

PYROCHLORE FROM THE SOKLI CARBONATITE COMPLEX, NORTHERN FINLAND

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LINDQVIST, KRISTIAN and REHTIJÄRVI, PENTTI 1979: Pyrochlore from the Sokli carbonatite complex, Northern Finland. *Bull. Geol. Soc. Finland* 51, 81—93.

Pyrochlore from the Sokli carbonatite complex has been studied in four phoscorite and two regolith samples. The crystal forms of the euhedral pyrochlores are either an octahedron or a combination of an octahedron and a cube. Twinning according to the spinel law was found on two occasions. Zoning and inclusions are common. After the recrystallization of metamict pyrochlore, fersmite and lueshite phases also occur in addition to the pyrochlore phase. Cell dimensions for the recrystallized pyrochlore vary between 10.375 Å and 10.426 Å. The Ce/La-ratio varies between 3.1 and 9.6. The low $\text{Nb}_2\text{O}_5/\text{Ta}_2\text{O}_5$ -ratio (4.9—177.9) indicates that the pyrochlore was crystallized in a relatively undifferentiated magma.

In weathering uranium is leached from pyrochlore and, as indicated by distribution studies, is rebound in supergene secondary minerals or amorphous material. A pyrochlore factor with heavy loading for uranium was found in a statistical study of an analyzed vertical sample series from weathered carbonatite.

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Introduction

The main geological features of the Sokli carbonatite complex have been given by Paarma (1970). Vartiainen and Woolley (1974, 1976) have discussed the age of the intrusion and its relation to the North Atlantic alkaline igneous province, and described the extensive aureole of fenites enveloping the plug. Paarma and Talvitie (1976) have discussed the tectonic and structural position of the intrusion and attributed the deposition of the Sokli plug to the opening of the Kantalahti deep fracture zone. Mäkelä and Vartiainen

(1978) have given the S-isotope data for sulphides in the proposed magmatometasomatic stages of the multi-stage carbonatite, established the temperature order of the stages, and presented an estimate of the temperature range of formation, from 600°C to 300°C. Pyrochlore from the complex is described in the present study.

The main rock types in the complex are phoscorites, silicosövitites, sövitites and rauhaugites. Calcite-rich carbonate rocks are dominant. Pyrochlore is present in all the main types of carbonatite and enriched in phoscorites (Paarma 1970). Phoscorites characterize the proposed stages I and III of the multi-stage carbonatite succession (Mäkelä and Var-

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tiainen 1978). The phoscorites of stage I are medium- to coarse-grained and massive in texture. Serpentinization of olivine is the only typical alteration phenomenon of these rocks. The heterogeneous phoscorites of stage III, which are considered post-intrusive metamorphic derivatives of the phoscorites of stage I, are distinguished by the presence of red phlogopite (tetraferriphlogopite), clinohumite and amphiboles.

Material and methods

Pyrochlore was investigated in six samples and a statistical study was made of the chemistry of a vertical sample series from weathered carbonatite, with special reference to the distribution of uranium. Pyrochlore was studied from the drill core samples 1003, 1004, 1008 and 1014 and from the regolith samples M 05 and M 06. The drill core samples are phoscorites with a main mineral composition as presented in Table 1. The regolith samples M 05 and M 06 belong to the vertical, 3.2 m deep series of 13 analyzed samples, M 01—M 13, from weathered carbonatite (see Fig. 6). All the samples are from the northern and northeastern parts of the complex.

A Philips wide-angle goniometer with Ni-filtered $\text{Cu}_{K\alpha}$ radiation was used in the X-ray diffraction studies. The cell dimensions were calculated using the XRAY-PARAM program of Ammon and Mauer (1967).

Heating in argon atmosphere was carried out in a Rigaku-Denki 8001 H-1500°C DTA/TG-apparatus at a rate of 10°C/min up to 1000°C. As recommended by Lima de Faria (1958, 1964) the pyrochlore concentrates, when heated in air, were kept for 1 h at 1000°C. According to Adams and Sharp (1970) heating studies of multiple oxides should be done both in air and in an inert atmosphere, especially when the recrystallization of different phases is being studied. To find out the effects of time on the recrystallization, an aliquot of the pyrochlore concentrate 1003 was also kept for 5 h at 1000°C. The electron probe microanalyses of the pyrochlore samples were carried out with a Cambridge Geoscan microprobe at Rautaruukki Oy, Raahe. The intensity data were corrected using the EMPADR VII program of Rucklidge and Gasparini (1969). The regolith samples were analyzed by Rautaruukki Oy at Raahe using mainly the X-ray fluorescence method. The correlations and R-mode rotated factors were calculated with the HYLPS statistical and mathematical program package developed by the Computing Centre, University of Helsinki. The distribution of uranium and thorium, or of uranium alone, was mapped, using either an autoradiographic method with Kodak CA 80—15 film or thermal neutron induced fission tracks with Bayer, Makrofol N 20 μm detectors (cf. Rehtijärvi and Liehu 1977), respectively.

