Painite, a new mineral from Mogok, Burma.

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Summary. A singly terminated transparent, deep-garnet-red crystal originally weighing 1·7 g. from a gem gravel from Mogok, Burma, proves to be a new mineral having Al_2O_3 76·2, SiO_2 5·6, B_2O_3 2·2, CaO 15·7, H_2O 0·7, Fe_2O_3 and MnO traces, total 100·4. Sp. gr. 4·01; ω 1·8159, ϵ 1·7875; H 8. The hexagonal unit cell has a 8·725, c 8·46 Å., space group $P6_3$, $P6_3/m$ or $P6_3 22$, and contains approximately 38 O. The name painite is proposed in honour of A. C. D. Pain who recognized the unusual nature of the crystal.

IN 1952 Mr. A. C. D. Pain sent to London a deep-garnet-red crystal weighing 1·7 g. which had been found in one of the small ruby mines near Ohngaing village, Mogok, Upper Burma. The crystal after passing through several hands came for examination to the London Chamber of Commerce Laboratory where its optical properties and density were accurately measured. As it was found impossible to identify the mineral from these constants it was passed to the British Museum Department of Mineralogy for further tests. Subsequent work has shown that the mineral is new to science and it has been named painite after Mr. A. C. D. Pain, the enthusiastic gem collector who first recognized the unusual nature of the crystal, agreed to a portion being sawn from the fractured base for chemical and X-ray work and subsequently presented the crystal to the British Museum (Natural History) where it is registered under the number B.M. 1954,192. The present weight of the crystal is 1·48 g.

X-ray determinations. When an X-ray powder photograph and an arc spectrogram did not provide a solution to the riddle of identification, a single-crystal X-ray examination was carried out on a small fragment of the sawn-off portion by stationary- and moving-film methods. The symmetry was found to be hexagonal and Weissenberg photographs of zero, 1st, and 2nd layer-lines about [0001] and [10$\bar{1}$0] showed the systematic space-group absence 000*l* for *l* odd: the space-group is thus $P6_3$, $P6_3/m$, or $P6_3 22$.

The cell dimensions were determined from the zero layer of back-reflection rotation photographs indexed by reference to Weissenberg photographs. For the *a*-axis the high-order reflections of type *hki*0 were plotted against $\sin^2\theta$ and extrapolated to $\sin^2\theta = 1$ but for the *c*-axis insufficient reflections of suitable spacing were available and the accuracy of the value for the *c*-spacing is consequently somewhat lower than that for *a*. The hexagonal cell dimensions are *a* 8·725±0·005, *c* 8·46±0·01.

An X-ray powder photograph of painite (fig. 1) has been indexed using these cell dimensions (table I).

Physical properties. The hardness is about 8. The refractive indices determined by the method of minimum deviation on a table spectrometer for sodium light are ω 1·8159, ϵ 1·7875; the mineral is thus uniaxial negative with $\omega - \epsilon$ 0·0284. Pleochroism ranges from ruby red for vibrations parallel to *c* to pale brownish-orange perpendicular to *c*.

The density of the whole crystal was first determined by hydrostatic weighing in ethylene dibromide and found to be 4·01±0·01. The crystal contains a number of inclusions, some rounded and others tabular and hexagonal in outline (fig. 5), as well as some feather-like sheets of minute cavities similar to those seen in gem-corundum. In view of the inclusions a second density determination was made on an inclusion-free fragment by flotation in Clerici solution and gave 4·00±0·02.

Morphology. The development of the crystal is shown in the photographs figs. 2 and 3 and the parallel perspective drawing fig. 4; in two-circle coordinates with the normal to *c*(0001) at $\rho = 0°$ and the normal to *a*(01$\bar{1}$0) at $\phi = 0°$, the view-points of these figures are: fig. 2, ϕ 90°, ρ 65°; fig. 3, ϕ 300°, ρ 45°; fig. 4, ϕ 257°, ρ 40°. It will be seen that the notably pseudorthorhombic appearance is due to four faces of the form *a*{10$\bar{1}$0} being well developed and one parallel pair very narrow.

