

# Wesselsite, SrCu[Si<sub>4</sub>O<sub>10</sub>], a further new gillespite-group mineral from the Kalahari Manganese Field, South Africa

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## Abstract

Wesselsite, SrCu[Si<sub>4</sub>O<sub>10</sub>], is a new mineral species from the Wessels mine, Kalahari Manganese Field, South Africa, and it belongs to the gillespite group. Wesselsite is tetragonal, space group *P4/ncc*; the unit cell parameters, refined from Gandolfi film data, are  $a = 7.366(1)$ ,  $c = 15.574(3)$  Å,  $V = 845.01$  Å<sup>3</sup>. The strongest lines are ( $d_{\text{obs}}/I_{\text{obs}}/hkl$ ) (7.79/35/002), (4.33/20/112), (3.89/20/004), (3.44/40/104), (3.33/100/202), (3.12/55/114), (3.03/50/212), (2.68/25/204), (2.61/30/220) and (2.32/30/116). Wesselsite is associated with hennomartinite, embedded in a matrix of sugilite, xonotlite, quartz and pectolite. Microprobe analyses of 111 samples show that it is the end-member of a solid solution series with effenbergerite, BaCu[Si<sub>4</sub>O<sub>10</sub>], with substitutions of Sr by Ba up to 50 mol.%. Wesselsite forms tiny subhedral plates in sizes not exceeding 50 × 50 × 5 μm, arranged in clusters of up to 200 μm. It shows a perfect cleavage parallel to {001}, has blue colour, white to light blue streak, and is uniaxial negative with  $\omega = 1.630(2)$ ,  $\epsilon = 1.590(5)$ , strongly pleochroic from blue ( $\omega$ ) to pale blue ( $\epsilon$ ). The calculated density is 3.32 g cm<sup>-3</sup>, the measured density is 3.2(1) g cm<sup>-3</sup>.

KEYWORDS: wesselsite, strontium copper silicate, gillespite group, effenbergerite, new mineral, Kalahari Manganese Field, South Africa.

## Introduction

IN the course of our study on the mineralogy of the Kalahari Manganese field (Rieck and Giester, in prep.) tiny, light-blue coloured particles were noticed on specimens provided by S. & H. Kaiser, Vienna. These grains were embedded between sugilite crystals and resembled effenbergerite, BaCu[Si<sub>4</sub>O<sub>10</sub>], which had recently been described from this locality (Giester and Rieck, 1994). As the assemblage of the matrix was distinctly different, Gandolfi photographs and EDX analyses were performed and the sample could finally be identified as the natural analogue of SrCu[Si<sub>4</sub>O<sub>10</sub>], synthesized and described by Pabst (1959). The new species is named for its type locality, which in turn was named by the geologist Dirk Roos in 1917 in honour of his colleague Hendrik Wessels (1875–1941). The mineral and the mineral name have been approved by the IMA Commission on New Minerals and Mineral Names. It has to be noted that the 'trade' name 'wesselite' for a purple variety of sugilite

exists. The type material is preserved in the systematic collection of the Institut für Mineralogie und Kristallographie, University of Vienna, under catalogue number 8H/01.055#1.

## Occurrence and paragenesis

Wesselsite was first found on 2 specimens (1 × 4 × 5 cm; 4 × 5 × 9 cm) originating from the central-eastern orebody of the Wessels mine. The mine is located in the Kalahari Manganese field, northwestern Cape province, Republic of South Africa. Details regarding the geology and mineralogy of the Kalahari Manganese field are given, among others, by Kleyenstuber (1984), Dixon (1985, 1986, 1989) and Von Bezing *et al.* (1991).

