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Embreyite, a new mineral from Berezov, Siberia

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SUMMARY. Embreyite is a new mineral that has been found only in old specimens collected at Berezov, Siberia. The composition is $Pb_{4\cdot97}(CrO_4)_{2\cdot00}(PO_4)_{1\cdot91}.0\cdot75H_2O$, or $Pb_5(CrO_4)_2(PO_4)_2.H_2O$ based on both wet and electron-probe analyses. Z = 1, D_{meas} 6·45, D_{calc} 6·41. Crystals are monoclinic with a 9·755 Å, b 5·636, c 7·135, β 103°5′; the space group may be $P2_1/m$. No single crystals were found. $\alpha = 2\cdot20$, $\beta = \gamma = 2\cdot36$. Colour in various shades of orange with a yellow streak. H = $3\frac{1}{2}$; no cleavages observed. Occurs with vauquelinite, crocoite, and phoenicochroite in the oxide zone assemblage from Berezov.

EMBREYITE was first noted on a specimen loaned by J. Jago in 1963. His specimen contained just enough material for a powder spindle, however, so it was not until I obtained additional material that this description could be completed. A fine specimen, rich in embreyite, was given me by Dr. Sainfeld at the Bureau des Recherches Géologiques et Minierès, and I recently had the opportunity to carefully examine all of the Beresov specimens at the British Museum (Natural History), where a considerable amount of embreyite turned up. There are at least two specimens at the B.R.G.M., twelve at the British Museum[2] (Natural History), and the original Jago specimen. These specimens comprise an estimated 10 grams of embreyite, and doubtless there are many other pieces in collections of Berezov material. I have scrutinized material from other notable chromate localities, particularly Dundas, Rhodesia, Brazil, and Wickenburg, but found no embreyite. Berezov, Siberia is the sole locality to the best of my knowledge.

A visit to the type locality was, of course, out of the question and I have been content to examine the literature and museum specimens. It seems quite probable that embreyite has been observed previously by several workers. The first notice may be from Macquart (1789) who observed an 'oxide jaune ou ocre de plomb' on his Berezov specimen number 24 (misprinted 34). And Hausmann (1813) clearly described embreyite on one specimen as '... theils dunkel ocher-braun, theils dunkel leber-braun; giebt aber ein zeisiggrünes Pulver'. John (1845) gave a similar description of embreyite on one of a suite of specimens he had purchased in Berlin. John said this: '5) Ein Nelken- und Haar-braunes Erz in dünnen amorphen Massen; matt und wachsartig glänzend, undurchsichtig und kaum an dünnen Kanten durchscheinend; von hell zeisiggrünem Striche.' Finally in 1880 Pisani published a brief description of a mineral that he did not name but referred to only as a chromo-phosphate of lead and copper.

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[2] B.M. nos. 36704, 39315, 94723, 40448, 60368, 94718, 39314, 60384, 39316, 60369, 58876, and 60387.

Little detail was given. The colour was stated to be red-orange with a yellow streak. The mineral (on Berezov specimens) occurred as botryoidal crusts with a drusy crystalline surface. His chemical analysis is presented in table I. All later workers have classed his mineral as some sort of vauquelinite, but none of them appears to have noticed that it was an orange, not a green mineral. I am not aware of any further mention of embreyite again until now.

TABLE I. *Chemical analyses of embreyite*

	1	2	3	4	5	6	7	8	9	10
PbO	72·25	75·30	74·7	74·9	75·0	74·4	0·333	74·73	70·60	75·61
CuO	2·53	1·20	1·62	1·68	1·45	1·70	0·021	1·71	4·57	—
CrO_3	13·08	—	13·4	13·5	13·6	13·4	0·134	13·46	15·50	13·55
P_2O_5	8·23	—	9·57	9·47	9·11	0·09	0·064	9·13	9·78	9·62
CO_2	1·04	—	—	—	—	—	—	—	—	—
H_2O	0·91	—	n.d.	n.d.	n.d.	0·91	0·050	0·91	—	1·22
ZnO	—	0·03	0·06	0·02	0·06	0·04	—	0·04	—	—
Fe_2O_3	—	0·01	0·01	0·04	0·01	0·02	—	0·02	—	—
Sum	98·04	—	99·4	99·6	99·2	99·56		[100·00]	100·45	100·00

1. Schwarzkopf Microanalytical Laboratory, analysts. Cu, Cr, Pb, by atomic absorption on 3·954 mg. H_2O under N_2 at 800° on 7·724 mg. CO_2 on 7·725 mg, precipitated as $BaCO_3$. P_2O_5 on 1·582 mg. CO_2 from cerussite contamination. B.R.G.M. specimen.
2. J. A. Allen analyst, all elements by atomic absorption on 5·842 mg. B.R.G.M. specimen.
3, 4, 5. Analyses on electron probe by R. F. Symes and A. M. Clark. All analyses on B.M. 94718.
6. Average of analyses after deducting cerussite from no. 1 and recalculating to 98·04 %.
7. Ratios.
8. Average analysis is recalculated to 100 %.
9. Pisani (1880).
10. $Pb_5(CrO_4)_2(PO_4)_2.H_2O$.

Embreyite occurs on those specimens rich in other chromates, particularly crocoite and phoenicochroite. It is later than crocoite, which it may implant and replace, and was not observed in direct contact with the still earlier phoenicochroite. Cerussite is later than, and may replace embreyite. Vauquelinite was also observed replacing embreyite directly. Embreyite also occurs as thick botryoidal crusts, which grade inward insensibly into complex, microcrystalline greenish to brown material. Powder patterns of this material suggest that it is a mixture, and spectrographic analysis shows Cr, Pb, Cu, and P. The strong lines of the powder patterns taken match no known chromate.

