

Barstowite, $3\text{PbCl}_2 \cdot \text{PbCO}_3 \cdot \text{H}_2\text{O}$, a new mineral from Bounds Cliff, St Endellion, Cornwall

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Abstract

Barstowite, ideally $3\text{PbCl}_2 \cdot \text{PbCO}_3 \cdot \text{H}_2\text{O}$ is a new mineral from a lead-antimony vein at the south-western end of Bounds Cliff, St Endellion, Cornwall. It occurs as very small (0.2–0.5 mm) subparallel elongate intergrown crystals which form aggregates (up to 3 mm) containing minor inclusions of galena and jamesonite. Other associated minerals are quartz, dolomite, phosgenite, cerussite, sphalerite, pyrite and chalcopyrite. Barstowite is colourless to white and is transparent with an adamantine lustre and white streak. It is brittle, has an imperfect prismatic cleavage, and an uneven fracture. Low reflecting, barstowite has a moderate bireflectance from grey to dark grey in hue and weak to moderate anisotropy. Internal reflections (colourless) are abundant. Measured reflectance values in air and oil are tabulated. Colour values relative to the CIE illuminant C for R_1 and R_2 in air respectively are: $Y\%$ 12.9, 13.3; λ_d 477, 476; $P_c\%$ 3.5, 3.7. VHN_{100} 111 (range 108–117); calculated Mohs hardness is 3. Infrared spectra of barstowite, phosgenite and cerussite are compared.

X-ray studies show that barstowite is monoclinic with space group $P2_1/m$ and a 4.218(2), b 9.180(2), c 16.673(4) Å, β 91.49(3)°. It has a cell volume of 645.38 Å³ with $Z = 2$. $D_{\text{calc.}}$ is 5.76 g/cm³, $D_{\text{meas.}}$ is 5.71 g/cm³. The strongest six lines of the X-ray powder pattern are [d in Å (I) (hkl)] 4.02 (10) (022); 2.296(8) (040; 125; 106); 2.377(6) (007; 026); 4.16(5) (004); 2.108(4) (200); 3.79(3) (014). The name is for the late Richard William Barstow, the Cornish mineral dealer.

KEYWORDS: barstowite, new mineral, lead, St Endellion, Cornwall.

Introduction and general geology

BARSTOWITE, ideally $3\text{PbCl}_2 \cdot \text{PbCO}_3 \cdot \text{H}_2\text{O}$, is a new mineral species found in a specimen collected from a NNE–SSW trending lead-antimony vein exposed on the foreshore between low and high water marks at Bounds Cliff, St Endellion, Cornwall [SX 0185 8125—lat. 50°35'48"N, long. 4°47'56"W]. This vein is one of several which outcrop along the North Cornwall coast from Port Isaac to Tintagel. Many of these, and others inland, were worked in the last century (Hamilton Jenkin, 1970; Dines, 1956, pp. 574–8), but there is no evidence of mining activity associated with this vein.

At outcrop, just above low water mark, the vein is 15–30 cm across and consists predominantly of quartz and dolomite with granular galena and minor amounts of cerussite, pyrite, sphalerite, chalcopyrite and jamesonite. Cavities in the vein contain alteration products, predominantly lead minerals such as phosgenite and barstowite, which probably formed as a result of the action of seawater on the assemblage. The host rocks are strongly cleaved pale greenish-grey slates of Upper Devonian age (Warr, 1988), which dip seawards at 20–30°. Consequently, as its outcrop in the cliff is obscured by landslips, the vein can be traced no more than a few metres from the sea. Access to the locality from the cliff

