Johninnesite, a new sodium manganese arsenosilicate from the Kombat Mine, Namibia

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ABSTRACT. Johninnesite, ideally $Na_2Mg_4Mn_{12}As_2^{5+}Si_{12}O_{43}(OH)_6$, is triclinic, $P1$ or $P\bar{1}$, with $a = 10.44(2)$, $b = 11.064(6)$, $c = 9.62(1)$ Å, $\alpha = 107.43(7)$, $\beta = 82.7(1)$, $\gamma = 111.6(1)°$, $V = 894(2)$ Å^3, and $Z = 1$. It occurs as yellow-brown fibrous aggregates, associated with rhodonite, kentrolite, and richterite, from the Kombat Mine in Namibia. Johninnesite has cleavages on $\{100\}$ and $\{010\}$, density of 3.48 (meas.), 3.51 (calc.) g/cm^3. It is biaxial negative, with $2V_x = 41.9°$, $\alpha = 1.6742(4)$, $\beta = 1.6968(3)$, $\gamma = 1.6999(3)$; dispersion $r > v$, distinct.

KEYWORDS: johninnesite, new mineral, Kombat Mine, Namibia.

OVER the last ten years, a remarkable suite of rare minerals has been encountered at the Kombat Mine in Namibia. Many of these rare species and their assemblages are similar to those from Långban, Sweden, and to some from Franklin, New Jersey. Among the uncommon minerals is one found in 1975, described herein, and preserved for investigation by John Innes, Senior Mineralogist of the Tsumeb Corporation. We have named this species johninnesite in honour of him, in recognition of his contributions to mineralogy, particularly to the mineralogy of Tsumeb and Kombat. The species and the name were approved by

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the Commission on New Minerals and Mineral Names, IMA. Type material is preserved at the Smithsonian Institution, Washington, DC, under catalogue no. NMNH 163207.

Physical and optical properties. Johninnesite occurs as fibrous aggregates of light-yellowish-brown colour. The aggregates are up to 2 cm in length on the type specimen and up to 4.5 cm in length on one unstudied sample, reported to us by John Innes. The lustre is vitreous and the streak is light brownish yellow. The hardness was not determined due to extreme friability of the aggregates. Cleavages are good on $\{100\}$ and poor on $\{010\}$. The density, determined using a Berman balance and temperature correction, is 3.48 (± 0.04) g/cm^3, compared with the calculated value of 3.51 g/cm^3.

Optically, johninnesite is biaxial negative with moderate 2V and distinct dispersion of the optic axes, $r > v$. The optical data are listed in Table I, and all the data were measured in sodium light on a spindle stage. The double variation method was used in determining the principal indices of refraction to ensure accuracy and precision. The optical orientation (Table I and fig. 1) was derived by combining the results for orientation of the optical indicatrix, as determined by the extinction curve method (Bloss, 1981), and the results for the

Table I. Optical data and optical orientation for johninnesite at 589 nm

Optical data

	α = 1.6742 (4)		$2V_x$ (meas.) = 41.9 (2)$^{\circ}$
	β = 1.6968 (3)		$2V_x$ (cal.) = 40.9°
	γ = 1.6999 (3)		r > v distinct

Spherical coordinates (as plotted in Fig. 1)

		ϕ	ρ
Crystallo-graphic directions	a	90.0°	81.2°
	-b	159.7°	72.8°
	c	0.0°	0.0°
	a*	69.7°	90.0°
	b*	0.0°	90.0°
	c*	330.4°	17.4°
Principal vibration directions and optic axes	x	221.9°	89.7°
	y	131.7°	59.9°
	z	312.4°	33.3°
	A_1	232.8°	71.7°
	A_2	31.0°	72.3°

Euler angles

θ	89.7°
ψ_y	30.1°
ϕ	41.9°

The numbers in parentheses are standard errors referring to last digit.

orientation of crystallographic axes determined on the same crystal by X-ray precession photography.

The tiny tabular crystal ($20 \times 50 \times 450$ μm) was examined. It is colourless in transmitted light and elongate along [001], with large (100) and poorly developed (010) faces. A twinning-like intergrowth was observed, but due to small grain size, it could not be confirmed. No zoning or inclusions were observed.

