

*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  $\text{Al}_2\text{O}_3$  76.2,  $\text{SiO}_2$  5.6,  $\text{B}_2\text{O}_3$  2.2,  $\text{CaO}$  15.7,  $\text{H}_2\text{O}$  0.7,  $\text{Fe}_2\text{O}_3$  and  $\text{MnO}$  traces, total 100.4. Sp. gr. 4.01;  $\omega$  1.8159,  $\epsilon$  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.

**I**N 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  $000l$  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  $hki0$  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  $a\ 8.725 \pm 0.005$ ,  $c\ 8.46 \pm 0.01$ .

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  $\omega\ 1.8159$ ,  $\epsilon\ 1.7875$ ; 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  $4.01 \pm 0.01$ . 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  $4.00 \pm 0.02$ .

*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  $\rho = 0^\circ$  and the normal to  $a(01\bar{1}0)$  at  $\phi = 0^\circ$ , the view-points of these figures are: fig. 2,  $\phi\ 90^\circ$ ,  $\rho\ 65^\circ$ ; fig. 3,  $\phi\ 300^\circ$ ,  $\rho\ 45^\circ$ ; fig. 4,  $\phi\ 257^\circ$ ,  $\rho\ 40^\circ$ . 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>I.</i>	<i>d</i> <sub>obs.</sub>	<i>d</i> <sub>calc.</sub>	<i>hkl.</i>	<i>I.</i>	<i>d</i> <sub>obs.</sub>	<i>d</i> <sub>calc.</sub>	<i>hkl.</i>
m	7.63	7.56	10 $\bar{1}$ 0	vw	1.389	1.386	10 $\bar{1}$ 6
vs	5.76	5.63	10 $\bar{1}$ 1	vvw	1.377	1.375	3362
vvw	4.37	4.36	11 $\bar{2}$ 0	vvw	1.353	1.353	4262
vw	4.24	4.23	0002				
s	3.70	{ 3.69 3.78	{ 1012 2020	w	1.340	{ 1.340 1.341 1.342	{ 51 $\bar{6}$ 1 3254 1126
m	3.45	3.45	2021	vw b	1.318	{ 1.316 1.321	{ 3145 2026
mw	3.03	3.04	1122	w	1.301	1.300	4154
m	2.820	{ 2.820 2.816	{ 0003 2022	w	1.292	1.292	{ 51 $\bar{6}$ 2 3363
mw	2.707	2.706	2130	w	1.275	1.274	4263
vw	2.649	2.643	10 $\bar{1}$ 3	vvw	1.268	1.264	2136
vs	2.520	2.518	3030	mw	1.260	{ 1.260 1.259	{ 4045 6060
s	2.370	{ 2.368 2.367	{ 1123 2132	vvw	1.243	{ 1.242 1.246	{ 4370 6061
w	2.260	2.260	2023	mw	1.231	{ 1.230 1.229	{ 5054 3036 4371
vw	2.182	2.181	2240				
vw	2.158	2.163	3032				
vvw	2.119	{ 2.115 2.112	{ 0004 2241				
m	2.093	2.095	3140	vw	1.211	{ 1.211 1.210	{ 3255 5270
mw	2.036	{ 2.037 2.034	{ 1014 3141				
s	2.008	2.007	2133	vw	1.200	1.198	5271
vvw	1.975	1.977	2242	vvw	1.169	1.170	3146
mw	1.904	1.903	1124	vvw	1.162	{ 1.163 1.159	{ 5272 2027
w	1.880	1.878	{ 3033 3142	vw	1.152	1.150	6063
vw	1.843	{ 1.843 1.846	{ 4041 2024	vvw	1.142	1.142	{ 5164 6171
ms	1.726	1.725	4042	vvw	1.139	1.137	4373
w	1.699	{ 1.700 1.698	{ 2134 3251	vvw b	1.132	1.130	4046
mw	1.682	1.681	3143	w	1.112	1.113	2137
vvw	1.651	{ 1.651 1.649	{ 1015 4150	vvw	1.095	1.094	3256
mw	1.620	{ 1.620 1.618	{ 3034 4151	vw	1.082	1.090	4480
mw	1.603	{ 1.604 1.603	{ 3252 1125	vvw	1.068	1.072	4156
vw	1.570	1.569	4043	vw	1.060	1.057	{ 0008 2247
vvw	1.545	1.545	2025	w	1.051		
vw	1.520	1.518	2244	w	1.048	1.047	{ 1018 3147
vvw	1.476	1.477	3253	vvw	1.040		
m	1.453	{ 1.454 1.456	{ 3360 2135	vw	1.028	1.028	1128
ms	1.423	{ 1.423 1.428	{ 4153 5052	vw	1.019	1.018	4047
mw	1.411	{ 1.410 1.409 1.408	{ 0006 4044 4261	w	1.014		
				vvw	1.009		
				vw	1.003		
				vvw	1.000		
				vvw	0.992	0.991	3257

