

## Paulmooreite, a new lead arsenite mineral from Långban, Sweden

PETE J. DUNN

*Department of Mineral Sciences, Smithsonian Institution  
Washington, D.C. 20560*

DONALD R. PEACOR

*Department of Geology and Mineralogy, University of Michigan  
Ann Arbor, Michigan 48109*

AND B. DARKO STURMAN

*Department of Mineralogy and Geology, Royal Ontario Museum  
Toronto, Ontario, Canada*

### Abstract

Paulmooreite is a new lead arsenite,  $Pb_2As_2O_6$ , from Långban, Värmland, Sweden. It was known in the Flink lists as #305 and #49. The new mineral is monoclinic,  $P2_1$ , with  $a = 8.558(5)$ ,  $b = 5.654(3)$ ,  $c = 13.606(8) \text{ \AA}$ ,  $\beta = 108.88(5)^\circ$ . The strongest lines in the X-ray diffraction pattern are  $3.30\ 100\ 21\bar{2}$  or  $210$ ,  $2.761\ 80\ 021$ ,  $2.905\ 80\ 11\bar{4}$ ,  $1.766\ 70\ 32\bar{5}$  or  $12\bar{6}$ , and  $3.02\ 70\ 21\bar{3}$  or  $202$ . Paulmooreite is colorless to light orange. The mineral has complex morphology; crystals are tabular either on  $\{001\}$  or  $\{100\}$ . The forms present are  $\{100\}$ ,  $\{001\}$ ,  $\{011\}$ ,  $\{10\bar{2}\}$ ,  $\{110\}$ , and  $\{111\}$ . There is one perfect cleavage,  $\{001\}$ . The density is 6.95 (meas), 6.86 (calc)  $\text{g/cm}^3$ . The hardness is approximately 3 (Mohs). Optically, paulmooreite is biaxial positive with  $2V_z = 65(5)^\circ$ . The refractive indices are greater than 1.9,  $Y$  is parallel to  $b$ ,  $Z \Delta c = 10(1)^\circ$ . The mineral occurs as euhedral crystals in vugs with green andradite and as colorless crystals on fracture surfaces.

### Introduction

This new mineral was discovered during an investigation of some unknown minerals from Långban, Sweden. The powder X-ray diffraction data did not match those of any known species, and we therefore proceeded on the assumption that this was a new mineral. Unknown to us at the time, this mineral had been previously noted by Gustav Flink (in Aminoff, 1921; Flink, 1924), a truly remarkable mineralogist who has contributed much to our understanding of the mineralogy of Långban (Moore, 1970). The new mineral was previously known as Flink #305 and Flink #49. The uniqueness of Flink #49 was also noted by Moore *et al.* (1971).

We take great pleasure in naming this new mineral in honor of Professor Paul Brian Moore of the Department of the Geophysical Sciences at the University of Chicago. We do so in recognition and com-

mendation of his contributions to mineralogy, most notably to the mineralogy of Långban, Sweden, and the insights he has provided to the complex paragenesis and structural relationships of pegmatite phosphates and to topological relationships in crystal structures. The new mineral had been previously examined but not described by Paul Moore, and he graciously gave us his available material and mineralogical notes.

The mineral and the name have been approved by the Commission on New Minerals and Mineral Names, IMA. The type specimens are deposited in the mineral collection of the National Museum of Natural History, Smithsonian Institution, under catalog numbers 134973 and 142974.

### Occurrence

Paulmooreite occurs as small, colorless to light orange crystals in varied parageneses on at least three

specimens. On NMNH specimen #134973, it occurs with fine-grained hematite which comprises most of the specimen. This hematite is coated with an impure calcite containing euhedral magnetite, which is coated, in turn, with calcite, mimetite, and paulmooreite. On specimen NMNH #142974 (Flink #305) (Riksmuseet Stockholm #252356) the principal matrix is also a fine-grained hematite overlain by a mixed zone of calcite and andradite which is in turn followed by isolated light orange crystals of paulmooreite in the interstitial spaces. No matrix specimen for Flink #49 was available, and the specimen is still in the Naturhistoriska Riksmuseet in Stockholm (Paul Moore, personal communication). Hence, the amount of paulmooreite known is very small, and the mineral must be considered very rare.

