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*New lead-copper minerals from the Mendip Hills
(Somerset).*

By L. J. SPENCER, M.A., Sc.D., F.G.S.

With chemical analyses by E. D. MOUNTAIN, B.A.

Mineral Department of the British Museum (Natural History).

[Read June 19, 1923.]

ALTHOUGH mining operations have been carried on in the Mendip Hills for a period of about 2000 years—probably since pre-Roman times, very little is known respecting the minerals that occur in the district. The reason for this is that most of the mines were exhausted previous to the development of mineralogy as an exact science; and furthermore only few specimens have been preserved in collections. During the nineteenth century operations were mainly confined to re-working the vast accumulations of refuse left by the earlier miners. This work was continued at the St. Cuthbert's Lead Works (1 mile ESE. of Priddy) up to the year 1908, since when all work has ceased on the Hill. The latest mining was for iron and manganese ores at Higher Pitts farm (1 mile SSE. of Priddy); here work ceased in 1893.

Several references to Mendip minerals are contained in John Wood-

ward's 'Catalogue of English Fossils',¹ which was written at a time, two hundred years ago, when some of the mines were still working. To quote a few of his entries, he says :

'*Mendip Green-Ore* runs with the greatest difficulty in the Fire, the white fibrous Lead-Ores with the greatest freedom of any in *England*.' (Vol. 1, part 1, p. 208.)

'Lead-Ore, flakey, and striated, the Striæ parallel to each other. 'Tis white, with a slight Eye of yellow. Its whole Appearance is like that of a Spar, and nothing like Lead appears, tho' it be very rich of that Metal. From . . . near *Bristol*.' (Vol. 1, part 1, p. 214.) [This specimen is a cleavage fragment of mendipite.]

'Lead-Ore, of a greenish yellow Colour, cavernous and porous; found partly in Ribs and partly in Lumps, after the Manner of *Boos-work*; in a Vein in *Green-hill*, near *Charter-house, Mendip, Somersetshire*. There was a considerable Vein of it, and several Pits, near 20 sunk in it; but it is now deserted.' (Vol. 2 [part 1], p. 27.) [This is pyromorphite.]

'A Mass, white, semidiaphanous, glossy, and very ponderous; doubtless holding Lead. On one side is a Crust of Manganese; and on the other a yellow Accretion, appearing to be Sulphur. Found but pretty rarely, in a Vein of Manganese in *Hartry-Liberty, Mendip, Somersetshire*.' (Vol. 2, p. 21.) [Cerussite with wad and pyromorphite.]

Fortunately, Woodward's collection² is still preserved, being in the Sedgwick (formerly Woodwardian) Museum at Cambridge. Dr. J. E. Marr, the Woodwardian Professor of Geology, has kindly given me facilities for seeing this collection, and on the 95 Mendip specimens I have been able to recognize the following species (as expressed in present-day nomenclature): Mendipite, hydrocerussite, cerussite, pyromorphite, galena, zinc-blende, smithsonite, limonite, wad, pyrolusite, calcite, barytes, quartz.

A readily recognizable coloured picture of the mineral mendipite is given in Philip Rashleigh's 'Specimens of British Minerals' (London, 1797, plate 30, fig. 3); and this mineral is also suggested by the description in A. F. Cronstedt's 'Mineralogy' of 1758 'Minera plumbi

¹ John Woodward (1665-1728), An attempt towards a natural history of the fossils of England; in a catalogue of the English fossils in the collection of J. Woodward, M.D. London, tome I, 1729; tome II, 1728.

² John Woodward's collection of 'Bodies digg'd up out of the Bowels of the Earth' has been carefully preserved in its original state in the old cabinets. Being one of the oldest collections of minerals (and fossils) now extant [cf. Min. Abstr., vol. 2, p. 7], it is of great historical interest. But, in addition, it contains much valuable information respecting forgotten occurrences of British (and foreign) minerals. The localities and conditions under which each specimen was found were recorded with greater care than is often the case at the present day; and the specimens were catalogued, numbered, and arranged most methodically.

californis. Radiated, or fibrous. White, from Mendip-Hills.' But it was left to the celebrated Swedish chemist, J. J. Berzelius, to give, exactly a hundred years ago, a scientific description of the mineral sufficient to characterize it as a distinct species. Beyond this, very little work appears to have been done on Mendip minerals.

More recently, a skeleton list of Somersetshire minerals was drawn up by Horace B. Woodward¹; and a brief general account 'Minerals of the Mendips' was given by F. W. Rudler.² A preliminary note on a new generation of minerals that have grown in the ancient (Roman?) lead slags was given by myself in 1898.³

The local museums of Wells, Weston-super-Mare, Taunton, Bath, and Bristol contain practically no specimens of Mendip minerals, and in the British Museum collection there are but few. The district itself is now a desolation of ancient shallow workings and waste heaps overgrown with vegetation, but with numerous small exposures made by rabbits and moles. It is instructive now to remember the origin of the word *endips*—namely, 'Myne-deepes.'⁴

The material which has enabled me to go a step farther with the work commenced in 1898 has been mainly supplied by the collection of the late Spencer George Perceval (1838–1922), part of which has recently come to the British Museum by bequest.⁵ Material from the private collection of Mr. Thomas Willcox of Wells, formerly manager of the St. Cuthbert's Lead Works and of the Higher Pitts mine, has also been generously given for investigation; and some specimens were collected by myself in April 1923.⁶

This material is practically all from the later workings at Higher

¹ H. B. Woodward, List of Minerals found in Somersetshire. *Geol. Mag.*, 1872, vol. 9, p. 129; *Geology of east Somerset and the Bristol coal-fields* (Mem. *Geol. Survey*), 1876, pp. 176–177.

² F. W. Rudler, *Handbook . . . Minerals of the British Islands . . . Museum of Practical Geology*, London, 1905, pp. 107–112.

³ L. J. Spencer, Leadhillite in ancient lead slags from the Mendip Hills. *Rep. Brit. Assoc.*, 1899, for 1898 (Bristol), p. 875; *Geol. Mag.*, 1899, pp. 71–72.

⁴ A good account of the history of mining in the Mendips is given by R. Hunt, 'British Mining', London, 1884, pp. 31, 131, 230. J. McMurtrie, *Notes on the forest of Mendip, its mining customs and ancient laws*. *Trans. Inst. Mining Engin.*, 1902, vol. 20 (for 1900–1901), pp. 523–532. T. Morgan, *Notes on the lead-industry of the Mendip Hills*. *Ibid.*, pp. 478–493.

⁵ A few smaller specimens from the S. G. Perceval collection were acquired by purchase through Mr. J. R. Gregory at the end of 1898.

⁶ My thanks are due to Mr. A. E. Culliford, the present owner of Higher Pitts farm.

Pitts farm in Wookey parish, on the southern edge of the Hill, 2 miles NNW. and 700 feet above Wells. Here oxide ores of iron and manganese occur as pockets in the Dolomitic Conglomerate (Keuper beds), mostly at its base and in cavities in the underlying Carboniferous Limestone. Scattered through the manganese-ore, which is mostly wad with much intermixed calcite, are small knobs of lead-ore. This is usually cerussite, but sometimes hydrocerussite or mendipite. Small amounts of secondary copper minerals are also rarely to be found. The deposit was worked by the 'Somerset Manganese and Iron Ore Company' from about 1890 to 1893,¹ and it was then that most of the best specimens were collected. Nothing is now known in the district about the earlier trials for copper-ore by the 'Little Down and Ebber Rocks Mineral Mining Company' in 1856, when an assay of 'green carbonate of copper, sulphuret, and grey copper' is said to have yielded 21.3% of copper.²

Unfortunately, the minerals at this locality, although crystalline, do not occur as distinct crystals. Any crystals that had been developed, e. g. calcite and cerussite, were afterwards much corroded. Only quartz is found as bright crystals and this in quite small amount. Crystallographic details are therefore lacking in the following descriptions. Neither has it been possible to give satisfactory determinations of the optical constants, since the refractive indices are in all cases very high, and attempts to grind prisms and plates were without success. The new results that have been obtained depend on the careful analytical work of Mr. E. D. Mountain, and the work is thus in a large measure the result of his co-operation.

