

The occurrence of hōgbomite and taaffeite in a spinel-phlogopite schist from the Mount Painter Province of South Australia

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SUMMARY. A spinel-phlogopite schist from the Mount Painter Province of South Australia forms part of a highly magnesium- and aluminium-rich unit and contains the minerals hōgbomite and taaffeite. Taaffeite nucleated in spinel during upper amphibolite facies metamorphism. During a subsequent upper amphibolite facies metamorphic event both spinel and taaffeite were partially replaced by hōgbomite. Chemical analyses of hōgbomite, taaffeite, and spinel are presented.

THE Mount Painter Province is situated approximately 560 km north of Adelaide and 360 km northwest of Broken Hill, with the oldest rocks present having a Lower Proterozoic age (Compston *et al.*, 1966). The specimen containing hōgbomite and taaffeite was collected 6 km west of Mount Painter and 1.6 km east of Mount Pitt within the poly-metamorphic basement rocks of the Mount Painter Complex (Coats and Blissett, 1971). The specimen is schistose and forms part of a highly magnesian and aluminous unit, which is interlayered with sillimanite gneiss and quartzite. The schists and gneisses of the complex were formed during two prograde upper amphibolite facies metamorphic events during the Precambrian; the second event produced migmatites.

Hōgbomite has been described from many localities recently (Woodford and Wilson, 1976; Čech *et al.*, 1976; Zakrzewski, 1977; Wilson, 1977) and is perhaps a more common mineral than originally thought. It has been found by the author at six localities in the Mount Painter Province and at one locality in the Olary Province of South Australia. Hōgbomite can contain large amounts of zinc (Wilson, 1977), cobalt (Čech *et al.*, 1976), and titanium (McKie, 1963); further, Wilson (1977) has described hōgbomite with substantial quantities of gallium and manganese.

Taaffeite is a rare Al-Mg-Be-Fe oxide and little is known of its paragenesis. It has been found in

three localities only (Hudson *et al.*, 1967; Kozhevnikov *et al.*, 1976) being initially described by Anderson *et al.*, (1951) in the form of two gemstones. A third taaffeite gemstone was described by Webster (1962). The localities from which these gemstones came are unknown.

Petrology and mineral chemistry. The specimen comes from a thin, light-coloured layer, which is found within sapphirine-bearing phlogopite schists. Both the taaffeite and hōgbomite are rare constituents of the rock, with phlogopite and spinel the dominant phases. Other minerals present are corundum, rutile, zircon, and monazite.

Phlogopite is coarse grained (up to 0.8 cm), light coloured and almost non-pleochroic in thin section. It has a 100 Mg/(Mg + Fe) value of 97 and contains approximately 50% of the eastonite end-member. Although the rock contains abundant rutile the phlogopite has a low (0.07 atoms per formula unit) titanium content.

Spinel occurs either as large, highly poikiloblastic grains up to 1 cm in diameter or as small (~ 1 mm) inclusion-free grains within phlogopite. The large spinel grains have inclusions of rutile, corundum, taaffeite, hōgbomite, and fine-grained phlogopite. Both the small and large spinel grains have a similar composition, being magnesian (Table I) and having a 100 Mg/(Mg + Fe) value of approximately 90. They contain minor quantities of zinc.

Taaffeite occurs exclusively within the large spinel porphyroblasts and has not been observed in contact with phlogopite. It is seen as low-birefringent, colourless, uniaxial negative, barrel-shaped hexagonal bipyramid crystals (fig. 1) whose apices are truncated by basal pinacoid faces; hexagonal cross sections are also present. Its habit would appear to be similar to that described by Kozhevnikov *et al.* (1976). It is platy parallel to (0001); from close microscopic examination some

TABLE I. *Chemical analyses of taaffeite, högbomite, and spinel from sample A.U. 454-166*

	Taaffeite				Högbomite		Spinel	
Al ₂ O ₃	71.95	72.43	72.35	71.71	65.34	66.42	68.54	67.93
Fe ₂ O ₃ *	0.71	0.50	0.63	0.55	5.19	3.94	1.66	1.86
FeO	3.14	2.80	2.73	2.52	3.88	4.53	5.04	4.93
MgO	19.84	20.26	20.27	20.12	18.21	19.27	24.61	24.38
ZnO	—	—	—	—	0.53	0.19	0.13	0.36
BeO*	4.36	4.30	4.32	4.31	—	—	—	—
TiO ₂	—	—	—	—	6.44	5.30	—	—
Total	100.00	100.32	100.29	99.21	99.59	99.65	99.98	99.46
	8(O)	8(O)	8(O)	8(O)	8(O)	8(O)	4(O)	4(O)
Al ³⁺	3.975	3.982	3.978	3.981	3.807	3.854	1.970	1.966
Fe ³⁺	0.025	0.018	0.022	0.019	0.193	0.146	0.030	0.034
Fe ²⁺	0.123	0.109	0.106	0.099	0.160	0.187	0.103	0.101
Mg	1.386	1.409	1.410	1.413	1.342	1.414	0.895	0.892
Zn	—	—	—	—	0.019	0.007	0.002	0.007
Be	0.491	0.482	0.484	0.488	—	—	—	—
Ti	—	—	—	—	0.239	0.196	—	—
R ³⁺	4.000	4.000	4.000	4.000	4.000	4.000	2.000	2.000
R ²⁺	2.000	2.000	2.000	2.000	1.521	1.608	1.000	1.000
ΣR	6.000	6.000	6.000	6.000	5.760	5.804	3.000	3.000
100 Mg/(Mg + Fe ²⁺)	91.9	92.8	93.0	93.5	89.4	88.3	89.7	89.8

* Calculated assuming perfect stoichiometry.

of the crystals appear to be composed of alternating plates of högbomite and taaffeite.

