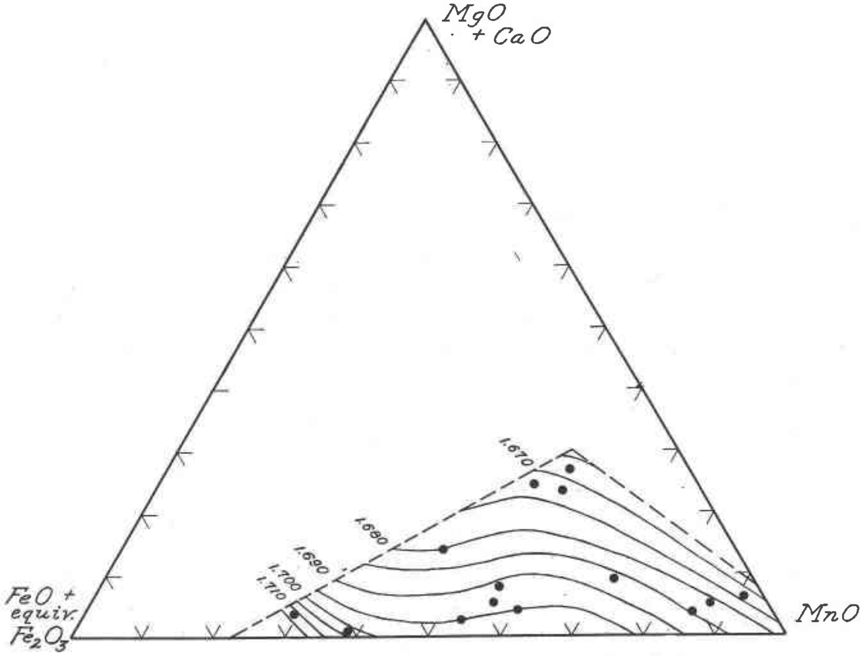


FIG. 3. Relationship between composition and γ index of triplite.

content have almost negligible effect upon changes in the values of the indices.

If triplite contains very minor amounts of $MgO+CaO$, it may be treated as a two-variable system in which the indices of refraction change directly with the iron content. This relationship is shown graphically in Fig. 4, in which γ is plotted against $\frac{FeO+\text{equiv. }Fe_2O_3}{MnO}$, for four triplites with $MgO+CaO$ less than 3.00%. However, relatively few triplites fulfill this last condition.

