

**Zeitschrift:** Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie  
**Band:** 73 (1993)  
**Heft:** 3  
  
**Artikel:** Hennomartinite and kornite, two new Mn<sup>3+</sup> rich silicates from the Wessels Mine, Kalahari, South Africa  
**Autor:** Armbruster, Thomas / Oberhänsli, Roland / Bermanec, Vladimir  
**DOI:** <https://doi.org/10.5169/seals-55578>

### **Nutzungsbedingungen**

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. [Mehr erfahren](#)

### **Conditions d'utilisation**

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. [En savoir plus](#)

### **Terms of use**

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. [Find out more](#)

**Download PDF:** 30.06.2025

**ETH-Bibliothek Zürich, E-Periodica, <https://www.e-periodica.ch>**

## Hennomartinite and kornite, two new $\text{Mn}^{3+}$ rich silicates from the Wessels Mine, Kalahari, South Africa

by Thomas Armbruster<sup>1</sup>, Roland Oberhänsli<sup>2,3</sup>, Vladimir Bermanec<sup>1,4</sup> and Roger Dixon<sup>5</sup>

### Abstract

Hennomartinite,  $\text{SrMn}_2^{3+}[\text{Si}_2\text{O}_7](\text{OH})_2 \cdot \text{H}_2\text{O}$ , is an orthorhombic (Cmcm,  $a = 6.245[1]$ ,  $b = 9.031[2]$ ,  $c = 13.404[2]$  Å,  $V = 756.0[1]$  Å<sup>3</sup>,  $Z = 4$ ) disilicate of the lawsonite structure type which occurs as anhedral poikiloblasts up to 1 mm, strongly intergrown with sugilite and serandite-pectolite. The mineral is translucent in thin section, pleochroic from yellowish brown to dark red-brown and has indices of refraction greater than 1.82. The calculated density is 3.68 g/cm<sup>3</sup>. The chemical composition was determined by electron microprobe analyses and IR-spectroscopy. The trivalent character of Mn is derived from stoichiometry and bond lengths obtained from a crystal structure analysis.

Kornite,  $(\text{K},\text{Na})(\text{Na},\text{Li})_2(\text{Mg},\text{Mn}^{3+},\text{Fe}^{3+},\text{Li})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$ , is a monoclinic amphibole (P lattice,  $a = 9.94[1]$ ,  $b = 17.80[2]$ ,  $c = 5.302[4]$  Å,  $\beta = 105.5[2]$ ,  $V = 904[4]$  Å<sup>3</sup>,  $Z = 2$ ). The calculated density is 3.15 g/cm<sup>3</sup>. The mineral forms bundles of extremely fine fibers (5–20 µ in diameter), often bent, maximum fibre length 0.2 mm. The mineral is dark red to brownish-lilac, biaxial ( $2V_x = 88\text{--}92^\circ$ ) with indices of refraction  $\alpha = 1.654(4)$ ,  $\beta = 1.675$  (calc),  $\gamma = 1.696(4)$  determined under white light. The optic orientation is  $Z = b$ ,  $Y : c = 60\text{--}65^\circ$  (in obtuse angle  $\beta$ ). The mineral is strongly pleochroic: X = pink, Y = dark red, Z = orange-red. The chemical composition was determined by electron and ion microprobe analyses.

Both new minerals occur together with idiomorphic sugilite (70%), serandite-pectolite (25%) as hydrothermal reaction products of primary Mn-ore at the Wessels Mine, Kalahari Manganese Field, Republic of South Africa.

**Keywords:** hennomartinite, kornite, sugilite, lawsonite, amphibole, new mineral, Mn-silicates, Kalahari Manganese Field, South Africa.

### Introduction

#### CHOICE OF NAMES

In the last two decades, many students starting in geology were fascinated by Henno Martin's book "Wenn es Krieg gibt, gehen wir in die Wüste", an English translation of which was published under the title "The sheltering desert". This book is a biography telling the story of two young German geologists, Henno Martin and Hermann Korn, who emigrated to South West Africa (today Namibia) when Hitler came to power in Germany. "They were not willing to participate in a suicide

of civilized nations" (MARTIN, 1970). When the war began they had been hiding for more than two years in the Kuiseb gorges surrounded by the Namib desert. Trained in geological field work, the two young scientists survived the loneliness and dangers of the desert by hunting and sharing water holes with wild animals. They were never intruders into the ecological equilibrium but became part of the system. In their remote hideout they had enough time to think about evolution and the adaptation of life which finally led to human intelligence, now misused (second World War) for the annihilation of mankind. It is this perspective which gives the book a timelessness

<sup>1</sup> Laboratorium für chemische und mineralogische Kristallographie, Universität Bern, Freiestr. 3, CH-3012 Bern, Switzerland.