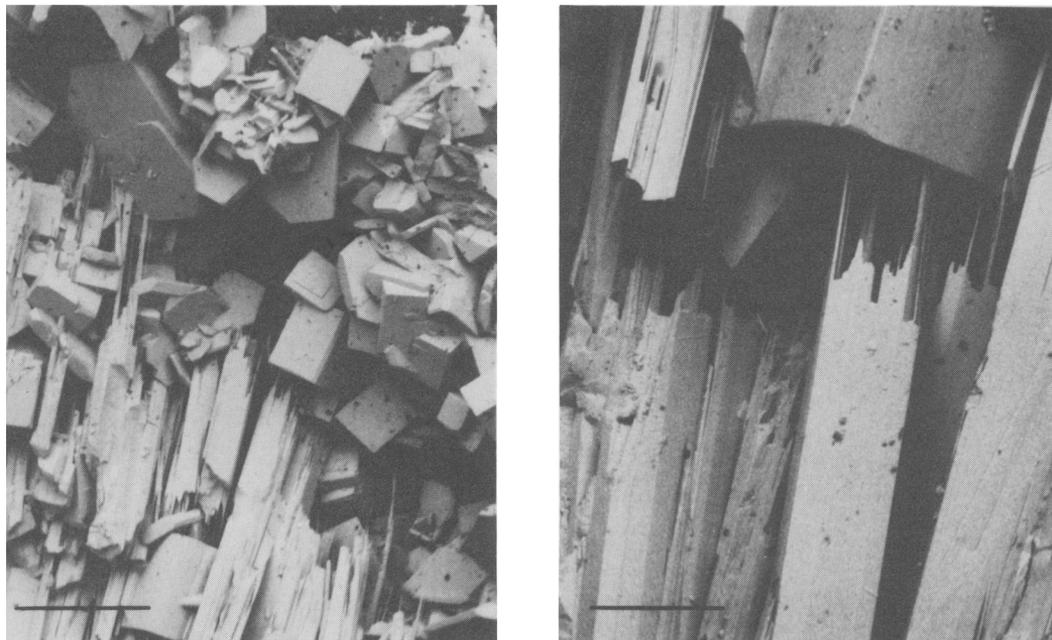


Fig. 1. Scanning electron photomicrographs of irregular prismatic barstowite with phosgenite (Scale bar: left 400 μm ; right 100 μm).

path is difficult due to dense undergrowth and the steep and unstable cliffs; the locality is best examined in good dry weather at springtime when the undergrowth is minimal, the tides are at their lowest, and there is no sea swell.

Barstowite is named after Richard William Barstow (1947–1982), the Cornish mineral dealer whose collection is now on display in the City of Plymouth Museum. The mineral and its name have been approved by the Commission on New Minerals and Mineral Names of the International Mineralogical Association. The type specimen is preserved at The Natural History Museum, London [statutory name: British Museum (Natural History)] as specimen BM 1990, 25 and polished section E. 1353.

Physical properties

Barstowite is colourless to white, with a white streak and an adamantine lustre. It is brittle with an imperfect prismatic cleavage and an uneven fracture. When cleavages and fractures are absent, the mineral is transparent. Very small (0.2–0.5 mm) subparallel intergrown crystals of barstowite are, superficially, not unlike cerussite (see Fig. 1) and form intergrowths with phosgenite and aggregates (<3 mm) which contain minor inclusions of galena and jamesonite.

The density, which was measured on six grains with a Berman Balance using ethylene dibromide, yielded the following results: 5.69, 6.10, 5.50, 5.59, 5.52, 5.83, average 5.71 g/cm^3 . Two grains (2 and 6) were seen to have minute inclusions of galena and jamesonite while all the grains may have had air/water trapped in the interstices of the subparallel intergrown crystals.

A polished section was prepared with some difficulty as the mineral is soft and susceptible to plucking. After grinding on plate glass with 800 mesh silicon carbide, the specimen was taken directly to the 1 μm diamond polishing stage; a well-lubricated Hyprocet pella lap was used and a good polish achieved rapidly. The mineral is easily scratched and it was decided to cease polishing at this stage. Barstowite has a VHN_{100} of 111 with a range of 108–117 from five indentations, the shapes of which were perfect to slightly concave. The equivalent Moh's hardness is 3.

