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UKULAITE* — $Ta_2Sn_2O_7$ — AND WODGINITE AS NCLUSIONS IN CASSITERITE IN THE GRANITE PEGMATITE IN SUKULA, TAMMELA IN SW FINLAND

BY

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ABSTRACT

Sukulaite, a new mineral with the formula $(Ta, Nb)_2Sn_2O_7$, was found as narrow rims surrounding wodginite inclusions in tantalian cassiterite in a specimen from the granite pegmatite in Sukula, Tammela, SW Finland. Under a binocular microscope the color of sukulaite is yellowish brown, translucent; in reflected light, light gray with a reddish or lilac tint. Reflectivity in oil is 3.4 % in Xe light. Polishing hardness is greater than that of cassiterite and wodginite. X-ray powder photograph shows the mineral to be isotypic with microlite. The space group is *Fd*3*m* with $a_0 = 10.57$ Å.

Chemical analyses of the wodginite suggest a variety with iron prevailing over manganese. Precession photographs show the systematic extinctions to be consistent with the space groups *C*2/*c* and *Cc*. Cell parameters are given for two wodginite crystals, microprobe analyses for three. The mineral is twinned on (100). The nature of oriented intergrowth with cassiterite is discussed.

INTRODUCTION

In a recent paper by one of the authors (Vorma, 1965) three columbite specimens associated with ainalite, the tantalian cassiterite of A. E. Nordenskiöld (1863) from the Penikoja granite pegmatite in Somero, SW Finland and two columbite specimens from the adjacent Torro pegmatite area were described. The columbite in all the five investigated specimens was in a disordered state. During the same study tapiolite from two specimens from the same pegmatite province was investigated and the disordered state was noted. The present work is a continuation of the study of ainalite specimens from the same pegmatite province (Tammela-Somero pegmatite province). This time the inclusions in the ainalite specimens from the pegmatite at Sukula in

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*) The name sukulaite is from the locality. The name is approved by the Commission on New Minerals and Mineral Names, IMA, May 1967.

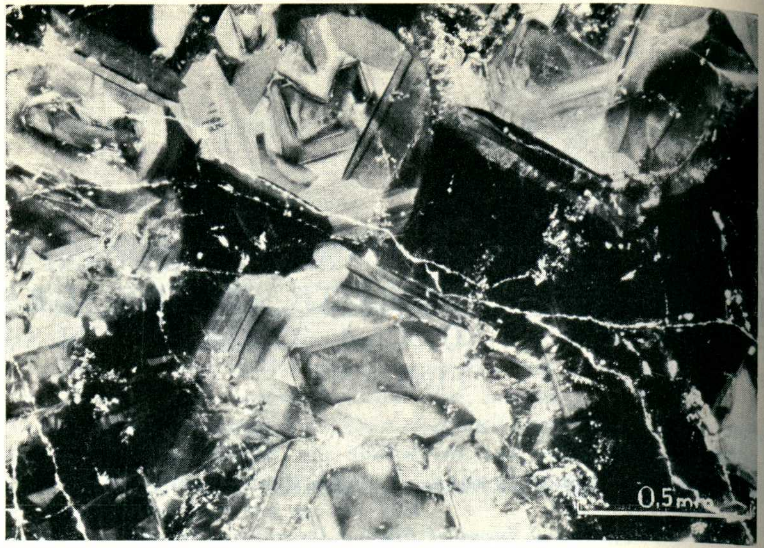


FIG. 1. Zoned cassiterite. Polished section, oblique illumination. Specimen no. 439. Sukula, Tammela, SW Finland.

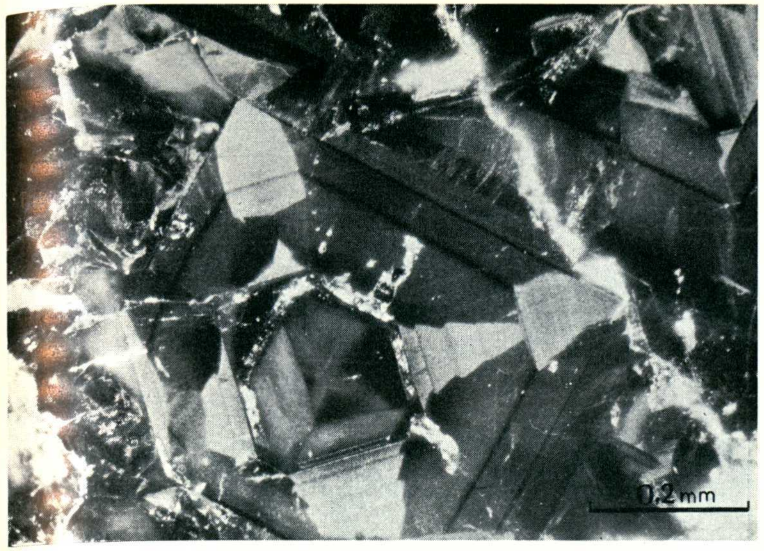


FIG. 2. Zoned cassiterite with overgrowth pyramids well developed. Polished section, oblique illumination. Specimen no. 439. Sukula, Tammela, SW Finland.