<sup>2</sup> Mineralogisch-Petrographisches Institut der Universität Bern, Baltzerstr. 1, CH-3012 Bern, Switzerland.

<sup>3</sup> Present address: Institut für Geowissenschaften, Universität Mainz, Saarstr. 21, D-55122 Mainz, Germany.

<sup>4</sup> Present address: Mineralosko-petrografski zavod PMF-a, Demetrova 1, 41000 Zagreb, Croatia.

<sup>5</sup> Geological Survey, Private Bag X112, Pretoria, 0001, South Africa.

and relevance at the end of the twentieth century, when ecological catastrophes and civil wars have become a major threat to our planet.

After two and a half years hiding in the desert, the two geologists surrendered to the South West African government and later worked as geologists drilling for water in the desert. Hermann Korn died 1946 in a traffic accident. Between 1947–1962 Henno Martin was a member of the Geological Survey of South Africa. In 1963 he became director of the Geologisch-Paläontologisches Institut, Universität Göttingen (Germany). Korn and Martin coauthored several papers on the structural geology of South West Africa. Martin's scientific work deals with Precambrian geology.

Admittedly, Henno Martin and Hermann Korn have no association with the Kalahari Manganese Fields (northwestern Cape Province, South Africa) nor did they ever publish anything on the mineralogy of Mn deposits. However, the Kalahari is a giant desert covering parts of Botswana, Namibia and South Africa and the two rare minerals named after Henno Martin and Hermann Korn occur together and even intergrown with each other, which seemed reason enough to us to honor the two geologists by naming the two Mn-silicates after them. The double name hennomartinite was preferred because martinite was previously used for a variety of whitlockite.

#### SAMPLE DESCRIPTION AND OCCURRENCE

The sample under investigation comes from the Wessels Mine which is located in the stratabound ore deposits of the Kalahari Manganese Field (Fig. 1). These deposits occur in a mid Proterozoic sequence of volcanogenic sediments. Due to its metamorphic overprint two main ore types are distinguished within the Kalahari Manganese Field, the Mamatwan ores in the southeast and the Wessels-type ores in the northwestern part of the deposit (Fig. 1). The Wessels-type ore was hydrothermally altered and metamorphosed and can be divided in three lateral types within the Wessels Mine: (a) carbonate rich ores with Mn-calcite, kutnahorite and rhodochrosite, (b) B and Li rich ores with sturmanite, gaudefroyite and sugilite, and (c) Ca, Ba, Li ores with andradite, inesite, hydroxylapophyllite, ruizite, barite and celestine (VON BEZING *et al.*, 1991). In a profile from hangingwall to footwall several occurrences of sugilite were distinguished (DIXON, 1985).

Unlike most of the known sugilite samples, which consist mainly of a dense felt of relatively