In reflected light, barstowite is moderately bireflectant from grey to dark grey with weak to moderate anisotropy. Internal reflections are abundant and, as a result, reflectance measurements on the most bireflectant grain could not be made. However, in one grain, an area was found over a cleavage plane where no obvious internal reflections were present and reflectance measure-

TABLE 1. Reflectance data and colour values for barstowite

λ_{nm}	R_1	R_2	imR_1	imR_2
400	14.2	14.8	3.54	3.84
420	14.0	14.65	3.35	3.62
440	13.85	14.4	3.20	3.50
460	13.7	14.1	3.09	3.37
470	<u>13.5</u>	<u>14.0</u>	<u>3.02</u>	<u>3.31</u>
480	13.4	13.9	2.99	3.26
500	13.25	13.7	2.90	3.17
520	13.1	13.5	2.84	3.11
540	12.9	13.4	2.78	3.04
546	<u>12.9</u>	<u>13.35</u>	<u>2.76</u>	<u>3.02</u>
560	12.8	13.2	2.73	2.99
580	12.7	13.1	2.69	2.95
589	<u>12.65</u>	<u>13.1</u>	<u>2.67</u>	<u>2.92</u>
600	12.6	13.0	2.66	2.91
620	12.5	12.9	2.63	2.88
640	12.5	12.9	2.62	2.86
650	<u>12.4</u>	<u>12.8</u>	<u>2.60</u>	<u>2.85</u>
660	12.4	12.8	2.59	2.83
680	12.3	12.75	2.57	2.82
700	12.3	12.7	2.56	2.80

COLOUR VALUES RELATIVE TO CIE ILLUMINANT C

	R_1	R_2	imR_1	imR_2
x	.303	.303	.297	.297
y	.309	.308	.301	.301
Y*	12.9	13.3	2.8	3.0
λ_d	477	476	475	475
P_e^*	3.5	3.7	6.8	6.7

ments in air and in oil were made using the procedures summarised in Criddle *et al.*, 1983, with an SiC standard (Zeiss no 472). The data are given in Table 1. Calculated refractive indices at 589 nm are (for R_1 and R_2 respectively) 2.10 and 2.12.

Infrared spectra

The infrared transmission spectrum of barstowite (Fig. 2) was recorded over the wavenumber range 4400 to 225 cm^{-1} using the KBr disk method, in a Philips PU9800 FTIR spectrophotometer. The spectra of phosgenite and cerussite are included in Fig. 2 for comparison and absorption frequencies are tabulated in Table 2. No absorptions were observed in the region 4400–

Table 2. Infrared absorption frequencies (cm^{-1}) of barstowite, phosgenite and cerussite from Fig. 2.

BARSTOWITE	PHOSGENITE	CERUSSITE
3400	3437	3439
2924		
2855		2404
1768	1817	
1716	1710	1727
1619		
1438	1512	1430
1385		1395
1339	1344	
	1130	
1096		1101
1051	1062	1051
845	836	839
719	758	824
671	648	678
598		
467	469	474
394	311	302
268		242

4000 cm^{-1} . All spectra were baseline corrected to remove the effects of scatter at high wavenumbers characteristic of lead minerals in KBr disks.

The barstowite spectrum has twin peaks at 1438 and 1339 cm^{-1} typical of carbonates containing another anion, Cl in this case. Peaks at 3400 and 1619 cm^{-1} indicate the presence of water of crystallisation and are the basis for the assignment of hydrogen to H_2O rather than OH^- in the formula. A sharp peak at 1051 cm^{-1} in the barstowite spectrum is a feature of carbonates with the aragonite structure, as can be seen in the cerussite spectrum. It would appear at first sight that the barstowite spectrum shows all the cerussite absorptions and hence is contaminated, but when superimposed in an expanded plot, non-coincidence of the peaks is apparent.

The similarity of the barstowite and phosgenite spectra is striking and must reflect a corresponding similarity in molecular grouping within the two minerals.