MENDIPITE.

(Orthorhombic, $2\text{PbO} \cdot \text{PbCl}_2$.)

As indicated above, this mineral had been collected long before it was recognized as a distinct species. There are four specimens in the Woodwardian collection at Cambridge. Two specimens came to the

¹ The official mining returns published by the Home Office for the years 1890 and 1891 give for manganese-ore from Higher Pitts mine 30 tons and 50 tons respectively.

² This is referred to by H. B. Woodward in Mem. Geol. Survey, East Somerset, 1876, p. 175, but I have been unable to trace the original source of the information. On p. 171 he quotes early assays of the argentiferous galena from this locality.

British Museum, in 1913, with the collection of Thomas Pennant (1726-1798).¹ The specimen examined by J. J. Berzelius² was found in the collection of the Academy of Sciences at Stockholm; and immediately after the publication of his description the mineral was recognized by W. Haidinger³ in the Rashleigh and Williams collections in Cornwall, and by A. Lévy⁴ in the Turner collection.

Berzelius referred to the mineral by a chemical name 'saltsyradt bly' and it was afterwards named cerasite (kerasine of F. S. Beudant in 1832, confusing it with phosgenite), chlor-spath (A. Breithaupt, 1832), berzélite (A. Lévy, 1837), mendipite (E. F. Glocker, 1839), and churchillite (A. Dufrenoy, 1856).

Apart from its occurrence in the Mendip Hills, the mineral has been found only in the Kunibert mine near Brilon in Westphalia.⁵ A recent, though doubtful, record is from the Altai Mtns. in Siberia.⁶ The transparent needles with the composition $2\text{PbO} \cdot \text{PbCl}_2$ prepared artificially by A. Ditte⁷ are presumably identical with mendipite. The published chemical analyses are:

	PbO.	Pb.	O.	Cl.	CO ₂ .	H ₂ O.	SiO ₂ .	Total.
I.	[90.20]	—	—	6.54	2.63	0.63	—	100.00
II.	90.13	—	—	[6.84]	1.03	0.54	1.46	100.00
III.	93.9	—	—	8.3	—	—	—	102.2
IV.	—	85.69	[4.44]	9.87	—	—	—	100.00

I & II. J. J. Berzelius, 1824. Churchill, Mendip Hills. The figures under I refer to a preliminary analysis mentioned in the original text; only those under II were tabulated by Berzelius.

III. R. Rhodius, 1847. Brilon, Westphalia. Sp. gr. 7.0.

IV. C. Schnabel, 1847. Kunibert mine, Brilon.

¹ See W. Campbell Smith, *Min. Mag.*, 1913, vol. 16, p. 337. As here mentioned, one of the specimens is entered in the Pennant MS. catalogue as coming from 'Galway'.

² J. J. Berzelius, *K. Vetenskaps-Acad. Handl.*, Stockholm, 1824, for 1823, p. 184; German translation in *Ann. Phys. Chem.* (Poggendorff), 1824, vol. 1, p. 272; English abstract in *Annals of Philosophy*, 1824, vol. 24 (n. ser. vol. 8), pp. 154-155.

³ *Edinburgh Journ. Sci.*, 1824, vol. 1, p. 379.

⁴ A. Lévy, *Annals of Philosophy*, 1824, vol. 24 (n. ser., vol. 8), p. 243; *Description d'une Collection de Minéraux*, 1837, vol. 2, p. 448.

⁵ R. Rhodius, *Ann. Chem. Pharm.*, 1847, vol. 62, p. 373. C. Schnabel, *Ann. Phys. Chem.* (Poggendorff), 1847, vol. 71, p. 516.

⁶ P. P. Pilipenko, *Mineralogy of the western Altai*. (Russ.) *Bull. Imp. Tomsk University, Tomsk*, 1915, no. 63 [*Min. Abstr.*, vol. 2, p. 111].

⁷ A. Ditte, *Compt. Rend. Acad. Sci. Paris*, 1882, vol. 94, p. 1180.

The earlier Mendip specimens hitherto determined as mendipite are recorded only from Churchill near the western end of the Hills; and the finer and more abundant material from Higher Pitts farm, (9 miles SE. of Churchill) does not appear to have been noticed until about 1890.¹ Two of the specimens found in the Woodwardian collection at Cambridge are entered in the catalogue as coming from 'Hartry-Liberty'.² It is quite possible, however, that the mineral has been found at several other places in the Mendips. A glance at the geological map shows a fringe of the Dolomitic Conglomerate all round the Carboniferous Limestone of the Hill, as well as several isolated patches on the top; and small deposits of manganese-ore have been worked at many places near the junction of these rocks. On the waste heap of a small pit worked about 50 years ago for manganese-ore at Priddy Hill farm (1½ miles NNE. of Priddy) my daughter, Sylvia M. Spencer, found in April 1923 a small specimen of mendipite.

At Higher Pitts the mineral occurs as nodules, with irregular corroded surfaces, embedded in manganese-ore. When broken open, these display the perfect prismatic cleavages giving the appearance of a columnar aggregate. Usually a single crystal-individual occupies the whole nodule; or at most two or three individuals are irregularly grouped together. In each nodule the mendipite cleavages extend right across and end abruptly at the surface. On the largest specimen in the S. G. Perceval collection (weighing, with the matrix, 3640 grams) the broken surface (12 × 8 cm.) of the mendipite shows only two individuals with the cleavages approximately uniform in direction over areas of 8 × 6 cm. The cleavage surfaces show a brilliant, pearly to silky lustre; while on the irregular end-fractures the lustre is resinous to adamantine in quality. The colour is usually a dirty white or grey, but sometimes yellowish or a delicate pink. Only occasionally is the material clear and transparent in the mass. The hardness is 2½.

Owing to a slight radial aggregation,³ even the smallest cleavage fragments do not give simple reflected images. A large number of measurements were made to determine the true angle between the

¹ This occurrence was briefly mentioned by H. B. Woodward, Proc. Geol. Assoc. London, 1890, vol. 11, p. cxcviii, and by F. W. Rudler in 1905 (loc. cit., p. 109).

² Now Harptree, on the north side of the Mendips. On Smitham Hill, above East Harptree, I have recently picked up bits of galena, smithsonite, wad, limonite, barytes, calcite, &c., from the rabbit burrows in the old waste heaps.

³ The two mendipite specimens from Harptree in the Woodwardian collection at Cambridge show a more pronounced divergent grouping, and in one of them the prisms radiate in all directions from a central point in the nodule.

prismatic cleavages, $mm = (110):(1\bar{1}0)$, but the results were not quite satisfactory. In measuring round the zone of cleavages, reflections were often observed at the positions $a(100)$ and $b(010)$ from the less distinct pinakoidal cleavages. Trials made at different times on different lots of material gave the mean values¹ for mm as $77^\circ 21\frac{1}{2}'$, $77^\circ 23\frac{1}{2}'$, $77^\circ 31'$, $77^\circ 20'$. The last of these is perhaps the most reliable, corresponding with the axial ratio, $a:b = 0.8002:1$.

Cleavage-fibres give straight extinction with positive elongation, and the optical characters agree completely with orthorhombic symmetry. The plane of the optic axes is parallel to $b(010)$ and the negative bisectrix (α) perpendicular to $a(100)$. A cleavage-flake lying on $m(110)$ shows an interference-figure of very large angle and negative sign at the side of the field of view towards the edge $a(100)$. The rings show anomalous colours and the brushes are bright blue. With plates cut approximately parallel to $a(100)$ and $c(001)$ the optic axes are still just outside the field of view even with $\frac{1}{12}$ -inch immersion with methylene iodide. The optic axial angle is thus near to 90° , but it could not be determined whether the acute bisectrix is the negative bisectrix ($\alpha = a$) or the positive bisectrix ($\gamma = c$) for stating the optical sign of the crystal. The refraction, birefringence, and dispersion are all high.²

Chemistry of Mendipite. (E. D. M.)