Table 1. Modal composition of phoscorites from Sokli (point counting).

	1003	1004	1008	1014
Drill code	R 260	R 274	R 289	R 330
Depth (m)	26.7—28.5	48.0—53.0	124.0—124.3	76.0
Pyrochlore	2.6	4.9	2.1	7.3
Magnetite	26.1	20.5	20.5	26.5
Mica	3.5	9.3	2.1	27.0
Apatite	18.3	19.5	19.6	21.0
Carbonate	3.5	4.3	33.6	12.8
Olivine	18.3	—	—	—
Serpentine	24.5	—	18.6	—
Clinohumite	—	39.2	—	3.5
Others	3.2	2.3	3.5	1.9

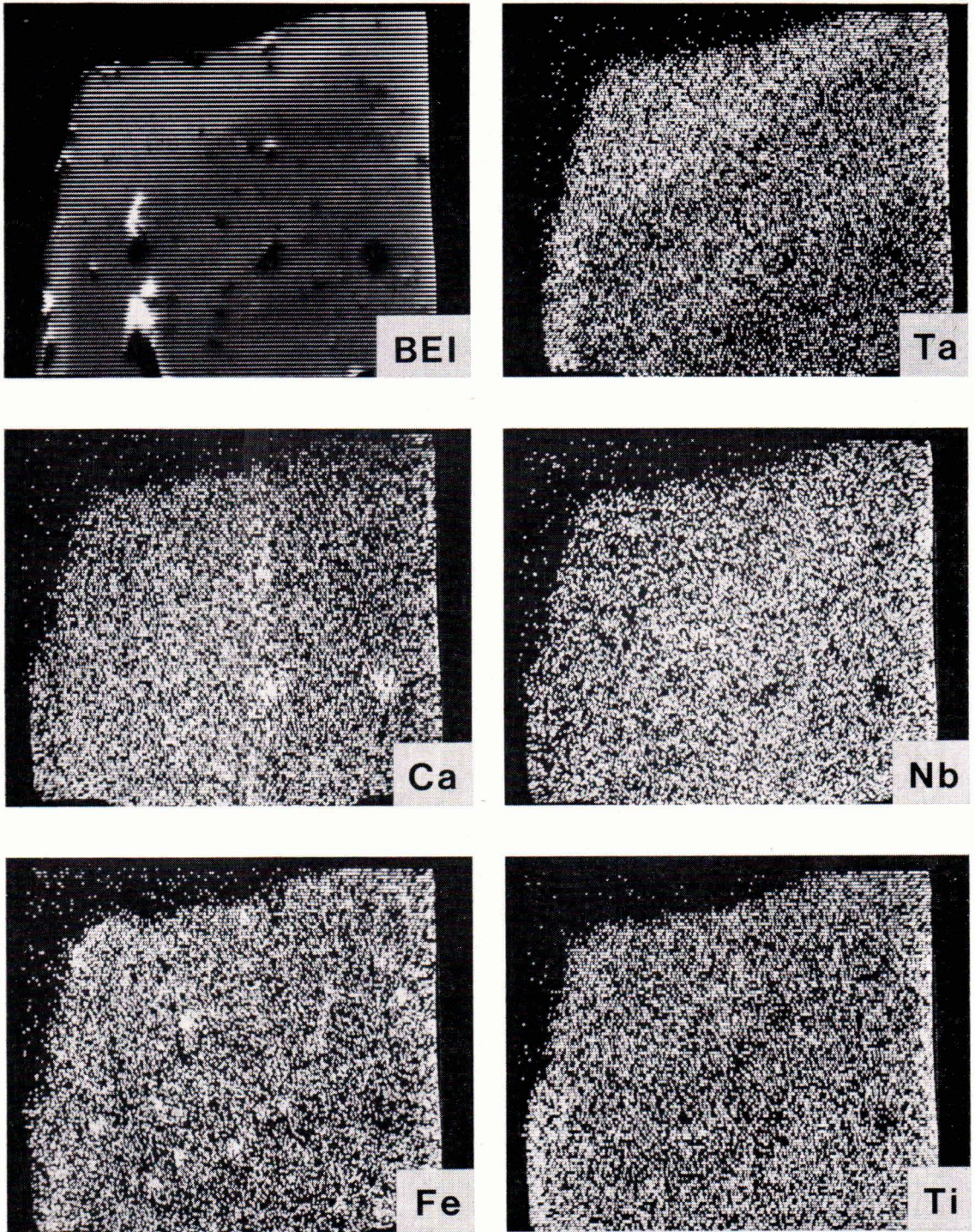


Fig. 1. Back-scattered electron image (BEI) and the distribution patterns for Ta, Nb, Ti, Ca and Fe in pyrochlore from phoscorite sample 1004. Photos by Dr. Jaakko Siivola, Geological Survey of Finland.

