

*Powellite from Traprain Law, Haddingtonshire,
Scotland.*

By M. H. BATTEY, M.Sc., Ph.D.

Geology Department, King's College, Newcastle upon Tyne, and

A. A. MOSS, B.Sc., Ph.D., F.S.A.

Department of Mineralogy, British Museum (Natural History).

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Summary. Powellite, appearing to be of primary late-magmatic origin, has been found associated with analcime, apophyllite, and calcite in a geode in phonolite. Data are: D 4.40, ϵ 1.984, ω 1.971, a 5.20 Å, c 11.43 Å, CaO 27.8, MoO₃ 61.8 (av.), WO₃ 11.4 (av.).

TRAPRAIN LAW, as MacGregor¹ explains (p. 520), is notable as the second locality at which nepheline was found in a 'palaeo-volcanic' rock, and the second recorded locality for sodalite in a British rock. To these distinctions may be added that of harbouring the first British crystal of the uncommon mineral powellite (CaMoO₄), which has been recognized in a geode, associated with apophyllite and analcime, in the phonolite forming the hill.

The material found so far is limited to a single subhedral crystal about 1 cm across, of tetragonal aspect, with striations on the pyramid faces parallel to the edge between the pyramid and prism. The complex crystal had re-entrant angles between adjacent pyramidal planes, giving it a twinned appearance, but no twin law was determinable and the mass was probably an aggregate of subparallel growth.

The mineral is soft, H. 3 to 4, and brittle, with conchoidal fracture. In small fragments there is no regularity of shape and no indication of cleavage: there is a tendency for the pieces to be in the form of long acuminate slivers. In larger pieces, however, there is a rough parting along sets of approximately parallel planes. These surfaces of discontinuity are growth surfaces, either striated or covered with a pattern of isosceles-triangular plates with a common orientation and an apical angle of about 40°. The mineral also breaks along surfaces faced with denticles produced by the steeply pyramidal intersection of planes

¹ A. G. MacGregor and F. R. Ennos, *Geol. Mag.*, 1922, vol. 59, p. 514.

covered with triangular plates. These interior striated growth surfaces may be coated with calcite moulded on the striations.

The powellite is greenish black in the mass, with a submetallic lustre; but in crushed material there is a variation from very pale green to dark green in reflected light, and the lustre is vitreous. In transmitted light

TABLE I. X-ray powder data for powellite from Traprain Law. Camera diam. 114.6 mm. Cu-K α radiation (Cu-K α_2 lines omitted). Intensities estimated visually.

d , Å.	I/I_1 .	hkl .	d , Å.	I/I_1 .	hkl .
4.68	60	101	1.090	30	1.1.10
3.07	100	103	1.080	40	318,424
2.83	50	004	1.039	8	501
2.59	50	200	1.034	20	336
2.28	40	211	1.008	45	512
2.25	20	114	0.9645	20	408
1.98	15	213	0.9511	20	435
1.92	80	204	0.9393	50	3.1.10
1.84	60	220	0.9047	30	428
1.685	70	116	0.9019	50	516
1.625	20	215	0.8974	5	419
1.581	90	303	0.8949	5	2.0.12
1.545	40	224	0.8853	50	532
1.434	10	321	0.8792	20	437
1.382	10	305	0.8717	10	600
1.351	15	323	0.8579	—	611
1.333	20	217	0.8460	—	2.2.12
1.303	20	400	0.8376	40	3.3.10
1.249	30	208	0.8333	40	604
1.246	60	316	0.8142	—	620
1.201	30	413	0.8110	—	536
1.188	30	404	0.7969	—	543
1.167	30	420	0.7941	—	624
1.128	30	228	0.7761	—	631

it is colourless to bluish-green and colour-zoning with well-defined boundaries between the different shades is apparent in some chips. The coloured fragments are dichroic with absorption ϵ' blue $>$ ω yellow-green. Palache¹ suggests that the more deeply coloured portions may be richer in molybdenum.

It is uniaxial, positive, with ϵ_{Na} 1.984, ω_{Na} 1.971 as determined by refraction of light through a prism of the mineral. Immersion measurement gave ω_{Na} 1.969. The specific gravity, determined by repeated flotation of a crystal fragment in Clerici's solution, is 4.40. Table I gives X-ray powder data for the mineral. The cell dimensions derived from this are a 5.20, c 11.43 Å.

