MINERALOGICAL MAGAZINE

JOURNAL OF THE MINERALOGICAL SOCIETY

Vol. 36 September 1967 No. 279

A new polytype of taaffeite—a rare beryllium mineral from the granulites of central Australia

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[Read 25 September 1967]

Summary. Chemical and single crystal X-ray studies have shown the existence of a 9-layer polytype of taaffeite. The parameters of the hexagonal unit-cell are *a* 5·675 Å, *c* 41·096 Å (a_{rh} 14·085 Å, α 23·24°). The oxide composition of the mineral is Al_2O_3 71·44, MgO 15·76, FeO 6·78, BeO 5·50 %. It is pale olive green, with refractive indices $\omega = 1{\cdot}739$, $\epsilon = 1{\cdot}735$, and a specific gravity of 3·68.

IN 1951, Anderson, Payne, and Claringbull described a new Be–Mg–Al oxide which they named taaffeite. The mineral was in the form of two faceted gemstones from unknown localities. Subsequently a third faceted stone, having the same properties as taaffeite, was identified in America (Webster, 1962). A synthetic Be–Mg–Al oxide, prepared by Geller *et al.* (1946), with similar, but not identical, *d*-spacings is probably also related to taaffeite.

The first paragenesis of taaffeite was described from China in 1956, where crystals of the mineral occur associated with fluorite, calcite, and phlogopite, and are epitaxially intergrown with nigerite on (0001). The original article, seen in reference in Peng and Wang (1963), is in Chinese and is unavailable to the authors. A somewhat cursory structural analysis of this mineral has been published by Peng and Wang (1963).

As the result of petrographic examination of high grade metamorphic material collected in the Musgrave Ranges during 1966 (D. R. H. and A. F. W.), an unusual green mineral bearing a superficial resemblance to chloritoid was observed. Subsequent investigation of the physical, X-ray, and chemical properties of the mineral (D. R. H.) indicated that it was related to taaffeite. With the limited data available at this time the name 'musgravite' was proposed for the mineral, and later approved by the Commission of New Minerals and New Mineral Names, IMA. More recent X-ray studies (I. M. T.), however, have shown the mineral to be a 9-layer rhombohedral polytype of taaffeite.

Field occurrence and petrology

The mineral was found 10 miles NNE. of Ernabella Mission in the Musgrave Ranges of central Australia. It occurs within a group of high grade metamorphic rocks (Wilson, 1959), comprising phlogopite-bearing meta-pyroxenites and meta-peridotites, and associated two-pyroxene–plagioclase granulites and two-pyroxene–hornblende–plagioclase granulites. These rocks are within 30 yds of the eastern margin of a large intrusive batholith of ferrohypersthene adamellite, considered to have charnockitic affinities (Wilson, 1960).

The new polytype is the major constituent of a nodule (10×9×5 cm), which occurs in a narrow phlogopite replacement zone in the meta-pyroxenite. The nodule is sheathed by dark green spinel of average thickness about 0·3 cm. Sapphirine is the only other mineral in the nodule, and is plentiful in the spinel rim and also sporadically distributed throughout the surrounding phlogopite.

The texture of the taaffeite nodule is decussate, and differs markedly from the granuloblastic textures of the surrounding rocks. The phlogopite surrounding the nodule is characterized by a schistose to decussate texture.

Mineralogy, chemistry, and X-ray data

Megascopically the mineral is pale olive green, and almost colourless and non-pleochroic in thin-section. The crystals average 0·03 mm in thickness and 0·50 mm in diameter, being platy parallel to (0001). There is a perfect basal cleavage or parting and a less perfect cleavage parallel to the rhombohedron (fig. 1).

The mineral is uniaxial and optically negative, with $\omega = 1{\cdot}739 \pm 0{\cdot}002$, and $\epsilon = 1{\cdot}735 \pm 0{\cdot}002$. The specific gravity is $3{\cdot}68 \pm 0{\cdot}02$ (calc. 3·69).

Chemistry. The chemical analyses, together with the subcell contents of the 9-layer rhombohedral polytype of taaffeite (described herein) and the 4-layer hexagonal polytype[1] (described by Anderson *et al.*, 1951), appear in table I. The mineral resists attack by hydrofluoric and sulphuric acid mixtures, and is infusible in sodium hydroxide and sodium carbonate. Major oxides, with the exception of beryllium, were determined by 'classical' gravimetric and volumetric techniques on a 0·5 g sample fused with potassium bisulphate. The results have been confirmed on a similarly fused sample, using 'rapid' colorimetric and volumetric methods. The beryllium was determined colorimetrically, by the method of Pollock (1956). Because of the refractory nature of the mineral, ferrous iron was determined on a sample fused with sodium metafluoborate under a nitrogen atmosphere in a vitreosil tube. The high ferrous iron content is confirmed by increases in weight during ignition, and an accompanying change in the colour of the mineral from green to brown.

