MINERALOGICAL MAGAZINE, JUNE 1986, VOL. 50, PP. 267–70

New data on painite

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ABSTRACT. A crystal of painite discovered in 1979 in a parcel of rough gem spinel from Burma represents the third known crystal of the species. This crystal is similar to the type crystal in most respects. Chemical analyses of both the new crystal and the type crystal confirmed the essential constituents reported by Moore and Araki (1976) and showed in addition the presence of trace amounts of Fe, Cr, V, Ti, Na, and Hf. Optical absorption spectra suggest that the red colour of painite is caused principally by Cr^{3+} and V^{3+}.

KEYWORDS: painite, new data, colour, Mogok, Burma.

PAINITE is one of the rarest minerals, known previously in only two crystals. This paper describes a third known crystal of the species, and provides additional data for the type specimen.

The first two crystals were from ruby gem gravels near Ohngaing village in the Mogok district of Burma. They were discovered by Mr A. C. D. Pain in the early 1950s and are now in the collection of the British Museum of Natural History. One of these (BM 1954,192) was used by Claringbull *et al.* (1957) for the original description of the species. A fragment of this crystal was used by Moore and Araki (1976) in their determination of painite's crystal structure and an additional fragment was placed in the US National Museum of Natural History (USNM 142506). No data have been published on the second crystal (BM 1961,144) that weighs 2.118 g (A. M. Clark, written comm., 1984). The third crystal (GIA 6979) was discovered at the Gemological Institute of America in 1979 by Mr Roger Kuchek in a parcel of rough gem spinel reportedly from Mogok, Burma.

X-ray crystallography. Painite is hexagonal. Moore and Araki (1976) determined its crystal structure and reported its space group as $P6_3$. Powder diffraction data for the 1979 crystal were obtained using a Debye–Scherrer camera and Cu-$K\alpha$ radiation. They confirmed its identity and least squares refinement provided the cell constants given in Table I. These are slightly larger than the cell constants determined by Claringbull *et al.* (1957) and Moore and Araki (1976) for the type crystal.

Table I. Physical properties and unit cell parameters of painite

		Type painite[1] BM (1954,192)	1979 painite GIA 6979
Unit cell parameters	a	8.715(2)[2]	8.755(4)
	c	8.472(2)[2]	8.491(7)
Refractive indices	ε	1.7875	1.788[3]
	ω	1.8159	1.816[3]
Color		deep 'garnet' red	brownish orange red
Pleochroism	ε	'ruby' red	dark red
	ω	pale brownish orange	pale orange red
Density(meas.)		4.01(1)	4.03(1)[4]
(calc.)[5]		3.996[2]	4.020

1. Claringbull et al. (1957) unless otherwise noted.
2. Moore and Araki (1976).
3. Refractometer.
4. Hydrostatic method.
5. Using B_2O_3 by difference.

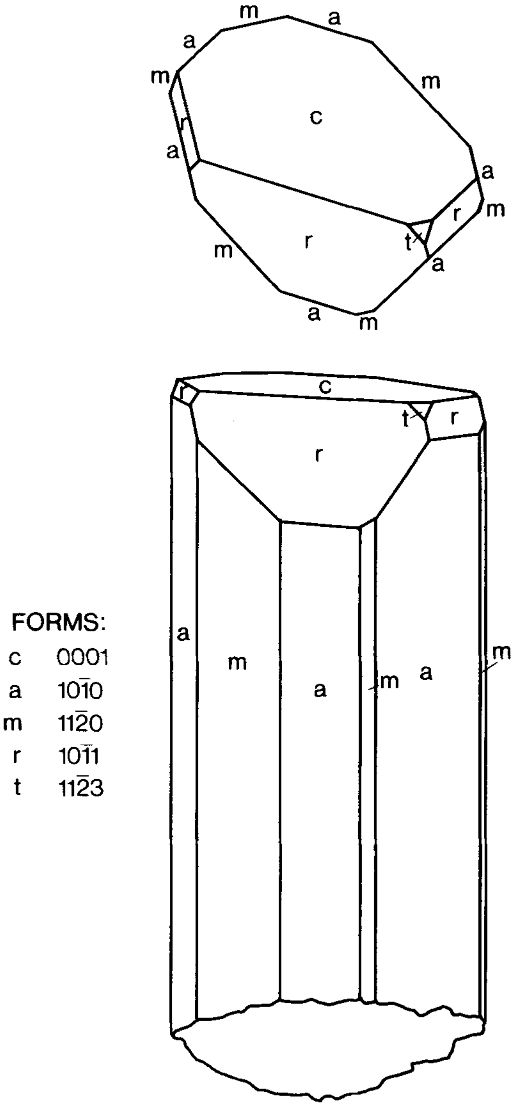

FIG. 1. Crystal drawing of 1979 painite (GIA 6979) exhibiting the forms $a\{10\bar{1}0\}$, $c\{0001\}$, $m\{11\bar{2}0\}$, $r\{10\bar{1}1\}$, and $t\{11\bar{2}3\}$.

