On the occurrence of the rare copper molybdate, lindgrenite, at Brandy Gill, Carrock Fell, Cumberland.

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LINDGRENITE, a basic copper molybdate $Cu_3(MoO_4)_2(OH)_2$, was first described in 1935 by Palache¹ from the oxidized zone of the great copper deposit at Chuquicamata, province of Antofagasta, Chile. A second occurrence has been recently described² from the Helena mine in the Seven Devils mining district, Adams Co., Idaho, the first recorded in the U.S.A. In this paper we are able to record a third occurrence; this time in Cumberland, adding another species to the list of British minerals.

The presence of the lead molybdate, wulfenite (PbMoO₄), in the higher part of Brandy Gill, at the western end of Carrock Fell, has been known for some time.³ The precise locality where it has been found is on a small dump, in the centre of the gill, about three-quarters of the way up, which was derived from an old trial-level driven eastward, from the east side of the gill, on a short east-west lead vein.⁴ There is another old trial-level, on the same vein, on the western side of the gill, which again has produced a number of rare and interesting minerals. It is, however, essential to differentiate between the two, although they are so close together, as the conditions that appear to have influenced the formation of some of the minerals found on the two dumps have a direct bearing on their occurrence.

The finding and identification by ourselves in 1949 (and subsequent

¹ C. Palache, Lindgrenite, a new mineral. Amer. Min., 1935, vol. 20, pp. 484-491. [M.A. 6-147.]

² R. S. Cannon and F. S. Grimaldi, Lindgrenite and cuprotungstite from the Seven Devils district, Idaho. Amer. Min., 1953, vol. 38, pp. 903-911. [M.A. 12-400.]

³ J. G. Goodchild, Geol. Mag., 1875, decade 2, vol. 2, p. 565.

⁴ As is often the case with such veins in the district, small amounts of copper are generally present, and the mineral contents of the vein may be variable over short distances.

years) of the lead tungstate, stolzite (PbWO₄), from the other trial on this same vein on the opposite, i.e. western, side of the gill, as well as on this small centre dump from the eastern level in 1951, suggested that there were undoubtedly intersections between the east-west lead vein and some of the north-south granitic suite of veins, which, farther south in and near Grainsgill, carry molybdenite, scheelite, wolframite, &c. Fragments of veinstone belonging to the granitic suite occur on the centre dump, and though it has not been possible to observe any such intersections on the eastern side, we have, nevertheless, found them in situ on the western side, the granitic veins in each case being slightly shifted by the east-west vein.¹

Although we have recently found a number of rare and unusual minerals from this particular locality in higher Brandy Gill, the discovery on the centre dump, in 1952, of traces of a dark olive-green material in some of the altered granophyre which forms the wall- and country-rock of the veins, suggested something out of the ordinary. As the result of breaking up a considerable amount of material, several small cavities were found in which were some minute, dark olive-green crystals, implanted on a pale yellowish-green crystalline mineral.

The granophyre in which they occur is considerably altered, and had every indication of having come from near one of the walls of the vein, as it was almost identical with similar altered granophyre which we found in situ forming the walls of the vein on the western side of the gill.

At first sight, these dark olive-green crystals rather suggested the copper arsenate, olivenite, but further examination showed that they were almost certainly not olivenite and were probably monoclinic; their identity, however, remained quite unknown.

Microchemical tests of the dark olive-green crystals have shown the presence of copper and molybdenum, and X-ray powder photographs (fig. 1), taken by Hartley at Leeds, have shown them to be lindgrenite, the pattern and spacings agreeing exactly with those of lindgrenite from the type locality, a photograph (fig. 1) of which was fortunately in the film library in the Department of Geology of the University of Leeds.

The yellowish-green crystalline mineral associated with the lindgrenite gives a pattern and spacings very close to those of the well-known pale blue Cumberland plumbogummite, identical yellowish-green specimens of which we have found elsewhere in the district and in Cornwall.

 $^{^1}$ The wulfenite was found only on the centre dump from the eastern level, and, so far, we have found no trace of molybdenum minerals on the west side.