TABLE I. Chemical analyses and subcell contents of the 9R and 4H polytypes of taaffeite. Subcell contents calculated to 8 oxygen atoms

	9R taaffeite	4H taaffeite		9R taaffeite		4H taaffeite	
SiO_2	0·30	—	Si^{4+}	0·014	4·00	—	
TiO_2	0·02	—	Ti^{4+}	0·001		—	
Al_2O_3	71·44	70·0	Al^{3+}	3·967		3·74	3·93
Fe_2O_3	0·40	5·9	Fe^{3+}	0·014		0·19	
FeO	6·78	—	Fe^{2+}	0·267	2·00	—	
MnO	0·02	—	Mn^{2+}	0·001		—	
BeO	5·50	11·0	Be^{2+}	0·623		1·20	2·11
MgO	15·76	13·4	Mg^{2+}	1·106		0·91	
P_2O_5	0·02	—	P^{5+}	0·001		—	
	100·24*	100·3					

9R taaffeite: Musgrave Ranges, central Australia, No. 14820, Univ. Queensland. Analyst: L. J. Sutherland.

4H taaffeite (Anderson, Payne, and Claringbull, 1951, p. 772).

* Includes CaO nil; H_2O+ nil; H_2O- nil; Cr_2O_3 trace.

X-ray data. A Laue photograph, fig. 2, taken along the direction of the optic axis, clearly shows that the mineral belongs to the Laue group $\bar{3}m$. Reflections present on the zero and upper level Weissenberg photographs, taken about the *a*-axis, have indices such that $-h+k+l$ is divisible by three, indicative of a rhombohedral lattice. Systematic

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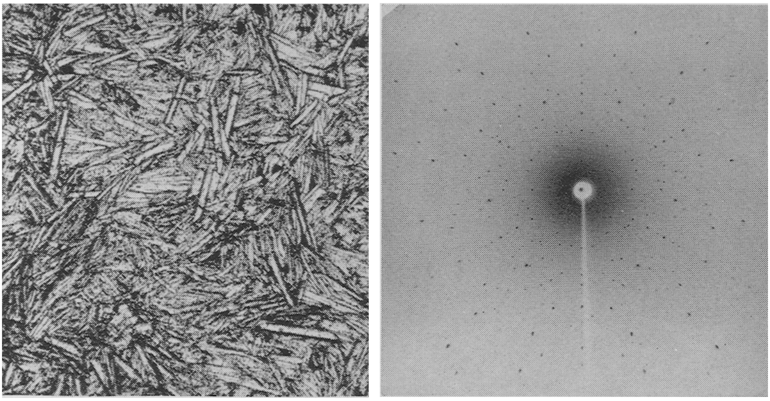
[1] Nomenclature of McKie (1963).

absences in reflections of the type $000l$, $hh\bar{2h}l$, and $h\bar{h}0l$ indicate the space group to be $R32$, $R3m$, or $R\bar{3}m$.

Accurate parameters obtained for the hexagonal unit-cell, using the method of Weisz, Cochran, and Cole (1948), are: a 5·675±0·002 Å, c 41·096±0·005 Å (a_{rh} 14·085±0·002 Å, α 23·24°±0·01°).



FIGS. 1 and 2: FIG. 1 (left). Portion of the 9R taaffeite nodule, showing the arrangement of lath-like taaffeite crystals. Rare, equidimensional grains of sapphirine are studded throughout the felted mass, and appear darker grey. (Plane polarized light, ×30). FIG. 2 (right). Laue photograph of the 9R polytype of taaffeite, taken along the optic axis.

The indexed X-ray powder data given in table II show that the agreement between the calculated and observed interplanar spacings is in general excellent, and confirm the reliability of the unit-cell parameters.

A feature of the c-axis rotation photographs is the presence of strong reflections that define a unit-subcell with a repeat distance along the axis of c' 4·566 Å. The hexagonal unit-cell therefore contains nine subcells having a 5·675 Å, c' 4·566 Å stacked one upon the other in the direction of the c-axis. The strong unit-subcell reflections are even more obvious on a^*c^* precession photographs taken using filtered Mo radiation. Except for a slight shift to higher θ values, the reflections are indistinguishable in intensity from the unit-subcell reflections from 4H and 5H högbomite polytypes recently discovered by one of us (I. M. T.).

The six crystals examined to date by single crystal X-ray methods give sharp reflections and are all of the 9R polytype. Weak reflections due to intergrown polytypes, such as those that occur in some högbomites, are absent.

McKie (1963) pointed out that the taaffeite-, nigerite-, högbomite-type structure is capable of tolerating large changes in the ionic radii of the principal cations without radical changes occurring in the unit-subcell dimensions. Considering the similarity of the compositions of the two taaffeite polytypes the notably smaller unit-subcell dimensions of the 9R polytype appear anomalous. The structural significance of these differences will be discussed in a subsequent article.