Chemical composition

A combination of electron probe microanalysis (for Pb and Cl) and elemental analyser (for C and H) was used to determine the chemistry of barstowite. The data are summarised in Table 3. Oxygen was calculated by stoichiometry and, as

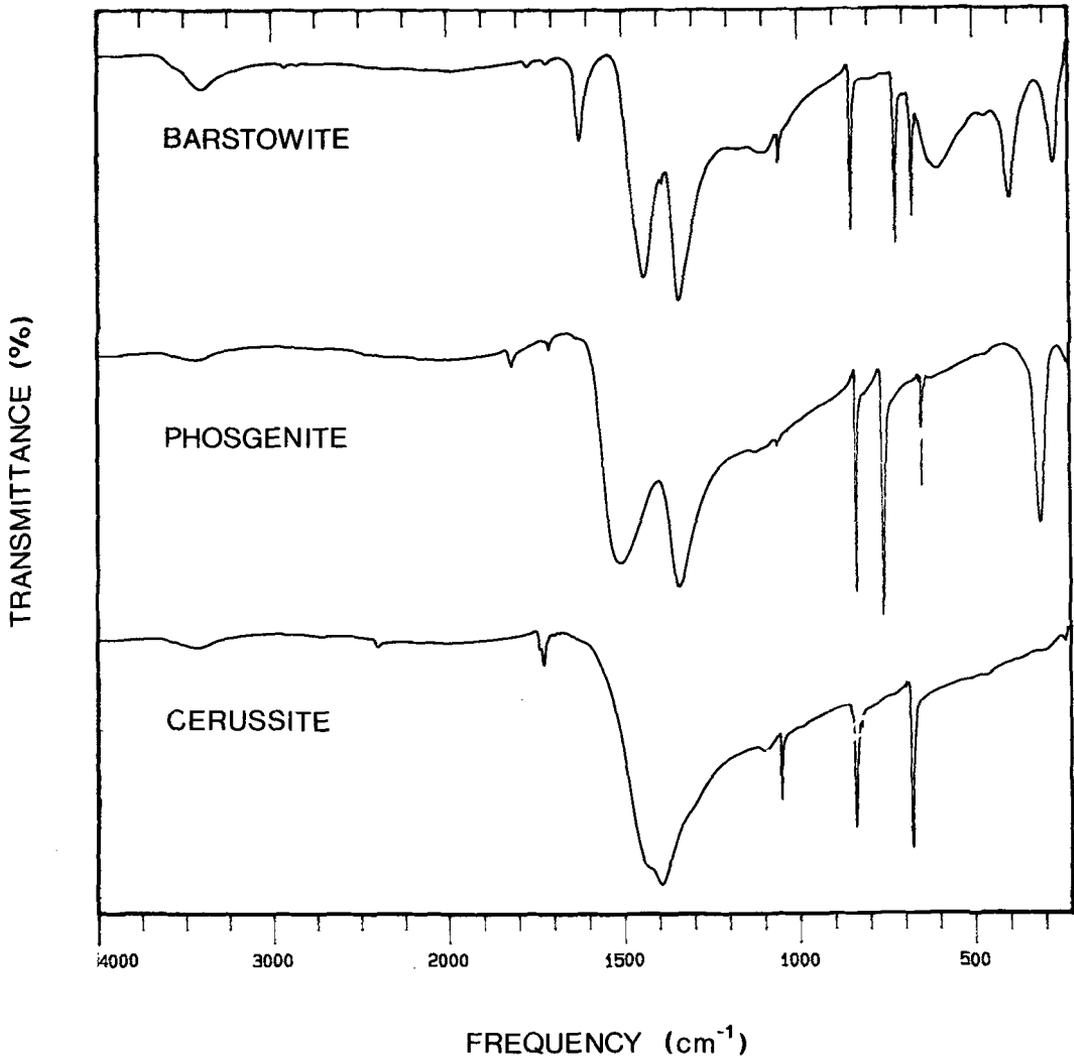


FIG. 2. Infrared absorption spectra of barstowite, phosgenite (BM 85166) and cerussite (BM 1926, 127).

noted, the infrared spectrum suggests that H_2O rather than OH is present. The loss of this H_2O and possibly other volatiles in the electron microprobe beam is believed to be the reason for the slightly high total of the combined analysis.