Table 2. X-ray data for the heated (recrystallized) pyrochlore concentrates from Sokli.

Phase hkl	1003						1004				1008				1014				
	Air 1 h		Argon		Argon 5 h		Air 1 h		Argon		Air 1 h		Argon		Air 1 h		Argon		
	I	d _{hkl}	I	d _{hkl}	I	d _{hkl}	I	d _{hkl}	I	d _{hkl}	I	d _{hkl}	I	d _{hkl}	I	d _{hkl}	I	d _{hkl}	
Pyrochlore																			
111	6	6.01	20	6.00	13	6.00	5	5.98	19	6.00	3	5.98	4	6.00	4	5.98	22	6.00	
311	6	3.13	20	3.13	11	3.13			17	3.13	7	3.20	3	3.20			23	3.15	
222	100	2.998	100	3.00	100	3.00	100	2.991	100	3.00	100	2.996	100	3.01	100	2.996	100	3.00	
400	20	2.596	27	2.600	23	2.598	22	2.593	28	2.598	22	2.597	23	2.608	22	2.597	27	2.600	
333.511			7	2.003	5	2.001			5	2.001							7	2.001	
440	42	1.837	52	1.839	44	1.838	38	1.835	43	1.836	24	1.837	27	1.843	38	1.838	53	1.839	
531																	3	1.759	
532															18	1.684			
622	26	1.566	36	1.569	31	1.567	26	1.565	27	1.566	19	1.566	21	1.573	26	1.567	42	1.567	
444	6	1.502	7	1.502	7	1.500	5	1.502	5	1.500							9	1.501	
711.551			4	1.457													3	1.457	
544							7	1.379							7	1.378			
a ₀ (Å)	10.390 ± 0.003		10.402 ± 0.002		10.395 ± 0.002		10.375 ± 0.007		10.389 ± 0.003		10.388 ± 0.006		10.426 ± 0.005		10.393 ± 0.008		10.399 ± 0.002		
V(Å ³)	1121.6		1125.6		1123.2		1116.8		1121.3		1121.0		1133.3		1122.6		1124.5		
Lueshite																			
100	31	3.90			5	3.91	47	3.90							62	3.89			
110	35	2.759			9	2.762	54	2.754							81	2.753			
200	16	1.952					23	1.948							33	1.949			
210	10	1.746					11	1.743							18	1.684			
211	10	1.594					14	1.592							22	1.591			
220	6	1.380					7	1.379							7	1.378			
a ₀ (Å)	3.903 ± 0.001				3.906 ± 0.001		3.897 ± 0.002								3.895 ± 0.002				
V(Å ³)	59.5				59.6		59.2								59.1				
Fer-smite																			
111.040											11	3.76	12	3.76					
121													6	3.45					
131	14	3.06	9	3.06	5	3.06	20	3.05	11	3.05	62	3.06	69	3.05					
200											7	2.874	3	2.876					
220			1	2.706											23	2.608			
002	20	2.596	27	2.600	23	2.598													
142			7	2.003	5	2.001			5	2.001							7	2.001	
232													6	1.803					
081													7	1.774					
082													7	1.526					
281	6	1.502	7	1.502	7	1.500	5	1.502	5	1.500							9	1.501	
a ₀ (Å)			5.81 ± 0.01								5.75 ± 0.05		5.74 ± 0.03						
b ₀ »			14.91 ± 0.01								15.00 ± 0.15		15.06 ± 0.05						
c ₀ »			5.20 ± 0.00								5.22 ± 0.07		5.21 ± 0.02						
V(Å ³)			450.6								450.2		450.4						

Pyrochlore minerals

Crystal habit, zonality and inclusions

The pyrochlore occurs as brown euhedral grains varying in size from 0.15 mm to 0.5 mm, and occasionally as large as 5 mm. The prevailing crystal forms are an octahedron or a combination of an octahedron and a cube. Pyrochlore twins were found in the samples 1003 and 1014. The twinning follows the spinel law and the twin plane is (111). Pyrochlore twins have been described earlier from the Lueshe carbonatite complex by Safiannikoff (1967). Frondel (1958) and van der Veen (1963) report twinning to be rare in minerals belonging to the pyrochlore group.