In habit, the lindgrenite crystals from Brandy Gill show marked differences from the Chuquicamata and recently described Idaho specimens. They are all tabular-prismatic parallel to a (100), elongated in the



FIG. 1. X-ray powder patterns of lindgrenite, taken on 9-cm.-diameter camera, Cu-K α radiation ($\lambda = 1.542$ Å.). 1. Chuquicamata, Chile. 2. Brandy Gill, Cumberland.

direction [001], the largest being about $1\frac{1}{2}$ mm. long: one of the most typical crystals (0.6×0.4 mm.) was detached and measured on a twocircle goniometer at Oxford by P. G. Embrey, who obtained measurements (table I) in close agreement with those of Palache.¹

TABLE I. Forms and measured angles of crystals of lindgrenite from Brandy Gill, Cumberland. (Orientation of Palache.)

					Palache.			
	Mean.*				Mean.		Cale.	
Forms.	Faces	. φ.	ρ.	Quality.	φ.	ρ.	φ.	ρ.
c 001	1	90° 00'	2° 17'	Fair	90° 00′	$2^{\circ} \ 15'$	90° 00′	$2^{\circ} 12'$
b 010	2	0 00	90 00	Fair	0 00	90 00	0 00	90 00
a 100	2	90 00	90 00	Good	90 00	90 00	90 00	90 00
r 121	2	$41 \ 20\frac{1}{2}$	$53 49\frac{1}{2}$	Fair	41 18	53 47불	41 20	$53 46\frac{1}{2}$
t 131	2	$-28 \ 10\frac{1}{2}$	60 21	Poor (v. small)	-28 $13\frac{1}{2}$	60 10	-28 13	$60 \ 10\frac{1}{2}$
101?	1	Not measurable		Not found				

* Individual measurements: b(010), $\phi = -0^{\circ}$ 7', 180° 8'; r(121), $\phi 41^{\circ}$ 25', 41° 16', ρ 53° 43' 53° 58'; $t(\overline{1}31)$, $\phi = -28^{\circ}$ 6', -28° 15', ρ 60° 10', 60° 32'.

The crystals (fig. 2) all show well-developed faces of a (100) and b (010), the a (100) faces being the more prominent and giving the crystals a tabular development parallel to them, whereas the Chilean and Idaho crystals show the tabular habit parallel to the b (010) faces: in the Brandy Gill crystals, too, the a (100) faces are usually vertically striated.

¹ The indices and letters of Palache are retained in lieu of the new setting in Dana's System of mineralogy, 7th ed. 1951, vol. 2, p. 1094, which is based on the X-ray unit cell of W. H. Barnes, Amer. Min., 1949, vol. 34, p. 163, correction, p. 611. [M.A. 10-537, 11-101.]

Two faces of r (121) are present on all the Brandy Gill crystals, while many of them also show two very narrow faces of t (131) on the opposite side: in every case there is a small but conspicuous face of c (001). Some of the crystals are doubly-terminated and show the same forms at





FIG. 2 Crystals of lindgrenite from Brandy Gill, Cumberland. (Actual size, approx. 1 mm. long.)

each end. On a number of crystals a narrow face is visible between the two r (121) faces. On the crystal measured by Embrey, although this small face gave a good reflection, both under a hand-lens and under the microscope, it was found impossible to obtain a signal. Tt appears to lie midway between (121) and (121), and if a genuine face (as seems likely) it is probably the orthodome (101), a new form (fig. 2, i and iii).

Through the courtesy of Miss J. M. Sweet, we have been able to examine several specimens of lindgrenite from Chuquicamata in the British Museum collection: these all show the thin platy habit, parallel to b (010), mentioned by both Palache and Dana as being the general habit of the mineral. Palache also

mentions that a few of the very smallest crystals were acicular prisms, with a square cross-section, and that the terminal face, c (001), was present only on a few crystals of tabular habit. In all these respects, therefore, the Brandy Gill crystals show considerable differences.

This occurrence of lindgrenite at Brandy Gill is perhaps one of the most interesting additions to the remarkable number of rare and unusual minerals that have recently come to light during our investigations in the Caldbeck district.