X-ray crystallography. Fibrous cleavage fragments elongated along [001] were used for Weissenberg and precession studies, which showed that johninnesite is triclinic with space group $P1$ or $P\bar{1}$. Least-squares refined lattice parameters were obtained utilizing powder X-ray diffraction data from a Gandolfi powder diffraction photograph. The parameters are $a = 10.44(2)$, $b = 11.064(6)$, $c = 9.62(1)$ Å, $\alpha = 107.43(7)$, $\beta = 82.7(1)$, $\gamma = 111.6(1)^{\circ}$, and $V = 984(2)$ Å^3. These values were compared with those of other arsenosilicates, but no clear relationship could be established. The powder diffraction data are listed in Table II. They were obtained with a 114.6 mm diameter Gandolfi camera, a powdered specimen, and Fe-$K\alpha$ X-radiation.

Chemical composition. Johninnesite was chemically analysed using an ARL-SEMQ electron microprobe with operating conditions: 15 kV acceleration potential, and 0.025 μA sample current, measured on brass. A wavelength-dispersive microprobe scan confirmed the absence of any other elements with atomic number greater than 8. The standards used were synthetic olivenite (As), manganite (Mn), and hornblende (Mg,Fe,Na,Si). The data were corrected using a modified version of the MAGIC-4 program. Schallerite and nelenite were employed as control standards. Water was determined using the Pen-
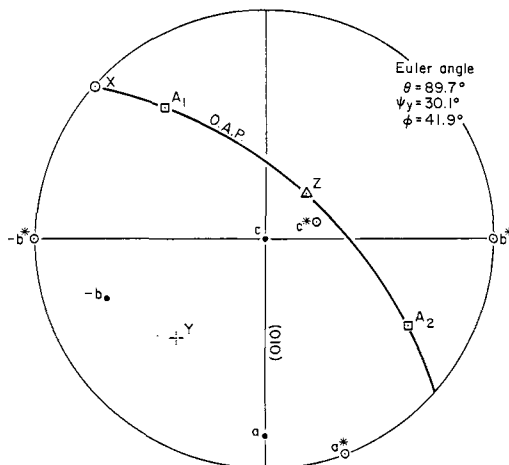

FIG. 1. Optical orientation for johninnesite.

Table II. X-ray powder diffraction data for johninnesite

I/I_o	d(Obs)	d(Calc)	hkl	I/I_o	d(Obs)
60	9.8	9.9	010	20	2.965
		9.7	100	20	2.892
1	9.2	9.2	001*	20	2.842
2	7.8	7.9	$01\bar{1}$*	100	2.676
5	7.3	7.3	$1\bar{1}1$*	2	2.630
40	5.99	5.96	110*	10	2.571^+
		5.96	011	40	2.479
				30	2.436
10	5.26	5.25	$1\bar{2}1$*	20	2.354
		5.20	$1\bar{2}0$	10	2.288
10	4.91^+	4.96	$02\bar{1}$		
		4.95	020	20	2.228
		4.85	200	10	2.190
				5	2.147
1	4.63	4.68	111	20	2.044
		4.68	$01\bar{2}$	1	1.994
		4.59	002		
10	4.39	4.33	$2\bar{2}1$	30	1.866
		4.32	201	20	1.796
				1	1.772
2	4.24	4.29	$2\bar{2}0$	10	1.726
		4.26	$20\bar{1}$	10	1.701
		4.19	$2\bar{1}\bar{1}$		
		4.18	102*	2	1.623
				30	1.606^+
30	4.06	4.10	$1\bar{2}2$	40	1.539^+
		4.04	$1\bar{2}1$	2	1.498
30	3.89^+	3.95	$02\bar{2}$	10	1.441
		3.94	$11\bar{2}$		
		3.93	021	5	1.427
		3.89	120	2	1.402
		3.89	$12\bar{1}$	2	1.386
		3.86	210	5	1.365
				2	1.359
30	3.67	3.68	$21\bar{1}$		
		3.68	$1\bar{1}2$	2	1.348
		3.67	$1\bar{3}1$	2	1.301
30	3.48	3.52	$1\bar{3}0$	5	1.279
		3.46	$2\bar{3}1$	2	1.262
		3.45	$3\bar{1}0$	5	1.214
40	3.38	3.42	$03\bar{1}$		
		3.39	112		
		3.36	202		
		3.36	$3\bar{1}1$		
		3.34	121*		
60	3.23	3.28	$3\bar{2}0$		
		3.23	300		
		3.18	$01\bar{3}$		
10	3.05	3.07	301		
		3.07	$1\bar{2}3$		
		3.06	003		
		3.03	$30\bar{1}$		
		3.02	122		

$^+$broad and/or diffuse reflection
*indices used in least-squares refinement

field method. The resultant analysis yielded: SiO_2 35.5, FeO 0.1, MgO 8.2, MnO 40.7, As_2O_5 10.6, Na_2O 3.1, H_2O 2.6, sum = 100.8 wt. % Calculation of unit cell contents for johninnesite yields:

$$Na_{2.06}Mg_{4.20}Fe_{0.03}Mn_{11.83}$$
$$As_{1.90}Si_{12.18}O_{43.22}(OH)_{5.95}.$$
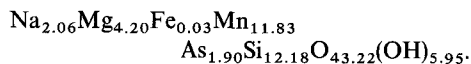
This yields the idealized formula, $Na_2Mg_4Mn_{12}As_2^{5+}Si_{12}O_{43}(OH)_6$.

