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Tomichite, a new oxide mineral from Western Australia

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SUMMARY. Tomichite, $(V,Fe)_4Ti_3AsO_{13}(OH)$, a new mineral species related to derbylite, has been found in the 'green leader' gold lodes at Kalgoorlie, Western Australia. It is monoclinic, with space group $P2_1/m$ or $P2_1$; a = 7.119 (3), b = 14.176 (5), c = 4.992 (2) Å, β = 105.05 (1)°, Z = 2. Strongest diffraction lines: 3.092 (4), 2.836 (9), 2.663 (10), 1.572 (5). Tomichite occurs as tiny euhedral crystals in quartz; associated minerals are vanadian muscovite, rutile, pyrite, and calaverite. Tomichite is black, has a black streak, lacks internal reflections, is moderately anisotropic, and has S.G. = 4.16 (meas.), 4.42 (calc.). Reflectivity values are 470 nm-15.9 %, 546 nm-16.3 %, 589 nm-16.6 %. Microhardness is VHN 800, using 50 g load.

IN February 1978, Mr S. A. Tomich, consulting geologist in Perth, Western Australia, presented one of the authors (EHN) with a small hand specimen reported to have originated at one of the gold mines at Kalgoorlie in Western Australia. Unfortunately, the exact location of the specimen is not known, but it is believed to have come from the now-defunct Perseverance Mine. The specimen consists largely of milky quartz with finely-dispersed green vanadian muscovite and irregular concentrations of pyrite. Accessory minerals include rutile, calcite, calaverite, and the new mineral described herein. Apart from the presence of the new mineral, the sample is quite characteristic of the gold-bearing lodes referred to locally as 'green leader'.[1]

The new mineral is named tomichite after Mr S. A. Tomich, and both mineral and name have been approved by the IMA Commission on New Minerals and Mineral Names. Offcuts from the original sample, which has been given the catalogue number 12591, have been donated to the British Museum (Natural History) and the Smithsonian Institution.

Occurrence. Tomichite occurs as small, euhedral tabular crystals up to 0.15 mm in longest dimension, in quartz. In cross-section, most of the crystals have the appearance of doubly-terminated prisms with the long dimension closely approximating the a-axis. The mineral has been recognized in only one specimen to date.

Optical and physical properties. Tomichite is black, has a black streak, is opaque to light, and does not exhibit internal reflections in air or under oil immersion. It is grey in reflected light, and does not exhibit detectable reflection pleochroism. Measured reflectivity values are: 470 nm—15.9 %; 546 nm—16.3 %; 589 nm—16.6 %. Reflectivity at 650 nm was not measured because of the low sensitivity of our measuring apparatus at that wavelength. Anisotropism between crossed polars is moderate, with anisotropism colours varying from yellowish-grey to dark grey, in both air and oil.

Vickers microhardness, using a 50 g load, is 800 ± 136 kg/mm^2. Specific gravity, determined by sink-float in Clerici solution, was found to be 4.16. The calculated value is 4.42. The discrepancy is attributed to a small amount of quartz adhering to the tomichite crystal used for the determination. No cleavage was observed.

Chemical composition. Electron microprobe analyses were made of four different crystals in the same polished section, using the following standards: pure elements for Fe, V, Ti, Sb, and Si; GaAs for arsenic. No other elements of atomic number greater than 10 were detected. The analyses were carried out on a MAC electron microprobe,

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[1] E. H. Nickel, *Proc. Australasian Inst. Min. Metall.*, 1977, no. 263, 9-14.

using crystal spectrometers. Corrections were made by means of the MAGIC IV computer program.[2] The results of the analyses are shown in Table I.

There are appreciable compositional variations, particularly with respect to Fe_2O_3 and TiO_2, as shown by the four separate analyses in Table I.

TABLE I. *Electron microprobe analyses of tomichite*

	Weight percent					Atomic proportions	
	Anal. 1	Anal. 2	Anal. 3	Anal. 4	Ave.		
V_2O_3	35.12	33.50	34.70	36.34	34.92	V	3.08
Fe_2O_3	10.11	13.56	11.57	10.32	11.39	Fe	0.94
TiO_2	40.63	35.66	36.80	36.60	37.42	Ti	3.10
As_2O_3	10.89	11.82	10.89	11.67	11.31	As	0.76
Sb_2O_3	0.95	1.22	1.26	1.44	1.22	Sb	0.06
SiO_2	0.34	0.11	0.24	0.15	0.21	Si	0.02
H_2O (calc.)	1.40	1.34	1.35	1.36	1.36	OH	1.00
	99.44	97.21	96.81	97.88	97.83		

The average of these analyses has been used to calculate the unit-cell formula, normalized to 13 O+OH (i.e. a total cation valency of 27), by analogy with derbylite (see below). This gives $(V_{3.08}Fe_{0.94})_{\Sigma=4.02}Ti_{3.10}(As^{3+}_{0.76}Sb^{3+}_{0.06}Si_{0.02})_{\Sigma=0.84}O_{13}(OH)$. The ideal formula can be given as $(V,Fe)_4Ti_3AsO_{13}(OH)$, with V > Fe. The excess of Ti over 3 and V+Fe over 4 in the calculated formula may be the result of failure to allow for the possible presence of some tetravalent vanadium. The combined As+Sb is less than one, suggesting partial occupancy of the site containing these atoms in the structure.