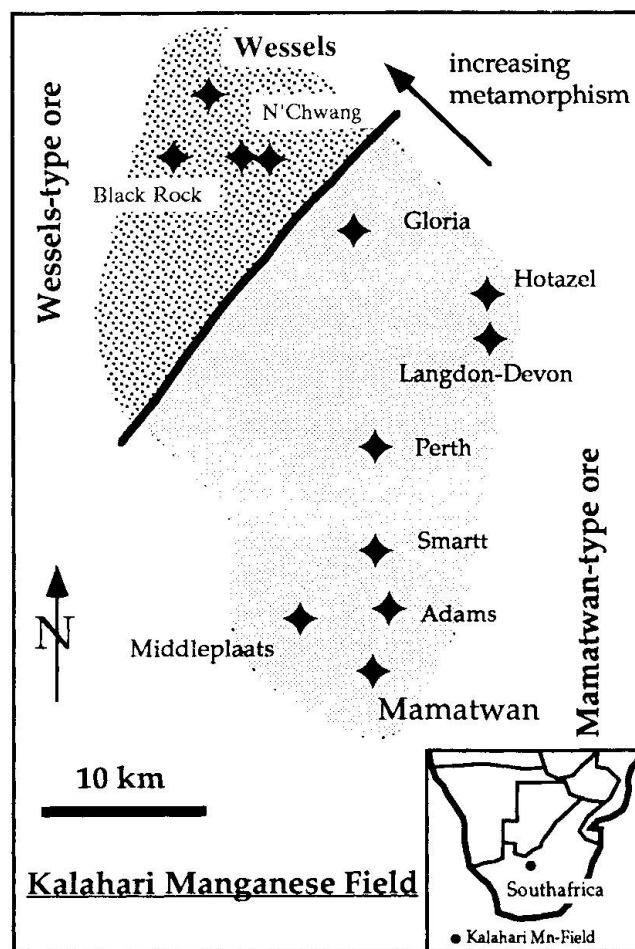


Fig. 1 Sketch map of the Kalahari Manganese Field.

pure sugilite – used as a semiprecious gemstone cut into cabochons – the investigated sample is coarse grained and granular. It has a light purple color with veins (2–10 mm thick) of white serandite-pectolite, often with fine seams of minute dark brown to red needles. From this sample single-crystals of sugilite were separated for structural analysis (ARMBRUSTER and OBERHÄNSLI, 1988). At this time we became aware of two further, hitherto unknown minerals.

In thin section, the rock consists of fibrous pectolite-serandite intergrown with idiomorphic sugilite crystals up to 0.5 mm in diameter. The serandite-pectolite veins show comb-like structures of large serandite-pectolite fibers. Two additional Mn-minerals, both striking due to their bright colors, were found in this sample. One mineral (hennomartinite) exhibits yellow-brown interference colors and forms poikiloblasts up to 1 mm overgrowing sugilite and serandite-pectolite (Figs 2 and 3). The other mineral (kornite) generally forms a fine grained dark red felt along pectolite veins (Fig. 4). On close inspection, the two new minerals can also be found intergrown with each other (Fig. 3). In general, the minute

dark red fibers of kornite rim the yellow brown poikilitic hennomartinite. These new minerals have now been approved as kornite and hennomartinite by the International Commission on New Minerals and Mineral Names. Holotype material is deposited (NMBE-B5564) at the Museum of Natural History, Bern.

### Hennomartinite

Hennomartinite is a rare mineral forming yellow-brown poikiloblast ca. 1 mm in diameter within small veins of serandite-pectolite. It also occurs less commonly in the form of a felty matrix in sugilite-rich parts of the sample.

### CHEMICAL AND STRUCTURAL CHARACTERISTICS

The chemical and structural characteristics of hennomartinite have already been published (ARMBRUSTER et al., 1992). The new mineral is orthorhombic (space group  $Cmcm$ ) and possesses a disilicate structure of the lawsonite type (BAUR, 1978) and nearly end-member composition  $SrMn_2^{3+}[Si_2O_7](OH)_2 \cdot H_2O$  with very minor  $Fe^{3+}$  substituting for  $Mn^{3+}$  and Ba for Sr (Tab. 1). Measurable quantities of Ca could not be expressed in the formula. Li and F were not found by ion microprobe analysis.

The valence of Mn was derived from stoichiometric considerations and from Mn–O distances obtained from a crystal structure refinement (ARMBRUSTER et al., 1992). The  $Mn^{3+}O_6$

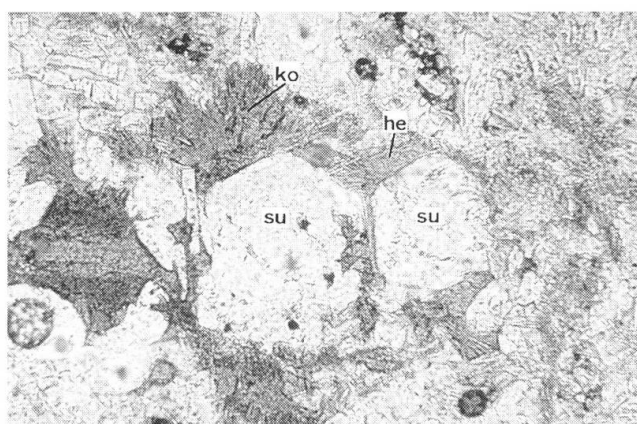


Fig. 2 Photomicrograph of a sugilite-serandite-pectolite rock. Hennomartinite overgrows the idiomorphic sugilite crystals (hexagons in the center) and covers a larger area in the left part of the micrograph. Kornite fibers grow on hennomartinite in the upper part of the photograph. Width of the micrograph: 2 mm.