The ideal formula is based on the assumption that manganese and arsenic are present as Mn^{2+} and As^{5+}, respectively, and that H occurs as (OH) rather than H_2O. The latter is likely because johninnesite occurs in a relatively high temperature vein assemblage and is an apparent equilibrium assemblage with (OH)-bearing richterite, which occurs as inclusions within johninnesite. Calculations of weight percentages based on other valence states for Mn and As yield unreasonable totals. Likewise, calculations of Gladstone–Dale values (Mandarino, 1981) give good agreement only for the assumed valence states. The association of kentrolite, which contains essential Mn^{3+}, with johninnesite in an apparent equilibrium relationship implies that local E_h conditions do not exclude the possibility of some Mn^{3+} in johninnesite. Likewise, the occurrence of a phase, such as a mcgovernite-like mineral that likely contains both As^{3+} and As^{5+}, implies that conditions were not incompatible with As^{5+}. Nevertheless, a portion of either Mn or As may be in some other valence state, as suggested by the unlikely value of 43 oxygens in the formula, which are required for charge balance. These relations are problematical, and determination of the specific valence states and number and type of anions must await a crystal structure analysis.

Occurrence. The Kombat Mine is located in the Otavi Valley, 37 km east of Otavi and 49 km south of Tsumeb, in northern Namibia. The ore deposits are sited on the north limb of the Otavi Valley synclinorium in a sequence of weakly metamorphosed, thin-to-massively bedded, shallow-water dolostones of the Upper Proterozoic Hüttenberg Formation, and immediately underlying a regionally disconformable contact with sulphidic slates and marls of the Kombat Formation. The mine is a small producer of Cu–Pb–Ag ores. The sulphide orebodies are epigenetic, hydrothermal and metasomatic replacement and fracture-filling deposits. A detailed presentation of the geology of these deposits is given by Innes and Chaplin (1985), from which this description was taken, with permission.

Associated with, but spatially separated from the sulphide Cu–Pb–Ag ores are at least six discrete lenses of iron-manganese ores distributed over a distance of 3 km along the regional disconformity. Magnetite–hematite ore is physically separate from the Mn-ores which consist of hausmannite, baryte, alleghanyite, calcite and pyrochroite. Many uncommon minerals, typical of the Franklin, New Jersey, and Långban, Sweden, parageneses, are also found in these Mn-ores.

A late-stage hydrothermal (presumably low-temperature) vein system is transgressive to the layering of the hausmannite–baryte ores, and displays two parageneses. One of these consists of ptygma-like veins of calcite with red and yellow arsenic minerals. The other, containing johninnesite, consists of crustiform and druse veins up

to 10 cm in thickness and contains nambulite (von Knorring *et al.*, 1978), manganite, brushite, serandite, baryte, cahnite, calcite, and gypsum (John Innes, pers. comm.). Johninnesite occurs within this paragenesis, referred to as an epithermal association by Innes and Chaplin (1985). It was found in early 1975 in the Zero-8 stope, 8-level, 1396 metre elevation, in the Kombat Central sector of the Kombat Mine.

The type sample consists of aggregates of acicular johninnesite crystals up to 2.5 cm in length, in apparent equilibrium with kentrolite (with $Mn:Fe = 3:1$) and rhodonite (with $Mn:Ca = 92:8$). Both kentrolite and rhodonite are somewhat equigranular, but they are present only as minor grains and permit no genetical interpretation. Tiny orange richterite crystals occur within johninnesite. Two other samples were described to us by John Innes: one which fits the description given above, and one which has a plumose growth of johninnesite fibres along the axis of a 3.5 cm wide nambulite vein cutting altered dolostone. The formation sequence (John Innes, pers. comm.) appears to be rhodonite > kentrolite > richterite > johninnesite > baryte > calcite, with calcite the last mineral formed. Because of the limited find, only once in the ten years of mining, johninnesite must be considered a very rare mineral.

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