The analyses of mendipite from the Mendip Hills made by Berzelius in 1823 evidently referred to impure material (see p. 71), while no later analyses have been made. A new analysis therefore seemed desirable, and for this purpose an abundance of good material from the locality of Higher Pitts was available.

The specimen in the S. G. Perceval collection selected for analysis consists of three or more crystal-individuals surrounded by cerussite, each individual being formed of a sub-parallel grouping of fibres. Towards the margin they are slightly discoloured yellow, while very thin films of manganese-ore in some places impart a sub-metallic lustre to the cleavage-surfaces, and, moreover, part of the material is opaque at

¹ Previously determined values of the cleavage-angle of mendipite are by J. J. Berzelius (in 1824), $77\frac{1}{2}^\circ$; W. Haidinger (1824), $77^\circ 33'$; A. Lévy (1824), $77^\circ 35'$; A. Breithaupt (1832), $77^\circ 30'$; W. H. Miller (1852), $77^\circ 24'$; and L. Fletcher (*Min. Mag.*, 1889, vol. 8, p. 178), $77^\circ 19'$.

² E. S. Larsen (*Bull. U.S. Geol. Survey*, 1921, no. 679, p. 108) gives, for mendipite from Brilon, Westphalia, the optic sign as positive, $2V$ nearly 90° , and refractive indices α 2.24, β 2.27, γ 2.31.

the surface. However, plenty of colourless, transparent material was easily collected.

A specific gravity determination was first made on this material in water by the pycnometer method and gave the result $D_4^{16.2} = 7.240$. Previous determinations, for comparison, are 7.077 (W. Haidinger, 1824), 7.377 and 7.400 (A. Breithaupt, 1832), and 7.0 (R. Rhodius, 1847, on mendipite from Westphalia). The determination was performed on 1.7517 grams of fragments which, after the experiment, had become slightly turbid at the surface. Previous attempts to cut a section of the mineral had caused a similar superficial opacity, but further investigation suggested that this was due rather to a breaking up of the fibres than to any chemical decomposition. A rough check on the specific gravity determined in carbon tetrachloride gave a slightly higher figure.

Preliminary chemical tests proved the material to be of a high degree of purity; lead and chlorine only were detected, neither iron nor manganese being present. Experiments with an absorption apparatus moreover showed the complete absence of water and carbon dioxide. When heated in a bulb-tube, the mineral becomes yellow and decrepitates violently, splitting up into dark-yellow fibres. Before these melt, a cloud of lead chloride vapour begins to fill the bulb and condense to a white sublimate on the side of the tube. The fibres then melt to a yellow liquid (lead oxide) which spreads over the surface of the bulb; and the sublimate, on further heating, melts in places to yellow liquid drops (lead chloride). On cooling, the lead oxide solidifies to a pale-yellow glass.

The mineral dissolves in dilute nitric acid, the more easily when heated. For the analysis, the material, weighing 1.0377 grams, was dissolved in this way; the chlorine was precipitated by silver nitrate and the lead subsequently determined as lead sulphate. The results obtained are tabulated below and correspond with the usually accepted formula $Pb_3Cl_2O_2$ or $2PbO \cdot PbCl_2$. Percentages calculated from this formula are appended for comparison, all calculations being made with the International Atomic Weights for 1921.

Results of Analysis of Mendipite.

	%	Molecular ratios.	Calculated values.	
PbO	92.51 ...	$\div 223.20 = 0.4144$	3.14 ...	92.42
Cl ₂	9.35 ...	$\div 70.92 = 0.1318$	1.00 ..	9.79
	<hr/>			<hr/>
	101.86			102.21
Less O \equiv Cl ₂	2.11			2.21
	<hr/>			<hr/>
	99.75			100.00

or, expressed in another way :

Pb	...	85.87	...	$\div 207.20 = 0.4144$	3.14	...	85.79
O	...	4.53	...	$\div 16.00 = 0.2831$	2.15	...	4.42
Cl ₂	...	9.35	...	$\div 70.92 = 0.1318$	1.00	...	9.79
		99.75					100.00

CHLOROXPHITE.

(Monoclinic, $2\text{PbO} \cdot \text{Pb}(\text{OH})_2 \cdot \text{CuCl}_2$.)

This new mineral has been found as green, blade-like crystals stabbing the mendipite of Higher Pitts. Since 1898 it has been known to me as 'green blades'; and now that sufficient material has been collected for a quantitative analysis, this is translated for general use as chloroxiphite, from $\chi\lambda\omega\rho\acute{o}s$, green, and $\xi\acute{\iota}\phi\omicron s$, a blade or straight sword. This will, no doubt, sometimes be pronounced chloroxi-phite (instead of chloro-xiphite), reminding one that, chemically, the mineral is an oxychloride.

The blades are in all cases completely embedded in the mendipite, but only occasionally are the longitudinal directions of the two crystals coincident: usually the chloroxiphite penetrates the mendipite cleavages obliquely as if they had been thrust in. The colour is a dull olive-green or pistachio-green, not unlike that of epidote; and in their habit, degree of symmetry, cleavage, and pleochroism the crystals also present a striking similarity to epidote. The lustre is resinous to adamantine, and the streak a very characteristic pale greenish-yellow. The mineral is very brittle and friable; hardness $2\frac{1}{2}$.

The largest crystals were those on the large specimen of mendipite mentioned above; these were about 3 cm. long, 1 cm. across, and 1 mm. in thickness. Unfortunately they had to be damaged and partly sacrificed in order to collect sufficient pure material for analysis. Usually the crystals are much smaller, and they are often interlaminated with mendipite and the blue mineral to be presently described. The crystals show sub-parallel grouping, and the large flat faces *c* are roughly striated parallel to their length. At their long edges are narrow faces *a*. Parallel to *c* is a perfect cleavage and parallel to *a* a poorer cleavage. On the goniometer scattered images and bands of reflected light are plentiful, and only an approximate value could be obtained for the more important angle *ac*. The mean of the eleven better readings (limits 61° to 64°) is $62\frac{3}{4}^\circ$. [The angle β of epidote between similar cleavages is $64^\circ 37'$.]

Crystals and cleavage-flakes lying on the face *c* exhibit a very striking pleochroism: bright emerald-green for vibrations parallel to the length and yellowish-brown for vibrations across the blades. Between crossed

nicols the extinction is parallel to the length of the blades. In convergent light a negative biaxial figure with many rings is seen partly in the field of view, the optic axial plane being parallel to the length of the blades and somewhere near the position of the face a . By tilting a plate to bring the optic axes within the field of view, the optic axial angle in oil was measured under the microscope as about 80° . The refraction and birefringence are both high.

The crystals are therefore monoclinic with elongation in the direction of the axis of symmetry. The face c can be taken as (001) and a as (100), giving the angle β as $62\frac{3}{4}^\circ$. The plane of the optic axes is perpendicular to the plane of symmetry, and the acute negative bisectrix near the vertical c -axis.

Chemistry of Chloroxiphite. (E. D. M.)

In spite of the fact, mentioned above, that the best specimen of this new mineral was sacrificed for analysis, it was only due to Dr. Spencer's meticulous industry that about half a gram of the material was collected for this purpose from several specimens. Fortunately it was fairly pure, only traces of mendipite and the blue mineral, with which it occurs in association, being in evidence. Most of the larger fragments, together weighing 0.4329 gram, were picked out to determine their specific gravity. This was done in water with a pycnometer and gave the result $D_4^{15.2} = 6.763$.

Qualitative chemical tests with this mineral give the usual reactions of lead, copper, chlorine, and water. When it is heated in a bulb-tube, some moisture first comes off and condenses on the tube; this is immediately followed by decrepitation, the crystals breaking up into irregular fragments, many of which are shot into the tube and get caught in the beads of moisture. A cloud of lead chloride vapour is formed in the bulb and condenses on the sides of the tube to a white sublimate melting to yellow drops of liquid; some of this was driven to the mouth of the tube, care being taken to prevent any fragments of the mineral in the tube from being mechanically transported with it, and proved to be lead chloride. The residue then melts to a brown liquid spreading, like lead oxide, over the surface of the bulb, and on cooling it solidifies to a bright-green glass; this residue consists of a mixture of copper and lead oxides. The mineral is easily soluble only in nitric acid, and the solution gives the reactions of lead, copper, and chlorine.

