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Zapatalite, a new mineral from Sonora, Mexico

SIDNEY A. WILLIAMS

British Museum (Natural History), London, S.W. 7, England[1]

SUMMARY. Zapatalite, $Cu_3Al_4(PO_4)_3(OH)_9 \cdot 4H_2O$, was first found at a small prospect north-west of Cerro Morita, 27 kilometers south-west of Agua Prieta, Sonora. It occurs in silicified and brecciated limestone with libethenite, chenevixite, beaverite, alunite, and pseudomalachite.

Zapatalite is pale (faience) blue with pale blue streak; H = $1\frac{1}{2}$, G = $3{\cdot}016 \pm 0{\cdot}026$. It is soluble in cold dilute acids and decomposed by 20 % KOH. Duplicate analyses on samples of about 9 and 15 mg gave CuO 27·92, 25·77 %; Al_2O_3 20·16, 20·26 %; P_2O_5 20·69, 22·51 %; H_2O 15·46, 15·79 %; insol. (baryte and quartz), 15·46, 15·79 %. This leads to the formula $Cu_3Al_4(PO_4)_3(OH)_9 \cdot 4H_2O$.

The cell can be indexed as tetragonal with a 15·22Å, c 11·52Å, and a volume of 2669Å^3. If $Z = 6$, empirical cell contents are $Cu_{19{\cdot}4}Al_{22{\cdot}8}(PO_4)_{17{\cdot}6}(OH)_{55{\cdot}4}22 \cdot 2H_2O$, and the calculated G = 3·017. Strongest lines of the powder pattern are 7·62 (10), 11·60 (10), 5·75 (7), 6·82 (7), 3·04 (5), 2·53 (5), 2·95 (4), and 2·88 (4).

Pale green in thin section with feeble dichroism in green, with $\epsilon > \omega$. The good basal cleavage is a length slow direction. Indices for Na-D are $\epsilon = 1{\cdot}635$, $\omega = 1{\cdot}646$. Usually uniaxial (—), but may be biaxial (—) with variable 2 V.

Named for Emiliano Zapata (1879–1919), a popular hero of the Mexican revolution. Type specimens to be left with British Museum (Natural History) and the University of Arizona.

ZAPATALITE, $Cu_3Al_4(PO_4)_3(OH)_9 \cdot 4H_2O$, was first found in the autumn of 1969 at a small prospect in Sonora. This prospect is at the north-west end of Cerro Morita and is about 27 km south-west of Agua Prieta, Sonora. The approximate coordinates are 31° 17′ N., 109° 50′ W.

The prospect pit where zapatalite occurs is in brecciated and intensely silicified limestone thought to be of Cretaceous age. The breccia has been cemented by baryte, calcite, drusy quartz, and minor amounts of sulphides. The workings are so shallow that everything exposed by mining has been oxidized, and only traces of hypogene sulphides may be found. The oxide assemblage suggests that tetrahedrite–tennantite was probably the most abundant sulphide, but none has been preserved. Cinnabar is the only sulphide present in comparative abundance, and traces of chalcopyrite and pyrite occur only where protected by enclosing quartz. Chalcosine, covelline, and argentite have been observed but are supergene.

A number of oxide minerals occur as thin colourful crusts on fractures and as minute crystals in cavities. Most abundant are libethenite, chenevixite, pseudomalachite, alunite, and beaverite. Chenevixite and pseudomalachite occur as tiny

[1] Permanent address: Phelps Dodge Corporation, Douglas, Arizona, 85607, U.S.A.

corroded crystals, and alunite and beaverite as clusters of small scales, all perched upon the libethenite. Less common are native silver, cornwallite, jarosite, hematite, goethite, malachite, and chrysocolla. Locally one may find massive and earthy pockets of yellow and brown antimonates of iron, zinc, and copper. X-ray powder data show the presence of several species, some of which occur in quantity sufficient for further examination.

