CONTRIBUTIONS TO THE CHEMISTRY OF TAPIOLITE – MANGANOTAPIOLITE, A NEW MINERAL

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Microprobe determinations and X-ray diffraction studies of tapiolite specimens from the granitic pegmatites of the Eräjärvi area, in Orivesi, southern Finland, revealed a new manganesedominant analogue of tapiolite. A small crystal, 1.5 mm long and 0.5 mm thick, from a narrow lithium pegmatite dyke shows some parts richer in Mn than Fe. The name manganotapiolite is used for this Mn-dominant member and ferrotapiolite for the common Fedominant member of the tapiolite group.

The tapiolite crystal studied is prismatic, showing poorly developed {100} faces. Manganotapiolite is dark brown, strongly pleochroic from yellowish brown to reddish brown, but thicker fragments are opaque. In reflected light the colour is grey with a weak bireflectance changing from light brownish grey to grey. Internal reflections are strong with red brown colour. The reflectance values measured in air are: 16.0–15.7 (470 nm), 14.7–14.1 (546 nm), 15.0–14.8 (589 nm), 15.1–14.6 (650 nm), and in oil: 4.5–4.0 (470 nm), 3.9-3.4 (546 nm), 4.3-3.8 (589 nm), 4.3-3.8 (650 nm). Density (calc.) is 7.72 g/cm³ and VHN (100 g load) 711.

Microprobe analyses on five points of one manganese-rich part gave: FeO 6.4, 6.2, 3.7, 3.9 and 3.2; MnO 6.7, 7.7, 8.6, 9.7 and 10.2; CaO 0.4, 0.2, 0.6, 0.2 and 0.4; Ta₂O₅ 78.1, 77.6, 78.6, 79.8 and 76.3; Nb₂O₅ 7.1, 7.6, 7.2, 6.7 and 8.5; TiO₂ 0.1, 0.1, 0.0, 0.0 and 0.0; SnO₂ 1.0, 1.2, 1.3, 1.0 and 1.0; Sb₂O₃ 0.0, 0.0, 0.0, 0.0 and 0.1; Total 99.8, 100.6, 100.1, 101.4 and 99.7 wt. %. The empirical formula calculated from the mean values of these results (based on O = 6 and Z = 2) is: $(Mn_{0.59} Fe_{0.32}Ca_{0.03})_{\Sigma 0.94}(Ta_{1.72}Nb_{0.27}Sn_{0.04})_{\Sigma 2.03}O_6$. The Fe/Mn ratio of the crystal, however, varies gradually and irregularly from 66/34 to 24/76. The ideal formula of the manganotapiolite unit cell is: $(Mn, Fe)_2$ (Ta,Nb)₄O₁₂, where Mn²⁺ > Fe²⁺ and Ta > Nb.

The X-ray single crystal and powder diffraction studies of the material including the five points analysed showed tetragonal symmetry with space group P4₂/mnm, a = 4.762 Å and c = 9.272 Å and V = 210.26 Å³. The strongest lines in the X-ray powder diffraction pattern are: 4.24 (40) (101), 3.367 (100) (110), 2.592 (90) (103), 2.381 (60) (200), 1.754 (90) (213), 1.682 (60) (220), 1.504 (40) (320, 302) and 1.411 (40) (303, 116). Precession photographs show very strong reflections of a cell of the rutile type and twinning on {013}. The crystal exhibits small inclusions of native antimony, microlite and cassiterite.

Key words: manganotapiolite, ferrotapiolite, new minerals, pegmatite Eräjärvi, Finland.