Fig. 3 Photomicrograph of hennomartinite overgrowing idiomorphic sugilite and serandite-pectolite needles. Width of the micrograph: 0.5 mm.

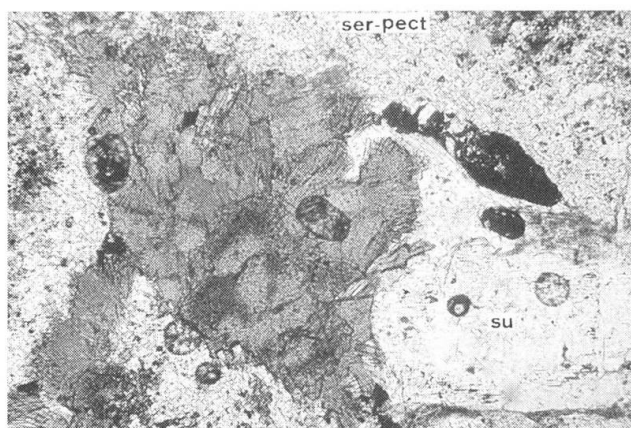


Fig. 4 Photomicrograph of a fine grained kornite felt with serandite-pectolite. To the right a sugilite crystal is visible. Width of the photomicrograph: 0.5 mm.

octahedron in hennomartinite displays the characteristic Jahn-Teller distortion leading to an elongated pseudo-tetragonal octahedron (two long and four short  $Mn^{3+}$ –O distances). The fundamental building block of the structure is  $Mn_2^{3+}(OH)_2[SiO_4]_2$  which is also observed in orientite, macfallite and ruizite (MOORE et al., 1985), but these minerals have a different stoichiometry.

### PHYSICAL AND OPTICAL PROPERTIES

Intergrowth with other minerals from the paragenesis (especially serandite-pectolite and sugilite) complicated the measurements of physical properties, such as hardness, cleavage, density etc. Hennomartinite has a Mohs hardness of ca. 4. With a 100 g load, the Vickers hardness varies between 200 and 400. Parting and cleavage were not observed. Hennomartinite is yellow-brown,

**Tab. 1** Chemical composition of hennomartinite and lawsonite.

	hennomartinite	lawsonite (BAUR, 1978)
	wt%	wt%
CaO	0.02	17.18
BaO	0.46	
SrO	24.32	
Mn <sub>2</sub> O <sub>3</sub>	37.82	
Fe <sub>2</sub> O <sub>3</sub>	0.53	0.90
SiO <sub>2</sub>	28.22	37.75
Al <sub>2</sub> O <sub>3</sub>	0.00	31.09
TiO <sub>2</sub>	0.00	0.33
H <sub>2</sub> O	8.62	4.00
Total	99.99	98.54
number of ions on the basis of ten O		
Ca	0.00	0.98
Ba	0.01	
Sr	0.98	
Mn <sup>3+</sup>	2.01	
Fe <sup>3+</sup>	0.03	0.04
Si	1.97	2.01
Al	0.00	1.95
Ti	0.00	0.01
O	7.00	7.00
OH	2.00	2.00
H <sub>2</sub> O	1.00	1.00

Note: H<sub>2</sub>O of hennomartinite was determined by difference to 100 wt%.

has a vitreous luster and is translucent; fluorescence was not observed under short- and long-wave UV radiation. The density was not measured (because of the intimate intergrowth) but calculated from cell dimensions and chemical composition, yielding 3.68 g/cm<sup>3</sup>.

In spite of the very close crystallochemical connection between hennomartinite and lawsonite the refractive indices of hennomartinite are much higher (>1.82) than lawsonite (1.665–1.685), due to the heavier metals (Mn, Sr) in hennomartinite. The new mineral shows strong pleochroism

from yellowish-brown to dark red-brown. These intense colors and the very high refractive indices did not allow the determination of the optical parameters more precisely. Spindle stage measurement under white light gave an optical axial angle of 63(1)° (Tab. 2). It remains unclear, however, whether the optical character is positive or negative.

#### X-RAY DIFFRACTION

An X-ray powder diffraction pattern was recorded with a Guinier camera at room temperature using Si as internal standard. The pattern shows the presence of minor sugilite, with which hennomartinite is closely intergrown. In the calculation of the unit cell dimensions (program GITTER, HUMMEL pers. comm.) all lines which overlapped with sugilite reflections were omitted (Tab. 3).