Tammela will be described. The study shows sukulaite — a new Ta-Sn oxide —, iron rich wodginite, tapiolite and native bismuth occurring as inclusions in cassiterite. This paper is mainly concerned with sukulaite and wodginite.

The pegmatite province of Tammela-Somero was described by Mäkinen in 1913 and recently by Aurola, 1963. The specimens investigated during the present study are from the collection of Dept. of Geology and Mineralogy, University of Helsinki, *viz.* nos. 439, 440, 443, 444, 445 and 446. All of these specimens were collected about one hundred years ago.

OCCURRENCE

Numerous pegmatite exposures with small abandoned quartz quarries are met with in the Sukula village and its surroundings. A small pegmatite quarry near the Kulmala farm house in Sukula is known, due to the type material for tapiolite (Nordenskiöld, 1863, p. 445). From the same quarry the occurrence of triphylite has been reported (*ref.* in Mäkinen, 1913, p. 96). An adjacent small quarry is mentioned by Nordenskiöld (*op.cit.*, p. 449) as a locality from which he described columbite. In one pegmatite dike at Sukula, triplite has been described (*ref.* in Mäkinen, 1913, p. 100). The Sukula pegmatite is characterized by quartz, microcline, albite, muscovite, biotite, tourmaline and beryl.

The specimens investigated during this study are listed in Table 1. No closer locality for these specimens is given than Sukula, Tammela. It is, however, highly probable that the specimens originate from the quarry near the Mäkitulokas farm house in Sukula. This quarry is distinct from both the above mentioned quarries where tapiolite and columbite have been described. The quarry at Mäkitulokas was mentioned by Nordenskiöld in 1863 (*op.cit.*, p. 452) as the locality where ainalite was found in Sukula.

The specimens consist of cassiterite in coarse granular masses, grain size being mostly about 1 mm, occasionally up to a few centimeters. When a polished section is studied under a binocular microscope (oblique illumination), very marked zoned structure is often observed in cassiterite. The cores of cassiterite grains are usually light yellow, transparent (diameter 0.2 mm). The transparent cores are then surrounded by numerous opaque, in obliquely illuminated light steel gray, zones of tantalian cassiterite. In places the growth bands are parallel to the bounding faces, in places the growth is sectoral (Figs. 1 and 2). Microprobe analyses of cassiterite indicate Ta_2O_5 amounts varying from point to point and from specimen to specimen between 0.*x* and 6 wt.- %. The highest Nb_2O_5 content is about 1 wt.- % (in specimen no. 445; 6 % for Ta_2O_5 was recorded at the same point). FeO contents amount in places up to 1 wt.- %, MnO and TiO_2 up to 0.*x* %. In addition to the Ta and Nb concentrations above, in the cassiterite structure (solid solution of tapiolite in cassiterite), numerous inclusions of opaque minerals were found in cassiterite, occurring partly as oriented intergrowths. So far iron rich wodginite, tapiolite, native bismuth and sukulaite have been identified (Table 1).

Table 1.

Identification of Sukula specimens

Specimen no.	Label	Phases observed and method of identification
439	Ainlite, Sukula, Tammela, 1861.	Zoned tantalian cassiterite (1, 3, 4) with inclusions of wodginite (1, 4), tapiolite (3, 4) and native bismuth (3, 4).
440	Ainalite, Sukula, Tammela, 1861. A present from A. E. Nordenskiöld.	Zoned tantalian cassiterite (1, 3, 4) with inclusions of wodginite (1, 2, 3, 4), sukulaite (1, 3, 4) and native bismuth (4).
443	Ainalite, Sukula, Tammela.	Tantalian cassiterite (1, 2, 3, 4) with inclusions of wodginite (1, 3, 4) and native bismuth (4).
444	Ainalite, Sukula, Tammela, 1870, F. J. W. (the initials of prof. F. J. Wiik).	Tantalian cassiterite (1, 3, 4) with inclusions of wodginite (1, 2, 3, 4), tapiolite (3, 4) and native bismuth (3, 4).
445	Ainalite, Sukula, Tammela, 1861.	Tantalian cassiterite (1, 3, 4) with inclusions of tapiolite (1, 3, 4) and native bismuth (3, 4).
446	Ainalite, Tammela.	Zoned tantalian cassiterite (1, 3, 4) with inclusions of wodginite (1, 4), tapiolite (3, 4) and native bismuth (4).

(1) = X-ray powder determination
(2) = X-ray single crystal study
(3) = electron probe microanalysis
(4) = detected on polished section

The sizes of the wodginite and tapiolite inclusions in cassiterite are mostly between 0.01 and 0.2 mm. The inclusions are sometimes quite irregular in shape, sometimes, however, lathlike. Due to the difficulty in distinguishing wodginite from tapiolite under reflected light no estimation is given of their relative abundance. Sukulaite has been identified so far in one specimen (no. 440). In this specimen the small wodginite inclusions are often surrounded by narrow ($< 20\ \mu$) rims of sukulaite (Figs. 3 and 4); in places sukulaite replaces wodginite almost completely. It should be mentioned that specimen no. 440 is rather strongly disintegrated pointing to the possible role of supergene processes in the origin of sukulaite.