The empirical formula (based on 17 atoms) is $Pb_{4.02}Cl_{5.82}C_{1.03}H_{1.97}O_{4.16}$ or $Pb_{1.03}(CO_3)_{1.03} \cdot Pb_{2.99}[Cl_{5.82}(OH)_{0.16}]_{5.98} \cdot 0.90H_2O$ which gives the simplified formula $3PbCl_2 \cdot PbCO_3 \cdot H_2O$.

X-ray crystallography

All fragments investigated consisted of sub-parallel intergrown crystals, and it was possible to

obtain meaningful results from Weissenberg photographs of two levels only. The unit cell parameters refined from the powder data (Table 4) show that barstowite is monoclinic with space group $P2_1$ or $P2_1/m$; a 4.218(2), b 9.180(2), c 16.673(4) Å, β 91.49(3)° and the cell volume is 645.38 Å³. For $Z = 2$, the calculated density is 5.77 g/cm³.

There is a powder pattern of an unnamed mineral in the JCPDS (25.1396) which is similar to that of barstowite as, also, is its chemistry (Melnikova, 1972). It is an unwritten convention in such circumstances to name the mineral after the earlier author but melnikovite has already

TABLE 3. Chemical composition of barstowite (in wt%)

	Pb	Cl	C	H	O	Total
1	-	-	1.12	0.18	-	-
2	75.82	18.45	-	-	-	-
3	75.33	18.60	-	-	-	-
4	75.27	18.96	-	-	-	-
5	75.47	18.67	1.12	0.18	6.03	101.46
6	74.03	19.00	1.07	0.18	5.72	100.00

1. C and H analysis by combustion using Perkin Elmer Mod. 240 elemental analyzer.
- 2-4. Electron microprobe analyses with Cambridge Instruments Microscan IX, operated at 20kV with mendipite standard (BM 1923,709). Radiations measured, Pb Mu Cl Ku.
5. Average analysis with oxygen by stoichiometry.
6. Ideal formula $3\text{PbCl}_2 \cdot \text{PbCO}_3 \cdot \text{H}_2\text{O}$.

TABLE 4. Indexed X-ray powder diffraction pattern of barstowite FeK α radiation, Mn filter, camera diameter 114.6 mm. Intensity I/I_0 is estimated.

$d_{\text{meas.}}$	I/I_0	$d_{\text{calc.}}$	hkl
8.33	1	8.334	002
8.03	1	8.041	011
6.17	2	6.170	012
5.55	1	5.556	003
4.76	2	4.753	013
4.59	1	4.590	020
4.42	1	4.425	021
4.16	5	4.167	004
4.02	10	4.021	022
3.79	3	3.794	014
3.72	1	3.724; 3.715	102; 111
3.54	2	3.539	023
3.52	2	3.515	112
3.45	1	3.451	112
3.40	1	3.402	103
3.313	2	3.317	103
3.085	1	3.085	024
3.045	3	3.042	121
2.923	2	2.926	104
2.853	1	2.854	114
2.779	2	2.778	006
2.734	1	2.733	123
2.679	2	2.689; 2.680	123; 033
2.652	2	2.649	105
2.513	1	2.513	124
2.477	3	2.477	130
2.464	3	2.467; 2.466	124; 034
2.377	6	2.381; 2.377	007; 026
2.345	1	2.348	106
2.296	8	2.295; 2.294; 2.293	040; 125; 106
2.254	1	2.254; 2.250	035; 125
2.212	1	2.213	042
2.145	1	2.143	134
2.108	4	2.108	200
2.098	3	2.098; 2.097	201; 107
2.084	1	2.085; 2.083	201; 008
2.057	2	2.057; 2.057; 2.055	202; 036; 210
2.030	3	2.032; 2.031	018; 202
2.011	2	2.010	044
1.952	1	1.954; 1.954	203; 142
1.903	2	1.902; 1.901	143; 204
1.890	1	1.890; 1.887; 1.887	045; 108; 143
1.873	1	1.872	127
1.850	2	1.850; 1.849	118; 108
1.798	1	1.798	223
1.769	1	1.769; 1.769	215; 046
1.726	1	1.725	224
1.685	2	1.683; 1.683	150; 119
1.623	2	1.622	146

entered the literature as a textural variety of pyrite.

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