On powdering the material for analysis, the striking greenish-yellow colour of its streak becomes evident. The first sample, which weighed

0.4376 gram, was first heated at different temperatures in order to determine the percentage of water contained in it. At 110° C. no change in colour or weight is to be observed; above this temperature the colour changes through yellow-brown and brown, finally to black at a temperature below 250°, these colour changes being accompanied by dehydration. All the water is expelled below 250°. It was next dissolved in fairly strong nitric acid, the solution being aided by gentle warming. The copper dissolves out first, giving the solution a bright-green colour which on dilution turns blue, while the lead is left as a white residue and dissolves more slowly. From the solution the chlorine, lead, and copper were successively separated as silver chloride, lead sulphate, and copper oxide in the usual way and weighed as such.

A check analysis was performed on the remaining material, which weighed 0.1585 gram. The results are tabulated below and correspond fairly closely with the formula $Pb_3CuCl_2O_8 \cdot H_2O$ or $2PbO \cdot Pb(OH)_2 \cdot CuCl_2$, the calculated composition according to which is added for comparison.

Results of Analyses of Chloroxiphite.

Portion I.—	%	Molecular ratios.		Calculated values.	
PbO ...	81.15	÷ 223.20	= 0.3636	3.59	81.45
CuO ...	10.90	÷ 79.57	= 0.1370	1.35	9.68
Cl ₂ ...	7.19	÷ 70.92	= 0.1014	1.00	8.63
H ₂ O ...	2.56	÷ 18.016	= 0.1421	1.40	2.19
	<hr/>				<hr/>
	101.80				101.95
Less O ≡ Cl ₂	1.62				1.95
	<hr/>				<hr/>
	100.18				100.00
Portion II.—					
PbO ...	79.82	÷ 223.20	= 0.3576	2.77	81.45
CuO ...	10.47	÷ 79.57	= 0.1316	1.02	9.68
Cl ₂ ...	8.97	÷ 70.92	= 0.1258	1.00	8.63
H ₂ O ...	2.52	÷ 18.016	= 0.1401	1.09	2.19
	<hr/>				<hr/>
	101.78				101.95
Less O ≡ Cl ₂	2.03				1.95
	<hr/>				<hr/>
	99.75				100.00

or, expressed in another way :

	I.	II.	Calculated values.
Pb ...	75.34	74.10	75.61
Cu ...	8.71	8.37	7.73
Cl ₂ ...	7.19	8.97	8.63
O ...	6.38	5.79	5.84
H ₂ O ...	2.56	2.52	2.19
	<hr/>	<hr/>	<hr/>
	100.18	99.75	100.00

DIABOLEITE.

(Tetragonal, $2\text{Pb}(\text{OH})_2 \cdot \text{CuCl}_2$.)

This is another new oxychloride of lead and copper found embedded in the mendipite of Higher Pitts, where it occurs in intimate association with the chloroxiphite and frequently embedded in this. With its bright sky-blue colour, brilliant lustre, and transparency, it closely resembles linarite or azurite in appearance. It shows, however, a tabular habit with a pearly cleavage parallel to the table, and when a fragment is examined under the microscope it shows a negative uniaxial interference-figure normal to the cleavage. It forms films and small patches of minute crystals which occasionally show square outlines. Crystal faces were observed in only three poorly developed crystals, each about 1 mm. across. One shows the pearly basal plane bounded by faces of a tetragonal pyramid with angle ce approximately $43\frac{1}{2}^\circ$. Another shows narrow faces of a tetragonal prism at 90° to c . The third is a low square pyramid (resembling licroconite in appearance) inclined at about 22° to the cleavage below. Assuming e to be (101) the angle $ce = 43\frac{1}{2}$ corresponds with the axial ratio $a:c = 1:0.95$. Assuming the two pyramids and the prism to be all of the same order, the forms observed are then c (001), a (100), e (101), o (307). The last crystal was used as a prism (of angle 22°) to give a rough measurement of the refractive index, namely 1.98. When viewed through the prism-faces the plates show a marked dichroism: ω deep-blue, ϵ pale-blue to almost colourless. The streak is pale-blue. The crystals are brittle and have a hardness of $2\frac{1}{2}$.

Other small patches of the same bright blue colour are dull in lustre and consist of a compact finely-granular aggregate, apparently of the same material but perhaps intermixed with some other mineral. Microchemical tests showed the presence of lead, copper, and chlorine, and uniaxial interference-figures were occasionally seen. Such material sometimes replaces the chloroxiphite blades, apparently as an alteration product. It also grades off into mere stains¹ invading the hydrocerussite and cerussite; but minute specks of the more definitely crystalline blue mineral are sometimes embedded in hydrocerussite and cerussite.

The characters here enumerated could be made to fit in with those of

¹ Possibly some of these blue stains are azurite. But the only azurite that I have seen from Higher Pitts is a very small piece in the collection of Mr. William H. Janes, of Wookey Hole, which was examined in the hope that it might be the new blue mineral. It shows crystalline particles embedded in a paler earthy material. Associated with it are malachite and limonite.

a mineral of the percyllite-boleite group, for example, with the pseudo-boleite as described by G. Friedel (1906). But chemically and in the specific gravity there is a marked distinction. The minerals of the percyllite-boleite group all approximate to the composition $\text{Pb}(\text{OH})_2 \cdot \text{CuCl}_2$, whilst the Mendip mineral has the formula $2\text{Pb}(\text{OH})_2 \cdot \text{CuCl}_2$. The species boleite, first described in 1891 from Boleo in Lower California, Mexico, has since been sub-divided into boleite, pseudo-boleite, and cumengeite. It has engaged the attention of the brilliant French mineralogists and crystallographers, E. Mallard, C. Friedel, A. Lacroix, G. Friedel,¹ and it presents a perplexing problem that still remains to be solved. Rather than helping to solve this problem, the Mendip mineral only adds further difficulties; and lacking sufficient material for a more complete investigation, we have, in desperation, named it diaboileite (from *δία*, apart or distinct from boleite).

Chemistry of Diaboileite (E. D. M.).

This mineral occurs associated with chloroxiphite in mendipite only as minute crystals, and, in order to ensure the homogeneity of the material collected for analysis, each fragment was examined optically by Dr. Spencer to obtain the characteristic uniaxial figure. Unfortunately, after every specimen had been ravaged, the quantity collected amounted to no more than 0.1218 gram.

Owing to the scarcity of pure material, qualitative tests had to be made on slightly impure material, but the results were justified. Essentially the reactions are the same as those for chloroxiphite, but the bulb-tube reactions are slightly distinct. The mineral first breaks up into fragments which are cleavage-flakes, with evolution of water, and this is followed by vapourization of lead chloride; there is no violent decrepitation. As before, the residue melts to a brown liquid which on cooling becomes a bright-green glass. The mineral is completely soluble in nitric acid showing the absence of silver, and its solution behaves like that of chloroxiphite.

The whole of the pure material collected for analysis was employed for the specific gravity determination and gave the result $D_4^{17.6} = 6.412$. It was then dried at 100° and powdered for analysis. The powder is pale-blue and on heating to 250° changes in colour through blue-green to a chocolate-brown, when all the water has been driven off. The solution

¹ For the latest work on boleite, see A. Hadding, 1919. [Min. Abstr., vol. 1, p. 76.]

and subsequent analysis were effected in a manner identical with that described for chloroxiphite, the following results being obtained, which agree well with the formula $\text{Pb}_2\text{CuO}_2\text{Cl}_2 \cdot 2\text{H}_2\text{O}$ or $2\text{Pb}(\text{OH})_2 \cdot \text{CuCl}_2$.

Results of Analysis of Diaboleite.