The prism faces *a*{10$\bar{1}$0}, *m*{11$\bar{2}$0}, *k*{12$\bar{3}$0}, and *l*{13$\bar{4}$0} all give excellent reflections, though some of the faces are very narrow strips. One prism face, seen to the left of fig. 2, is strongly striated, and is an oscillatory combination of *a*(1$\bar{1}$00), *k*(2$\bar{3}$10), and *l*(3$\bar{4}$10). The basal plane *c*(0001) and the pyramids *o*{11$\bar{2}$1}, *p*{11$\bar{2}$2}, *q*{20$\bar{2}$1}, *r*{10$\bar{1}$1}, and *s*{10$\bar{1}$2} are matt, with rounded edges, but are sensibly plane and readily identifiable; it is not, however, possible to make measurements with any better accuracy than about 1 to 2°, and the axial ratio is therefore taken from

TABLE I. X-ray powder data for painite.

I.	$d_{\text{obs.}}$	$d_{\text{calc.}}$	*hkil.*
m	7·63	7·56	$10\bar{1}0$
vs	5·76	5·63	$10\bar{1}1$
vvw	4·37	4·36	$11\bar{2}0$
vw	4·24	4·23	0002
s	3·70	3·69	$10\bar{1}2$
		3·78	$20\bar{2}0$
m	3·45	3·45	$20\bar{2}1$
mw	3·03	3·04	$11\bar{2}2$
m	2·820	2·820	0003
		2·816	$20\bar{2}2$
mw	2·707	2·706	$21\bar{3}0$
vw	2·649	2·643	$10\bar{1}3$
vs	2·520	2·518	$30\bar{3}0$
s	2·370	2·368	$11\bar{2}3$
		2·367	$21\bar{3}2$
w	2·260	2·260	$20\bar{2}3$
vw	2·182	2·181	$22\bar{4}0$
vw	2·158	2·163	$30\bar{3}2$
vvw	2·119	2·115	0004
		2·112	$22\bar{4}1$
m	2·093	2·095	$31\bar{4}0$
mw	2·036	2·037	$10\bar{1}4$
		2·034	$31\bar{4}1$
s	2·008	2·007	$21\bar{3}3$
vvw	1·975	1·977	$22\bar{4}2$
mw	1·904	1·903	$11\bar{2}4$
w	1·880	1·878	$30\bar{3}3$
			$31\bar{4}2$
vw	1·843	1·843	$40\bar{4}1$
		1·846	$20\bar{2}4$
ms	1·726	1·725	$40\bar{4}2$
w	1·699	1·700	$21\bar{3}4$
		1·698	$32\bar{5}1$
mw	1·682	1·681	$31\bar{4}3$
vvw	1·651	1·651	$10\bar{1}5$
		1·649	$41\bar{5}0$
mw	1·620	1·620	$30\bar{3}4$
		1·618	$41\bar{5}1$
mw	1·603	1·604	$32\bar{5}2$
		1·603	$11\bar{2}5$
vw	1·570	1·569	$40\bar{4}3$
vvw	1·545	1·545	$20\bar{2}5$
vw	1·520	1·518	$22\bar{4}4$
vvw	1·476	1·477	$32\bar{5}3$
m	1·453	1·454	$33\bar{6}0$
		1·456	$21\bar{3}5$
ms	1·423	1·423	$41\bar{5}3$
		1·428	$50\bar{5}2$
			$42\bar{6}0$
mw	1·411	1·410	0006
		1·409	$40\bar{4}4$
		1·408	$42\bar{6}1$
vw	1·389	1·386	$10\bar{1}6$
vvw	1·377	1·375	$33\bar{6}2$
vvw	1·353	1·353	$42\bar{6}2$
w	1·340	1·340	$51\bar{6}1$
		1·341	$32\bar{5}4$
		1·342	$11\bar{2}6$
vw b	1·318	1·316	$31\bar{4}5$
		1·321	$20\bar{2}6$
w	1·301	1·300	$41\bar{5}4$
w	1·292	1·292	$51\bar{6}2$
			$33\bar{6}3$
w	1·275	1·274	$42\bar{6}3$
vvw	1·268	1·264	$21\bar{3}6$
mw	1·260	1·260	$40\bar{4}5$
		1·259	$60\bar{6}0$
vvw	1·243	1·242	$43\bar{7}0$
		1·246	$60\bar{6}1$
mw	1·231	1·230	$50\bar{5}4$
		1·229	$30\bar{3}6$
			$43\bar{7}1$
vw	1·211	1·211	$32\bar{5}5$
		1·210	$52\bar{7}0$
		1·209	0007
vw	1·200	1·198	$52\bar{7}1$
vvw	1·169	1·170	$31\bar{4}6$
vvw	1·162	1·163	$52\bar{7}2$
		1·159	$20\bar{2}7$
vw	1·152	1·150	$60\bar{6}3$
vvw	1·142	1·142	$51\bar{6}4$
			$61\bar{7}1$
vvw	1·139	1·137	$43\bar{7}3$
vvw b	1·132	1·130	$40\bar{4}6$
w	1·112	1·113	$21\bar{3}7$
vvw	1·095	1·094	$32\bar{5}6$
vw	1·082	1·090	$44\bar{8}0$
vvw	1·068	1·072	$41\bar{5}6$
vvw	1·060	1·057	0008
			$22\bar{4}7$
vw	1·051		
w	1·048	1·047	$10\bar{1}8$
			$31\bar{4}7$
vvw	1·040		
vw	1·028	1·028	$11\bar{2}8$
vw	1·019	1·018	$40\bar{4}7$
w	1·014		
vvw	1·009		
vw	1·003		
vvw	1·000		
vvw	0·992	0·991	$32\bar{5}7$