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Introduction

In 1863 the well-known explorer and mineralogist A. E. Nordenskiöld described a tetragonal Fe-Ta oxide tapiolite as a new mineral from the Skogböle pegmatite, Kemiö, SW Finland. Brögger (1897) confirmed the status of two related species with the same chemical formula (Fe,Mn)(Ta,Nb)₂O₆: the orthorhombic tantalite-columbite and the tetragonal tapiolite-»mossite». Since then chemical analyses have shown that the Fe/Mn and Nb/Ta ratios of the orthorhombic series vary within wide limits; the iron and manganese-dominant members of columbite (ferrocolumbite and manganocolumbite) and tantalite (ferrotantalite and manganotantalite) are characteristic accessories, especially in granitic pegmatites. On the other hand, tapiolite analyses given in the literature (see Moreau and Tramasure 1965; Beugnies and Mozafari 1968; Clark and Fejer 1978, and Knorring and Fadipe 1981) show that the substitution of Fe by Mn and Ta by Nb in the tetragonal series is much more restricted. The Fe/Mn and Ta/Nb ratios of the mineral never drop below unity. Recent chemical analyses and X-ray diffraction studies have revealed that »mossite» does not exist in nature and the name has been discredited (Dunn et al. 1979). The maximum amount of Mn in tapiolite has been reported by Čech (1973), who shows that tapiolite from Maršikov, Czechoslovakia, contains 5.96 % MnO and 9.15 % FeO (or, according to the re-analysis by Clark and Fejer 1978, 4.17 % MnO and 9.67 % FeO), giving the formula $(Fe_{0.65}Mn_{0.43})_{1.08}(Ta_{1.90})$ Nb_{0.07})_{1.97}O_{6.00}.

Tapiolite very similar in composition has been reported by Khvostova and Arkhangelskaya (1970), who found tapiolite with 5.63 % MnO, 5.49 % Fe₂O₃ and 4.19 % FeO (Fe/Mn = 0.61/0.39) from the East Siberian pegmatite deposits. Because both of these specimens contain more Fe than Mn, the minerals must refer to manganoan tapiolites (Fleischer 1971).

The first of the present authors studied the middle Proterozoic granitic pegmatites of the Eräjärvi area in Orivesi, southern Finland and encountered tapiolite as a rare accessory in some dykes in addition to other Nb-Ta minerals (columbite-tantalite, wodginite and microlite) (Lahti 1981). Later, detailed pegmatite studies (tin prospecting) carried out by the authors (M. V. and S. I. L.) in the same area revealed that tapiolite occurs in at least eight pegmatite deposits, most of them lithium pegmatites. X-ray diffraction and microprobe studies showed that one small zonal crystal from a narrow lithium pegmatite dyke is extremely rich in manganese. Some parts of it contain more Mn than Fe, and the mineral is described in this study as a new variety of tapiolite. The first of the authors (S.I.L.) is responsible for the x-ray diffraction studies and physical determinations and second (B.J.) for microprobe analyses. In the light of the discovery, the authors proposed the name manganotapiolite for this Mn analogue of tapiolite solid solution. The Commission on New Minerals and Mineral Names of I.M.A. confirmed the name by vote on 26th March, 1983. Type material will be deposited at the Mineralogical Museum of the Geological Survey of Finland.

On the basis of the discovery of manganotapiolite and on the evidence of experimental studies that there is a complete isomorphous series (Moreau and Tramasure 1965, Turnock 1966), the authors proposed the species name ferrotapiolite for the common Fe-dominant member; tapiolite is considered as a group name covering both species. The Commission on New Minerals and Mineral Names of I.M.A. confirmed this nomenclature of the tapiolite group by vote on 14th June, 1983.

Occurrence

The manganotapiolite-ferrotapiolite crystal studied was encountered in the border zone of a pegmatite dyke one metre wide (called the Tiainen dyke by the present authors) south of the Talas dyke whose mineralogy was reported earlier (Lahti 1981). The two dykes are parallel and separated by a mica schist strip some two metres wide.

The Tiainen dyke is slightly zoned. The border zone is some centimetres wide and consists of fine-grained albite-quartz-muscovite pegmatite. The tapiolite crystal studied occurred as a very small prism in albitic plagioclase associated with schorl and apatite. The X-ray studies performed with Gandolfi and Debye-Scherrer cameras on several parts of the crystal, microprobe determinations and microscope studies on the polished sample showed that the mineral has numerous silicate inclusions, very small inclusions of native antimony and a few cassiterite grains. Microlite occurs throughout the sample as many-branched exolutions (Fig. 1.).