Zoning seems to be marked and common in the Sokli pyrochlore. In the pyrochlore of sample 1004 tantalum together with uranium and/or thorium shows zonal distribution (Figs. 1 and 2). However, in most cases there are no significant differences in the distribution of the main components. According to van der Veen (1963) such zonality is due to metamictization. Petruk and Owens (1975) reported only minor differences in the distribution of the main components of zonal pyrochlore from the Oka carbonatite complex, the greatest differences being found in the distribution of iron, uranium and thorium.

A grey or greenish grey mantle can be seen around the weathered Sokli pyrochlore grains. Semenov et al. (1968) identified the greyish green non-transparent substance in the altered marginal zone of brown pyrochlore from Ilimaussaq as igdloite (lueshite). According to van der Veen (1963) pyrochlore from the Mbeya carbonatite complex alters first to fersmite, later on to columbite.

Magnetite, apatite and carbonate inclusions are common in the Sokli pyrochlore grains. Also, a Hf-rich ZrO_2 -mineral (?) was found in pyrochlore from sample 1008. According to Heinrich (1966) magnetite inclusions are



Fig. 2. Zonal distribution of uranium and thorium in pyrochlore from phoscorite sample 1004. Kodak CA 80—15 film, radiation time 26 d. The phoscorite sample contained 108 ppm of U and 1263 ppm of Th (INAA method).

common in pyrochlore. The larger pyrochlore crystals in the Mbeya carbonatite generally contain apatite, calcite, iron oxide and fluorite inclusions (Fawley and James 1955). von Eckermann (1974) reports wollastonite inclusions in pyrochlore from Alnö, Wimmenauer (1964) apatite inclusions in pyrochlore from Kaiserstuhl, and Deutzmann (1964) rutile inclusions in zoned varieties of dark pyrochlore from Kaiserstuhl.

Thermal behaviour

No thermal reactions could be recorded during the heating of pyrochlore concentrates

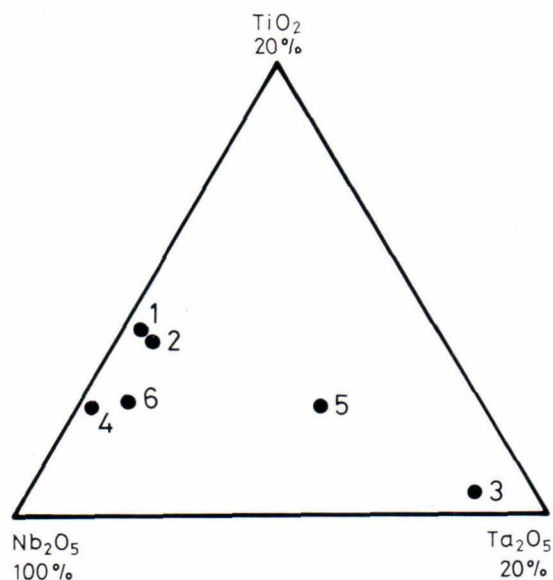


Fig. 3. Nb_2O_5 -, TiO_2 - and Ta_2O_5 -weight proportions in pyrochlore from samples 1003 (1), 1004 (2), 1008 (3), 1014 (4), M 05 (5) and M 06 (6).

from the samples 1003, 1004 and 1008. In earlier studies on the thermal behaviour of pyrochlore, Kulp et al. (1952) and Krivokoneva and Sidorenko (1971) obtained similar negative results. According to Jäger et al. (1959), weak exothermal peaks may arise at 400°C and 600°C . The peak temperature depends on the state of oxidation and the rate of recrystallization. Pyrochlore from sample 1014 exhibited an exothermal reaction at 540°C , which may have been due to the recrystallization of pyrochlore (cf. Gorzhevskaya and Sidorenko 1962).

The mean loss of weight in the heating of the pyrochlore concentrates was 8.9%. Similar results have earlier been attributed to the loss of water (Vlasov 1966). The loss of weight of the pyrochlore concentrate from sample 1003 did not continue under prolonged heating, 5 h at 1000°C .

During the heating studies, both in argon and in air, the pyrochlore concentrates turned yellow or reddish yellow.