### Physical properties

Paulmooreite is colorless to light orange, and the streak is colorless. The mineral has an adamantine luster on cleavage and fracture surfaces. The luster of the crystal faces is also very high and resembles that of cerussite. The mineral is very brittle; the degree of brittleness is similar to that of wulfenite. The density could not be measured with great accuracy due to the extremely small amount of material available and the fact that the density is much greater than known heavy liquids. Careful observation of rate-of-sinking in Clerici solution, relative to the rate-of-sinking of crystals of similar size and configuration of chemically-analyzed species of known density provided an estimated density of 6.9g/cm<sup>3</sup>. Paul Moore (personal communication) obtained a specific gravity of 7.01 from a number of crystals with a Berman microbalance. Both measurements are in good agreement with the calculated value of 6.86 g/cm<sup>3</sup>. The hardness (Mohs) is approximately 3. There is one perfect cleavage, {001}, which is very easily produced. The mineral does not luminesce in ultraviolet radiation. Paulmooreite is readily soluble in 1:1 HNO<sub>3</sub> and whitens within minutes in 1:1 HCl to an opaque white color.

### Optical data

Paulmooreite is biaxial positive with  $2V_z = 65(5)^\circ$ . The dispersion of the optic axes is very strong,  $r > v$ . The true refractive indices could not be determined because they are too high, but  $\beta$  is greater than 1.9 and is estimated to be between 1.9 and 2.0. Partial birefringence was measured with the tilting compensator as  $\gamma - \beta = 0.080$ , and maximum birefringence was calculated from  $2V$  and partial birefringence

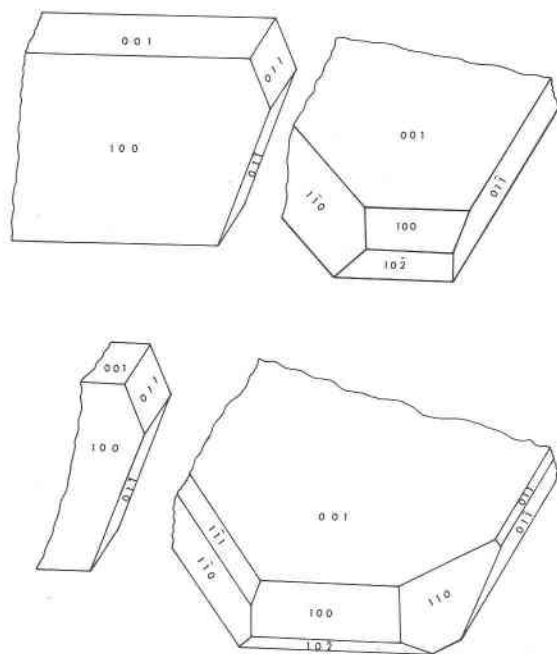


Fig. 1. Crystal drawings of paulmooreite showing the diversity of morphological development.

as  $\gamma - \alpha = 0.110$ . The orientation of the indicatrix is  $Y$  parallel to  $b$ ,  $Z \wedge c = 10(1)^\circ$  in acute angle between crystallographic axes  $a$  and  $c$ . Paulmooreite is not pleochroic.

### Morphology

Paulmooreite occurs as monoclinic euhedral crystals up to 0.5 mm, tabular on {100} or {001}. The crystals are lustrous and occur as euhedrons both in vugs and coating fractures in the matrix. Four paulmooreite crystals were examined and measured using the two-circle reflecting goniometer. The forms {100}, {001}, and {011} are present on all four crystals. In addition, several crystals exhibited the forms {10 $\bar{2}$ }, {110}, and {111}. Crystal drawings are shown in Figure 1 and demonstrate the morphological diversity of this species. A scanning electron photomicrograph of paulmooreite is shown in Figure 2.

### Chemistry

Paulmooreite was chemically analyzed with an ARL-SEM-Q electron microprobe utilizing an operating voltage of 15 kV and a beam current, determined using a beam-current monitor, of 0.15  $\mu$ A. The standards used were synthetic olivenite for arsenic and PbO for lead. A wavelength-dispersive scan indicated the absence of any other elements with atomic num-

ber above 9, except for trace amounts of barium and manganese. There was insufficient material for a spectrographic analysis. The data were corrected using the MAGIC-4 computer program. The resultant analysis yielded 69.23 PbO, 30.07 As<sub>2</sub>O<sub>3</sub>, sum = 99.30 percent, in excellent agreement with the theoretical composition of 69.29 PbO, 30.71 As<sub>2</sub>O<sub>3</sub>, sum = 100.00 percent. The chemical formula of paulmooreite, derived from this analysis and the crystallographic and physical properties, is Pb<sub>2</sub>As<sub>2</sub>O<sub>5</sub>. This composition has been confirmed through the solution of the crystal structure by Araki and Moore (personal communication).