Coarse-grained microcline-bearing pegmatite predominates in the middle of the dyke. The biggest microcline crystals and quartz aggregates may reach 10-20 cm in diameter. The microcline is grey or white and microperthitic. The intermediate zone contains bervl. tourmaline, lepidolite, apatite, Fe-Mn-phosphates, wodginite. columbite. cassiterite, zircon and montebrasite as accessories concentrated on the cleavelandite and sugar albite replacement bodies and fracture fillings crossing the dyke. The most typical accessories are roundish blue green apatite grains and small prismatic crystals of yellow beryl and tourmaline. Tourmaline usually occurs as black or dark green crystals, 2-10 mm in diameter, but the colour may also be pink, light green or blue. Associated with lithium minerals, the tourmaline crystals may be zoned with a green core rimmed in pink; some crystals also show longitudinal zonality. Lepidolite occurs as a pink fine-scaled mass or as larger individual sheets often associated with pink-green tourmaline, and small, white montebrasite and brown sicklerite nodules. The sicklerite



Fig. 1. Photomicrographs of manganotapiolite-ferrotapiolite specimen illustrating a) a normal heterogenous and b) a well-polished »homogeneous» part of a polished section. The irregular black or dark grey parts in tapiolite (t, light grey) consists of small holes and cracks, silicates and microlite (m) exsolutions. Light small grains are native antimony (s). Reflected light, oil immersion, crossed nicols.

nodules are probably pseudomorphs after lithiophilite as in other pegmatite dykes in the area. According to the microprobe analysis, one sicklerite sample analysed contains 15.4 wt % FeO (total) and 27.6 % MnO, corresponding to an Fe/Mn ratio of 0.35/0.65. The nodule is rimmed by hureaulite, frondelite and vivianite, which also replace the host mineral sicklerite. Wodginite occurs as dark brown anhedral crystals or crystal aggregates, some mm in diameter, in certain parts of the dyke. Associated minerals may include zircon, cassiterite and black thucholite spherules. Columbite, which is rare in the dyke, was encountered as thin (below 1 mm thick) black plates with lithium minerals.

Appearance and physical properties

The crystal studied is prismatic, about 1.5 mm long and 0.5 mm thick, but some parts with Mn > Fe are no more than 100 µm wide. The mineral is opaque with adamantine to submetallic luster. Very thin fragments are translucent. The colour and streak are dark brown. No cleavages were found.

The hardness of the Mn-rich parts measured with a Leitz Durimet device is 711 kg/cm² when a 100 p load was used. The result is an arithmetic mean value of seven measurements (limits $665-752 \text{ kg/cm}^2$). For lack

Table 1. The reflectance of manganotapiolite measured in air and in oil. SiC standard (National Physical Laboratory no. 87), Shott interference graduated filter, band width 15 nm, objective 45:1 A = 0.85 in air and 60:1 A = 0.95 in oil, immersion oil DIN 58884.

wawelength nm	R % in air	R% in oil
470	16.0 - 15.7	4.5 - 4.0
546	14.7 - 14.1	3.9 - 3.4
589	15.0 - 14.8	4.3 - 3.8
650	15.1 - 14.6	4.3-3.8

of material the authors could not measure the specific gravity. The density calculated from the empirical formula is 7.72 g/cm³.

Small grains of the mineral are pleochroic from yellowish brown to reddish brown, but thicker grains are opaque. In reflected light the colour is grey with a weak bireflectance changing from light brownish grey to grey. Internal reflections are strong with a red-brown colour. The reflectance values measured in air and in oil are given in Table 1. The sample does not polish well and the cracks, holes, inclusions and irregular microlite exsolutions found throughout it must markedly reduce the values.

Chemical data

Analyses 1-11 in table 2 show the chemical data of the manganotapiolite-ferrotapiolite crystal examined compared with the chemistry of tapiolite specimens from the other deposits in the area (nos. 13-21). The chemical data on the tapiolite specimens are presented in Figure 2.

The samples were analysed by means of a Jeol Superprobe electron microprobe with accelerating potential 15 kV, specimen current 100 nA and beam diameter about 1 μ m. The standards used in the determinations were: manganocolumbite (for Mn, Fe, Nb, Ta and W), ilmenite (for Ti), cassiterite (for Sn), antimony (for Sb) and wollastonite (for Ca).

The substitution of the $Mn(Ta,Nb)_2O_6$ component in tapiolite is limited to 20 mol. % in most of the specimens studied. Two crystals richer in Mn were encountered in the same dyke (Tiainen dyke). Analysis 12 (Table 2, Fig. 2) was done on the tapiolite crystal occurring as an inclusion in the wodginite crystal aggregate in the middle of the dyke. Analyses 1–11 were performed on the crystal studied in detail. Most parts of Table 2. The chemical composition (as oxides and atoms based on 6 oxygens) of the examined manganotapiolite-ferrotapiolite crystal (no. 1–11) compared with the composition of Mn-rich tapiolite (12) from the same deposit and tapiolite specimens from the other pegmatite deposits of the Eräjärvi area (no. 13– 21). Microprobe analyses by Bo Johanson and partly by Tuula Hautala.