X-ray diffraction studies

The unheated pyrochlore proved to be metamict. The unit cell dimensions for the recrystallized pyrochlore varied between 10.375 Å and 10.426 Å. The length of the a-axis for the pyrochlore phase recrystallized in air was found to be less than for the corresponding phase recrystallized in argon (Table 2). Three mineral phases were identified: pyrochlore, fersmite (CaNb_2O_6) and lueshite (NaNbO_3). The generation of lueshite seems to be favoured by the air atmosphere. Gorzhevskaya and Sidorenko (1962) have obtained perovskite and fersmite when heating metamict pyrochlore, and lueshite when heating crystallized pyrochlore. Lima de Faria (1964) has, in addition to some unidentified reflections, obtained three phases when heating pyrochlore: a pyrochlore phase with $a_0 = 10.4$ Å, a cubic NbO_2 -phase, and a fersmite phase. The metaniobate ($\text{Na}_2\text{Nb}_2\text{O}_6$) crystallized by Sørum (1955), during heating of pyrochlore from Søve with calcium oxide, exhibits the same powder pattern as lueshite.

Chemical composition

The chemical composition of the pyrochlore minerals is presented in Table 3, with reference samples from Alnö and Oka included for comparison. The atomic proportions between the A-atoms in pyrochlore (general formula $\text{A}_{2-m}\text{B}_2\text{O}_6(\text{O}, \text{OH}, \text{F})_{1-n} \cdot p\text{H}_2\text{O}$) from the phoscorite samples are presented in Table 4. The pyrochlore from sample 1008 proved to be uranpyrochlore (cf. Hogarth 1977).

In the pyrochlore from the samples studied, the Ce/La-ratio varies between 3.1 and 9.6. The proportions of the B-atoms (Nb, Ta, Ti) are presented in Fig. 3. The pyrochlore minerals contain a notable amount of tantalum; the $\text{Nb}_2\text{O}_5/\text{Ta}_2\text{O}_5$ -ratio varies between 4.9 and

Table 3. Chemical composition of the pyrochlore minerals from Sokli, with reference samples from Alnö, Sweden (von Eckermann 1974) and Oka, Canada (Petruk and Owens 1975) included for comparison (%o, n.d. = not detected).

	1003	1004	1008	1014	M 05	M 06	Alnö	Oka
Al ₂ O ₃	0.00	0.03	0.16	0.07	0.11	0.06	0.00	n.d.
SiO ₂	0.04	0.05	0.61	0.01	0.01	0.04	0.00	3.16
CaO	17.75	16.63	9.29	18.18	11.64	13.62	17.01	5.06
TiO ₂	5.08	4.45	0.57	2.83	2.52	2.78	6.06	5.14
MnO	0.04	0.07	0.08	0.09	0.04	0.03	0.30	0.23
FeO	0.22	2.47	1.30	0.70	1.02	0.31	0.24	3.00
Fe ₂ O ₃							2.40	
Ce ₂ O ₃	1.99	1.38	1.01	0.89	0.93	0.43		3.49
Ce (La) O ₂							0.16	
La ₂ O ₃	0.56	0.22	0.11	0.12	0.16	0.14		0.79
ThO ₂	5.26	3.67	2.08	5.17	3.51	3.98	1.32	n.d.
U ₃ O ₈	0.21	0.30	27.52	0.34	11.64	7.44	0.03	20.73
Nb ₂ O ₅	55.70	52.19	48.94	55.16	44.29	52.30	61.87	49.62
Ta ₂ O ₅	0.34	0.80	10.01	0.31	4.71	0.98	0.10	3.88
ZrO ₂	0.29	2.20	3.35	1.77	4.03	3.36	2.55	0.27
F	4.4	5.7	1.6	3.3	1.6	3.6	2.75	
Na ₂ O	3.91 ¹	3.72 ¹	1.16 ¹	4.45 ¹			3.33	0.00
SrO								1.18
MgO	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.58	n.d.
K ₂ O							0.26	
Nd ₂ O ₃								0.58
H ₂ O ⁺							2.13	
H ₂ O ⁻							0.28	

¹ Instrumental neutron activation analysis (INAA)

177.9. The Nb₂O₅/Ta₂O₅-ratio in pyrochlore from various carbonatite locations varies between 7 and 6000, mostly between 100 and 500 (van der Veen 1963). The highest values are found for pyrochlore crystallized from a differentiated magma in late-magmatic or post-magmatic stages. Pyrochlore from Kaiserstuhl, for example, shows a Nb₂O₅/Ta₂O₅-ratio mainly about 600, a value that is con-

sidered typical of carbonatites (van Wambeke 1964).

Uranium is readily leached from pyrochlore during weathering processes and rebound in supergene minerals and substances. The weathered pyrochlore grains are lighter in colour than the unweathered grains and are surrounded by a grey or greenish grey mantle. The only notable radioactive mineral in the phoscorite is pyrochlore (see Fig. 2 and Fig. 4). In weathered (regolith) samples in addition to pyrochlore also secondary apatite and fine-grained limonite contain marked amounts of uranium (Fig. 5). Ferric hydroxides and amorphous substances are known to have a considerable capacity for sorbing uranyl ions (Lovering 1955, Rozhkova et al. 1958, Weijden et al. 1976). According to Altschuler et al. (1958) and Rozhkova et al. (1958), calcium phosphate may also concentrate uranium from surrounding waters.