The matrix consists primarily of subhedral grains of sugilite, embedded in xonotlite, quartz, and pectolite. In small vugs hennomartinite, as well as euhedral crystals of sugilite, pectolite, xonotlite and wesselsite, are found. This type of mineral assemblage is quite different from that which recently

yielded crystals of effenbergerite (Giester and Rieck, 1994). Since approval of wesselsite the authors became aware of two further samples (both with approximate dimensions  $5 \times 5 \times 2$  cm) with a mineral content slightly different from the type specimen. The matrix lacked xonotlite, eventually indicating a separate position within the orebody. Subsequent analyses revealed a variable substitution of strontium by barium up to 50 mol.%.

#### Physical and optical properties

Wesselsite occurs as subhedral plates with maximum dimensions of  $50 \times 50 \times 5$   $\mu\text{m}$ , arranged in clusters with a diameter of up to 200  $\mu\text{m}$ , embedded in xonotlite and pectolite. Wesselsite is brittle with a perfect cleavage parallel to {001}. A measurement of the hardness was hampered by the small size of the grains. No twinning has been observed. The density of wesselsite, measured under a microscope by suspension of crystals in heavy liquids at room temperature, is 3.2(1). The limited accuracy of this value compared with the theoretical value of 3.32 has to be attributed to the size of fragments available, and to the intergrowth with minerals of the matrix. No fluorescence has been

observed under either short-wave or long-wave ultraviolet radiation. Wesselsite is blue, probably with a white to light blue streak. It is optically uniaxial, the refractive indices, obtained on a spindle stage at 589 nm are  $n_o$  and  $n_e = 1.630(2)$  and 1.590(5). The respective data for synthetic  $\text{SrCu}[\text{Si}_4\text{O}_{10}]$ , determined by Pabst (1959), are  $n_o$ ,  $n_e = 1.628, 1.588$ . A strong pleochroism from blue in  $\omega$  and pale blue to pale pink in  $\epsilon$  is observable.

#### Chemistry

The samples used for chemical analysis were carefully separated from the surrounding matrix by treatment with hydrochloric acid and subsequent washing. The measurements by energy-dispersive X-ray analysis (EDX) were performed on a scanning electron microscope (SEM) Jeol JSM-6400 with the program system LINK eXL10. To minimize beam damage an operating voltage of 20 kV was used. The analysed area was 200  $\mu\text{m}^2$  in all cases; data were automatically corrected for ZAF effects. The standards used were  $\text{SrSO}_4$  (Sr), CuO (Cu), and  $\text{SiO}_2$  (Si). The mean analytical results (and ranges) for three samples from the type specimen were SrO 24.0 (23.4–24.5), CuO 18.8 (18.7–19.0),  $\text{SiO}_2$  56.9