	TiO2 Ti	FeO Fe	MnO Mn	MgO Mg	CaO Ca	Ta2O5 Ta	Nb2O5 Nb	WO3 W	SnO₂ Sn	Sb2O3 Sb	Σ Ox.
1	-	$3.2 \\ 0.22$	$\begin{array}{c} 10.2 \\ 0.70 \end{array}$	$0.0 \\ 0.00$	$\begin{array}{c} 0.4 \\ 0.04 \end{array}$	76.3 1.68	8.5 0.31	-	$\begin{array}{c} 1.0 \\ 0.03 \end{array}$	0.1 0.00	99.7
2	-	3.9 0.26	9.7 0.66	$0.0 \\ 0.00$	$0.2 \\ 0.02$	79.8 1.75	$6.7 \\ 0.24$	-	$1.0 \\ 0.03$	-	101.3
3	-	$3.7 \\ 0.25$	8.6 0.59	$0.0 \\ 0.00$	$0.6 \\ 0.05$	78.6 1.74	$7.2 \\ 0.27$	-	$1.3 \\ 0.04$	_	100.0
4	$0.1 \\ 0.01$	$6.2 \\ 0.42$	$7.7 \\ 0.53$	0.0	$0.2 \\ 0.02$	$77.6 \\ 1.70$	$7.6 \\ 0.28$	_	$1.2 \\ 0.04$	_	100.6
5	-	6.9 0.47	6.1 0.42	0.0	0.8	80.6 1.77	$6.1 \\ 0.22$	-	$1.0 \\ 0.03$	$0.1 \\ 0.00$	101.6
6	0.1	6.4 0.43	6.7 0.46	0.0	0.4	78.1	7.1 0.26	-	1.0	-	99.8
7	-	7.7 0.53	7.2 0.50	0.0	0.1	77.0	6.3 0.24	-	0.8	Ξ	99.1
8	-	7.3 0.50	6.5 0.45	0.0 0.00	0.4 0.04	75.7 1.68	$7.2 \\ 0.27$	Ξ	$1.1 \\ 0.04$	$1.4 \\ 0.05$	99.6
9	-	8.4 0.57	$\begin{array}{c} 6.1 \\ 0.42 \end{array}$	0.0 0.00	$\begin{array}{c} 0.3 \\ 0.03 \end{array}$	$77.3 \\ 1.70$	$7.7 \\ 0.28$	_	0.8 0.03	0.0	100.6
10	_	8.1 0.56	5.0 0.35	0.0 0.00	$\begin{array}{c} 0.4 \\ 0.04 \end{array}$	$78.6 \\ 1.77$	$6.2 \\ 0.23$	_	0.9 0.03	$\begin{array}{c} 0.1 \\ 0.00 \end{array}$	99.3
11		9.7 0.66	4.9 0.34	0.0	$\begin{array}{c} 0.1 \\ 0.01 \end{array}$	$78.9 \\ 1.73$	$6.7 \\ 0.25$		0.8 0.03	0.0	101.1
12	$\begin{array}{c} 0.1 \\ 0.01 \end{array}$	$\begin{array}{c} 10.2\\ 0.71 \end{array}$	4.8 0.34	0.0 0.00	$0.1 \\ 0.01$	83.1 1.88	2.0 0.08	$\begin{array}{c} 0.3 \\ 0.01 \end{array}$	$\begin{array}{c} 0.2 \\ 0.01 \end{array}$	_	100.8
13	0.0 0.00	$\begin{array}{c} 12.9 \\ 0.91 \end{array}$	$2.9 \\ 0.21$	0.0 0.00	$0.0 \\ 0.00$	83.6 0.91	$\begin{array}{c} 1.0 \\ 0.04 \end{array}$	0.0 0.00	0.4 0.01	_	100.8
14	$\begin{array}{c} 0.0 \\ 0.00 \end{array}$	$\begin{array}{c} 12.5\\ 0.88 \end{array}$	$\begin{array}{c} 2.6 \\ 0.19 \end{array}$	0.0 0.00	$\begin{array}{c} 0.0\\ 0.00 \end{array}$	84.9 1.94	$\begin{array}{c} 0.6 \\ 0.02 \end{array}$	0.1 0.00	0.2 0.01	-	100.9
15	$\begin{array}{c} 0.5 \\ 0.03 \end{array}$	$\begin{array}{c} 14.6 \\ 1.00 \end{array}$	0.9 0.06	0.0 0.00	_	75.9 1.69	$6.1 \\ 0.23$	-	$\begin{array}{c} 1.3 \\ 0.04 \end{array}$	_	99.3
16	$\begin{array}{c} 1.9 \\ 0.12 \end{array}$	$\begin{array}{c} 14.3 \\ 0.97 \end{array}$	$\begin{array}{c} 1.7 \\ 0.12 \end{array}$	$\begin{array}{c} 0.0\\ 0.00 \end{array}$	_	76.1 1.68	4.8 0.18	-	0.9 0.03	-	99.7
17	$\begin{array}{c} 0.4 \\ 0.03 \end{array}$	$14.4\\1.01$	$\begin{array}{c} 1.3 \\ 0.09 \end{array}$	0.0 0.00	-	80.0 1.81	$2.5 \\ 0.10$	-	$1.0 \\ 0.03$	-	99.6
18	$\begin{array}{c} 0.8 \\ 0.05 \end{array}$	$\begin{array}{c} 14.6 \\ 1.00 \end{array}$	0.7 0.05	0.0 0.00	$0.0 \\ 0.00$	73.3 1.64	$5.7 \\ 0.21$	-	$\begin{array}{c} 3.4 \\ 0.11 \end{array}$	_	98.5
19	$\begin{array}{c} 0.3 \\ 0.02 \end{array}$	15.9 1.07	$\begin{array}{c} 0.5 \\ 0.03 \end{array}$	$\begin{array}{c} 0.0\\ 0.00 \end{array}$	$0.0 \\ 0.00$	76.7 1.68	$\begin{array}{c} 6.6 \\ 0.24 \end{array}$	$0.0 \\ 0.00$	0.8 0.03	_	100.8
20	$\begin{array}{c} 2.3 \\ 0.14 \end{array}$	$\begin{array}{c} 16.2 \\ 1.06 \end{array}$	$\begin{array}{c} 0.4 \\ 0.03 \end{array}$	0.0 0.00	-	$72.3 \\ 1.54$	$\begin{array}{c} 8.6 \\ 0.31 \end{array}$	0.0 0.0	0.3 0.01	_	100.1
21	$\begin{array}{c} 1.7 \\ 0.10 \end{array}$	$\begin{array}{c} 14.9 \\ 1.01 \end{array}$	$\begin{array}{c} 0.3 \\ 0.02 \end{array}$	0.0 0.00	-	79.2 1.75	$\begin{array}{c} 3.8\\ 0.14\end{array}$	0.1 0.00	$\begin{array}{c} 0.2 \\ 0.01 \end{array}$	_	100.2