Native bismuth occurs in each investigated specimen as very small inclusions in cassiterite. The grain size varies from 0.01 to 0.03 mm. Only some few grains were found in each polished section.

Point count analyses were made of the polished sections. The opaque inclusions in cassiterite amounted from 0.6 % to 3.6 % (wodginite + tapiolite + native bismuth + sukulaite). The silicate inclusions were present about 2—4 %, in specimen no. 443 this figure amounted to 19 %.

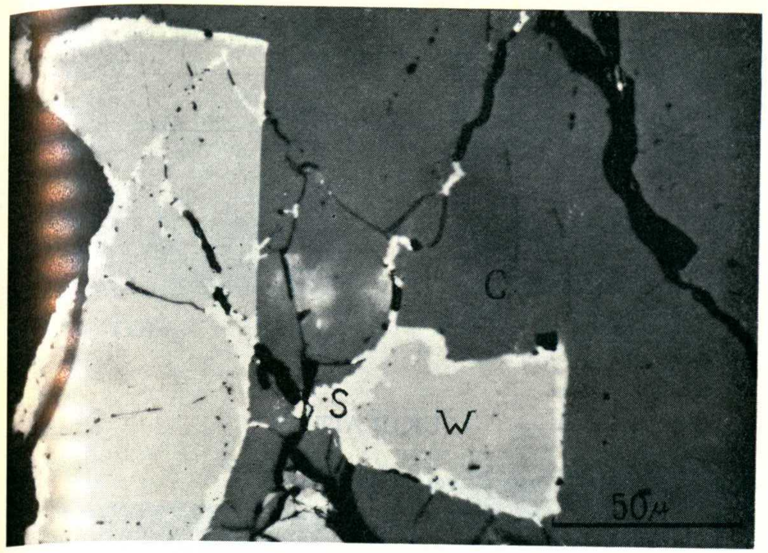


Fig. 3. Sukulaite (s), wodginite (w) and cassiterite (c). Polished section. Specimen no. 440. Sukula, Tammela, SW Finland.

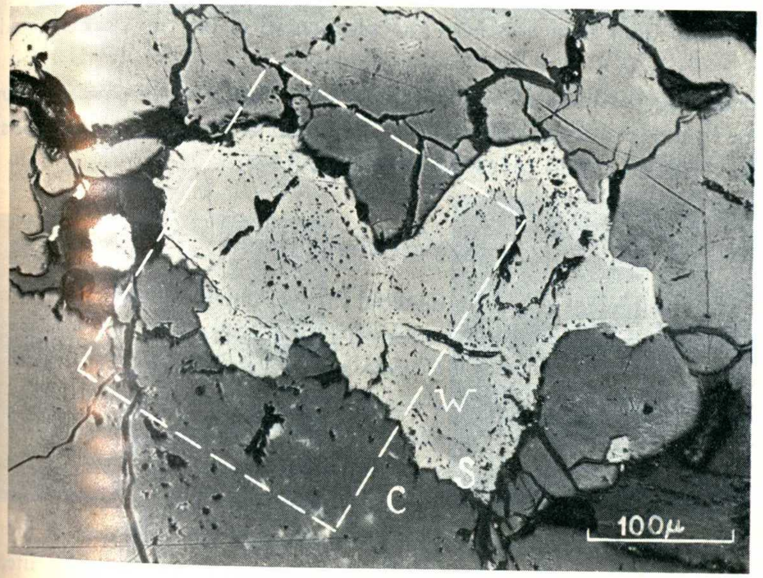


Fig. 4. Sukulaite (s) occurring as a rim between wodginite (w) and cassiterite (c). The area bounded by the broken line refers to the Fig. 5. Polished section. Specimen no. 440. Sukula, Tammela, SW Finland.

TABLE 2.

Chemical composition of sukulaite. Electron microprobe analysis by J. Siivola

	Wt.-%		Atomic prop.	
Ta_2O_5	47	Ta	313	286
Nb_2O_5	8	Nb	60	
TiO_2	1	Ti	13	
MnO	2	Mn	28	336
FeO	1.7	Fe	24	
SnO_2	40	Sn	284	
	(99.7)	O	1 328	

SUKULAITE

Physical properties

Under a binocular microscope the color of sukulaite is yellowish brown, translucent, under reflected light gray with a reddish or lilac tint. The color is lighter than that of cassiterite and wodginite. Between crossed nicols the mineral has strong internal reflections, certainly partly due to the small grain size, in reddish brown, making it impossible to judge whether the mineral is optically isotropic or not.