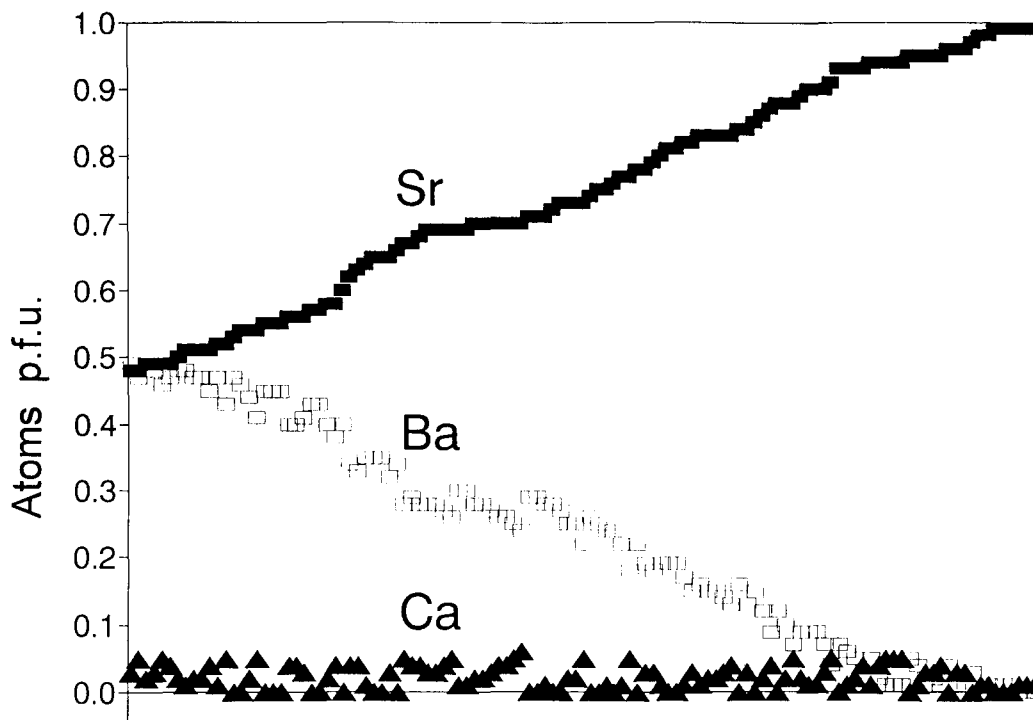


FIG. 1.  $M^{2+}$  cation ratio of 111 wesselsite samples, plotted in order of increasing strontium content.

TABLE 1. X-ray powder diffraction data for wesselsite

$d_{\text{calc}}$	$d_{\text{obs}}$	$I/I_0$	h	k	l
7.7870	7.79	35	0	0	2
4.3294	4.33	20	1	1	2
3.8935	3.89	20	0	0	4
3.4422	3.444	40	1	0	4
3.3294	3.330	100	2	0	2
3.2229	3.224	15	2	1	1
3.1185	3.119	55	1	1	4
3.0339	3.033	50	2	1	2
2.6756	2.677	25	2	0	4
2.6043	2.605	30	2	2	0
2.4698	2.470	5	2	2	2
2.3417	2.342	5	3	0	2
2.3232	2.322	30	1	1	6
2.2316	2.231	10	3	1	2
2.1647	2.164	5	2	2	4
1.9989	2.000	20	3	1	4
1.8821	1.8828	10	1	0	8
1.8415	1.8417	20	4	0	0
1.8090	1.8092	10	3	2	4
1.7749	1.7747	5	4	1	1
1.7336	1.7324	25	3	1	6
1.6471	1.6462	10	4	2	0
1.6114	1.6118	20	4	2	2
1.5857	1.5864	10	3	3	4
1.4938	1.4934	5	3	1	8
1.4344	1.4346	15	2	0	10
1.4093	1.4096	5	3	2	8

*Equipment:* Gandolfi camera, 114.6 mm radius, Cu-K $\alpha$  radiation, Ni-filter, film data not corrected for shrinkage. Intensities estimated visually. Lattice parameters refined by the program NBS\*AIDS83 (Mighell *et al.*, 1981). Indexed by comparison with a theoretical powder pattern, calculated on the crystal structure, given by Chakoumakos *et al.*, 1993.

(56.6–57.4), total 99.7 wt.%. The empirical formula is Sr<sub>0.98</sub>Cu<sub>1.00</sub>Si<sub>4.01</sub>O<sub>10.00</sub> (based on 10 oxygen p.f.u.), simplified SrCuSi<sub>4</sub>O<sub>10</sub>, which requires SrO 24.47, Cu 18.78, and SiO<sub>2</sub> 56.75 wt.%.

Chemical analyses of wesselsite crystals taken from the two specimens, which were obtained later, yielded partially substantial amounts of Ba, as well as small quantities of Ca; BaSO<sub>4</sub> and CaSO<sub>4</sub> were used as standards. No other elements were found in either measurement above the detection limits. Including these new data, in all 111 samples were analysed, each measurement consisting of at least three spots within the grain. The variation of the chemical composition within one sample was <0.1 wt.% for Ba and Sr, <0.2 wt.% for Ca, Cu and Si in all cases. The analytical results are shown in Fig. 1, covering the

solid solution series wesselsite–effenbergerite from We<sub>50</sub>Ef<sub>50</sub> to We<sub>100</sub>Ef<sub>0</sub>. The calcium content ranges from 0.0 to 0.06 atoms p.f.u. (mean value 0.022) and shows no correlation with the Sr/Ba molar ratio.