Morphology. The type crystal, weighing 1.7 g, is pseudo-orthorhombic in appearance due to the greater development of four of the six prism faces of the form $a\{10\bar{1}0\}$. The crystal, exhibiting a total of ten forms, is roughly equidimensional with rounded (water-worn) edges (Claringbull *et al.*, 1957; figs. 2, 3, and 4).

The 1979 crystal is considerably smaller. It weighs 0.27 g and measures 8.91 × 3.36 × 2.81 mm. Like the first, it appears pseudo-orthorhombic due to unequal development of prism faces (in this case those of two forms, $a\{10\bar{1}0\}$ and $m\{11\bar{2}0\}$), but it is much more elongate in habit (fig. 1). It exhibits only five crystal forms, but one of these, $t\{11\bar{2}3\}$, was not reported on the type crystal. The face intersections are much less rounded than those on the type crystal suggesting that the 1979 crystal has undergone less stream wear.

Inclusions. Claringbull *et al.* (1957) reported the presence of several kinds of inclusions in the type crystal. These included rounded and tabular, hexagonal grains and feather-like sheets of minute cavities. Hornytzkyj and Clark (1983) identified one of the inclusions in the type crystal as phlogopite and suggested that the type crystal may have originated in the metamorphosed limestones which occur in the Mogok area.

The 1979 crystal contains three district types of inclusions. Numerous tube-like cavities up to 1 mm in length parallel the *c*-axis. Three-phase inclusions up to 0.1 mm containing isotropic cube-shaped crystals are distributed throughout. Highly birefringent, reddish crystals with an irregular or

Table II. Chemical analyses of painite

	1	2	3	4	5
Na_2O	NA	NA	-	0.20	0.42
CaO	15.7	7.17	8.33	6.68	7.54
FeO#	NA	NA	-	0.05	0.04
B_2O_3	2.2	NA	5.17	NA	NA
Al_2O_3	76.2	69.02	68.19	68.27	68.06
V_2O_3	NA	NA	-	0.17	0.21
Cr_2O_3	NA	NA	-	0.25	0.48
SiO_2	5.6	-	-	-	-
TiO_2	NA	NA	-	0.83	1.16
ZrO_2	NA	18.77	18.31	17.56	17.66
HfO_2	NA	NA	-	0.58	0.80
H_2O	0.7	NA	-	-*	NA
Total	100.4	94.96	100.00	94.59	96.37

1. Claringbull et al. (1957) - wet chemical analysis.
2. Moore and Araki (1976) - microprobe analysis.
3. Theoretical $CaZrBAl_9O_{18}$.
4. Type crystal (this study) - average of 6 microprobe analyses.
5. 1979 crystal - average of 7 microprobe analyses.

NA = Not analysed.

\# Total iron reported as FeO.

* Absence of water indicated by the single crystal infrared spectrum in the 4000 - 3000 cm^{-1} region.

fibrous appearance and up to 0.5 mm in maximum dimension are clustered in two regions near the centre of the 1979 painite crystal.

Physical properties. The physical properties of type painite and the 1979 crystal, summarized in Table I, are similar in all respects.

Chemistry. The original chemical analysis by Claringbull *et al.* (1957) reported major amounts of Si, Al, B, and Ca, and they proposed the formula $Ca_4SiBAl_{20}O_{38}$. More recently, Moore and Araki (1976) found essential Zr, but no Si. Based upon their structure analysis, they proposed the formula $CaZrBAl_9O_{18}$. Both Moore and Araki (1976) and Povarennykh *et al.* (1978) demonstrated that the borate exists as BO_3 units.

Analyses of the 1979 crystal and a fragment of the type crystal borrowed from the US National Museum of Natural History (NMNH 142506) were performed using a MAC electron microprobe (operating conditions: 15 kV, 0.05 μA; standards: albite for Na, wollastonite for Ca, fayalite for Fe, kyanite for Al, Corning glass 'W' for V, chromic oxide for Cr, quartz for Si, rutile for Ti, zircon for Zr and Hf). A second fragment of the type crystal obtained from Paul B. Moore was analysed by single crystal energy dispersive X-ray fluorescence. Table II presents a comparison of the analyses of painite.