#### INFRARED SPECTRUM

By careful separation under a binocular microscope it was possible to extract enough material for the preparation of a KBr-pellet. The IR spectrum (ARMBRUSTER et al., 1992) shows absorptions near 3500 and 1600 cm<sup>-1</sup> characteristic for H<sub>2</sub>O and/or OH vibrations. Bands between 1200 and 850 and 600 and 350 cm<sup>-1</sup> resemble those of lawsonite (LABOTKA and ROSSMAN, 1974; MOENKE, 1961).

#### Kornite

In a detailed study on sugilite and associated metamorphic silicate minerals from the Wessels Mine, Kalahari Manganese Field, DIXON (1989) distinguished two groups of amphiboles on the basis of their color. One group (group A), dark red through red and pink to blue, was strongly pleochroic. Group B comprised pale green am-

**Tab. 2** Cell dimensions, strongest X-ray powder diffraction lines (XRD), and refractive indices of hennomartinite and lawsonite (BAUR, 1978).

	hennomartinite	lawsonite
formula	SrMn <sub>2</sub> (Si <sub>2</sub> O <sub>7</sub> )(OH) <sub>2</sub> · H <sub>2</sub> O	CaAl <sub>2</sub> (Si <sub>2</sub> O <sub>7</sub> )(OH) <sub>2</sub> · H <sub>2</sub> O
space group	Cmcm	Cmcm
cell dimensions [Å]	6.255(1), 9.034(1), 13.397(2)	5.847(1), 8.795(3), 13.142(6)
strongest XRD lines [Å]	2.83, 2.69, 4.80, 2.40	2.72, 2.62, 2.13, 6.56
refractive indices	> 1.82	1.665, 1.675, 1.685



Tab. 3 Room temperature XRD powder pattern of hennomartinite from the Wessels Mine.

$I_{calc}$	$d_{meas}$	$d_{calc}$	h	k	l
10		6.70	0	0	2
30	5.149	5.136	1	1	0
86	4.804	4.796	1	1	1
42	sug	4.516	0	2	0
56	4.287	4.279	0	2	1
26	3.752	3.745	0	2	2
66	3.373	3.371	1	1	3
22	3.347	3.3510	0	0	4
100	2.833	2.8304	2	0	2
82	2.807	2.8066	1	1	4
58	2.715	2.7117	1	3	0
98	2.695	2.6910	0	2	4
24	2.666	2.6579	1	3	1
26	sug	2.5683	2	2	0
48	2.518	2.5138	1	3	2
68	2.401	2.3982	2	2	2
26	2.379	2.3766	1	1	5
54	2.231	2.2266	2	2	3
20	2.113	2.1080	1	3	4
20	2.018	2.0151	0	4	3
20	2.009	2.0050	3	1	1
11		1.8724	0	4	4
40	1.819	1.8169	2	0	6
14	1.795	1.7942	1	1	7
30		1.7650	2	4	2
14		1.7629	0	2	7
11		1.7353	3	1	4
14		1.7269	0	4	5
27		1.7122	3	3	0
30		1.6931	2	4	3
38	1.687	1.6856	2	2	6

Hennomartinite is closely intergrown with sugilite, thus the powder pattern always shows the presence of sugilite lines which are indicated by sug and omitted in the observed pattern. Intensities are calculated (LAZY-PULVERIX: YVON et al., 1977) from refined coordinates (ARMBRUSTER et al., 1992) for Guinier symmetry and  $FeK\alpha_1$  radiation.

phiboles. The brightly colored amphiboles were less common than the pale green type. Electron microprobe analyses of group A amphiboles revealed deficiencies of C site cations ( $Mn^{3+}$ ,  $Fe^{3+}$ , Al, Mg), in extreme cases down to 4.5 a.p.f.u. DIXON (1989) had no access to an ion probe but admitted that Li can be an important constituent of alkali amphiboles where it is ordered on the C site. Furthermore he noticed that the reddish amphiboles (group A) were enriched in  $Mn^{3+}$  while the pale-green ones were  $Fe^{3+}$  rich. The electron microprobe analyses of group A amphiboles by DIXON (1989) are extremely similar and probably identical to the kornite defined in this study.