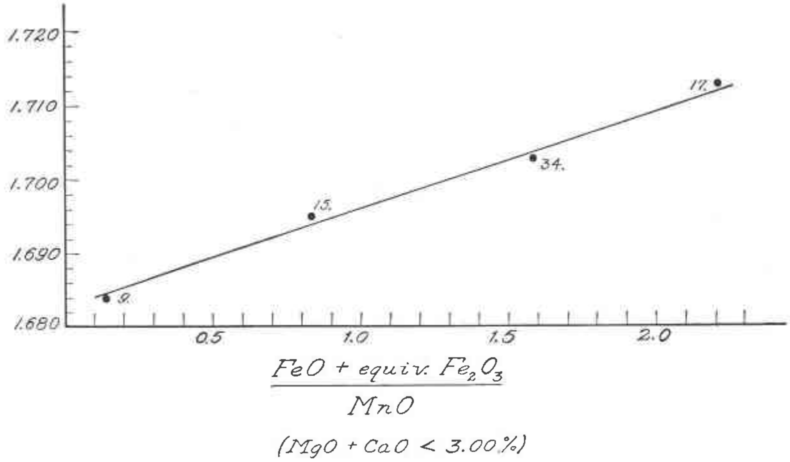


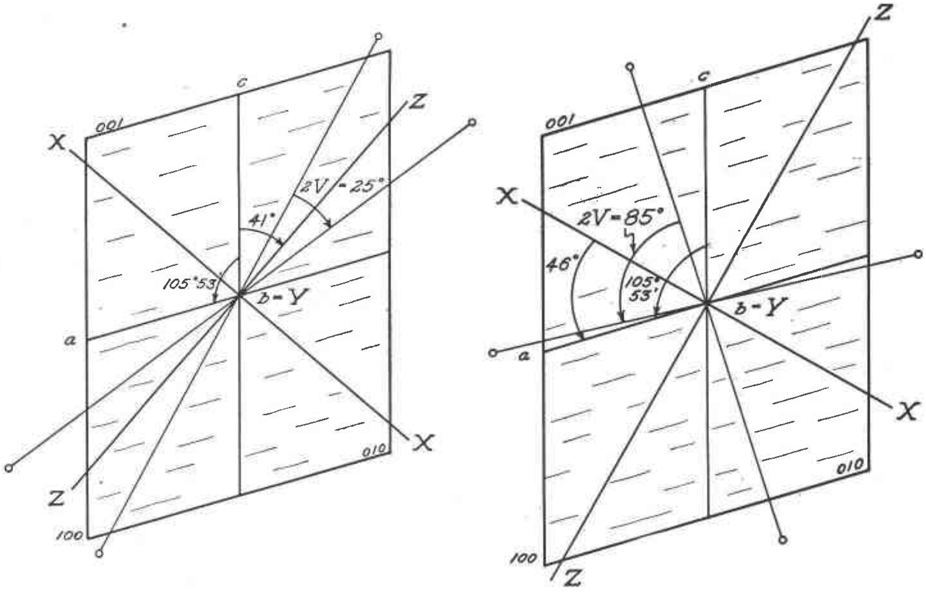
FIG. 4. Relationship between γ index and $\frac{FeO+\text{equiv. }Fe_2O_3}{MnO}$ in triplites that have $MgO+CaO<3.00\%$.

Henderson (1928) employed the name zwieselite for iron-rich triplite. However, since three variables and not two are important in triplite, this designation should not be retained and the varietal name ferroan triplite is preferable.

Other Optical Properties

The optical orientation of triplite varies with the composition, although too few data are available to systematize the relationships. It seems clear that with increasing amounts of MgO and CaO the optical angle (2V) decreases to as low as 25°, for $MgO+CaO=15.91\%$ (Anal. 1). Most triplites are optically positive with a large 2V and $b=Y$. In two cases, however, the mineral is optically negative with a large 2V (Anal. 2 and 9). Figures 5*a* and 5*b* illustrate the differences in optical orientation for two triplites of markedly different chemical composition.

Hurlbut (1936) reported a peculiar orientation for triplite from the 7U7 Ranch, Arizona, which was said to have $X=b$, $Z\wedge a=22°$, $2V=28°$, and to be optically positive. This orientation was based on the assumption that (100) was the best cleavage (Hurlbut, priv. comm.). More recent work indicates that (001) is the best cleavage with (010) as next best (Pehrman, 1939, Richmond, 1940, and Wolfe and Heinrich, 1947) and $(\bar{3}01)$ as another possible cleavage (Pehrman, 1939). The front pinacoid (100) was found by Wolfe and Heinrich (1947) as a poor cleavage direction on only one crystal from the Mica Lode pegmatite. If the new cleavage orientation is applied to Hurlbut's data and it is assumed the cleavage he used as (100) is actually (010), his optical orientation becomes inconsistent with a monoclinic symmetry. Unfortunately, it was impossible to check this orientation, for a specimen of triplite from this locality kindly submitted to the writer from the Harvard Mineralogical Museum proved to be badly weathered and nearly opaque due to secondary oxides of iron and manganese. Type material from Mt. Loma, Arizona (Anal. 9), also described by Hurlbut (1936) was checked by the



(a) (b)

FIG. 5. Optical orientation of triplite. *a*. From Mica Lode (Anal. 1); *b*. From School Section (Anal. 2).

writer and found to have an optical orientation very similar to that for School Section material (Anal. 2) (Fig. 5*b*).