Microprobe investigation indicated that the mineral is a Mg-Fe-Al oxide. Consistently low totals compared with associated anhydrous phases led the author to believe that an element not analysed for, presumably beryllium, was present. A spinel porphyroblast, known to contain minor taaffeite (< 4%), was separated from the rock matrix and analysed by atomic absorption spectrophotometry by Dr K. R. Turnbull of the Geology Department of the University of Adelaide. The porphyroblast, with included taaffeite, was found to contain 307 ppm beryllium, compared to a bulk rock beryllium content of 5.3 ppm. In Table I BeO in taaffeite has been calculated assuming perfect stoichiometry. Separation of taaffeite from the specimen for X-ray diffraction investigation was not attempted. The limited amount of sample available, the inclusion of taaffeite within spinel, its occurrence in minor amounts, and its partial replacement by högbomite would have made such separation extremely difficult. In any case, unit sub-cell reflections of taaffeite have only slightly higher θ values than the reflections from 4H and 5H högbomite polytypes (Hudson *et al.*, 1967) and they are indistinguishable in intensity. Thus the ubiqui-

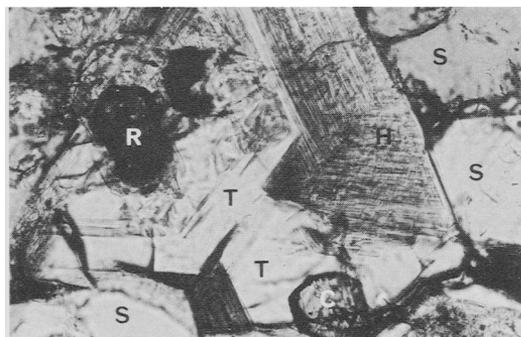
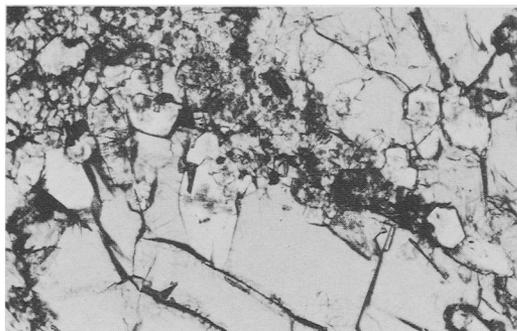
tous presence of högbomite in taaffeite at the Mount Painter occurrence would affect any X-ray work carried out. McKie (1963), in his detailed study of högbomite, suggested that the structures of högbomite and taaffeite could be identical. The composition and structural formula of the Mount Painter taaffeite are outlined in Table I.

The taaffeite is more magnesian than those described by Hudson *et al.* (1967) and Anderson *et al.* (1951) and is slightly more aluminous. It is found in contact with spinel, rutile, corundum, and högbomite and is replaced by högbomite (fig. 2).

Högbomite occurs either as uniaxial negative, honey-brown crystals in spinel or as wispy replacement products in spinel and taaffeite. Within taaffeite it appears to take the form of (0001)-plates, alternating with the taaffeite. It is more aluminous but less titaniferous when associated with taaffeite. Högbomite, accompanied by corundum, has formed at the expense of spinel. The abundance of rutile as inclusions in the spinel and the presence of högbomite rims on some rutile grains (fig. 2) suggests that rutile has supplied Ti ions to högbomite during its formation. A possible reaction for the formation of högbomite thus is: spinel + rutile + O₂ ⇌ högbomite + corundum. The spinel and högbomite in the specimen under discussion have

almost identical $Mg/(Mg+Fe)$ values, which is consistent with the above reaction. Rims of hematite around magnetite and garnet and the exsolution of magnetite from spinel in adjacent rocks suggest that high f_{O_2} is an important factor in högbomite formation, at least in the Mount Painter region. A högbomite crystal from immediately adjacent to the sample under discussion was found to be the 5H polytype (D. McKie, written comm.).

Högbomite is found in contact with all phases in the rock. Rutile grains are often separated from taaffeite by a rim of högbomite. Analyses of the högbomite are given in Table I.



FIGS. 1 and 2. FIG. 1 (top). Taaffeite crystals (light coloured) in spinel; note the shapes of crystals. ($\times 34$, plane-polarized light). FIG. 2 (bottom). Taaffeite crystals (T) being replaced by (and ?intergrown with) högbomite (H). Note the högbomite rim around the rutile grain (R). Other phases present are corundum (C) and spinel (S). ($\times 88$, plane-polarized light).

Conclusions. Micro-textural observations indicate that högbomite has formed at the expense of spinel and taaffeite under upper amphibolite facies conditions. The original assemblage was phlogopite-spinel-taaffeite, which developed during an initial high grade metamorphic event. A subsequent migmatite-forming metamorphic event under conditions of high oxygen fugacity (Teale, in prep.), led to the partial replacement of spinel by a högbomite-corundum-hematite assemblage. During this event taaffeite also appears to be partially replaced along specific structural layers by högbomite.

The beryllium content (5.3 ppm) of the bulk rock is high in comparison with other rock types (Taylor, 1966). It would appear to be an original constituent of the pre-metamorphic sediment; there is no evidence of metasomatic activity.

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