Tab. 4 Chemical composition of kornite and related minerals.

	kornite	leakeite (HAWTHORNE et al., 1992)
	wt%	wt%
$K_2O$	3.56	1.12
$Na_2O$	7.61	9.69
$Li_2O$	1.96	1.42
$MgO$	10.03	10.96
$Mn_2O_3$	13.17	3.86
$Fe_2O_3$	4.93	12.23
$SiO_2$	56.06	55.80
$Al_2O_3$	0.00	1.27
$TiO_2$	n.d.	0.03
$CaO$	0.00	0.50
$H_2O$	2.68*	1.63
F	n.d.	1.08
TOTAL	100.00	99.11
number of ions on the basis of ten O and two OH		
K	0.65	0.20
Na	2.10	0.75
Li	1.12	0.81
Mg	2.13	2.32
$Mn^{3+}$	1.43	0.42
$Fe^{3+}$	0.52	1.31
Si	8.00	7.93
Al	0.00	0.07
Ti	n.d.	0.00
Ca	0.00	0.08
OH	2.00	1.51
F	n.d.	0.49

\* - calculated as difference to 100%

#### CHEMICAL CHARACTERISTICS

A polished thin section mount, one inch in diameter, was used for electron and ion-microprobe analyses. Seven analyses were carried out by mean of an electron microprobe using the following standards: albite (Na,Si),  $MnSiO_3$  (Mn), olivine (Fe,Mg), sanidine (K) and anorthite (Al,Ca). Sugilite was used as Li standard for the ion-probe.  $H_2O$  could not be determined due to scarcity of the material so it was calculated from stoichiometry. Mean analytical results are given in Tab. 4. Additional experimental details are given in ARMBRUSTER and OBERHÄNSLI (1988) and ARMBRUSTER et al. (1992). Following HAWTHORNE (1983), the amphibole formula was normalized on 46 negative charges ( $22 O + 2 OH^-$ ) leading to the empirical formula  $(K_{0.65}Na_{0.31})_{\Sigma 0.96}(Na_{1.79}Li_{0.21})_{\Sigma 2.00}-(Mg_{2.12}Mn_{1.43}^{3+}Fe_{0.52}^{3+}Li_{0.91})_{\Sigma 5.00}Si_8O_{22}(OH)_2$ . The simplified formula is  $(K,Na)(Na,Li)_2(Mg,Mn^{3+},Fe^{3+},Li)_5[Si_8O_{22}](OH)_2$ .

Tab. 5 The main crystallographic and optical data of kornite compared with related minerals.

	kornite	eckermannite	leakeite
formula	$\text{KNa}_2(\text{Mg}_2\text{Mn}^{3+}\text{Li})[\text{Si}_8\text{O}_{22}](\text{OH})_2$	$\text{Na}_3(\text{Mg,Fe})_4\text{Al}[\text{Si}_8\text{O}_{22}](\text{OH})_2$	$\text{NaNa}_2(\text{Mg}_2\text{Fe}_2^{3+}\text{Li})[\text{Si}_8\text{O}_{22}](\text{OH})_2$
space group	P-lattice	C2/m	C2/m
cell dimensions [Å]	a 9.94(1) b 17.80(2) c 5.302(4) $\beta$ 105.5(2)°	a 9.762 b 17.892 c 5.284 $\beta$ 103.17°	a 9.822(3) b 17.836(6) c 5.286(2) $\beta$ 104.37(3)°
refractive indices	$n_x$ 1.654 pink $n_y$ 1.675(calc) dark red $n_z$ 1.696 orange-red $2 V_x$ 88–92°	1.614–1.636 blue-green 1.625–1.644 pale blue-green 1.630–1.649 yellow-green 74°	1.667 dark mauve-red 1.675 dark mauve-red 1.691 light pink-red 59–71°

Note: Refractive indices of eckermannite from TRÖGER (1982).

This idealized formula is comparable with eckermannite (end member  $\text{Na}_3(\text{Mg,Fe})_4\text{Al}[\text{Si}_8\text{O}_{22}](\text{OH})_2$ ) and especially with leakeite (end-member formula is  $\text{Na}_3(\text{Mg}_2\text{Fe}_2^{3+}\text{Li})[\text{Si}_8\text{O}_{22}](\text{OH})_2$ ) (HAWTHORNE et al., 1992). Kornite has no Al in octahedral position, as eckermannite has, but all three-valent cations are mostly  $\text{Mn}^{3+}$  with lesser  $\text{Fe}^{3+}$  (in the C position). For the distinction between leakeite and kornite the  $\text{Mn}^{3+}/\text{Fe}^{3+}$  ratio is decisive. The C position in kornite is predominantly occupied by  $\text{Mn}^{3+}$  while in leakeite  $\text{Fe}^{3+}$  is dominant. Less important is the fact that in kornite K is dominant on the A position, while Na is dominant in leakeite. Kornite with  $\text{Li} > 0.50$ ,  $\text{Mn} > 1.00$  and  $\text{K} > 0.50$  p.f.u. would be named lithian potassium manganese magnesio-arfvedsonite under the IMA amphibole scheme (HAWTHORNE, 1983) as there is no  $\text{Fe}^{2+}$  and no  $^{\text{VI}}\text{Al}$ . It is not emphasized that  $\text{K} > \text{Na}$  on the A position of kornite, because it would logically loom with an enormous increase in names for the amphiboles (LEAKE, pers. comm.).