Triplite shows considerable variation in color from salmon pink to dark brown with the darker colors prevailing in the iron-rich varieties and the lighter colors more characteristic for types poorer in iron. Variable amounts of magnesium and calcium have apparently no marked effect on the color. The absorption formula is variable; recorded examples are: Lemnäs, Kimito, Finland, $X<Y<Z$ (Anal. 33); La Rioja, Argentina, $X>Y>Z$ (Anal. 12); Reagan Mining District, Nevada, $X>Y\geqq Z$ (Anal. 7); Haddam Neck, Conn., $X>Z>Y$ (Anal. 5); and Mica Lode, Colo., $X=Z>Y$ (Anal. 1).

Pehrman (1939) found an irregular color distribution in triplite from Lemnäs, Kimito, Finland, and ascribed the origin of the colorless patches to local replacement of iron and manganese by calcium. Similar color irregularities occur in triplite from the Mica Lode pegmatite. Not only do randomly distributed patches show a lower color density, but they also are characterized by a markedly lower dispersion and somewhat lower birefringence.

Henderson (1933) states, "There is a rather prominent zoned structure present and these zones are composed of triplite which has a duller luster and a more pronounced brown color without the reddish tint. When the mineral is powdered and examined under the microscope these different bands are indistinguishable from each other." This zoning may well be that due to incipient alteration so commonly found in triplite. The relative positions of the zones are not given by Henderson. Zoned triplite also has been reported by Glass (1935) from the Morefield mine, Virginia, where cores are salmon colored and outer parts are brown-black. This too may be the result of alteration.

The dispersion is $r>v$ and ranges from weak to strong.

Specific Gravity

There are available 22 specific gravity determinations on analyzed triplite including five by the writer (Anal. 1, 2, 3, 8, and 9). These analyses were plotted on the triangular diagram used as a base for Figs. 1–3. It was not possible, however, to contour the diagram in terms of specific gravity values. This appears to be due, in part, to wide variations in the quality of the determinations and in part to the influence of variations in the fluorine content. The value of G in unaltered triplites ranges from 3.55 to 3.97. In general the specific gravity increases with increasing FeO and decreases with increasing $MgO+CaO$.

That the variation in fluorine has a marked effect on G is shown in Fig. 6. For three triplites, whose $FeO+$equivalent Fe_2O_3, MnO, and

MgO+CaO contents are similar, *G* is plotted against weight percent fluorine. The graph reveals a significant decline in *G* with increasing fluorine, other elements being nearly constant.

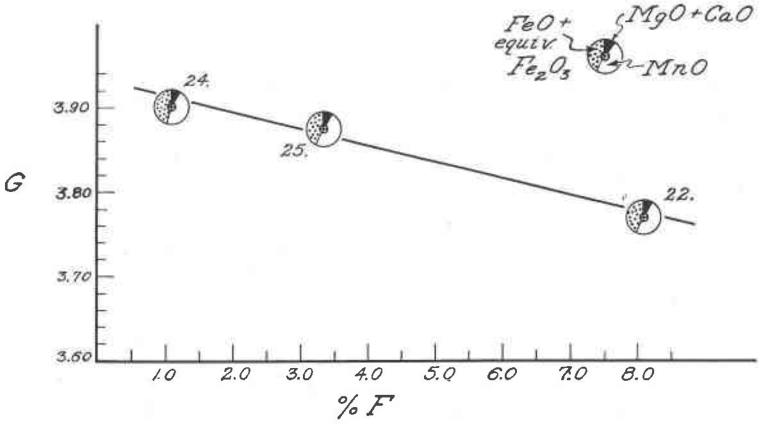


FIG. 6. Relationship between specific gravity and fluorine content in triplites whose contents of FeO, MnO, and MgO+CaO are similar.