X-ray crystallography. Single-crystal precession photographs show that tomichite is monoclinic, with space group $P2_1/m$ or $P2_1$. Unit-cell parameters, refined from Gandolfi powder data, are $a = 7.119$ (3), $b = 14.176$ (5), $c = 4.992$ (2) Å, $\beta = 105.05$ (1)°. Two formula units can be accommodated in the unit cell.

Powder diffraction data, obtained on a 58 mm-diameter Gandolfi camera, using Cu-$K\alpha$ radiation, are given in Table II. Intensities were estimated visually by comparison with a calibrated intensity scale. Powder diffraction data for derbylite, kindly provided by P. B. Moore, are included for comparison.

A crystal-structure analysis of tomichite is currently in progress.

Discussion. The X-ray data show quite conclusively that tomichite is closely related to derbylite, $Fe^{3+}_4Ti^{4+}_3Sb^{3+}O_{13}(OH)$,[3] and it is reasonable to assume that, in tomichite, Fe^{3+} has been partially replaced by vanadium, and Sb^{3+} by arsenic. Assuming strict analogy with this derbylite, the valencies of the cations in tomichite could be expected to be: V^{3+}, Fe^{3+}, Ti^{4+}, As^{3+}, and Sb^{3+}. The co-existence of reduced ionic species such as V^{3+}, As^{3+} and Sb^{3+} with the oxidized form of iron, Fe^{3+}, seems anomalous in terms of the standard electrode potentials of these ions; however, certain

TABLE II. *X-ray powder diffraction data for tomichite and derbylite*

Tomichite*				Derbylite (calc.)**	
hkl	$d_{calc.}$	$d_{obs.}$	$I_{obs.}$	*d*	*I*
110				6.239	1.8
120	4.935	4.944	2		
001				4.809	1.9
011	4.564	4.557	1.5		
$\bar{1}01$				4.521	1.7
$\bar{1}11$	4.324	4.305	1		
021				3.995	2.5
$\bar{1}21$				3.825	2.4
111	3.433	3.433	1		
210	3.341	3.343	1	3.367	1.5
140	3.150	3.153	2	3.185	2.7
121				3.184	1.0
220	3.093	3.092	4	3.119	4.9
$\bar{2}21$				2.940	1.0
041				2.875	1.1
131	2.832	2.836	9	2.852	10.0
$\bar{1}41$				2.810	1.4
$\bar{2}31$	2.662	2.663	10	2.672	9.3
$\bar{1}02$	2.485	2.486	2	2.473	3.2
051				2.464	1.1
$\bar{1}12$	2.448	2.449	1		
060	2.363	2.361	1	2.391	1.4
231	2.215	2.215	2		
151				2.232	2.2
$\bar{2}51$	2.129	2.129	2	2.143	1.0
122	2.022	2.023	3	2.027	1.6
202	1.769	1.768	2	1.777	1.3
$\bar{1}62$	1.712	1.712	3	1.719	1.4
360	1.645	1.644	1		
$\bar{4}02$	1.611	1.611	2	1.611	1.0
280				1.593	1.6
351	1.572	1.572	5	1.586	2.8
				etc.	
a	7.119 (3) Å			7.160 (1) Å	
b	14.176 (5)			14.347 (3)	
c	4.992 (2)			4.970 (1)	
β	105.05 (1)°			104.61 (2)°	

* 58 mm Gandolfi camera. Cu-$K\alpha$ radiation
** Calculated pattern. (P. B. Moore, *pers. comm.*)

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[2] J. W. Colby, *Proc. 6th Nat. Conf. Electron Probe Anal.*, Pittsburgh, Penn., 27–30 July 1971.

[3] P. B. Moore and T. Araki, *N. Jb. Min., Abh.*, 1976, **126**, 292–303.

mineral structures apparently have a stabilizing effect, since the co-existence of V^{3+} and Fe^{3+} have been reported in goldmanite,[4] and As^{3+} and Fe^{3+} in karibibite.[5]

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[4] R. H. Moench and R. Meyrowitz, *Am. Mineral.*, 1964, **49**, 644–55.

[5] O. V. Knorring, Th. G. Sahama, and P. Rehtijärvi, *Lithos*, 1973, **6**, 265–72.