Table 4. A-atom proportions in pyrochlore minerals (%o).

	1003	1004	1008	1014
Fe	0.6	7.2	5.4	1.9
Ca	65.6	62.2	49.4	64.1
Na	26.2	25.2	11.2	28.4
U	0.2	0.2	29.3	0.2
Ce	4.1	1.8	1.8	1.1
La	2.5	0.3	0.2	0.1
Th	0.7	2.9	2.4	3.9
Mn	0.1	0.2	0.3	0.3



Fig. 4. Distribution of uranium and thorium in phoscorite sample 1008. Kodak CA 80—15 film, radiation time 26 d. Pyrochlore is the only detected radioactive mineral. The phoscorite sample contained 943 ppm of U and 397 ppm of Th. (INAA method).

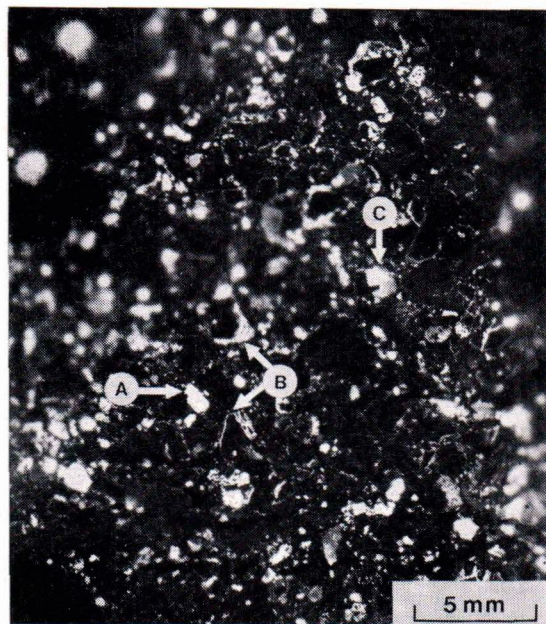


Fig. 5. Distribution of uranium in weathered carbonatite. Regolith sample M 02. Macrofol 20 μm detector, radiation time for thermal neutrons 3 h. Uranium-bearing minerals are A) pyrochlore, B) secondary apatite and C) fine-grained limonite. The sample contained 530 ppm of U and 463 ppm of Th (INAA method).

The sample series from weathered carbonatite

The regolith samples have been analyzed for Al, Ba, C, Ca, Ce, Fe, K, La, Mg, Mn, Na, Nb, P, S, Si, Sr, Ta, Th, Ti, U, V and Zr and the loss on ignition (L.I.) measured (see Fig. 6 and Tables 5 and 6). The statistical study is based on 12¹ samples.

A strong positive correlation can be seen between the elements Nb, Th, U, Na and Ta (Table 5), which are also the main components of the pyrochlore. The results of an R-mode rotated factor analysis are presented in Table 6. The loadings for the main components in pyrochlore are high in factor 2, which hence may be designated the pyrochlore factor.

¹ The contents of U, Th and Ta are missing for one sample

Calcium and strontium show positive correlation to P and C, which may be explained by the presence of apatite (francolite-collophane) and Ca-(Sr)-carbonate. Magnetite and its weathered derivatives (iron oxides and hydroxides) may be responsible for the positive correlation between Fe, Mn and V. Factor 1 is considered a combined magnetite and apatite-carbonate factor. Judging from the factor loadings and correlations, uranium seems to be mainly bound in pyrochlore, or to be in close association with it, also in weathered carbonatite.

Conclusions

Pyrochlore from the Sokli carbonatite complex, northern Finland, has been studied in four phoscorite samples and in two