Zapatalite is uncommon at the locality. It occurs as massive, poorly crystalline material filling cavities, and appears to have replaced both libethenite and pseudomalachite. It may, in turn, alter to chrysocolla.

Physical properties. Zapatalite is pale blue (faience blue) with a similar but paler streak. The colour is in the Blue-Green group, R.H.S. 111.A (Royal Horticultural Society, London). Upon casual examination it resembles chrysocolla, chalcoalumite, or, as I first thought, chalcophyllite.

The hardness on Mohs' scale is approximately $1\frac{1}{2}$ and it is gummy or sectile when pressed with a needle. The specific gravity is 3·016 $\pm$0·026, when measured in toluene at 24 °C on the Berman balance. Four trials were made on coarse powders weighing between 4 and 7 mg.

Chemistry. Optical emission spectrographic analysis showed strong lines for Cu, P, and Al, and minor amounts of Si, Ba, Fe, As, Sr, and Zn. Subsequent work showed the Si, Ba, and Sr to be due to admixed baryte and quartz. It was not feasible to separate these two minerals, at least in preparing quantities sufficient for analysis, so the chemical analysis was planned to separate quartz and baryte as insoluble residue. Analyses of the residues in the duplicate runs showed that, in each case, they consisted entirely of quartz and slightly strontian baryte.

Two samples were dried at 150° and 800 °C and water loss determined. A pyrosulphate fusion of the remainder was taken into solution and analyzed for Cu, Al, and P. The results of the two analyses, and a partial analysis for minor elements, are shown in Table I. Columns 6 and 7 in this table show the empirical cell contents adjusted so that $P_2O_5 = 9$. Errors given relate to cell volume and specific gravity determinations only. Analytical error is clearly larger but could not be determined; comparison of the two columns will give an idea of its magnitude.

Analysis 3 in table I is of slightly greenish zapatalite, which had previously shown small Fe and Zn peaks upon X-ray fluorescence analysis. Small amounts of Fe^{3+} and Zn^{2+} may substitute for Al and Cu respectively but, at least at the type locality, such substitutions are quite limited.

Zapatalite is readily soluble in dilute, cold HNO_3 and HCl and is decomposed by 20 % KOH.

Optics. In thin section zapatalite looks micaceous and might be mistaken for chrysocolla, or even a chlorite. Most orientations show the trace of the good basal cleavage, a direction that is invariably length slow with extinction parallel thereto.

Basal sections give a figure that is sensibly uniaxial negative, but some larger grains may give biaxial figures with small to moderate $2V_\alpha$. These anomalous grains may

TABLE I. *Chemical analyses of zapatalite*

	1	2	3	4	5	6	7
CuO	27·92 %	25·77 %	—	31·85 %	29·51 %	21·6±0·2	18·3±0·2
Al_2O_3	20·16	20·26	—	23·98	25·22	12·2±0·1	11·3±0·1
P_2O_5	20·69	22·51	—	25·63	26·33	9·0±0·1	9·0±0·1
H_2O^+	15·46	15·79	—	18·54	18·94	52·9±0·4	48·9±0·4
Insol.	15·83	15·54	6·37				
Fe_2O_3	—	—	1·16				
ZnO	—	—	0·25				
As_2O_5	< 0·03	—	—				
Total	100·06	99·87	—	100·00	100·00		

1. Analysis on 9·385 mg.
2. Analysis on 15·580 mg.
3. Partial analysis on 7·421 mg.
4. Analyses 1 and 2 recalculated to 100 % and then averaged.
5. $Cu_3Al_4(PO_4)_3(OH)_9 \cdot 4H_2O$.
6. Empirical cell contents for analysis 1 adjusted so $P_2O_5 = 9$.
7. Empirical cell contents for analysis 2 adjusted so $P_2O_5 = 9$.

All analyses by Schwarzkopf Microanalytical Laboratories, Woodside, N.Y.