	%	Molecular ratios.	Calculated values.
PbO	72.09 ...	$\div 223.20 = 0.3230$	2.10 ... 72.36
CuO	12.90 ...	$\div 79.57 = 0.1621$	1.06 ... 12.90
Cl ₂	10.89 ...	$\div 70.92 = 0.1536$	1.00 ... 11.50
H ₂ O	6.14 ...	$\div 18.016 = 0.3407$	2.22 ... 5.84
	<hr/> 102.02		<hr/> 102.60
Less O \equiv Cl ₂	2.46		2.60
	<hr/> 99.56		<hr/> 100.00

or, written in another way :

Pb	66.98 ...	$\div 207.20 = 0.3230$	2.10 ... 67.17
Cu	10.31 ...	$\div 63.57 = 0.1621$	1.06 ... 10.31
Cl ₂	10.89 ...	$\div 70.92 = 0.1536$	1.00 ... 11.50
O	5.29 ...	$\div 16.00 = 0.3306$	2.15 ... 5.18
H ₂ O	6.14 ...	$\div 18.016 = 0.3407$	2.22 ... 5.84
	<hr/> 99.56		<hr/> 100.00

HYDROCERUSSITE.

(Rhombohedral, $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$.)

Hitherto, hydrocerussite has been a rare mineral found in very small quantities at only a few localities. This is surprising, since the mineral is identical in composition with 'white lead' (cerussa) which is produced artificially in large quantities. In the British Museum mineral collection, apart from the material to be now described, it is sparingly represented as films of minute pearly scales on seven specimens from Långban in Sweden, Wanlockhead in Dumfriesshire, and Leadhills in Lanarkshire.¹

The species was first established, and named hydrocerussite, by A. E. Nordenskiöld² in 1877, on material from Långban in Sweden. It was recognized by A. Lacroix in 1885 from Wanlockhead in Scotland,³

¹ The two specimens from Leadhills (a locality not mentioned in the literature for hydrocerussite) were purchased for the collection in 1861 as 'aurichalcite'.

² A. E. Nordenskiöld, *Nya mineralier från Långban*. Geol. Förel. Förh. Stockholm, 1877, vol. 3, p. 381.

³ A. Lacroix, *Sur un hydrocarbonate de plomb (hydrocerussite) de Wanlockhead (Écosse)*. Bull. Soc. Min. France, 1885, vol. 8, pp. 35-36.

and in 1896 in the ancient lead slags at Laurion in Greece.¹ More recently, it has been recorded from the Altai Mountains in Siberia.²

Nordenskiöld in his brief description of the mineral incorrectly stated it to be 'quadratic', and (without quantitative analysis) he suggested the formula $2\text{PbCO}_3 \cdot \text{H}_2\text{O}$. É. Bertrand³ in 1881 determined the six-sided scales to be optically uniaxial with negative sign; and G. Flink⁴ in 1901, from measurements on minute crystals from Långban, described them as holohedral-hexagonal with the axial ratio $a:c=1:1.4187$. M. F. Heddle⁵ in 1889 gave an analysis of the Wanlockhead mineral (which he unnecessarily renamed 'plumbonacrite') from which he deduced the formula $\text{PbCO}_3 \cdot 3\text{PbO} \cdot \text{H}_2\text{O}$. The true formula of the mineral, viz. $3\text{PbO} \cdot 2\text{CO}_2 \cdot \text{H}_2\text{O}$ or $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$, has hitherto been based on analyses made by L. Bourgeois⁶ in 1888 on artificially-prepared material; this was minutely crystalline as hexagonal scales and resembled the natural mineral in being optically uniaxial and negative. The refractive indices (ω 2.09, ϵ 1.94) have also been determined only on artificial material.⁷ The previously published chemical analyses are:

	I.	II.	III.	IV.	V.
PbO ...	92.85	82.45	86.7	86.5	86.2
CO ₂ ...	4.76	11.68	11.5	11.3	—
H ₂ O ...	2.01	3.05	2.8	2.5	—
Insol. ...	0.78	1.19	—	—	—
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
	100.40	99.62	101.0	100.3	—

I. M. F. Heddle, 1889. Wanlockhead, Scotland.

II. P. P. Pilipenko, 1915. Ridderovsky mine, Altai Mtns., Siberia. Also Fe_2O_3 0.68, CaO 0.62, (K,Na)₂O trace. Sp. gr. 6.02.

III-V. L. Bourgeois, 1888. Artificial crystalline material. Sp. gr. 6.14.

¹ A. Lacroix, Les minéraux néogènes des scories plombeuses athéniennes du Laurium (Grèce). Compt. Rend. Acad. Sci. Paris, 1896, vol. 123, pp. 955-958. A. Lacroix and A. de Schulten, Bull. Soc. Franç. Min., 1908, vol. 31, pp. 79-90.

² P. P. Pilipenko, 1915, loc. cit. [Min. Abstr., vol. 2, p. 111.]

³ É. Bertrand, Bull. Soc. Min. France, 1881, vol. 4, p. 87.

⁴ G. Flink, Bull. Geol. Inst. Univ. Upsala, 1901, vol. 5 (for 1900), pp. 94-95. plate 3, figs. 11 and 12. Arkiv Kemi, Min. Geol., 1910, vol. 3, no. 85, p. 162.

⁵ M. F. Heddle, Min. Mag., 1889, vol. 8, p. 202; Mineralogy of Scotland, 1901, vol. 1, p. 147.

⁶ L. Bourgeois, Sur la reproduction artificielle de l'hydrocérusite, sur la composition chimique de cette espèce minérale et sur la constitution du blanc de céruse. Bull. Soc. Franç. Min., 1888, vol. 11, pp. 221-225. Preliminary note in Compt. Rend. Acad. Sci. Paris, 1886, vol. 103, p. 1090.

⁷ E. S. Larsen, Bull. United States Geol. Survey, 1921, no. 679, p. 202.

In striking contrast with this supposed rarity of the mineral is the relative abundance of its occurrence in the Mendip Hills, although curiously it has not previously been recorded from this locality. One specimen in the S. G. Perceval collection, consisting mainly of large crystals of hydrocerussite, weighs 486 grams; and in April 1923 I was able to collect on the waste heaps at Higher Pitts some fifty good specimens in pieces up to 50 grams in weight. Nor is it restricted to recent finds. In the Woodwardian collection (1728) it is present on five specimens from 'Hartry-Liberty, Mendip' [now Harptree]: two of these consist entirely of large (4 cm.), corroded crystals of hydrocerussite, and are entered in the catalogue (vol. 2, p. 21) as 'Two Samples, from another of these Manganese-Mines. They appear like Talc; but are very ponderous, and doubtless hold Lead'. A crystallized mass weighing $274\frac{1}{2}$ grams was in the collection of T. Pennant (1726-1798)¹; and Berzelius's analyses of mendipite (see p. 71) suggest that hydrocerussite was present in his material.

At Higher Pitts the mineral occurs as a zone of alteration around the mendipite, or as isolated patches, often associated with cerussite, embedded in the manganese-ore. Groups of crystals partly or completely altered to cerussite have also been found. The crystals, which are of enormous size in comparison with the hydrocerussite previously known, are of two habits:

(1) Thick-tabular crystals, bounded by the base and prism, measuring 2 to 3 cm. across and $\frac{1}{2}$ to 1 cm. in thickness. They are usually of irregular outline, but some crystals show the suggestion of a hexagonal prism. They are irregularly grouped together with interspaces, and are sometimes penetrated by plates of crednerite.

(2) Lenticular crystals up to 5 cm. across and 1 cm. in thickness. These were at first thought to be pseudomorphs of cerussite after calcite. On one group the coating of cerussite is quite thin, and when this was in part chipped off parallel to the base it was seen that the bulk of the crystals consists of fresh hydrocerussite. In another group the point of attachment of one crystal shows a small central area of hydrocerussite; whilst in others only coarsely crystallized cerussite is to be seen. A triangular or radiating grouping of the twinned cerussite sometimes to be seen on the surface of the lenticular pseudo-crystals suggests that

¹ See W. Campbell Smith, *Min. Mag.*, 1913, vol. 16, p. 331. This specimen (B.M. 1913,69), presented by the Earl of Denbigh in 1913, bears the label 'Halkin' (Flintshire), but to judge from its general appearance and association with crednerite and green and blue copper stains, it is difficult to believe that it is not from the Mendip Hills.

there may be some definite crystallographic orientation between the cerussite and the hydrocerussite. One of these pseudo-crystals, consisting wholly of cerussite, shows very distinctly the form of an obtuse rhombohedron with a triangular basal plane on one side. Approximate measurements with the contact goniometer gave $rr = 60^\circ$ and $cr = 35^\circ$. These are in agreement: from $rr = 60^\circ$ is calculated $cr = 35^\circ 13'$ and the axial ratio $a : c = 1 : 0.61$. These values do not correspond with those given for hydrocerussite by G. Flink (1901, loc. cit.): and further the symmetry is rhombohedral rather than holohedral-hexagonal.