We endeavoured, in particular, to document the occurrence of any colour-causing transition elements which could account for the red colour of painite. Although Anderson (1974) observed absorption lines in the visible spectrum of painite which were typical of Cr, neither of the earlier analyses reported Cr or any other trace elements. Our analyses of both the 1979 crystal and the type crystal indicate the presence of trace amounts of Na, Hf, Fe, Cr, V, and Ti. The last four are regarded as possible colouring agents.

Optical spectroscopy. The optical absorption spectrum of type painite measured in this study consists of three bands at 553, 450, and 402 nm and a shoulder at 608 nm (fig. 2). The $E \perp c$ spectrum resembles that of chromian-vanadian-grossular garnet (tsavorite), if allowances are made for shifts in band positioning (see Schmetzer and Ottemann, 1979). The absorption bands at 402, 553, and 608 nm are attributed to the overlapping contributions of Cr^{3+} and V^{3+}. Weaker features occur in the $E \perp c$ spectrum between 700 and 710 nm (fig. 3) which are appropriate for the characteristic weak spin-forbidden absorptions of Cr^{3+}. The 450 nm

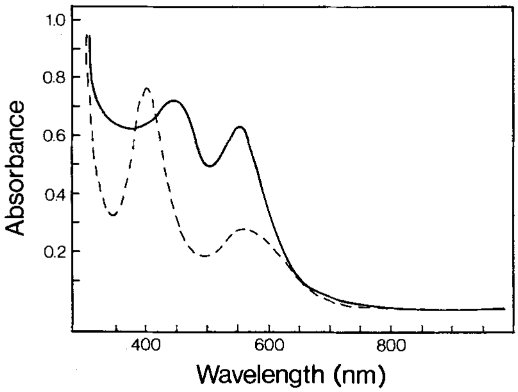

FIG. 2. Optical absorption spectrum of type painite (BM 1954,192). Solid line polarized $E \parallel c$; dashed line plotted for $E \perp c$. Plotted for 600 μm thickness.

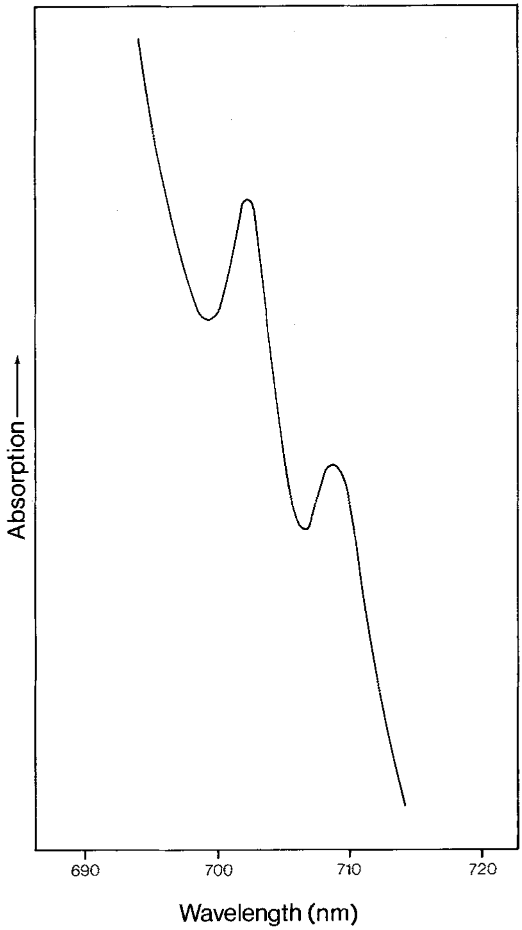

FIG. 3. Detail of $E \perp c$ optical absorption spectrum of 1979 painite (GIA 6979) between 690 and 720 nm. Sample thickness: 2.8 mm.

band cannot be assigned on the basis of the available data.

Based upon the optical spectra, we conclude that the colour of painite is due principally to the presence of Cr^{3+} and V^{3+}.

Acknowledgements. We thank Roger Kuchek for bringing his discovery of the third painite crystals to our attention. Paul B. Moore provided the remaining portion of the type crystal fragment used in his structure determination. John White of the US National Museum of Natural History provided an additional fragment of the type crystal. A. M. Clark supplied information on the status of the two painite crystals in the collection of the British Museum (Natural History). Randy Heuser and Arthur Chodos of the California Institute of Technnology and Carol Stockton of the Gemological Institute of America assisted in carrying out the microprobe and XRF analyses. John McCloy and Susan Kingsbury of the Gemological Institute of America drafted the figures.

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[*Manuscript received 31 July 1985*]