Calculation of the Gladstone–Dale relationship for pure wesselsite using the constants of Mandarino (1981) yields a superior compatibility,  $(1 - (K_p/K_c)) = -0.001$ .

#### X-ray powder study

The material of wesselsite, available to date, is unsuitable for a single crystal X-ray investigation. A powder diffraction pattern (Table 1) of a pure wesselsite cluster (a Sr end-member, as confirmed by EDX) was obtained with a Gandolfi camera. The unit cell parameters, refined by least squares treatment of 27 lines, are listed in Table 2. The results of the film data compare excellently with those reported for synthetic SrCu[Si<sub>4</sub>O<sub>10</sub>] (Pabst, 1959; ASTM:12–511). A few reflections for wesselsite have been re-indexed based on a theoretical powder pattern calculated with the program Lazy Pulverix (Yvon *et al.*, 1977).

#### Discussion

By chemistry and X-ray powder diffraction, it has been proven that wesselsite belongs to the gillespite group. Representatives are synthetic BaCu[Si<sub>4</sub>O<sub>10</sub>], SrCu[Si<sub>4</sub>O<sub>10</sub>] and MCr[Si<sub>4</sub>O<sub>10</sub>] with  $M = \text{Ca, Sr, Ba}$  (Pabst, 1959; Lin *et al.*, 1992; Janczak and Kubiak, 1992; Chakoumakos *et al.*, 1993; Belsky *et al.*, 1984; Miletich and Allan, 1996), as well as the minerals cuprorivaite, CaCu[Si<sub>4</sub>O<sub>10</sub>] (Pabst, 1959), gillespite, BaFe[Si<sub>4</sub>O<sub>10</sub>] (low-pressure phase gillespite I, Hazen and Burnham, 1974; Hazen and Finger, 1983) and effenbergerite, BaCu[Si<sub>4</sub>O<sub>10</sub>] (Giester and Rieck, 1994). For a detailed description and illustrations of the gillespite structure type, a sheet silicate with unbranched single layers formed by four-membered rings [Si<sub>4</sub>O<sub>12</sub>], see Giester and Rieck (1994) and references cited therein.

The cell dimensions of type wesselsite are well within the range reported for synthetic SrCu[Si<sub>4</sub>O<sub>10</sub>], as shown in Table 2. At present, the solid-solution series between wesselsite and effenbergerite is confirmed only for compositions ranging from We<sub>50</sub>Ef<sub>50</sub> to We<sub>100</sub>Ef<sub>0</sub>. A cation ordering of Sr and Ba atoms, which might be possible especially for the intermediate representatives, could not be studied up to now on the natural specimens. Synthesis experiments by the method proposed by Pabst (1959) at temperatures of 800°C from various mixtures of BaCO<sub>3</sub>, SrCO<sub>3</sub>, CuO and SiO<sub>2</sub> might yield suitable material for single crystal X-ray studies of ordering phenomena.

TABLE 2. Unit cell data for wesselsite and related compounds

References	1	2	3	4	5
$a_0$ [Å]	7.366(1)	7.37	7.3707(2)	7.442(2)	7.456(1)
$c_0$ [Å]	15.574(3)	15.57	15.5904(6)	16.133(5)	15.543(1)
V [Å <sup>3</sup> ]	845.01	845.7	846.9	893.5	864.1

References: (1) wesselsite, this study, (2) synthetic SrCu[Si<sub>4</sub>O<sub>10</sub>] (Pabst, 1959), (3) synthetic SrCu[Si<sub>4</sub>O<sub>10</sub>] (Chakoumakos *et al.*, 1993), (4) effenbergerite, BaCu[Si<sub>4</sub>O<sub>10</sub>] (Giester and Rieck, 1994), (5) synthetic SrCr[Si<sub>4</sub>O<sub>10</sub>] (Miletich and Allan, 1996)