A characteristic feature of hydrocerussite is the very good cleavage in one direction—parallel to the base. On this surface the mineral is snow-white with pearly lustre, and somewhat similar to leadhillite in appearance, though the cleavage is not so perfect as that of leadhillite. On the irregular or sub-conchoidal cross-fractures, showing a resinous lustre, the trace of the basal cleavage is not usually conspicuous, and the mineral is then difficult to distinguish at sight from cerussite. The reflection from the cleavage is caught in only one position; and with a corroded or irregularly broken fragment the specimen may have to be turned about in the light before the cleavage shines up.

The mineral is brittle, and has a hardness of $3\frac{1}{2}$. The specific gravity, using $2\frac{1}{2}$ grams of selected material, was determined (in 1904) to be $D_4^{25} = 6.80$, a value widely different from that previously given (see p. 81). Attempts to develop etch-figures on the cleavage surface were without success. Cleavage-flakes under the microscope give centrally a good uniaxial interference-figure of negative sign with fairly strong birefringence.

In the ancient lead slags at Priddy, which I examined in 1898 (loc. cit.), there were, in addition to small crystals of cerussite, anglesite, and leadhillite, also some minute pearly scales which were optically uniaxial and negative, and which dissolved completely with effervescence in cold dilute nitric acid. Other very similar, but rather larger, scales left a white residue of lead sulphate in nitric acid. The latter were determined to be the optically uniaxial form of leadhillite, and the former were no doubt hydrocerussite.

Chemistry of Hydrocerussite (E. D. M.).

In view of the fact that concordant analyses made on pure, naturally-occurring hydrocerussite are entirely lacking, an investigation of the chemical nature of the large quantities of pure material at our disposal called for attention. Since the year 1898 an excellent specimen of this

mineral from the Mendip Hills has been in the possession of Dr. Spencer, but owing to the obscurity of its origin it had been laid aside in the hope that some evidence on the subject might accrue.¹ It had been tested chemically and optically and an approximate figure obtained for its specific gravity, viz. 6.80, which, however, did not tally with the value previously published; consequently this specimen was examined first.

Preliminary chemical tests showed the presence of chlorine as the only impurity, while there was a trace of manganese towards the margin of the material. When it is heated in a bulb-tube, water is given off which condenses in the tube and there ensues a violent decrepitation into irregular cleavage-scales which, as was the case with chloroxiphite, often get attached to the water in the tube; the remainder turn dark-yellow and melt to a pale-yellow liquid which spreads over the surface of the bulb and cools to a pale-yellow glass (lead oxide).

The loss in weight, due to water, carbon dioxide, and lead chloride, when heated at various temperatures, was first determined. Between 150° and 200° the yellow colour becomes perceptible and with rising temperature increases to an orange colour just before fusion. These experiments gave the following results:

Temperature	...	110°.	150°.	200°.	250°.	Ignition.
Loss in weight	...	nil	nil	0.87	2.76	13.60 %

After heating at 250°, all the water was found to have been driven off.

The water and carbon dioxide were next determined simultaneously in a separate portion of the mineral, by igniting a gram of the powdered material in a silica tube and collecting these products in the usual apparatus; both the water and carbon dioxide come off readily. An attempt to check these values by the loss in weight of the substance proved abortive owing to the fact that some of the lead chloride had volatilized.

In a third portion, dissolved in dilute nitric acid, the chlorine was determined as silver chloride and the lead as lead sulphate by the usual methods. These determinations gave the following results, which agree with the formula $3\text{PbO} \cdot 2\text{CO}_2 \cdot \text{H}_2\text{O}$ or $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$.

¹ This specimen was given to me at Priddy in June 1898, together with the samples of ancient lead slags in which I found crystals of leadhillite. The superficial resemblance of the material to leadhillite was at the time puzzling. It is now evident that the specimen belongs to the material that, a few years before, had been found at Higher Pitts.—L. J. S.

Results of Analysis I of Hydrocerussite.

	%	Molecular ratios.		Calculated values.
PbO ...	86.52	$\div 223.20 = 0.3877$	3.04	86.33
CO ₂ ...	11.21	$\div 44.005 = 0.2547$	2.00	11.35
H ₂ O ...	2.23	$\div 18.016 = 0.1238$	} 1.00	2.32
Cl ₂ ...	0.27	$\div 70.92 = 0.0038$		—
	<hr/> 100.23			<hr/> 100.00
Less O \equiv Cl ₂	0.06			
	<hr/> 100.17			

One of the specimens of hydrocerussite acquired with the Perceval collection was next thoroughly examined with the two-fold purpose of establishing its identity with the specimen just described and to serve as a check analysis for the above figures. The specific gravity determined in water with a pycnometer gave the value $D_4^{17.1} = 6.786$. The analysis was performed on the lines already described and gave the following results:—

Results of Analysis II of Hydrocerussite.

	%	Molecular ratios.		Calculated values.
PbO ...	86.43	$\div 223.20 = 0.3872$	3.35	86.33
CO ₂ ...	11.32	$\div 44.005 = 0.2572$	2.23	11.35
H ₂ O ...	2.00	$\div 18.016 = 0.1110$	} 1.00	2.32
Cl ₂ ...	0.32	$\div 70.92 = 0.0045$		—
	<hr/> 100.07			<hr/> 100.00
Less O \equiv Cl ₂	0.07			
	<hr/> 100.00			

These values agree well with the figures of the first analysis and also with the formula. The chlorine, which is persistent throughout the material, cannot, of course, be considered as an essential constituent, but considering the purity of the material it could not be due to the presence of mendipite, the percentage of which would correspond to about three. There would appear to be two possible explanations. The impurity may be another mineral interlaminated with the hydrocerussite; or the chlorine can be accounted for by the assumption of the isomorphous replacement of hydroxyl, the percentage of which is low compared with the calculated value, by chlorine. The latter suggestion, which is the more probable, would imply the possible existence of an end-member of the composition $2\text{PbCO}_3 \cdot \text{PbCl}_2$, which, however, must not be confused with the mineral phosgenite $\text{PbCO}_3 \cdot \text{PbCl}_2$.

CREDNERITE.

(Monoclinic ?, $\text{CuO} \cdot \text{Mn}_2\text{O}_3$.)

Since the original description¹ of this mineral in 1847-9 from Friedrichroda in Gotha, Thuringia, there has been no more mention of it in the literature,² apart from repetitions in the text-books, and its existence as a distinct species has been doubted. The following are all the published analyses of crednerite, from which Rammelsberg deduced the formula $3\text{CuO} \cdot 2\text{Mn}_2\text{O}_3$.

	MnO.	Mn ₂ O ₃ .	O.	CuO.	BaO.	CaO.	H ₂ O.	Insol.	Total.
I.	55.73	—	—	43.85	—	—	—	—	99.58
II.	22.96	31.25	—	42.13	0.52	0.63	0.25	0.63	98.35
III.	64.24	—	8.83	23.73	2.01	—	—	—	98.81
IV.	56.29	—	8.58	32.35	3.08	0.76	—	—	99.06
V.	54.72	—	6.51	34.65	2.71	—	—	—	98.59
VI.	51.69	—	n.d.	40.02	1.04	—	—	—	—
VII.	52.55	—	5.78	40.65	1.48	—	—	—	100.46

I. H. Credner, 1847. Sp. gr. 4.98.

II. H. Credner, 1849. Sp. gr. 5.034.

III-VII. C. Rammelsberg, 1849. Sp. gr. 4.959 and 4.977.