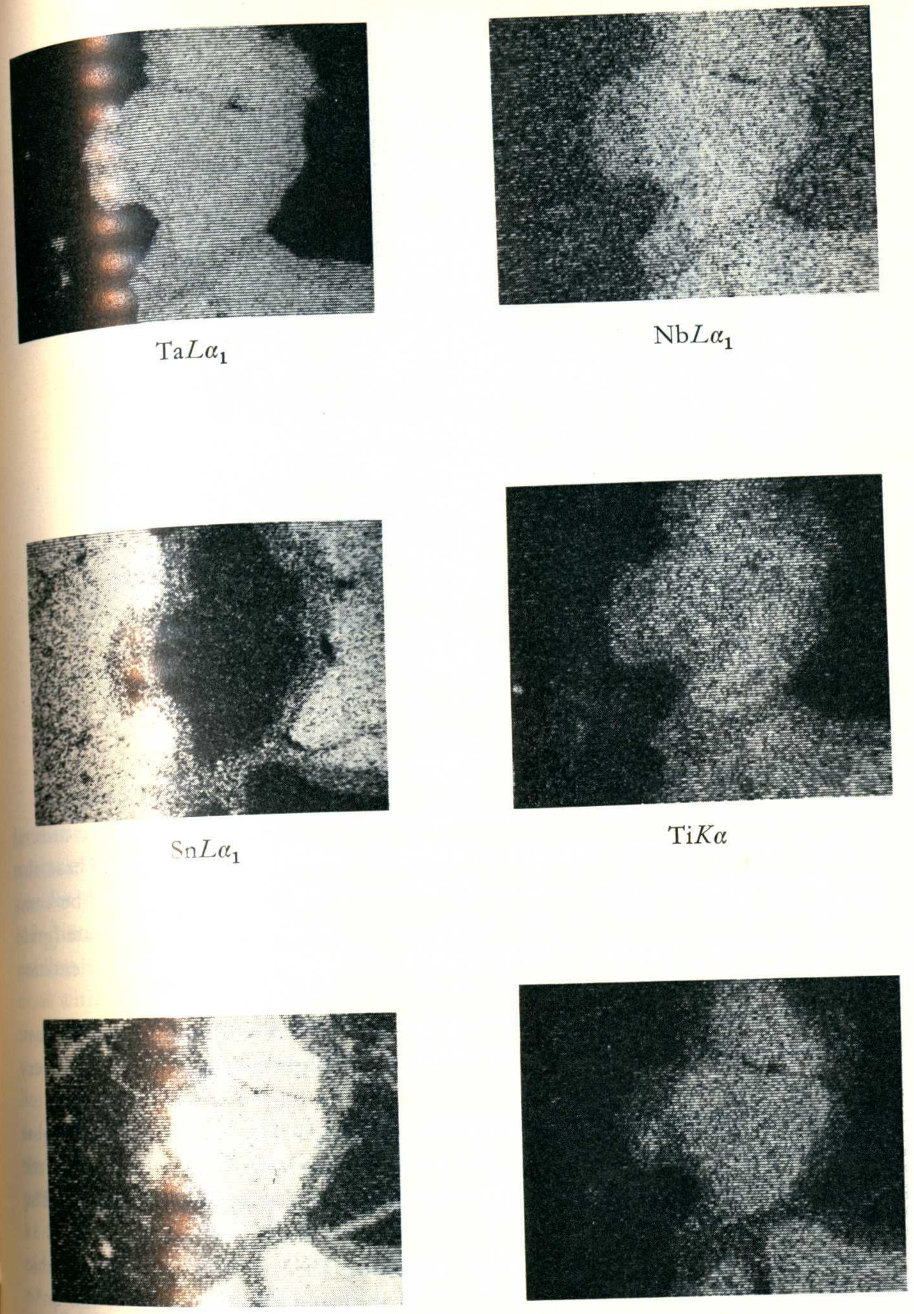
The reflectivity of sukulaite was measured in xenon light in oil immersion with a photomicrographic exposure meter. R turned out to be 13 % higher than that of cassiterite, relatively. If taking $R = 3$ % for cassiterite in oil, then $R = 3.4$ % for sukulaite in oil. This also concerns the pigmentation on the grain boundaries of sukulaite.

The polishing hardness of sukulaite is greater than that of cassiterite and wodginite. Due to the scantity of material, density could not be determined. For synthetic $Ta_2Sn_2O_7$, Gasperin (1955) gives the density as 8.34.

Chemical composition

There was insufficient sukulaite material for wet chemical analysis. The composition could be tested only with an electron probe microanalyser (model Geoscan). All the elements between Na and U were scanned, but only Ta, Nb, Sn, Mn, Fe and Ti were found (see Fig. 5). The result of the analysis is given in Table 2. The analysis nearly corresponds to $(Ta, Nb)_2Sn_2O_9$ with Ta : Nb = 78 : 22.

The role of iron and manganese in sukulaite is questionable. The mineral occurs as aggregates, the grain size being approximately 5 μ. The grains are often thinly coated with an unidentified mineral (Fig. 6). Because the diameter of the electron beam used was of the same magnitude ($< 2\mu$) as the grain size of sukulaite, and the effective penetration of the beam is of the same order, it is quite possible that the analysis given also includes the coating on the sukulaite grains.