The chromates at Berezov usually occurred in gold-bearing quartz veins, and the reader is referred to Arzruni (1885) for further details on the geology and mineralogy of these veins.

Physical properties. Pure embreyite is dull orange in colour (approximately henna) and varying matches were obtained with the Royal Horticultural Society colour chart, from 171B to 177C. The streak is primrose Yellow, 4A. The lustre may be dull to sparkling and resinous, and crystalline material is transparent or transluscent in mass. The hardness on Mohs scale is $3\frac{1}{2}$. The specific gravity (at 24 °C) was measured eight times on quantities varying from 5 to 13 mg and is 6·45±0·12. The mineral was immersed in toluene using the Berman balance.

No cleavage was observed, even in thin sections, and the fracture is irregular and brittle.

Chemical analysis. Spectrographic analysis showed major Pb, Cr, P, and minor Cu, and X-ray fluorescence scan gave the same results. A closed tube test yielded water. Wet chemical analyses were planned on the basis of this information, and are presented in table I. Electron probe analyses, also presented, were done later using crocoite, anglesite, linarite, Cu, Pb, and Cr as standards. These results agreed well with the wet analyses. The results suggest the formula $Pb_5(CrO_4)_2(PO_4)_2.H_2O$, and the empirical cell contents ($Z = 1$) are $Pb_{4\cdot97}(CrO_4)_{2\cdot00}(PO_4)_{1\cdot91}.0\cdot75H_2O$. The substitution of Cu for Pb is probably slight and values of CuO in excess of 2 % may well represent contamination by vauquelinite or the unidentified phases mentioned earlier. It also seems probable that the chromate–phosphate ratio is fixed at 1:1.

Embreyite does not readily dissolve in cold reagents. In dilute HNO_3 or HCl it becomes coated white with $Pb(NO_3)_2$ or $PbCl_2$.

Crystallography. The drusy crystalline crust, which is typical of embreyite, consists invariably of tiny tabular crystals with the plane of flattening approximately normal to the surface of the crust. These crystals are usually dull and poorly suited for measurement. They are clearly rhombohedral with only c {0001} and r {$10\bar{1}1$} as bounding faces, and the ρ angle for {$10\bar{1}1$} is approximately $70\frac{3}{4}°$. Optical examination of these crystals showed that they are not single but are composite and show sectored zoning and multiple twinning. Commonly, each 60° sector of the tablet (of hexagonal outline) consists of two embreyite crystals whose extinction directions are a few degrees apart and with feathery extinction in a wishbone pattern at 60° to the length of the two wedges. The tablets just as commonly are a bewildering jumble of embreyite optical domains, but some fragments could be obtained which gave sharp extinction. One of these fragments (taken from B.M. 40448) was oriented with its β optical direction polar on a spindle stage, and, as hoped, it gave a clear rotation pattern.

Further examination of this fragment by Weissenberg exposures showed that embreyite is monoclinic, and the cell chosen has a 9·755 Å, b 5·636, c 7·135 (all ±0·003 Å) and β 103° 5′±2′. This gives a cell volume of 382 Å³ and $Z = 1$ with D_{calc} 6·41 as compared with D_{meas} 6·45. The space group is probably $P2_1/m$, but it should be noted that the Weissenberg patterns were faint, even after very long exposures.

The powder pattern indexes well with this cell and the results are presented in table II. The powder spindle used for gathering the data was prepared from a tiny amount of the same crystals as were used for single-crystal work. A number of other powder patterns were taken and the results show that cell dimensions and β vary slightly—the usual result is line splitting, particularly of the 3·167 Å line.

Optics. In thin section embreyite is orange and shows pleochroism from honey yellow (α) to amber (β and γ). Birefringence is high, and embreyite could be mistaken for vauquelinite, iranite, or hemihedrite; its appearance is distinctively different from that of crocoite or of course phoenicochroite. Dispersion is low, and $2V_\alpha$ is sensibly 0° or up to 11° (by universal stage). The indices were determined in S–Se melts for white light as $\alpha = 2{\cdot}20$, $\beta = \gamma$ 2·36, all ±0·04. The optic orientation was not fully determined except to note that $\beta = b$ [010].

TABLE II. *Powder data for embreyite. Cr-Kα radiation, 114 mm camera (Wilson)*

I/I_0	d_{meas}	d_{calc}	*hkl*
3	6·941	6·950	001
60	4·751	4·751	200
3	4·378	4·378	011
32	3·563	3·564	201
28	3·475	3·476	$21\bar{1}$
		3·475	002
100	3·167	3·167	$20\bar{2}$
		3·167	300
		3·165	$30\bar{1}$
60	2·818	2·818	020
17	2·608	2·612	021
4	2·407	2·405	$31\bar{2}$
		2·408	311
23	2·314	2·317	003
		2·319	212
32	2·213	2·211	221
		2·208	$40\bar{2}$
31	2·187	2·189	410
		2·191	$11\bar{3}$
		2·189	022
31	2·105	2·107	401
		2·105	321
		2·105	320
		2·105	222
45	1·917	1·918	203
26	1·789	1·790	023
		1·788	$41\bar{3}$

Plus nine additional lines to 1·207

Conclusions. Embreyite clearly differs from other lead chromates described to date. The mere fact of its existence, and that of the massive Pb–Cu chromates and phosphates mentioned previously, suggests that older analyses of vauquelinite might be unreliable. Any attempts to clarify the chemistry of vauquelinite and fornacite should not be based on these older analyses.

The name is to honour Peter G. Embrey, mineralogist of the British Museum (Natural History).

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