Crednerite is present in considerable amount on several of the specimens from Higher Pitts in the S. G. Perceval collection. It usually occurs on the outside of the nodules of lead-ore, between the cerussite and the enclosing wad. It then forms radiating fan-like groups or hemispherical masses of thin plates. It is also present as single plates penetrating crystals of hydrocerussite. Lastly, a few small (1-2 mm.) spherules consisting of a radial aggregation of plates are occasionally found embedded in the mendipite. It is intimately associated with cerussite, hydrocerussite, and malachite. Masses which appear to consist of a nearly pure aggregate of crednerite plates when examined in thin sections showed angular spaces filled with white and green carbonates. The material frequently shows a greenish tinge on the surface, due to the presence of films of malachite, which is also seen as silky tufts and small, clear prisms. The mineral is iron-black with a bright metallic lustre. It is quite opaque, even in thin section, and gives a sooty black streak. Hardness 4; the plates are neither brittle nor pliable. The single crystals are bright lamellae up to 1 cm. across

¹ H. Credner, Neues Jahrb. Min., 1847, p. 1; Ann. Phys. Chem. (Poggendorff), 1849, vol. 74, p. 546; C. Rammelsberg, *ibid.*, p. 559.

² In error, A. Raimondi, Minéraux du Pérou, Paris, 1878, p. 238, confused it with lampadite.

and $\frac{1}{10}$ mm. in thickness. They show on the surface three sets of striae and overlapping portions at angles near 60° (measured 56° to 63°), suggestive of twinning. Parallel to the surface of the plates there is a perfect cleavage; and at the edges there are cleavages parallel to the striations and inclined to the large surface at about 76° . The crystals are therefore perhaps monoclinic, but pseudo-hexagonal by twinning.

Chemistry of Crednerite (E. D. M.).

As might have been expected from the evidence afforded by the thin section of this mineral, the best material that could be collected by hand-picking effervesced in dilute acid with evolution of carbon dioxide. Some means, therefore, had to be devised to separate the crednerite from this intimate intergrowth with the carbonates of copper and lead. Some of the material was accordingly tested to ascertain what acid would best attack the carbonates and leave the crednerite. The latter is apparently insoluble in any concentration of nitric acid, so that dilute nitric acid proved suitable for the purpose. The portion for analysis was therefore ground to a fine powder, digested for about an hour in warm 1 in 5 nitric acid, washed, and dried at 105° .

The purified material was subjected to a preliminary chemical examination, but still showed the presence of the same impurities. Before the blowpipe the mineral is practically infusible, while the borax bead and flame tests demonstrate the presence of manganese and copper. It is readily soluble in strong hydrochloric acid with evolution of chlorine, the solution becoming a dark brownish-green and giving the reactions of copper and manganese. Specific gravity determinations on the powdered material in water with the pycnometer gave the value $D_4^{16.0} = 4.972$.

The analysis was performed on two separate portions. The main portion, weighing just over a gram, was first ignited to determine the consequent loss in weight due to water and carbon dioxide driven off. It was then dissolved in concentrated hydrochloric acid and the lead impurity separated, by evaporation with a little sulphuric acid, as lead sulphate. From the filtrate, suitably diluted, the copper was precipitated by hydrogen sulphide, the copper sulphide ignited with sulphur in a Rose crucible and weighed as cuprous sulphide. Finally, the manganese was precipitated from alkaline solution by ammonium sulphide and the manganous sulphide treated in a similar way.

The second portion, weighing a tenth of a gram, was used to determine the available oxygen, probably combined with manganous oxide as

Mn_2O_3 . It was decomposed by strong hydrochloric acid, and the chlorine evolved was driven over into a potassium iodide solution, the liberated iodine being estimated in the usual way. The analysis gave the following results, agreeing with the formula CuMn_2O_4 or $\text{CuO} \cdot \text{Mn}_2\text{O}_3$.

<i>Results of Analysis of Crednerite.</i>					
MnO	...	54.40	MnO	54.40	} 92.80 Crednerite.
O	...	6.22	O	6.22	
CuO	...	36.57	CuO	32.18	
			CuO	4.39	} 6.10 Malachite.
H ₂ O	} ...	1.88	H ₂ O	0.50	
CO ₂			CO ₂	1.21	
PbO	...	0.88	CO ₂	0.17	} 1.05 Cerussite.
			PbO	0.88	
		99.95			
			99.95		

The composition of the crednerite portion, recalculated to 100%, becomes:

	%		Molecular ratios.		Calculated values.		
MnO	...	58.62	...	$\div 70.93 = 0.8265$	1.97	...	59.75
O...	...	6.70	...	$\div 16.00 = 0.4189$	1.00	...	6.74
CuO	...	34.68	...	$\div 79.57 = 0.4358$	1.04	...	33.51
		100.00				100.00	

In calculating the percentage composition of the pure material, sufficient carbon dioxide was first subtracted to form cerussite with the lead oxide, and the remaining carbon dioxide and water were considered as constituents of malachite. In the specimen from which the material was collected, the crednerite plates occur quite distinct from the wad enclosing the nodule, so that all the manganese determined in the analysis was considered as an essential constituent.

Assuming the above mineral composition of the material analysed, a correction of the specific gravity for the impurities is necessary. Taking the specific gravities of malachite and cerussite as 4.0 and 6.5 respectively, we obtain the corrected value of 5.03.

WULFENITE.

(Tetragonal, PbMoO_4 .)

Berzelius, in 1824, mentioned in connexion with his description of mendipite that the specimen showed a small yellow portion which before the blowpipe gave the reactions of lead molybdate. In Greg and Lettsom's 'Mineralogy of Great Britain and Ireland' (1858, p. 411) this is the only record of wulfenite as a British mineral, and it was regarded as doubtful. The mineral has, however, since been found at

Lauchentyre (Lackentyre) in Kirkcudbrightshire¹ and in the Caldbeck Fells in Cumberland.²

Although I have made a careful search for wulfenite from the Mendips it has so far been found in very small amount on only three specimens from Higher Pitts farm. One is a small piece of hydrocerussite, which was obtained from the S. G. Perceval collection through Mr. J. R. Gregory, in November 1898; and the following details are taken from my note-book under that date. A single crystal, about 2 mm. across, is embedded in hydrocerussite, with which is some cerussite and small crystals of manganite. It is clear and transparent and very pale wine-yellow in colour. Measurement of a detached fragment showed the form to be that of the tetragonal bipyramid $n(111)$ with the polar edges truncated by $e(101)$; one small face $u(102)$ is also present. The measured angle $mn(111) : (\bar{1}11)$ $80^\circ 22'$ (limits $80^\circ 19' - 80^\circ 23'$), corresponds exactly with the value given by Dana for wulfenite. Approximate determinations of the refractive index were also obtained through the prism of $40^\circ 10'$ formed by the faces (111) and $(0\bar{1}\bar{1})$. The dispersion is high, and for the yellow part of the spectrum the values obtained were ω 2.41 and ϵ 2.32. Blowpipe and microchemical tests made on other fragments detached from the same crystal proved the material to be lead molybdate.

The second specimen is a small corroded fragment of cerussite, recently given by Mr. T. Willcox. It shows a small (3 mm.), white to pale-yellowish patch of finely granular material, on the surface of which are minute (less than $\frac{1}{4}$ mm.), pale-yellow crystals with high lustre. These are mostly rounded and flattened, and under the microscope they show uniaxial interference-figures of negative sign. One crystal was seen to have the form of a low square pyramid. The white material when examined in oil under a $\frac{1}{2}$ -inch objective is seen to consist of an aggregate of very small grains with high refraction. Both this and the crystals when tested on a microscope slide with hydrochloric acid and zinc yielded crystals of lead chloride and a residue of molybdenum-blue.

The third specimen was found, in April 1923, on the old waste heaps. It shows a small (1 cm.) patch of thin-lenticular crystals ($\frac{1}{2}$ cm. across)

¹ M. F. Heddle, *Phil. Mag.*, 1866, ser. 4, vol. 31, p. 253; *Mineralogy of Scotland*, 1901, vol. 2, p. 182.