#### PHYSICAL AND OPTICAL PROPERTIES

Kornite occurs in bundles of fine fibers (5–20  $\mu$  in diameter), often bent, with a maximum fibre length of less than 200  $\mu$ . The mineral is dark red to brownish-lilac, transparent with a vitreous luster and does not fluorescence under long-wave or short-wave ultraviolet light. The [001] fibers are brittle with a cleavage parallel to [001] but the plane was not determined. The calculated density is 3.15 g/cm<sup>3</sup>, the observed density and hardness could not be measured because the fibers are too small and intergrown. Hardness, streak, twinning and IR absorptions were not determined because

Tab. 6 Room temperature XRD data of kornite.

I/I <sub>0</sub>	d <sub>meas</sub>	d <sub>calc</sub>	h	k	l	flag
medium	8.890	8.901	0	2	0	*+
medium	8.427	8.436	1	1	0	+
medium	5.077	5.044	1	3	0	+
weak	4.756	4.790	2	0	0	*+
medium	4.442	4.450	0	4	0	*+
medium	3.357	3.360	1	3	1	o
strong	3.257	3.260	2	4	0	+
strong	3.132	3.143	3	1	0	+
weak	2.938	2.921	0	5	1	*
strong	2.812	2.812	3	3	0	+
medium	2.680	2.682	1	5	1	o
strong	2.553	2.554	0	0	2	*
medium	2.391	2.395	4	0	0	*
medium	2.372	2.377	3	5	0	+
weak	2.272	2.277	0	7	1	*
weak	2.213	2.215	0	4	2	*
medium	2.038	2.041	4	0	–2	*
medium	2.038	2.039	2	0	2	*
medium	1.900	1.9049	5	1	0	*
weak	1.852	1.8445	0	9	1	*
weak	1.812	1.8232	5	3	0	+
weak	1.689	1.6778	0	8	2	*
weak	1.594	1.5966	6	0	0	*
medium	1.558	1.5537	6	0	–2	*
medium	1.558	1.5520	4	0	2	*
weak	1.480	1.4835	0	12	0	*
weak	1.283	1.2828	0	12	2	*
weak	1.276	1.2771	0	0	4	*

The flags for each reflection indicate the method which was applied for its determination:

\* Precession photograph MoK $\alpha$ -radiation

+ Weissenberg photograph hk0, FeK $\alpha$ -radiation

o Rotation photograph of the crystal mounted parallel to c, FeK $\alpha$ -radiation. Intensities were estimated by eye.

of low quantity and small grain sizes of the mineral.

A spindle stage equipped polarizing microscope was used to determine  $2V_x = 88\text{--}92^\circ$  and to orient the crystal for the determination of pleochroism, optic orientation and refractive indices. Refractive indices were measured with white light for maximum intensity, yielding  $\alpha = 1.654(4)$ ,  $\beta = 1.675$  (calc),  $\gamma = 1.696(4)$ . Dispersion was not determined. The optic orientation measured relative to the morphology is:  $Z = b$ ,  $Y : c = 60\text{--}65^\circ$  (in obtuse angle  $\beta$ ). Pleochroism:  $X = \text{pink}$ ,  $Y = \text{dark red}$ ,  $Z = \text{orange-red}$  (Tab. 5).