TABLE II. *Indexed powder data for zapatalite; Cr-K radiation, 114·6 mm Wilson camera*

I/I_0	d_{meas}	d_{calc}	*hkl*	I/I_0	d_{meas}	d_{calc}	*hkl*	I/I_0	d_{meas}
99	11·601 Å	11·518 Å	001			3·045 Å	332	8	2·096
8	9·167	9·185	011	48	3·042 Å	3·045	050	22	2·046
100	7·617	7·612	020			3·045	340	7	2·001
69	6·817	6·808	120	40	2·951	2·944	051	30	1·896
73	5·754	5·759	002			2·944	341	28	1·749
9	4·812	4·814	130	37	2·882	2·880	004	11	1·628
44	4·584	4·593	022	25	2·747	2·745	251	11	1·563
17	4·439	4·442	131	9	2·671	2·661	143	8	1·540
4	3·977	3·964	231	28	2·596	2·661	350	8	1·521
32	3·819	3·807	032			2·539	224	14	1·501
3	3·639	3·616	113	45	2·531	2·538	252	15	1·476
29	3·504	3·516	141			2·537	060	13	1·451
30	3·412	3·405	232	13	2·460			11	1·423
		3·404	240	12	2·398			7	1·370
30	3·262	3·264	241	18	2·396			11	1·286
29	3·115	3·126	232	16	2·292			12	1·199
		3·108	142	32	2·205				

have been partially dehydrated during preparation of the thin section or they may show incipient replacement by chrysocolla. The uniaxial grains show feeble dichroism in green with $\epsilon > \omega$. Refractive indices for the sodium D line are $\epsilon = 1{\cdot}635$, $\omega = 1{\cdot}646$.

X-ray results. No single crystals or undistorted crystal fragments could be found. Measurement of the rotation photograph of a tiny cleavage flake suggested a basal

spacing in excess of 11Å, but the crystal was far too bad to use for examination of the layer lines.

Powder photographs of zapatalite show numerous, slightly diffuse lines. Measurements of several patterns taken from fragments in different specimens indicate that a small but real variation in cell dimensions occurs; the cause of the variation was not investigated.

Attempts at indexing the powder pattern were unsuccessful until a solution was found by R. J. Davis of the British Museum (Natural History). The proposed cell he found indexes the lines quite well, and its high symmetry was later supported by the optical study. The cell volume gives a calculated specific gravity of 3·017, which agrees suspiciously well with the measured value of 3·016.

The proposed tetragonal cell has a 15·223 Å, c 11·518 Å, and a volume of 2669·36 Å^3. If $Z = 6$ the theoretical cell contents are $Cu_{18}Al_{24}(PO_4)_{18}(OH)_{54}.24H_2O$, while the empirical cell contents (Hey, 1939; 1954) are $Cu_{19\cdot4}Al_{22\cdot8}(PO_4)_{17\cdot6}(OH)_{55\cdot4}\cdot22\cdot2H_2O$.

The indexed powder data are presented in table II. The measured d values are averages from several spindles.

The name is in honour of Emiliano Zapata (1879–1919) who led revolts in his home state of Morelos and played a major and beneficial role in the Mexican Revolution (Womack, 1969; Millon, 1969). The mineral has been approved by the Commission for New Minerals and New Mineral Names, I.M.A. Type specimens will be deposited at the British Museum (Natural History) and at the University of Arizona.

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REFERENCES

HEY (M. H.), 1939. On the presentation of chemical analyses of minerals. *Min. Mag.* **25**, 402–12.
—— 1954. A further note on the presentation of chemical analyses of minerals. Ibid. **30**, 481–97.
MILLON (R. P.), 1969. *Zapata, the ideology of a peasant revolution.* International Publishers, New York, N.Y.
WOMACK (J.), 1969. *Zapata and the Mexican revolution.* A. Knopf, New York, N.Y.

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