Alteration

The following minerals have been classed as alteration products of triplite: pseudotriplite (Blum, 1845), "a substance near heterosite" (Dana, 1892), alluaudite (Dana, 1892 and Hintze, 1933), dufrenite (Kovar and Slavik, 1900), phosphosiderite (Sellner, 1924), heterosite and purpurite (Müllbauer, 1925), metatriplite (de Jesus, 1933), lemnäsite (Pehrman, 1939), apatite (Pehrman, 1939 and Heinrich, 1948), and vivianite (Sellner, 1924 and Mason, 1941B). The alteration products of iron-manganese phosphate minerals have been thoroughly investigated by Mason (1941A) who demonstrates the following:

1. That pseudotriplite was originally described as an alteration of triphyllite by Fuchs (1835) and furthermore is synonymous with heterosite.
2. That alluaudite contains sodium and was considered by Lacroix (1910) to be an alteration of natrophilite.
3. That the heterosite of Müllbauer (1925) is actually ferri-sicklerite and his purpurite is heterosite, and that they both clearly are alterations of triphyllite and not of triplite. Mason (1941A, p. 149) states, "Derivation of heterosite and purpurite from triplite must be considered doubtful, to say the least."

Kovar and Slavik (1900) state that the alteration of triplite begins with replacement of fluorine by hydroxyl to form triploidite and continues with the subsequent oxidation of iron and manganese. They cite as evidence for the first change two analyses of "triplite," one from

Vienna, Moravia, with only a trace of fluorine and the other from Cyrillhof, Moravia, with 0.88% fluorine. These are, of course, triploidite, and not triplite, as was also recognized by Frondel (1949). The authors give no evidence, other than the low fluorine contents, that either was derived from triplite through replacement of fluorine by hydroxyl. In fact they state specifically that the analysis of the Cyrillhof mineral (renamed wolfeite by Frondel, 1949) was conducted on "Möglichst frische Triplitstücke" (p. 401). Thus it appears probable that they were dealing with iron-rich triploidite of primary rather than of secondary origin and that the Vienna pegmatite contained both triplite and triploidite. The coexistence of triplite and triploidite in the same pegmatite is reported from Branchville, Connecticut; Hagendorf, Bavaria; Skrumpetorp, Sweden (wolfeite); and Vavřinec Hill, Bohemia. There is no proof that triploidite forms by alteration of triplite, although Scholz (1925) also states that triplite plus water will yield triploidite.

Mason (1941A) has shown that all of the iron in iron-manganese phosphates will be oxidized to the ferric state before any of the manganese is changed to the manganic state. The oxidation of the iron and replacement of fluorine in triplite probably proceed simultaneously. This is shown by analysis 14 (metatriplite from Portugal), in which all of the iron and some of the manganese have been oxidized, but much of the fluorine remains. The material, metatriplite (de Jesus, 1933), represents an early stage in the alteration of triplite. The structural identity of the type metatriplite with ordinary triplite has been established by Mason (pers. comm.) by means of *x*-ray powder photographs. Metatriplite very likely is the same material that commonly forms a thin darker, non-vitreous alteration shell around many triplite masses. This material has a lower specific gravity and lower indices than triplite and is nearly opaque due to very abundant minute dark brown inclusions (specks of Fe_2O_3 and Mn_2O_3?). It, too, has been shown to be structurally identical with triplite (Wolfe and Heinrich, 1947).

The only valid species formed as weathering products of triplite are, therefore, dufrenite, phosphosiderite, and vivianite. Lemnäsite, which Mason (1941A) has shown to be identical with alluaudite, is said by Pehrman (1939) to have been formed from triplite by reaction with Na-bearing solutions that also formed cleavelandite and is thus of hydrothermal origin. Similarly the dark manganiferous apatite described by the same author as forming shells on triplite in the Lemnäs pegmatite must be a reaction product with Ca solutions. Dark brown apatite found by the writer (Heinrich, 1948) as an alteration of triplite is believed to have been formed through supergene alteration by $CaCO_3$ waters.