- not determined

Sampling localities (see Lahti 1981):

112.	Tiainen	16.	Seppälänniemi
13 14.	Katila	17.	Keskimetsä
15.	Seppälänranta	18.	Seppälänranta

19. Pellonreuna 20. & 21. Mäenlaki (about 200 m NEE from the Keskimetsä dyke)



Fig. 2. Variation in chemical composition of tapiolites from Eräjärvi pegmatite area. Numbers of analyses refer to Table 2.

it contain nearly equal amounts of Mn and Fe, although some small parts richer or poorer in Mn were also detected. The parts with Mn > Fe are no more than 100 μ m in diameter. They do not represent separate inclusions according to microprobe images, line profiles and quantitative analyses, but the variation of the Mn and Fe content is irregular and gradual within the crystal.

Analyses 7–11 in Table 2 represent the chemical compositions of iron-rich parts of the crystal whereas nos. 1–6 are from a certain Mn-rich part that was later separated for X-ray crystallographical measurement. As Figure 2 shows, the Fe/Mn ratio of the crystal varies within extremely wide limits, from 66/34 to 24/76. The empirical formula of the Mn-rich part studied, calculated from the mean values of the results and based on six oxygens, is: $(Mn_{0.59}Fe_{0.32}Ca_{0.03})_{\Sigma 0.94}$ $(Ta_{1.72}Nb_{0.27}Sn_{0.04})_{\Sigma 2.03}O_6$ when Z = 2. This is consistent with the ideal formula of the manganotapiolite unit cell: $(Mn, Fe)_2$ $(Ta, Nb)_4O_{12}$, where $Mn^{2+} > Fe^{2+}$ and Ta > Nb.