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### References

- Belsky, H.L., Rossman, G.R., Prewitt, C.T. and Gasparik, T. (1984) Crystal structure and optical spectroscopy (300 to 2200 nm) of CaCrSi<sub>4</sub>O<sub>10</sub>. *Amer. Mineral.*, **69**, 771–6.
- Chakoumakos, B.C., Fernandez-Baca, J.A. and Boatner, L.A. (1993) Refinement of the Structures of the Layer Silicates  $MCuSi_4O_{10}$  ( $M = Ca, Sr, Ba$ ) by Rietveld Analysis of Neutron Powder Diffraction Data. *J. Solid State Chem.*, **103**, 105–13.
- Dixon, R.D. (1985) Sugilite and associated minerals from the Wessels mine, Kalahari Manganese field. *Trans. Geol. Soc. South Africa*, **88**, 11–7.
- Dixon, R.D. (1986) Metamorphism in the Kalahari Manganese field. *Geocongress '86 Extended Abstracts*; Geol. Soc. South Africa, 505–8.
- Dixon, R.D. (1989) Sugilite and associated metamorphic silicate minerals from Wessels mine, Kalahari Manganese field. *Bull. Geol. Survey, South Africa*, **93**, 1–47.
- Giester, G. and Rieck, B. (1994) Effenbergerite, BaCu[Si<sub>4</sub>O<sub>10</sub>], a new mineral from the Kalahari Manganese Field, South Africa: description and crystal chemistry. *Mineral. Mag.*, **58**, 663–70.
- Hazen, R.M. and Burnham, C.W. (1974) The crystal structures of gillespite I and gillespite II: a structure determination at high pressure. *Amer. Mineral.*, **59**, 1166–76.
- Hazen, R.M. and Finger, L.W. (1983) High-pressure and high-temperature crystallographic study of the gillespite I–II phase transition. *Amer. Mineral.*, **68**, 595–603.
- Janczak, J. and Kubiak, R. (1992) Refinement of the Structure of Barium Copper Silicate BaCu[Si<sub>4</sub>O<sub>10</sub>] at 300K. *Acta Crystallographica*, **C48**, 1299–301.
- Kleyenstuber, A.S.E. (1984) The mineralogy of the manganese bearing Hotazel formation of the Proterozoic Transvaal sequence of Griqualand West, South Africa. *Trans. Geol. Soc. South Africa*, **87**, 267–75.
- Lin, H.C., Liao, F.L. and Wang, S.L. (1992) Structure of BaCuSi<sub>4</sub>O<sub>10</sub>. *Acta Crystallographica*, **C48**, 1297–9.
- Mandarino, J.A. (1981) The Gladstone-Dale relationship: Part IV. The compatibility concept and its application. *Canad. Mineral.*, **70**, 441–50.
- Mighell, A.D., Hubbard, C.R. and Stalick, J.K. (1981) NBS\*AIDS83. A FORTRAN Program for Crystallographic Data Evaluation, NBS Technical Note 1141.
- Miletich, R. and Allan, D.R. (1996) The gillespite-type Cr<sup>2+</sup> silicates BaCrSi<sub>4</sub>O<sub>10</sub> and SrCrSi<sub>4</sub>O<sub>10</sub>. *Z. Kristallogr., Suppl. Issue*, no 11, p. 88.
- Pabst, A. (1959) Structures of some tetragonal sheet silicates. *Acta Crystallographica*, **12**, 733–9.
- Von Bezing, K.L., Dixon, R.D., Pohl, D. and Cavallo, G. (1991) The Kalahari Manganese field, an update. *Mineral. Record*, **22**, 279–97.
- Yvon, K., Jeitschko, W. and Parthe, E. (1977) Lazy Pulverix, a computer program for calculating X-ray and neutron diffraction powder patterns. *J. Applied Crystallography*, **10**, 73–4.

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