the X-ray study ($c:a = 0{\cdot}970 \pm 0{\cdot}002$). From this the angles between the several pyramids and the basal plane were calculated and compared with the observations:

Calc.	*o* 62° 43′,	*p* 44° 7′,	*q* 65° 57′,	*r* 48° 14′,	*s* 29° 15′
Obs.	64°	46½°	68°	49½°	30½°

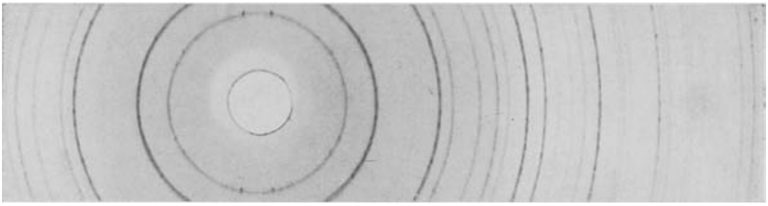

FIG. 1. X-ray powder photograph of painite. 11·46 cm. diameter camera, Cu-Kα radiation.

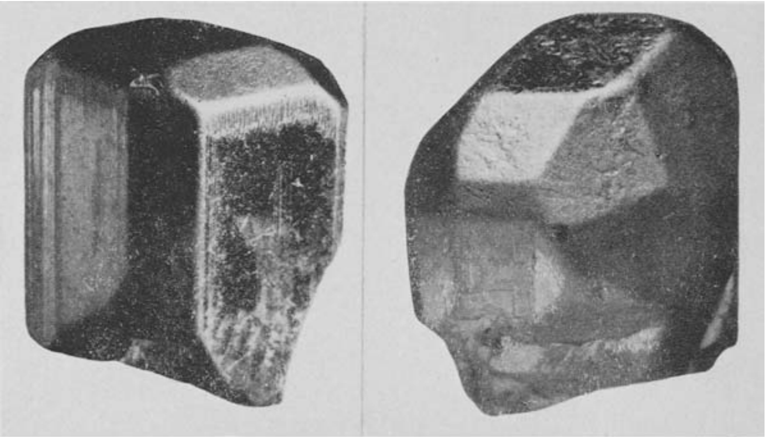

FIG. 2. FIG. 3.

FIGS. 2 and 3. Photographs of the crystal of painite from two viewpoints: fig. 2 (left) about 15° from the normal to $m(2\bar{1}\bar{1}0)$, and fig. 3 (right) nearly normal to $(\bar{1}101)$.

Chemistry. Painite is a highly resistant mineral, insoluble in acids, and only slowly attacked by fusion with sodium carbonate or with sodium pyrosulphate. For the chemical analysis it proved necessary to recover the unattacked material from the first sodium carbonate fusion (1 hour) and repeat the operation. The determination of B_2O_3 was made on a portion of 18 mg., and the remainder of the analysis in duplicate

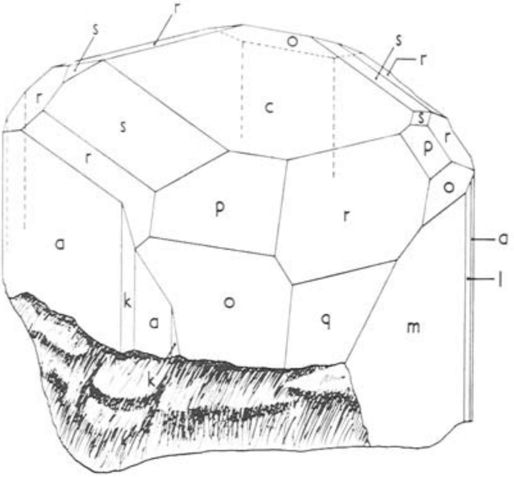

FIG. 4. Parallel perspective drawing of the crystal of painite, from a viewpoint between *r* $(\bar{1}011)$ and *p*$(\bar{2}112)$.