$TaL\alpha_1$ $NbL\alpha_1$

$SnL\alpha_1$ $TiK\alpha$

$FeK\alpha_1$ $MnK\alpha_1$

FIG. 5. Electron probe scanning pictures showing the distribution of Ta, Nb, Sn, Ti, Fe and Mn in sukulaite, wodginite, and cassiterite. *Cf.* Fig. 4. Specimen no. 440. Sukula, Tammela, SW Finland.

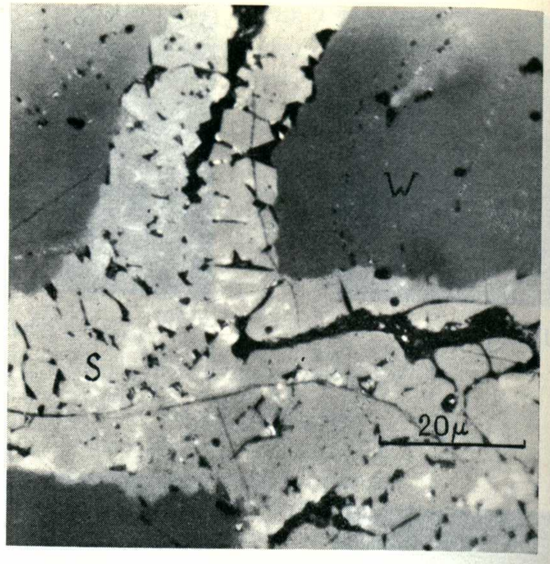


FIG. 6. Idiomorphic sukulaite (s) and wodginite (w). Polished section. Oil immersion. Specimen no. 440. Sukula, Tammela, SW. Finland.

X-ray crystallography

Debye-Scherrer photographs from an aggregate of sukulaite showed the mineral to be cubic with $a_o = 10.57$ Å. The powder data are given in Table 3. These also contain some diffraction lines of the adjacent cassiterite which could not be completely separated from sukulaite. Due to the aggregate nature of the preparate (grain size in it ~ 5 μ) the intensities of reflections may be affected by preferred orientation if present.

The powder data show sukulaite to be isotypic with microlite and thus to have the space group *Fd*3*m*. No work could be done on single crystals due to their very small grain size.

Gasperin, 1955, synthesized the compound $Ta_2Sn_2O_7$ by heating equal weights of powdered SnO_2 and Ta_2O_5 with a globule of tin. According to Gasperin the compound is isotypic with the minerals of the microlite-pyrochlore group. The material synthesized by Gasperin is yellow, transparent. Measured density is 8.34 and calculated density 8.21 (Structure Reports for 1955, vol. 19, p. 392). Cubic system, $a_o = 10.48$ Å. The work of Gasperin indicates the tin to be in the Sn^{2+} state. As shown, sukulaite is isotypic with microlite as is also the compound synthesized by Gasperin. Thus we can conclude that sukulaite is rather $Ta_2Sn_2O_7$ than $Ta_2Sn_2O_9$ (*cf.* p. 178), in consistency with the structure formula of the atopite structure type.

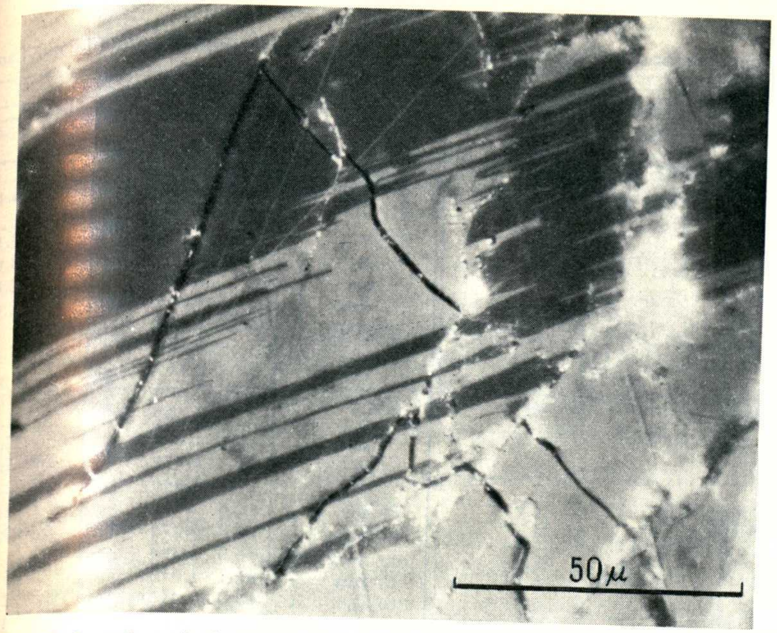


FIG. 7. Lamellar twinning in wodginite. Polished section. Nicols + —8°. Specimen no. 440. Sukula, Tammela, SW Finland.