² J. G. Goodchild, *Geol. Mag.*, 1875, dec. 2, vol. 2, p. 565; *Trans. Cumberland and Westmorland Assoc. Adv. Lit. Sci.*, 1885, no. 9 (for 1883-4), p. 188. This mineral was also mentioned by S. G. Perceval from Treffarn Rocks, Pembrokeshire (*Geol. Mag.*, 1866, vol. 3, p. 377), but afterwards said to be 'brookite' (*loc. cit.*, p. 518).

of wulfenite embedded in black calcite, which surrounds a nodule of aragonite in wad. This material shows only a faint tinge of yellow, and until it was examined it had been passed as cerussite. The aragonite, a rare mineral at Higher Pitts, forms a compact aggregate of large, white prisms, altering to calcite.

PYROMORPHITE and MIMETITE.

(Hexagonal, $3\text{Pb}_3\text{P}_2\text{O}_8 \cdot \text{PbCl}_2$ and $3\text{Pb}_3\text{As}_2\text{O}_8 \cdot \text{PbCl}_2$.)

To judge from John Woodward's entries in 1728 'green lead-ore' must at one time have been mined in considerable quantities on the Mendip Hills. This is also suggested by the name Green Ore of a hamlet three miles east of Priddy, a name which dates back several centuries.¹ The seven specimens mentioned by Woodward,² from Green Hill and Blagen [now Blagdon] Hill, both near Charterhouse, are still carefully preserved in the Cambridge collection. A recent examination of these proves them to be pyromorphite. They are cellular masses of pale yellowish-green, small-botryoidal material, partly coated with pinkish-yellow clay. One of the Green Hill specimens 'shot into little green Crystals' shows a crust of pale-green prisms (2×1 mm.) on reddish grit (Old Red Sandstone). His 'yellow Accretion, appearing to be Sulphur' from Hartry-Liberty [now Harptree] quoted above (p. 68) consists of a crust of minute, yellowish-green crystals of pyromorphite on a mass of large twinned crystals of cerussite with wad.

It is therefore strange that there is no record in modern literature of the occurrence of pyromorphite in the Mendips. It is not mentioned in H. B. Woodward's lists of 1872 and 1876, nor by S. G. Perceval³ in 1874. In H. B. Woodward's lists, however, there appears 'Mimetene. Near Blagdon (R. H. Valpy)', but without any further information. Recent inquiries and search for these minerals at and near Blagdon, on the north side of the Mendips, were without result.

Mimetite was found in April 1923 on the waste heaps at Higher Pitts farm, but only in very small amounts. It forms crystalline crusts on calcite, or sometimes on cerussite, with wad and earthy limonite, and is orange-yellow to orange-red in colour with a brilliant lustre. The minute ($\frac{1}{4}$ mm.) crystals are prismatic and confusedly aggregated. Sometimes they show a sub-parallel grouping producing a sheaf-like

¹ Here was formerly a cell of the now ruined Glastonbury Abbey, and in the fifteenth century the 'Prior of Greene Oare' had differences with the miners.

² J. Woodward, loc. cit., vol. 1, pp. 208, 213; vol. 2, pp. 27, 28.

³ S. G. Perceval, Supplementary note on minerals found in Somersetshire. Geol. Mag., 1874, vol. 10, p. 166.

aggregate, as opposed to the barrel-shaped habit so often displayed by this mineral. Blowpipe and microchemical tests proved the material to be chloro-arsenate of lead with no phosphate.

ALTERATION PRODUCTS AND PSEUDOMORPHS.

Following the above descriptive account of the new and rarer minerals, a few general remarks on the 'paragenesis' of this strange assemblage of minerals at Higher Pitts may not be out of place. Various speculations have naturally been indulged in, but these need not all be committed to print.

The nodules of mendipite are always surrounded by zones of alteration products, the alteration having evidently proceeded in the direction :

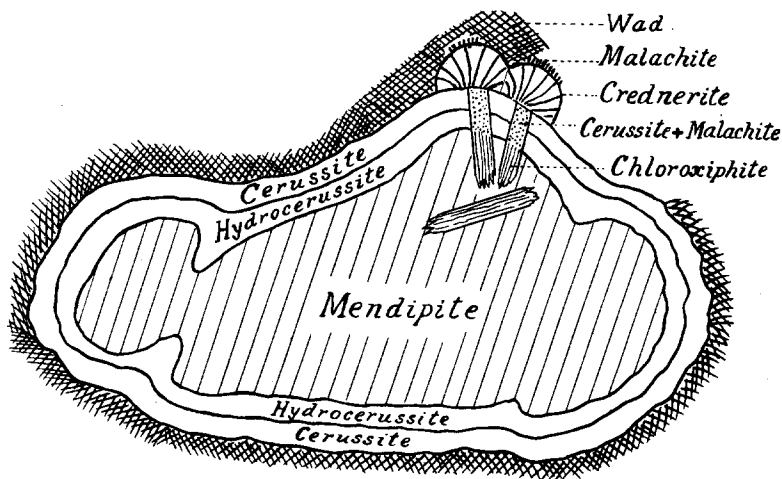
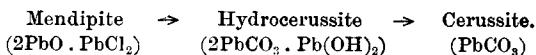
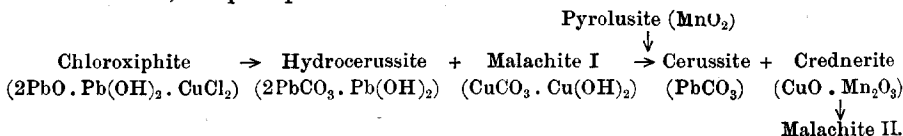


FIG. 1. Diagram to represent the alteration products of Mendipite and Chloroxiphite.

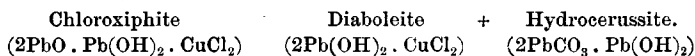
As an intermediate product, phosgenite ($\text{PbCl}_2 \cdot \text{PbCO}_3$) might have been expected, but no trace of this could be detected. The final product, cerussite, is frequently found as lumps of white, pure, crystalline material, the largest in the collection weighing 628 grams. At times, cavities in the manganese-ore are partly occupied by a loose crystal of cerussite; these are often well-developed twin-crystals, but always much corroded. The mendipite, never apparently having been developed as distinct crystals, yielded no pseudomorphs. But good pseudomorphs of cerussite after hydrocerussite have been found (p. 82).

The series of changes involved in the alteration of the chloroxiphite is less clear, but perhaps followed in the order :



The chloroxiphite is often associated with patches of a green, compact material with dull lustre, which as far as could be determined consists of a fine-grained mixture of cerussite (or perhaps sometimes hydrocerussite) and malachite. The lath-shaped outlines of the chloroxiphite crystals can sometimes be traced into the zones of hydrocerussite and cerussite, being then marked out by this green, compact material, i. e. pseudomorphs of cerussite (or hydrocerussite) and malachite after chloroxiphite (see fig. 1). Beyond the nodule, in contact with the manganese-ore, the copper from the chloroxiphite perhaps gave rise to the crednerite. The latter suffered a later alteration back to malachite, which in this generation developed as silky tufts or as small, clear prisms.

The relations of the diaboileite are still less clear. It appears to be more stable than the chloroxiphite, and may perhaps have been derived from it (some of the blades presenting the appearance of pseudomorphs of diaboileite after chloroxiphite); and it also persists in the hydrocerussite and even the cerussite zones. This would suggest a second type of alteration of the chloroxiphite :



The nodules containing these lead (and copper) minerals are relatively few and scattered, and it would seem that they are really foreign to the deposit of manganese-ore. It is possible that, as lumps of galena¹ derived from veins in the Carboniferous Limestone, they were deposited with the Dolomitic Conglomerate (a beach deposit surrounding the limestone hill), and that by the action of sea-water they were at that period converted into the oxychloride, mendipite. That such an origin of the mendipite is possible is suggested by the development of various lead oxychlorides in the ancient lead slags at Laurion in Greece, which have been exposed to the action of sea-water.²

¹ Associated with small amounts of some copper-ore (not chalcopyrite, since there is no trace of iron in the nodules).

² See also A. Russell, *Min. Mag.*, 1920, vol. 19, p. 64.