¹ C. Palache, Amer. Journ. Sci., 1899, ser. 4, vol. 7, p. 367.

Two 100 mg portions of the crushed mineral, purified by centrifuging in Clerici's solution, were used for the estimation of calcium, molybdenum, and tungsten. A third portion of 50 mg was used to estimate tungsten by the method of Bush and Higgs.¹ The results obtained are given in table II.

TABLE II. Analysis of powellite from Traprain Law.

	I.	II.	III.	Atomic proportions		
				I.	II.	
CaO	27.8	27.8		Ca	1.00	1.00
MoO ₃	61.9	61.7	61.9*	Mo	0.87	0.86
WO ₃	10.9	11.6	11.7†	W	0.10	0.10
Total	<u>100.6</u>	<u>101.1</u>				

* By measurement of the optical density of solution *B* (see text).

† Determined by the method of Bush and Higgs (*loc. cit.*).

The mineral was decomposed by fusion with sodium carbonate, the melt leached with water and filtered; the residue of calcium carbonate was dissolved in a little hydrochloric acid and the solution made up to a convenient volume (150 ml) in a volumetric flask (solution *A*). The filtrate containing the molybdate and tungstate was similarly diluted (solution *B*). The calcium was estimated as oxalate on a solution made from equal aliquots of solutions *A* and *B*, this procedure being adopted in order to include the small amount of calcium not precipitated as calcium carbonate. The total (Mo,W)O₃ was estimated on an aliquot of solution *B* by precipitation of the oxinates. The molybdenum was separated as sulphide by passing hydrogen sulphide into an aliquot of solution *B* containing ammonium tartrate and ammonia, and making acid with sulphuric acid. The sulphide was dissolved in dilute nitric acid and taken to fumes with sulphuric acid, the molybdenum being converted to the hexavalent state with a few drops of nitric acid, after which the molybdenum was estimated as oxinate. The tungsten content was then calculated from the difference in weight of the two oxinate precipitates. The molybdenum was also estimated by measurement of the optical density at 235 m μ of solution *B* suitably diluted ($\times 20$).

An accurate method for the estimation of molybdenum and tungsten when present together has not, as far as we know, been worked out and the methods we have used are, in our opinion, the best available at the present time.

The paragenesis of the Traprain Law powellite is unusual. Generally the mineral has been described as of secondary occurrence in scheelite-bearing or copper-bearing lodes, or in contact metamorphic deposits. Palache *et al.*² mention, however, an occurrence in vugs in altered rhyolite in Nevada, which may bear comparison with the present case. The host rock at Traprain Law is described as a phonolite, or phonolitic trachyte, carrying 'soda-orthoclase' and orthoclase (with occasional

¹ G. H. Bush and D. G. Higgs, *Analyst*, 1955, vol. 80, p. 536.

² C. Palache, H. Berman, and C. Frondel, *Dana's System of Mineralogy*, 7th edn, vol. 2, New York, 1951, p. 1081.

albite-oligoclase), fayalitic olivine, aegirine-augite, nepheline, sodalite, analcime, and magnetite. An analysis is given by MacGregor and Ennos.¹ At Traprain Law there is no indication of a secondary origin. The crystal appeared to be a primary deuteric product in part moulded upon apophyllite, with calcite of contemporaneous or somewhat later precipitation. Analcime, present as euhedral crystals in the geode, has been shown by earlier workers to be also a primary mineral of the rock fabric.

Kuroda and Sandell² have shown that, whilst molybdenum is a siderophile and chalcophile element, nevertheless in a silicate environment it is concentrated in silicic and, more especially, in alkaline magmatic derivatives, notably in certain rhyolites, trachytes, and phonolites. Thus, although the occurrence of powellite is unexpected, the concentration of molybdenum in the Traprain Law magma is in accord with our knowledge of the behaviour of this element. It is hoped later to pursue the question of its distribution in certain of the Midland Valley rocks and their minerals.

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¹ Loc. cit.

² P. K. Kuroda and E. B. Sandell, *Geochimica Acta*, 1954, vol. 6, p. 35.