Gasperin *(op.cit.)* claims Ta to be in the position 16(c) and Sn in 16*(d)* in the synthetic $Ta_2Sn_2O_7$ while in microlite the position 16*(d)* is occupied by Ta. The structure determination by Gasperin is based on the 28 strongest reflections of the powder data. It must be emphasized that in a structure of microlite type all the reflections with h, k and l = even have the same contribution from Sn and Ta regardless of their distribution between the positions 16*(c)* and 16*(d)*. All the reflections with h, k and l = odd, however, have contributions from atoms in these positions with opposite signs; thus these reflections are weak compared with most of those with h, k and l = even. To judge whether sukulaite does belong to the microlite-pyrochlore group or not (Ta in the position 16*(d)* or in 16*(c)*) one ought to record accurate intensity data from the reflections with h, k and l = odd. Due to the very small size of the preparate and its aggregate nature with possibly some preferred orientation, it has been impossible for us to get such data *.

WODGINITE

In five out of the six investigated ainalite specimens a mineral, at first regarded as columbite, was found as inclusions. The identification was carried out by means

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*) The X-ray scattering curve for $(Ta_{0\cdot78}Nb_{0\cdot22})$ is practically the same as that of dysprosium (at least up to $sin\Theta/\lambda = 0.8$ $Å^{-1}$). The intensities of the reflections in the powder data of $Dy_2Sn_2O_7$ (ASTM 13—187) are very similar to those of sukulaite.

TABLE 3.

X-ray powder data for sukulaite from Sukula granite pegmatite in Tammela, SW Finland. Camera dia. 57.3 mm, Cu*Ka*

hkl	I_0	$d_0(Å)$	$d_c(Å)$
111	vw	~6.04*	6.10
(cassit.)	w	3.351	
311	w	3.175	3.187
222	vs	3.046	3.051
400, (+ cassit.)	ms	2.640	2.642
511, 333	vvw	2.034	2.034
?	vvw	1.953	
440	s	1.866	1.869
(cassit.)	vw	1.767	
620, (+ cassit.)	vw	1.670	1.671
622	s	1.589	1.593
444	m	1.524	1.526
711, 551	w	1.479	1.480
(cassit.)	vw	1.440	
642, (+ cassit.)	vw	1.415	1.412
731, 553	vw	1.374	1.376
?	vvw	1.340	
800	mw	1.3189	1.3213
662	m	1.2105	1.2125
840	m	1.1796	1.1818
911, 753	vw	1.1587	1.1602
844	mw	1.0780	1.0788
933, 771, 755	vw	1.0635	1.0623
10.2.2; 666	m	1.0171	1.0171
880	vw	.9346	.9343
11.3.1; 971; 955	w	.9228	.9235
10.6.2	m	.8938	.8933
12.0.0; 884	mw	.8811	.8808
11.5.1; 777	vw	.8716	.8718
11.5.3; 975	w	.8485	.8490
12.4.0	mw	.8360	.8356
13.1.1; 11.7.1; 11.5.5; 993	w	.8085	.8083
10.6.6	mw	.8065	.8060
12.4.4	w	.7973	.7967
13.3.1; 11.7.3; 997	w	.7905	.7900

*) Due to the very small preparate and long exposure time the background at small Θ angles is very strong and hence the data are not very accurate at small Θ angles.

of Debye-Scherrer photographs (camera dia. 57.3 mm). Subsequent electron microprobe analyses (Table 4) and X-ray single crystal study showed that the mineral, thought to be columbite, was iron rich wodginite. No phase corresponding in composition to columbite was detected. Tapiolite was encountered as inclusions in cassiterite in four specimens. Presumable wodginite and tapiolite were present as inclusions in every specimen concerned (see Table 1).

In polished section under reflected light wodginite is grayish white and weakly pleochroic. Anisotropism is distinct. Twinning is often observed; occasionally the twinning is lamellar (Fig. 7).

TABLE 4.

Chemical data and the unit cells of wodginites

	1	2	3	4	5	6
Ta_2O_5	70.49	70.05	74.1	65	60	61
Nb_2O_5	7.63	1.35	14.5	9	16	13
SnO_2	8.92	13.20	—	10	10	10
MnO	10.87	9.04	5.5	5	2	2
FeO	1.34	1.87	5.9	8	6	7
TiO_2	—	2.39	—	2	3	4
CaO	0.42	—	—	—	—	—
MgO	0.37	—	—	—	—	—
SiO_2	—	0.60	—	—	—	—
Loss of ignition	0.18	—	—	—	—	—
	100.22	98.50	100.0	99	97	97
	Unit cell contents					
Ta	8.29	8.40	8.45	7.4	6.7	6.8
Nb	1.49	0.27	2.74	1.7	3.0	2.4
Sn	1.54	2.32	—	1.7	1.6	1.6
Mn	3.98	3.38	1.95	1.8	0.7	0.7
Fe	0.48	0.69	2.07	2.8	2.1	2.4
Ti	—	0.79	—	0.6	0.9	1.2
O	32.00	32.00	32.00	32.0	32.0	32.0
	Cell parameters					
a_0	9.52 Å	9.47 Å	9.46 Å	9.48 Å	—	9.48 Å
b_0	11.47	11.42	11.50	11.44	—	11.45
c_0	5.10	5.09	5.14	5.11	—	5.11
β	91° 18′	91° 02′	90° 53′	90° 37′	—	90° 42′