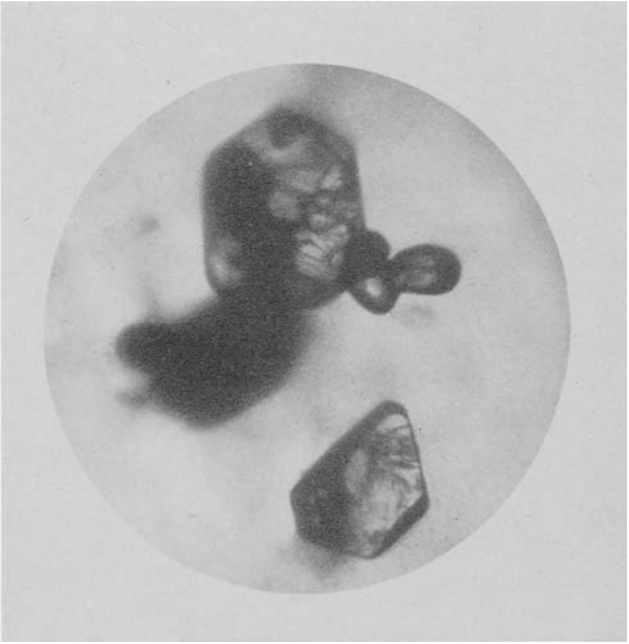

FIG. 5. Photomicrograph through *c*(0001) of inclusions in painite, some tabular with hexagonal outline and others rounded.

on portions of 38 mg. and 17 mg. The results are shown in table II; the assessed probable errors are based on assumed limits of Al_2O_3 ±0·3 %, SiO_2 ±0·5 %, B_2O_3 ±0·3 %, and CaO ±0·2 %, together with ±0·02 in the density; the probable error of the density determination (4·01±0·01) was doubled to allow for the inclusions, although a separate determination by flotation on a small fragment free from inclusions gave 4·00±0·01, indicating that these do not affect the density appreciably. The water was assumed to be an impurity adsorbed during grinding, and therefore no correction to the density was made for adsorbed water.

TABLE II. Chemical analyses and empirical unit-cell contents of painite.

Al_2O_3	76·2	Al	20·20±0·14	Σ (cations) 26·09±0·22
SiO_2	5·6	Si	1·26±0·11	
B_2O_3	2·2	B	0·85±0·12	
CaO	15·7	Ca	3·78±0·05	
H_2O	0·7	O	37·88±0·22	
	100·4			

The empirical unit-cell contents clearly indicate an oxygen content of 38, and suggest a cation content Ca_4SiBAl_{20}, but this would only require 37½ oxygen, and it is evident that either the oxygen or the total cations must be a non-integral number.

The nature of painite. Painite appears to be more closely related chemically to compounds of the 'β-alumina' type[1] (e.g. $3CaO.16Al_2O_3$) than to any other compound we have been able to trace. However, the cell-dimensions do not support this affinity. A relationship is suggested by the cell-dimensions to compounds isostructural with $BaAl_2O_4$ (a 5·21×$\sqrt{3}$ = 9·00; c 8·76)[2] but this must be excluded because the packing density of these is only about two-thirds that of painite. It is evident from the high density, very close to that of corundum, that the oxygen atoms of the structure must be nearly close-packed: but there is no obvious structural relationship either to corundum or to spinel.

We wish to acknowledge the assistance of Miss J. Tolliday, Miss E. Fejer, and Mr. D. Williams with the X-ray determinations.

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[1] K. Lagerqvist, S. Wallmark, and A. Westgren, Zeits. anorg. Chem., 1937, vol. 234, p. 12 [M.A. 7–235].

[2] S. Wallmark and A. Westgren, Arkiv Kemi, Min. Geol., 1937, vol. 12B, no. 35 [M.A. 8–366].