the X-ray study ( $c:a = 0.970 \pm 0.002$ ). From this the angles between the several pyramids and the basal plane were calculated and compared with the observations:

Calc.	$o\ 62^\circ 43'$ ,	$p\ 44^\circ 7'$ ,	$q\ 65^\circ 57'$ ,	$r\ 48^\circ 14'$ ,	$s\ 29^\circ 15'$
Obs.	$64^\circ$	$46\frac{1}{2}^\circ$	$68^\circ$	$49\frac{1}{2}^\circ$	$30\frac{1}{2}^\circ$

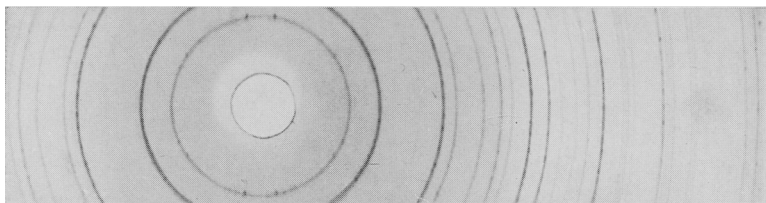


FIG. 1. X-ray powder photograph of painite. 11.46 cm. diameter camera, Cu-K $\alpha$  radiation.

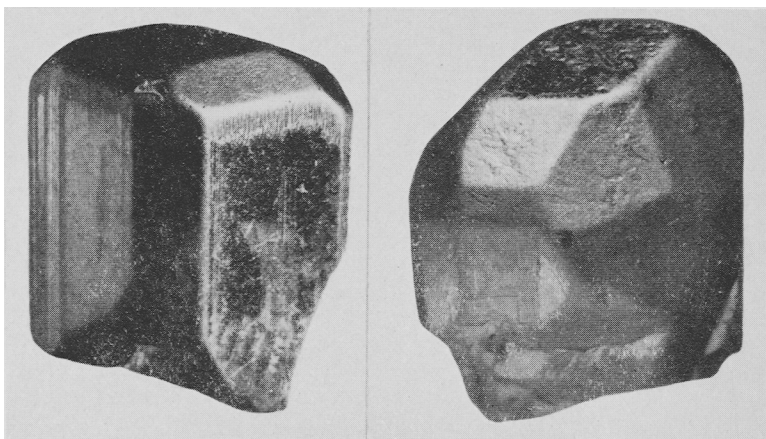


FIG. 2.

FIG. 3.

FIGS. 2 and 3. Photographs of the crystal of painite from two viewpoints: fig. 2 (left) about  $15^\circ$  from the normal to  $m(2\bar{1}10)$ , and fig. 3 (right) nearly normal to  $(1101)$ .