1. Wodgina, Australia (Nickel *et al.*, 1963).
2. Bernic Lake, Manitoba (Nickel *et al.*, 1963).
3. Ruanda (Bourguignon and Mélon, 1965). Corrected for impurities.
4. Sukula, Tammela, SW Finland. Specimen no. 440. Electron microprobe analysis by J. Siivola.
5. » » » » » » 443. » » » » » »
6. » » » » » » 444. » » » » » »

Chemical composition

The analyses in Table 4 reveal that the wodginite from Sukula is characterized by high Ta_2O_5, Nb_2O_5 and SnO_2 contents (see also Fig. 5). The Fe/Mn ratio exceeds one. The other published wodginite analyses are given in the same Table 4. The unit cell contents are calculated assuming 32 oxygen atoms per cell (Nickel *et al*, 1963). It is seen that the Tammela wodginite is the iron richest so far recorded. The mineral originally named wodginite is a manganese tin tantalate. In the case of the Tammela mineral we are dealing with an iron tin tantalate. As the crystal chemistry of wodginite is only slightly known we think it unwise to give any special name to the iron rich wodginite. Mention should be made that also the Ruanda wodginite (Table 4, column 3) is richer in iron than in manganese.

The tapiolite inclusions in the ainalite specimens concerned are richer in tantalum than the wodginite. The composition in each of the six quantitatively analyzed crystals is practically the same, viz. Ta_2O_5 74 %, Nb_2O_5 8 %, FeO 10 %, MnO 1 %, TiO_2 3 % and SnO_2 2 %. These electron microprobe analyses indicate that the Ta/Nb ratio is much higher than that in wodginite. The same also applies to the Fe/Mn ratio. The low figure for SnO_2 in tapiolite compared with that in wodginite is also noteworthy.

X-ray crystallography

Two crystals of Tammela wodginite were investigated by single crystal methods. The Buerger precession photographs showed the mineral to have systematic extinctions consistent with the space groups *C*2/*c* and *Cc*. The cell parameters of the investigated specimens are given in Table 4, columns 4 and 6. The space groups are the same and the cell parameters very similar to those given for wodginite by Nickel *et al.* (1963). The β angle, however, is smaller than that of any previously published wodginite. Bourguignon and Mélon (1965, p. 299) recognize that some of the Ruanda wodginite specimens do not exhibit the doubling of some characteristic reflections in their powder data, even though these have all the other characteristics of wodginite. The authors mentioned attribute this to the variation of the β angle. Comparing the Fe/Mn ratio in the wodginites in Table 4 with the β angle it is presumable that the increasing Fe content decreases β. The synthetic compound *G* of Moreau and Tramasure (1965, p. 354) corresponding to iron free Mn rich wodginite with cell parameters $a_o = 9.45$ Å, $b_o = 11.40$, $c_o = 5.09$ and $\beta = 91°14'$ also supports this. If this assumption is correct the identification of iron rich wodginites using X-ray powder methods must be carried out with care. Mention should also be made that the Tammela wodginites do not show the 110 reflection (at 7.2 Å) in their single crystal photographs even though this reflection is allowed in the space groups *C*2/*c* and *Cc*. All the other low angle reflections characteristic of wodginite (see Nickel *et al.*, 1963), however, are present in the single crystal data of Tammela wodginites.

Both single crystals of the Tammela wodginites investigated by the Buerger precession method were twinned on (100). The β angle deviates in both cases so much from 90° (90°42' and 90°37') that there was no difficulty in detecting the twinning law.

The orientation law of wodginite inclusions in respect to their host, cassiterite, was revealed by precession photographs. These show in addition to the wodginite phase weak extra diffractions which could easily be attributed to cassiterite. The oriented intergrowth was observed to obey the rule *:

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*) The same orientation law was also verified by X-ray single crystal photographs for a disordered columbite intergrown with cassiterite (specimen from the Penikoja pegmatite quarry, Somero, SW Finland).

$x_c \| x_w$, *i.e.*, the 4.73 Å axis of cassiterite is parallel to the 2 × 4.73 Å axis of wodginite and hence
the *yz*-plane of cassiterite is almost parallel to the *yz*-plane of wodginite, on which plane

$z_w \perp (011)_c$, *i.e.*, $z_w \| [10\bar{1}]_c$ and hence $y_c \wedge y_w \approx 34°$, where the subscripts *c* and *w* refer to cassiterite and wodginite, respectively.

Ramdohr showed 1961 (p. 478) that in exsolved columbite in cassiterite the columbite *a* axis (3 × 4.75 Å axis) is parallel to the cassiterite *a* axis (4.73 Å axis). Thus it seems that the exsolved wodginite phase and columbite phase in cassiterite are oriented according to the same rule (*cf.* Haapala *et al.*, 1967).