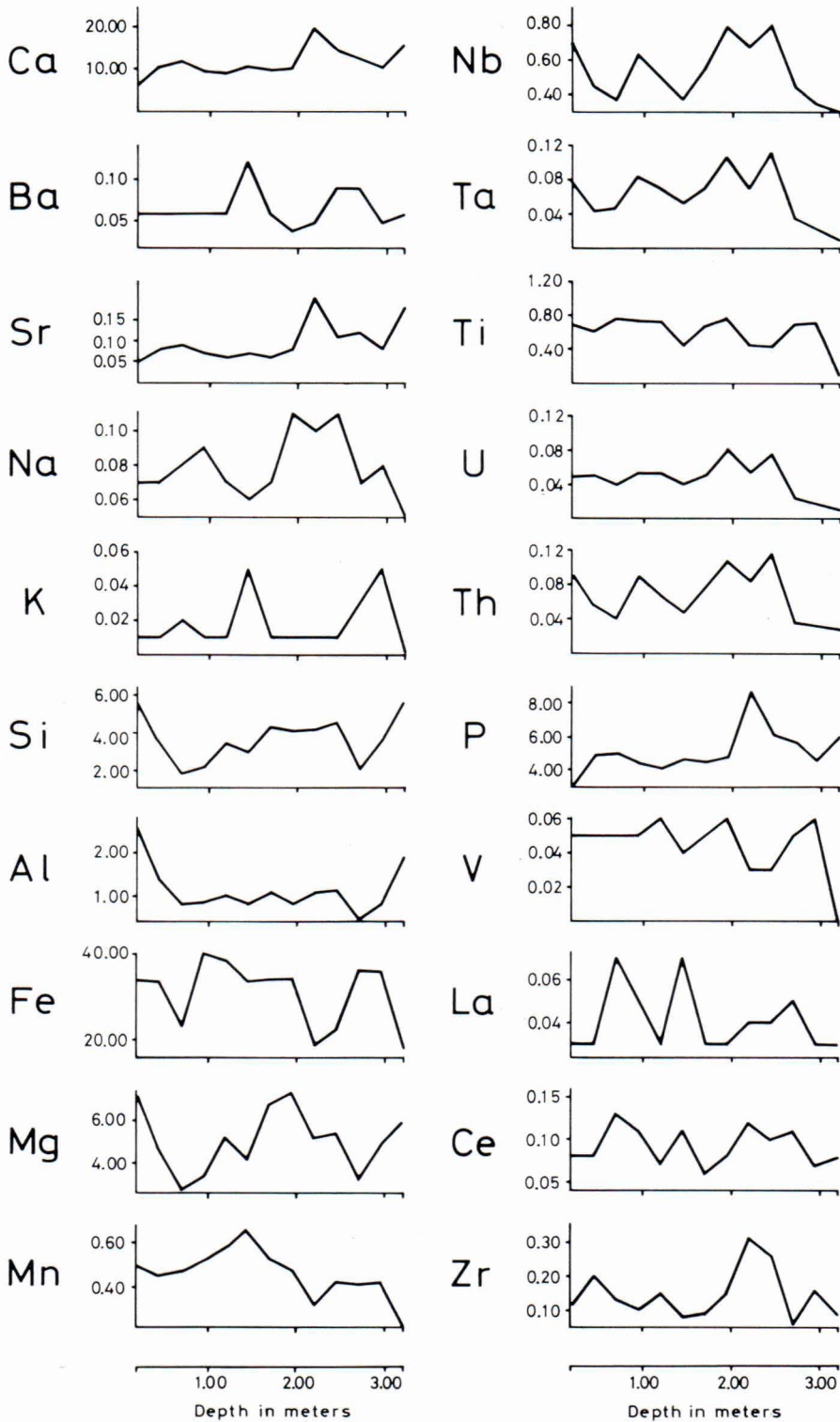


Fig. 6. Variation in the content of elements in a vertical sample series from weathered carbonatite, Sokli (%).

Table 5. Correlations of the analytical data from weathered carbonatite samples, Sokli.

	Al	Ba	Ca	Ce	Fe	K	La	Mg	Mn	Nb	P	S	L.I.	Si	Sr	Ti	V	Zr	Ta	Th	U	C	Na	
Al	1000																							
Ba	-252	1000																						
Ca	-210	309	441	1000																				
Ce	-421	85	-806	-330	1000																			
Fe	-209	813	-120	456	246	1000																		
K	-453	813	-120	456	246	1000																		
La	-503	587	80	819	-60	770	1000																	
Mg	-584	394	-175	745	-33	-473	-767	1000																
Mn	-255	361	-732	101	733	545	325	-92	1000															
Nb	113	305	-62	-115	97	-364	-393	509	50	1000														
P	-257	36	981	454	-717	-103	50	-167	686	44	1000													
S	-237	69	51	527	-164	-81	461	-492	42	8	8	1000												
L.I.	643	229	291	-213	551	-176	228	266	506	300	165	-180	1000											
Si	796	274	85	-594	-366	-539	-715	873	-389	334	45	-390	659	1000										
Sr	-18	111	943	357	781	-214	-43	-88	867	119	916	-94	411	207	1000									
Ti	-299	255	-642	4	688	90	99	-135	727	265	-576	3	849	-509	696	1000								
V	-322	194	-691	-121	777	187	44	-57	727	497	644	151	-7	222	435	164	1000							
Zr	14	-255	584	189	503	355	224	114	324	497	644	151	-7	222	435	164	1000							
Ta	-76	-158	-231	-87	235	-179	-180	371	375	911	-145	332	-446	124	-380	428	441	1000						
Th	124	-274	-132	-180	120	-372	-374	513	163	969	-46	253	-270	339	231	271	267	494	1000					
U	-128	-244	-186	-131	204	-202	-229	357	366	833	-95	244	-482	85	-369	447	497	539	892	1000				
C	157	320	735	150	-755	68	-1	127	-641	160	680	214	674	427	749	-814	-814	228	363	229	-397	1000		
Na	-310	-287	244	267	-118	-245	-57	113	-47	824	532	443	-473	-48	86	285	230	649	818	798	824	-131	1000	