OCCURRENCE AND DISTRIBUTION

Triplite has been found at the following localities:

U.S.A. Maine: Auburn; Harndon Hill, Stoneham; Buckfield (a U. S. Nat. Mus. spec. from this locality is apatite). *Connecticut:* Haddam Neck; Middletown; Branchville; Paul Anderson farm, 5 miles south of Cobalt. *New Hampshire:* Palermo Mine, North Groton. *Virginia:* Rutherford and Morefield mines, Amelia. *South Dakota:* Etta Mine, Keystone; High Climb Mine, Custer; Margaret Tin Mine, Pennington Co.; an unidentified locality cited as "Rapid City." *Colorado:* Mica Lode and School Section pegmatites, Eight Mile Park, Fremont Co.; Deadmans Canyon, Turkey Creek, El Paso Co.; Big Boulder pegmatite and two other pegmatites ½ mile to the northeast, Crystal Mountain Area, Larimer Co. *Arizona:* 7U7 Ranch and Mt. Loma, near Hillside; near Wickenburg. *Nevada:* Southeast side Kern Mtns., near Reagan, White Pine Co. *California:* Stewart Mine, Pala; Camp Signal, 9 miles north of Goffs, San Bernadino Co.

Argentina: Salado, La Rioja; San Luis and San Rogue, Sierrá de Córdoba; San Judas Tadeo pegmatite, Punilla Valley, Córdoba. *Bolivia:* Near Fabulosa Mine, headwaters of Rio Lallana, Cordillera Real. *Brazil:* Serro Branco, Picuhy, Parahybla.

Portugal: Mangualde. *France:* Alluad, La Vilate, and Chatres, all near Chanteloube; Chabanne and Hureaux, in Saint Sylvestre; Compreignac; Bessines; Charmasse, in Mesvre, Saône-et-Loire.

Germany: Marchaney, Wildenau-Plössberg, Pleystein, Hühnerkobel, Hagendorf, Döfering near Waldmünchen, Frath, Blötz, Brandten, Harlachberg, Hörnelberg, Birkhöhe and Kammermayer-Keller by Zwiesel, all in Bavaria; Geyer, Saxony; Schönfeld (state unknown).

Bohemia: Vavřinec Hill, near Domažlice; Poběžovice; Schlaggenwald; Havírky near Pisek. *Moravia:* Víden; Vienna, Gross-Meseritsch; Cyrillhof, Gross-Meseritsch; Punau, Marienbad; Königswart, Marienbad (2 localities). *Silesia:* Peilau, Reichenberg.

Norway: Brevig; Landaas, Iveland. *Sweden:* Horrsjöberg, Wermland; West of Lake Skrumpetorp, Östergötland; Lilla Elysjö, Krockek, Linköping; Varuträsk. *Finland:* Sukula, Tammela; Viitaniemi, Eräjärvi parish, near Oriväsi; Lemnäs, Kimito; Mattkärr, Kimito; Helsingfors.

Southwest Africa: Karibib District; Erongo Area; Sandamab; Otjimboyo; North of Arandis. *Southern Rhodesia:* Tchetchenini Hill, Lomagundi. *Cape Province:* Wolf Kop, northeast of Kenhardt.

Siberia: Djidinskoe, Western Baikal. *India:* Banekhap, Singar, and Abraki Pahar, Pichhli, all in the Gaya District, Bihar Province, Bengal. *Korea:* Denso-men District, Heian-hokudo.

PARAGENESIS

Triplite occurs chiefly in pegmatites but also to a limited extent in hydrothermal veins of the high temperature variety. The occurrences may be grouped into the following types:

I. Pegmatites.
   A. Granitic pegmatites with a relatively simple and subordinate hydrothermal assemblage.
   B. Granitic pegmatites with a well developed phosphate assemblage.
   C. Granitic pegmatites characterized by a lithium phase.
   D. Granitic pegmatites with a tin-lithium phase.