DISCUSSION

Comparing the chemical analyses of the Sukula wodginites (Table 4) with those of the coexisting tapiolite (p.184) it is seen that the Ta/Nb ratio is considerably lower in wodginite than in tapiolite. The fractionating of Ta and Nb is more advanced in tapiolite than in wodginite. This is evidently partly due to the fact that the exsolution of wodginite in cassiterite takes place earlier than that of tapiolite. Cassiterite is isotypic with tapiolite and heterotypic with columbite-tantalite. This explains why more tapiolite than columbite-tantalite is dissolved in cassiterite (Schröcke, 1966, p. 9) and why the columbite-tantalite phace exsolves before the tapiolite phase (Ramdohr, 1961, p. 478). This same explanation can certainly be extended to the assemblage wodginite-tapiolite in cassiterite.

The stability range and crystal chemistry of wodginite is not fully known. The experimental works of Turnock (1965, 1966) and Schröcke (1966) indicate that the occurrence of wodginite, either without other tantalates or with tantalite, indicates relatively high oxygen pressure of the genetic conditions while tantalite is stable over a relatively large range of oxygen pressure. The occurrence of tapiolite is indicated by relatively low oxygen pressure. According to Turnock the partial pressure of oxygen will control which of the above mentioned minerals will form.

Turnock prepared synthetic wodginite in the system $MnTa_2O_6$-$FeTa_2O_6$-O as well as in the system $FeTa_2O_6$-$MnTa_2O_6$-$FeTaO_4$ in the join $MnTa_2O_6$-$FeTaO_4$. The wodginite phase produced was $Mn^{2+}_{2-2w}Fe^{3+}_{3w}Ta_{4-w}O_{12}$ with $0.08 < w < 0.29$ (Turnock, 1966). According to Turnock wodginite may contain ferric but not ferrous iron. Tin is not an essential element. Wodginite is a solid solution between AB_2O_6 and ABO_4 types.

Moreau and Tramasure 1965 (p. 354) prepared the *G* phase, analogous in cell dimensions to the wodginite phase, by heating Mn_2O_3 and Ta_2O_5 (1 : 1) in air at 1 050° for 95 hrs. The authors mentioned also produced the wodginite phase in the binary system $FeTa_2O_6$-$MnTa_2O_6$ (*op.cit.* pp. 376—378). For a composition

$(Fe_{0.1}Mn_{0.9})Ta_2O_6$ the wodginite phase was produced at 1 050°C in nitrogen in 50 hrs simultaneously with tantalite, while for the compositions $(Fe_{0.2}Mn_{0.9})Ta_2O_6$ and $(Fe_{0.3}Mn_{0.7})Ta_2O_6$ the wodginite phase was produced simultaneously with tapiolite.

Schröcke (1966, pp. 33—34, 46) has described a monoclinic phase analogous to wodginite in the quaternary system $FeNbO_4$-(Fe, Mn) (Nb, Ta)$_2O_6$. According to him: »Im Bereich von 900—1 100°C gibt es 3 quaternäre, homogene Mischkristallräume: einen alseitig um $FeNbO_4$ mit α-PbO_2- bzw. Wolframitstruktur, einen um $FeTa_2O_6$ mit Rutil- bzw. Trirutilstruktur und einen randlich um das Columbitsystem, ausgehend von dessen Zweistoffsystemen $FeNb_2O_6$-$MnNb_2O_6$-$MnTa_2O_6$ mit α-PbO_2- bzw. Columbitstruktur. Dieser wird sich bei 1 100° kaum mehr als 10—15 Mol.-% in den quaternären Raum erstrecken und sich mit sinkender Temperatur wesentlich verkleinern. Auch der $FeNbO_4$-Raum verkleinert sich bis auf 900° beträchtlich ausser der Ecke gegen $MnTa_2O_6$. An diesen Bereich des $FeNbO_4$-Raumes ist die monocline Aufspaltung analog dem Wodginit gebunden». On pp. 46—47 Schröcke discusses the role of Fe^{3+} in the columbite-, α-PbO_2- and wolframite structures with Fe : (Ta, Nb) > 1 : 2 as a cause of monoclinic distortion. Schröcke's statement, after discussing the chemical analyses of Bernic Lake and Wodgina wodginites, »Wenn an der Richtigkeit der Analysen nicht gezweifelt wird, muss es offenbar mehrere Gebiete der komplexen Mischkristalle vom ABO_4 und AB_2O_6 geben mit monoklin deformierter α-PbO_2-, Wolframit- oder Columbitstruktur. Das Wodginitproblem bedart offenbar noch weiterer Mineralanalysen und experimentaller Arbeit», receives additional support from a comparison of the compositions of Ruanda and Tammela wodginites with those of synthetic wodginites. So far synthetic wodginite, corresponding in composition (Fe/Mn ratio) either to Ruanda or Tammela wodginites, has not been produced. Certainly the extensive replacement of manganese by tin should have some influence on the stability field of wodginite.

In one of the investigated specimens from Sukula the new mineral sukulaite — $Ta_2Sn_2O_7$—replaces wodginite. The given formula is derived on crystallochemical bases. In tapiolite Ta occurs as pentavalent, in cassiterite Sn as tetravalent. In sukulaite at least one of these cations has to occur in a lower oxidation state. The sequence wodginite-tapiolite-sukulaite possibly reflects the gradual decrease of the partial pressure of oxygen.

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