*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

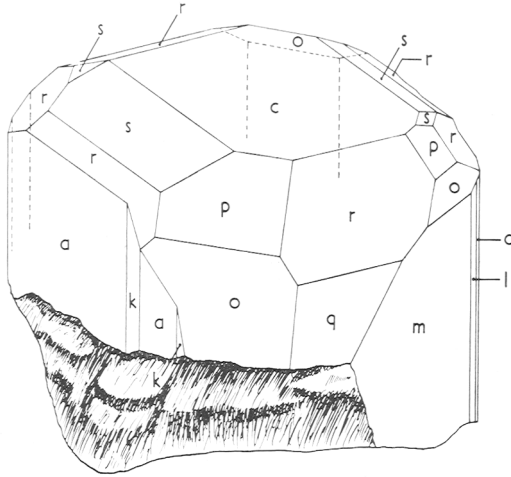


FIG. 4. Parallel perspective drawing of the crystal of painite, from a viewpoint between  $r$  (1011) and  $p$  ( $\bar{2}112$ ).

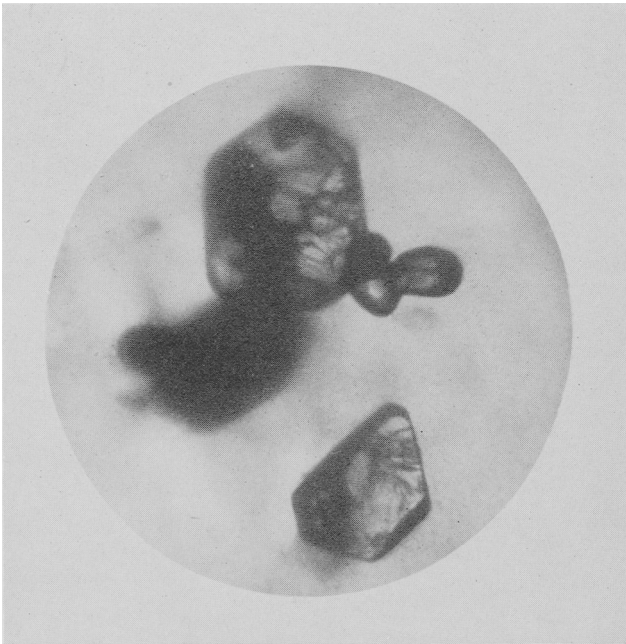


FIG. 5. Photomicrograph through  $c(0001)$  of inclusions in painite, some tabular with hexagonal outline and others rounded.

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  $\text{Al}_2\text{O}_3 \pm 0.3\%$ ,  $\text{SiO}_2 \pm 0.5\%$ ,  $\text{B}_2\text{O}_3 \pm 0.3\%$ , and  $\text{CaO} \pm 0.2\%$ , together with

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

$\text{Al}_2\text{O}_3$	76.2	Al	$20.20 \pm 0.14$	} $\Sigma$ (cations) $26.09 \pm 0.22$
$\text{SiO}_2$	5.6	Si	$1.26 \pm 0.11$	
$\text{B}_2\text{O}_3$	2.2	B	$0.85 \pm 0.12$	
CaO	15.7	Ca	$3.78 \pm 0.05$	
$\text{H}_2\text{O}$	0.7	O	$37.88 \pm 0.22$	
	100.4			

$\pm 0.02$  in the density; the probable error of the density determination ( $4.01 \pm 0.01$ ) was doubled to allow for the inclusions, although a separate determination by flotation on a small fragment free from inclusions gave  $4.00 \pm 0.01$ , 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.

The empirical unit-cell contents clearly indicate an oxygen content of 38, and suggest a cation content  $\text{Ca}_4\text{SiBAL}_{20}$ , but this would only require  $37\frac{1}{2}$  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 ' $\beta$ -alumina' type<sup>1</sup> (e.g.  $3\text{CaO} \cdot 16\text{Al}_2\text{O}_3$ ) 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  $\text{BaAl}_2\text{O}_4$  ( $a \ 5.21 \times \sqrt{3} = 9.00$ ;  $c \ 8.76$ )<sup>2</sup> 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.

<sup>1</sup> K. Lagerqvist, S. Wallmark, and A. Westgren, *Zeits. anorg. Chem.*, 1937, vol. 234, p. 12 [M.A. 7-235].

<sup>2</sup> S. Wallmark and A. Westgren, *Arkiv Kemi, Min. Geol.*, 1937, vol. 12B, no. 35 [M.A. 8-366].