#### X-RAY DIFFRACTION

Only a few individual crystals could be separated from the hand specimen. The maximum size of the separated fibers was  $0.005 \times 0.020 \times 0.1$  mm. Gandolfi-photographs of bundles of such small fibers did not lead to measurable films, thus the diffraction pattern was obtained from various long exposure (up to 14 days) single-crystal photographs which are much more sensitive for this purpose because the crystal is oriented in the diffraction position. Three different techniques were applied: (1) precession photographs  $0kl$ ,  $k0l$  with Zr filtered  $\text{MoK}\alpha$ -radiation, (2) Weissenberg  $hk0$  photograph with Mn filtered  $\text{FeK}\alpha$ -radiation, (3) rotation photograph, crystal mounted parallel to  $c$  ( $\text{FeK}\alpha$ -radiation). In general, X-ray reflections were diffuse due to the bending and cleavage of the fibers. The measured reflections (Tab. 6) suggest a primitive lattice. The observed systematic extinctions are in agreement with space groups  $P2_1/m$  and  $P2/a$  which have already been described for amphiboles (Hawthorne, 1981). Refinement of cell dimensions using the program GITTER (Hummel pers. comm.) with the data in Tab. 6 yielded  $a = 9.94(1)$ ,  $b = 17.80(2)$ ,  $c = 5.302(4)$  Å,  $\beta = 105.5(2)^\circ$ .

#### References

- ARMBRUSTER, TH. and OBERHÄNSLI, R. (1988): Crystal chemistry of double-ring silicates: Structure of sugilite and brannockite. *Amer. Mineral.*, 73, 595–600.
- ARMBRUSTER, TH., OBERHÄNSLI, R. and BERMANEC, V. (1992): Crystal structure of  $\text{SrMn}_2(\text{Si}_2\text{O}_7)(\text{OH})_2 \cdot \text{H}_2\text{O}$ , a new mineral of the lawsonite type. *Eur. J. Mineral.* 4, 17–22.
- BAUR, W.H. (1978): Crystal structure refinement of lawsonite. *Amer. Mineral.*, 63, 311–315.
- DIXON, R.D. (1985) Sugilite and associated minerals from Wessels mine, Kalahari manganese field. *Trans. Geol. Soc. South Africa*, 88, 11–17.
- DIXON, R.D. (1989): Sugilite and associated metamorphic silicate minerals from Wessels mine Kalahari manganese field. *Bull. Geol. Survey of Republic of South Africa*, 93, 1–47.
- HAWTHORNE, F.C. (1981): Crystal chemistry of the amphiboles. In *Reviews in Mineralogy: Amphiboles and other hydrous pyriboles*. Vol. 9A. 1–95. Ed. P.H. Ribbe. Mineral. Society of America, Washington D.C.
- HAWTHORNE, F.C. (1983): The crystal chemistry of the amphiboles. *Can. Mineral.*, 21, 173–480.
- HAWTHORNE, F.C., OBERI, R., UNGARETTI, L. and GRICE, J.D. (1992): Leakeite,  $\text{NaN}_2(\text{Mg}_2\text{Fe}_2^{3+}\text{Li})\text{Si}_8\text{O}_{22}(\text{OH})_2$ , a new alkali amphibole from the Kajlidongri manganese mine, Jhabua district, Madhya Pradesh, India. *Amer. Mineral.*, 77, 1112–1115.
- LABOTKA, TH.C. and ROSSMAN, G.R. (1974): The infrared pleochroism of lawsonite: the orientation of the water and hydroxide groups. *Amer. Mineral.*, 59, 799–806.
- MARTIN, H. (1970): Wenn es Krieg gibt, gehen wir in die Wüste. Verlag der S.W.A. Wissenschaftlichen Gesellschaft, Windhoek.
- MOENKE, H. (1962): *Mineralspektren*. Akademie-Verlag, Berlin.
- MOORE, P.B., SHEN, J. and ARAKI, T. (1985): Crystal chemistry of the  $(\text{M}_2^{3+}(\text{TO}_4)_2)$  sheet: structural principles and crystal structure of ruizite, macfallite and orientite. *Amer. Mineral.*, 70, 171–181.
- TRÖGER, W.E. (1982): *Optische Bestimmung der gesteinsbildenden Minerale*. 5th edition. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.
- VON BEZING, K.L., DIXON, R.D., POHL, D. and CAVALLO, G. (1991): The Kalahari Manganese Field: an update. *Mineral. Rec.*, 22, July–August, 279–297.
- YVON, K., JEITSCHKO, W. and PARTHE, E. (1977): LAZYPULVERIX, a computer program, for calculating X-ray and neutron diffraction powder patterns. *J. Appl. Cryst.*, 10, 73–74.

Manuscript received April 18, 1993; revised manuscript accepted August 23, 1993.