TABLE II. X-ray powder data for the 9-layer rhombohedral polytype of taaffeite. Fe radiation, Mn filter, λ(Fe-K_α) 1·9373. Camera 114·6 mm diam. Intensities estimated visually and indexing on hexagonal unit-cell: *a* 5·675 Å, *c* 41·096 Å

I	d_{obs}	*hkil*	d_{calc}	*I*	d_{obs}	*hkil*	d_{calc}
25	13·7	0003	13·698	10	1·5044	$0.1.\bar{1}.26$	1·5047
5	4·89	$10\bar{1}1$	4·880	40	1·4868	$0.2.\bar{2}.22$	1·4871
40	4·57	0009	4·566	1	1·4742	$1.2.\bar{3}.17$	1·4729
30	4·21	$01\bar{1}5$	4·218	20	1·4447	$2.0.\bar{2}.23$	1·4451
3	3·77	$10\bar{1}7$	3·769	80	1·4189	$22\bar{4}0$	1·4188
10	3·55	$01\bar{1}8$	3·551	18*b*	1·3682	$0.2.\bar{2}.25$	1·3663
20	3·15	$1.0.\bar{1}.10$	3·153	1*b*	1·3559	$22\bar{4}9$	1·3549
15	2·975	$0.1.\bar{1}.11$	2·974	1*b*	1·3442	$1.1.\bar{2}.27$	1·3413
30	2·836	$11\bar{2}0$	2·838	13*b*	1·3289	$2.0.\bar{2}.26$	1·3294
3	2·776	$11\bar{2}3$	2·779	5*b*	1·2788	$1.0.\bar{1}.31$	1·2799
55	2·658	$1.0.\bar{1}.13$	2·659	15*b*	1·2539	$1.3.\bar{4}.13$	1·2517
25	2·520	$0.1.\bar{1}.14$	2·520	3	1·2360	$3.1.\bar{4}.14$	1·2363
15	2·438	$20\bar{2}2$	2·440	3	1·2322	$1.1.\bar{2}.30$	1·2336
100	2·408	$11\bar{2}9$	2·410	3	1·2292	$40\bar{4}1$	1·2281
5	2·390	$02\bar{2}4$	2·390	3	1·2202	$40\bar{4}4$	1·2200
20	2·353	$20\bar{2}5$	2·354	3	1·2154	$04\bar{4}5$	1·2152
35*b*	2·271	$1.0.\bar{1}.16$	2·276	10*b*	1·2039	$1.2.\bar{3}.26$	1·2038
15	2·108	$0.2.\bar{2}.10$	2·109	15	1·1670	$0.4.\bar{4}.11$	1·1672
70	2·052	$2.0.\bar{2}.11$	2·053	13	1·1414	0.0.0.36	1·1416
5	1·9390	$0.2.\bar{2}.13$	1·9401	8	1·1330	$0.4.\bar{4}.14$	1·1334
20	1·8843	$2.0.\bar{2}.14$	1·8843			} Band of 8 weak, diffuse lines	
1	1·8548	$12\bar{3}2$	1·8500				
10	1·7758	$0.2.\bar{2}.16$	1·7756	5	1·0790	$2.1.\bar{3}.31$	1·0791
8	1·7470	$12\bar{3}8$	1·7469	3	1·0721	$14\bar{5}0$	1·0725
13	1·7228	$0.2.\bar{2}.17$	1·7233	3	1·0625	$3.2.\bar{5}.13$	1·0620
5	1·6380	$03\bar{3}0$	1·6382	3	1·0587	$1.1.\bar{2}.36$	1·0591
8	1·6230	$0.2.\bar{2}.19$	1·6236	20	1·0440	$14\bar{5}9$	1·0441
25	1·6011	$2.1.\bar{3}.13$	1·6015	10	1·0378	$2.2.\bar{4}.27$	1·0378
15	1·5690	$1.2.\bar{3}.14$	1·5697	25	1·0266	$4.0.\bar{4}.22$	1·0265
22	1·5417	$03\bar{3}9$	1·5420	15	1·0120	$0.2.\bar{2}.37$	1·0121
3	1·5230	0.0.0.27	1·5221	15	0·9842	$4.0.\bar{4}.25$	0·9841

Film corrected for shrinkage. *b* denotes broad line.

Discussion of origin

The decussate texture of the nodule indicates that the taaffeite has developed by recrystallization at high temperature of a suitable source during the emplacement of the ferrohypersthene adamellite. It is suggested that the sapphirine-bearing taaffeite nodule is a pseudomorph of a corundum crystal. One of us (A. F. W.) has recently found nodules of corundum of comparable size and shape in an amphibolitic terrain near Mt. Isa, Queensland. Some of these corundum crystals are entirely replaced by a decussate intergrowth of 2:1 layer-silicates, rich in Al and Mg. The crystals occur in roof pendants of phlogopite schists in a biotite granite.

A comparable phenomenon is the development of sapphirine in an essentially thermal metamorphic environment, as was suggested recently by Hudson and Wilson (1966) and is presently being further investigated by one of us (A. F. W.).

Acknowledgements. The authors are indebted to Dr. C. Kennard and Mr. J. Mills of the University of Queensland for some preliminary single crystal X-ray photographs. Mr. A. S. Bagley prepared the initial X-ray powder diffraction photograph. Thanks are also due to Mr. W. R. Ryall of the University of Sydney for his assistance in the preparation of the computer programme used to index the X-ray powder data.

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[*Manuscript received 22 November 1966; revised 31 March 1967*]