II. High temperature veins.
  A. Tin veins.
  B. Tungsten veins.
  C. Phosphatic veins with Al and Ti minerals.

Granitic pegmatites in which the hydrothermal mineral assemblage is relatively simple may contain triplite. Examples are Córdoba, Argentina, Skrumpetorp, Sweden, and Eight Mile Park, Colorado. Mineral associates of the triplite are albite, beryl, muscovite, sulfides, tourmaline, and columbite.

Occurrences of triplite in the more complex phosphatic type of pegmatite are represented by the Bavarian and French localities, Mangualde in Portugal, Domažlice and Poběžovice in Bohemia, the Gaya district of Bengal, and Stoneham, Maine. Triphylite, apatite, and many other phosphates may accompany triplite. Columbite, beryl, sulfides, muscovite, and tourmaline are other typical associates. Minor cassiterite may be present, but both Sn and Li are subordinate.

Triplite-bearing lithium pegmatites with lepidolite and either or both spodumene and amblygonite occur in the Black Hills, near Wickenberg in Arizona, at Haddam Neck, Connecticut, and at Tammela, Finland. Various other phosphates usually are present as are beryl, tourmaline, muscovite, and tantalum minerals.

In the Karibib and Erongo areas of Southwest Africa occur triplite-bearing pegmatites characterized by cassiterite, lepidolite, tourmaline, wolframite, tantalite, and muscovite. The pegmatite assemblage at Lemnäs, Finland is similar, and the Geyer, Saxony occurrence also belongs here.

Only six vein occurrences of triplite have been recorded. The Korean deposit at Heian-hokudo (Ishibashi, 1944) is a tin-tungsten deposit with cassiterite, teallite and stannite, wolframite and scheelite, and the bismuth minerals, bismuthinite, native bismuth, and cosalite. Molybdenite and several other common sulfides also are present. Other tin veins that contain triplite occur in Bolivia (Ahlfeld, 1926) and at Schlaggenwald, Bohemia. At the former cassiterite, stannite, molybdenite and other sulfides appear; at the latter cassiterite and molybdenite also are found. Triplite occurs in tungsten veins near Aurum, Nevada and at Camp Signal, near Goffs, California. Huebnerite is the tungsten mineral common to both deposits. The Nevada occurrence also has scheelite and the bismuthinite-native bismuth-cosalite assemblage.

The Horrsjöberg, Sweden, occurrence of triplite ("talc-triplite") is unique. Quartz veins contain svanbergite, lazulite, apatite, triplite, pyrophylite, damourite, rutile, ilmenite, garnet, tourmaline, and pyrite (Igelstrom, 1883).

In pegmatites triplite is usually the product of hydrothermal solutions and forms by replacement, for commonly it is associated with sodic plagioclase in secondary structural units. Apparently, it is developed during the early stages of the hydrothermal phase. However, Pehrman (1945) has placed it in the magmatic stage. The mineral has not been observed in vugs, but large, rough, partly faced crystals are recorded from three localities:

(1) Hagendorf, Bavaria (Laubmann and Steinmetz, 1920).
(2) Lemnäs, Kimito, Finland (Pehrman, 1939).
(3) Mica Lode, Eight Mile Park, Fremont Co., Colorado (Wolfe and Heinrich, 1947).

Within a single pegmatite district triplite may show a very marked variation in composition, as for example, in Colorado (Anal. 1–3); Arizona (Anal. 8 and 9); and Kimito, Finland (Anal. 33 and 34). In some other districts the composition is relatively uniform: Bavaria (Anal. 19–21 and Anal. 16 and 17); Königswart, Marienbad, Moravia (Anal. 25 and 26), and Argentina (Anal. 10–12).

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