The niobium content does not vary largely in the manganotapiolite-bearing specimen studied, but the range of the substitution of Ta by Nb is larger in ferrotapiolite specimens. The amount of »mossite» component (Mn,Fe)Nb₂O₆ in manganotapiolite varies between 11 and 16 mol. % and in the analysed ferrotapiolite specimens between 2 and 16 mol. %. The analytical results indicate higher contents of calcium in manganotapiolite but much higher titanium in the ferrotapiolite samples. The variation of these elements is moderate in the manganotapiolite-ferrotapiolite crystal.

X-ray studies

A Mn-rich part (Table 2, anal. 1-6) of the polished tapiolite specimen was separated for X-ray studies. The b-axis and c-axis 0, 1, 2 and 3-level precession photographs showed tetragonal symmetry for the mineral with space group P4₂/mnm (k + 1 = 2n in Table 3. X-ray powder data for manganotapiolite. Debye-Scherrer camera diam. 114.6 mm, Ni-filtered Cu radiation λ CuK α 1.54178 Å.

hkl	d meas.	d calc.	I/I_{O}
002*	4.64	4.64	20
101*	4.24	4.24	40
110*	3.367	3.367	100
112*	2.724	2.724	20
103*	2.592	2.593	90
200*	2.381	2.381	60
210	1 2 1 2 2	2.130	}10
202	3 2.122	2.118) 10
211*	2.075	2.076	10
114*	1.910	1.909	<10
213*	1.754	1.754	90
105	1.727	1.728	< 10
220	1.682	1.684	60
221	1.657	1.657	<10
222	1.582	1.582	10
006	1.545	1.545	20
310) 1 504	1.506	140
302	} 1.004	1.501	} 1 0
223	1.476	1.478	<10
312	1.431	1.432	< 10
303 116	} 1.411	$\begin{array}{c} 1.412\\ 1.405\end{array}$	}40

 reflection used in computing unit cell dimensions

0kl reflections). The spots in the films are large owing to the compositional variation of the crystal. The X-ray powder diffraction pattern was recorded from the same grain with a Debye-Scherrer camera. The measured and calculated d-values of the mineral are given in Table 3. The unit cell dimensions computed from the powder data are: a =4.762 (5) Å, c = 9.272 (5) Å, V = 210.26 Å³.

The Debye-Scherrer photographs show that the manganotapiolite studied has an ordered structure. The 002 (d 4.64 Å) and 101 (d 4.24 Å) reflections, which are lacking in the films of disordered tapiolite (cf. Hutton 1958), are distinct in the powder photographs. The single crystal precession photographs indicate, however, an intermediate structure for the mineral. Manganotapiolite has a strong substructure of rutile type and therefore only some weak reflections can be seen in the c-axis 1 and 2-level precession photographs.

Discussion

Several authors have studied the composition field of natural and synthetic tapiolite. According to the experimental studies of Moreau and Tramasure (1965), and of Turnock (1966), tapiolite has a rather restricted range of bulk composition in the system FeTa₂O₆-MnTa₂O₆-FeNb₂O₆-MnNb₂O₆. Of the end members, only FeTa₂O₆ has tetragonal tapiolite structure; the others have an orthorhombic structure corresponding to columbite-tantalite. Turnock (1966) studied the binary system MnTa₂O₆-FeTa₂O₆ at one atmosphere total pressure and various temperatures. He showed that the maximum amount of MnTa₂O₆ solid solution in tapiolite decreases significantly with decreasing temperature so that at 1500°C the extent of substitution is 68 mol. % MnTa₂O₆ and at 1000°C 58 mol. %. Tantalite exsolves at compositions richer in Mn. To keep manganese and iron divalent the experiments were carried out at low oxygen pressures.

The substitution of MnTa₂O₆ in natural tapiolites extends to 40 mol. % (manganoan tapiolite from Maršikov, Czechoslovakia) according to summaries on the composition of tapiolite given in the literature. Most of the tapiolite analyses, however, show relatively low amounts of manganese (below 20 mol. % MnTa₂O₆). Because the manganeserich varieties are rare in nature, their physical properties and unit cell data are not sufficiently known. In his synthetic studies, Turnock (1966) produced several intermediate members between tetragonal FeTa₂O₆ and Fe_{0.4}Mn_{0.6}Ta₂O₆ and reported their unit cell dimensions.