regolith samples. The pyrochlore is euhedral exhibiting crystal forms of an octahedron and a combination of an octahedron and a cube. Twinning according to the spinel law was found on two occasions and zonality is common.

The X-ray diffraction studies show that the pyrochlore is metamict. When heated up to 1000°C, a lueshite and/or a fersmite phase crystallized in addition to the pyrochlore phase. The crystallization of lueshite seems to be favoured by the air atmosphere. The calculated cell dimensions for pyrochlore range between 10.375 Å and 10.426 Å, with the recrystallization in an inert atmosphere resulting in larger unit cell volumes than in air. DTA/TG studies show a weak exothermal peak, possibly indicating recrystallization, at about 540°C. The loss of weight in the experiments averages 8.9 %.

Electron probe microanalysis of the pyrochlore minerals proved one of them to be uranopyrochlore. The pyrochlore minerals were found to contain a notable amount of tantalum. The Ce/La-ratio varies between 3.1 and 9.6 and the Nb₂O₅/Ta₂O₅-ratio between 4.9 and 177.9. The low Nb₂O₅/Ta₂O₅-ratio indicates that pyrochlore was crystallized in a relatively undifferentiated magma.

In weathered samples uranium is partly leached from pyrochlore and affixed to supergene minerals. The distribution studies show that uranium is enriched in secondary calcium phosphate and iron oxides. The R-mode rotated factor analysis of the sample series from weathered carbonatite revealed a pyrochlore factor and an apatite-carbonate factor. The heavy loading for uranium in the pyrochlore factor together with the correlations indicate that most of the uranium present in the weathered samples is still closely associated with pyrochlore.

Table 6. R-mode rotated factor analysis of the correlations.

N=12	Factor loadings					Communa- lity
	1.	2.	3.	4.	5.	
Al	0.09	-0.04	-0.83	0.29	0.17	0.82
Ba	0.01	-0.17	-0.08	-0.93	-0.14	0.93
Ca	-0.99	0.01	0.10	0.00	-0.08	0.99
Ce	-0.38	-0.02	0.37	-0.31	-0.70	0.87
Fe	0.83	0.01	0.33	-0.09	0.23	0.86
K	0.14	-0.23	0.32	-0.89	-0.08	0.96
La	-0.00	-0.23	0.33	-0.59	-0.65	0.93
Mg	0.07	0.40	-0.51	0.23	0.67	0.93
Mn	0.79	0.17	0.23	-0.46	0.01	0.92
Nb	0.04	0.94	-0.06	0.16	0.10	0.92
P	-0.97	0.10	0.21	0.00	-0.02	0.99
S	0.04	0.28	-0.01	0.05	-0.92	0.94
L.I.	-0.39	-0.32	-0.83	-0.10	0.09	0.97
Si	-0.21	0.23	-0.78	0.22	0.48	0.98
Sr	-0.96	-0.15	-0.01	0.13	0.00	0.97
Ti	0.70	0.25	0.56	0.19	-0.09	0.92
V	0.74	0.27	0.57	0.06	0.09	0.95
Zr	-0.57	0.62	0.07	0.18	-0.03	0.74
Ta	0.26	0.96	0.03	-0.00	-0.04	0.99
Th	0.13	0.96	-0.13	0.13	0.04	0.98
U	0.22	0.93	0.14	0.06	0.04	0.95
C	-0.81	-0.14	-0.35	-0.31	0.16	0.92
Na	-0.20	0.39	0.29	0.14	-0.21	0.97
			Eigenvalues			
	7.7	6.0	4.6	1.8	1.3	

Acknowledgements — The positive attitude of Rautaruukki Oy and a research contract with the Ministry of Trade and Industry have made this work possible. Our thanks go especially to Prof.

Heikki Paarma and Mr. Heikki Vartiainen, Phil. lic., for their encouraging support during the various phases of the study.

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