### X-ray crystallography

Single crystals were studied using the Weissenberg and precession methods. The extinctions were initially observed to be consistent only with space group  $P2_1/c$ . However, very careful examination of the photographs revealed the presence of extremely weak reflections of the type  $h0l$  with  $l$  odd, the strongest of which is 005. The true space group is therefore  $P2_1$ , although the deviation of the structure from space group  $P2_1/c$  is extremely small. The reflections violating the rule for a  $c$  glide are not due to multiple reflection because they appear with the same relative intensity on both precession and Weissenberg photographs. The lattice parameters obtained from the single-crystal techniques were refined by least squares using the data obtained from a multi-crystalline powder-mount Gandolfi diffraction pattern. The pattern was obtained with CuK $\alpha$  radiation (Ni filter) and N.B.S. silicon as an internal standard. The refined lattice parameters are:  $a = 8.558(5)$ ,  $b = 5.654(3)$ ,  $c =$

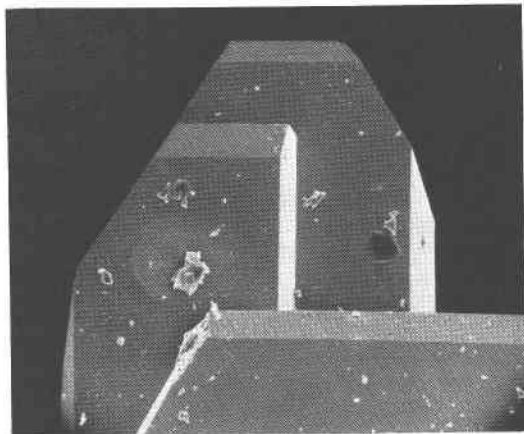


Fig. 2. Scanning electron photomicrograph of paulmooreite (magnification 180 $\times$ ).

Table 1. X-ray diffraction data for paulmooreite

$d_{\text{obs}}$	$d_{\text{calc}}$	hkl	$I/I_0$	$d_{\text{obs}}$	$d_{\text{calc}}$	hkl	$I/I_0$
6.45	6.44	002	30	1.867	1.866	321	2
6.12	6.09	102	30		1.865	031	
4.26	4.35	012	50	1.818	1.820	415	5 B
4.06	4.07	202	40		1.810	215	
	4.05	200		1.766	1.768	325	70
3.50	3.49	113	40		1.767	126	
				1.725	1.726	033	60 B
					1.725	231	
3.42	3.42	013	50				
	3.41	211					
3.30	3.30	212	100	1.691	1.693	423	15
	3.29	210			1.692	412	
3.22	3.22	004	20		1.690	421	
3.02	3.02	213	70	1.666	1.668	233	20
	3.01	202			1.664	231	
2.905	2.908	114	80	1.612			10
				1.596			5
2.761	2.761	021	80				
2.708	2.705	104	20	1.579			5
2.676	2.681	214	15	1.553			10
	2.671	121		1.526			5
2.565	2.564	122	1	1.502			2
	2.560	312		1.488			2
2.506	2.506	304	15	1.439			2
2.453	2.452	115	20	1.415			5
2.360	2.361	023	15	1.405			2
	2.359	221		1.380			5
2.258	2.263	106	5	1.347			5
2.218	2.219	223	15	1.310			5
	2.216	206					
2.167	2.165	123	15	1.290			1
				1.267			2
2.128	2.124	024	1	1.255			5
	2.024	400	60	1.229			5
1.998	2.003	322	2	1.207			1
	2.001	412		1.198			1
	2.001	321					
1.954	1.954	124	10	1.160			5
	1.952	320		1.139			2
				1.130			2
				1.090			2
				1.072			5

13.606(8)Å,  $\beta = 108.88(5)^\circ$ . The indexed diffraction data are listed in Table 1.

### Acknowledgments

The authors are indebted to Dr. Sidney Williams for a critical reading of the manuscript; to Richard Johnson and Grover Moreland for preparation of polished sections; and to Charles Obermeyer for assistance with the microprobe.

### References

- Aminoff, G. (1921) Svensk mineralogisk forskning. *Geol. Fören. Förh.*, 43, 188–201.
- Flink, G. (1924) Förteckning på Stockholms Högskolas samling av nya eller ofullständigt beskrivna mineral från Långban (försättning). *Geol. Fören. Förh.*, 46, 704–709.
- Moore, P. B. (1970) Mineralogy & chemistry of Långban-type deposits in Bergslagen, Sweden. *Mineral. Record.*, 1, 154–172.
- , F. E. Wickman, R. Blix, O. Gabrielson, M. E. Gillberg and A. Parwel (1971) The Flink collection of unknown Långban minerals: a progress report. *Geol. Fören. Förh.*, 93, 289–301.

Manuscript received, August 1, 1978;  
accepted for publication, September 2, 1978.