The cell data obtained by the present authors for Eräjärvi manganotapiolite agree

well with those reported by Turnock for synthetic manganotapiolite (e.g. he gives a = 4.765 Å and c = 9.276 Å for $Mn_{0.6}Fe_{0.4}$ Ta_2O_6 , and a = 4.762 Å and c = 9.264 Å for $Mn_{0.5}Fe_{0.5}Ta_2O_6$), but both the a and c-axes are longer than those of manganoan tafrom Maršikov, Czechoslovakia piolite (a = 4.758 Å and c = 9.271 Å) reported by Čech (1973). This is consistent with the observation by Moreau and Tramasure (1965), and by Beugnies and Mozafari (1968) and verified with synthetic studies by Turnock (1966) that an increase can be expected in the unit cell volume when the amount of Mn increases.

The microhardness value of the Eräjärvi manganotapiolite is lower (VHN 711) than that given in published data. Čech (1973) gives VHN 945-1037 (30.2 p load) for the Maršikov manganoan tapiolite, and Beugnies and Mozafari (1968) measured VHN 931-1072 for the five ferrotapiolite samples. Vlasov (1966), however, gives much lower hardness values, i.e. 796-824 kg/mm², for tapiolite from the USSR. The Eräjärvi manganotapiolite is full of cracks and holes, which must considerably reduce the hardness of the mineral. Similarly the reflectance values are slightly lower in the Eräjärvi manganotapiolite than in the Maršikov manganoan tapiolite. This is, however, consistent with the observations that the reflectance is enhanced with increasing FeO content. There is no doubt, however, that the cracks, inclusions and exsolutions in the sample cause a drop in the values.

The mineral parageneses and internal structures of the pegmatite dykes in the area indicate that the crystallization of the dykes was a complicated event (Lahti 1981, p. 15-22, 74-76). The crystallization conditions varied largely throughout the area and therefore many minerals, especially those in thinner dykes and near their contacts,

zoned. The manganotapiolite-ferroare tapiolite crystal studied and also columbite, wodginite and some silicate crystals (tourmaline and micas) from the same pegmatite dyke vary considerably in chemical composition. One of the columbite crystals analysed has compositions between TiO₂ 1.3, FeO 16.9, MnO 4.7, Ta₂O₅ 15.5, Nb₂O₅ 59.0, WO₃ 0.7, SnO₂ 0.1 wt % and TiO₂ 0.3, FeO 6.6, MnO 10.9, Ta₂O₅ 39.5, Nb₂O₅ 44.1, WO₃ 0.2, SnO₂ 0.1 wt %. These analyses show Fe/Mn ratios between 0.87/0.24 and 0.37/0.62 (calculated on the basis of six oxygens), which are near to the corresponding values of the manganotapiolite-ferrotapiolite crystal. The composition of some of the analysed wodginite crystals from the middle parts of the dyke varies between TiO₂ 0.2, FeO 1.7, MnO 8.8, Ta₂O₅ 73.1, Nb₂O₅ 3.7, WO₃ 0.1, SnO₂ 13.5 wt % and $\rm TiO_2$ 0.1, FeO 0.7, MnO 9.7, $\rm Ta_2O_5$ 65.5, Nb₂O₅ 3.7, WO₃ 0.0, SnO₂ 20.8 wt %. The Fe/Mn ratio of the mineral does not vary much, but the variation in the SnO₂ content is marked. The authors have not found reports of wodginite with such a high content of SnO₂ in the literature.

Tapiolite is not a stable mineral with columbite-tantalite in the Tiainen dyke or any other dykes of the area, but in some pegmatites wodginite and tapiolite are in association. Manganoan tapiolite close (Table 2, anal. 12) occurs as inclusions in wodginite in the Tiainen dyke and ferrotapiolite crystals were observed in wodginite samples from the Pellonreuna and Keskimetsä dykes (Lahti 1982). The observations are consistent with the experimental studies. With reference to the studies by Turnock (1966), the presence of tapiolite indicates low oxygen pressure and that of columbitetantalite much higher oxygen pressure. The oxygen fugacity in the melt was probably one of the most important factors controlling the crystallization of Nb-Ta minerals in different parts of the pegmatite dykes.

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