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STEACYITE, A NEW NAME, AND A RE-EVALUATION OF THE NOMENCLATURE OF "EKANITE"-GROUP MINERALS

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Abstract

Ekanite from the type locality (Sri Lanka), $ThCa_2Si_8O_{20}$, is metamict and gives only a very poor Debye-Scherrer diagram; heated Sri Lanka ekanite is body-centred tetragonal, with *a* 7.46, *c* 14.96 Å. Natural ekanite from the Tombstone Mountains, Yukon Territory (Szymański *et al.* 1982) has the same chemical composition and gives a powder pattern that matches that of heated ekanite from Sri Lanka. The crystal structure of ekanite is characterized by Si_8O_{20} sheets, space group *I*422, *a* 7.483(3), *c* 14.893(6) Å. Steacyite corresponds to $Th(Na,Ca)_2(K_{1-z}\square_z)Si_8O_{20}$, $z = 0.39$, described by Perrault & Richard (1973) under the name "ekanite". The crystal structure of steacyite is characterized by discrete pseudocubic arrangements of Si_8O_{20}, space group *P4/mcc*, *a* 7.58(1), *c* 14.77(2) Å, $Z=2$. Powder diagrams of ekanite and steacyite show significant differences. A Th–Ca–K silicate from central Asia was described by Ginzburg *et al.* (1965) under the name "ekanite"; it corresponds to $Th(Ca,Na)_2(K_{1-z}\square_z)Si_8O_{20}$, with *z* between 0.23 and 0.40. Space group, cell dimensions and powder pattern are essentially identical to those of steacyite; this mineral should receive a name other than ekanite. These two minerals may define a continuous series. The name honors H.R. Steacy of the Geological Survey of Canada. Iraqite (Livingstone *et al.* 1976) gives a powder pattern identical to that of steacyite and is presumed isostructural. It corresponds to $(RE,Th)Ca_2(K_{1-z}\square_z)Si_8O_{20}$, with $z = 0.47$.

Keywords: new mineral name, steacyite, Ca–Na "ekanite", Saint-Hilaire, "kanaekanite", iraquite, mineral series steacyite – Na,Ca "ekanite".

Sommaire

L'ékanite du lieu d'origine (Sri Lanka), $ThCa_2Si_8O_{20}$, est métamicte et donne un diagramme Debye-Scherrer de mauvaise qualité; l'ékanite chauffée du Sri Lanka est quadratique à maille centrée. *a* 7.46. *c* 14.96 Å. L'ékanite naturelle du mont Tombstone (territoire du Yukon) (Szymanski *et al.* 1982) a la même composition chimique et donne un diagramme de poudre identique à celui de l'ékanite chauffée du Sri Lanka. La structure cristalline de l'ékanite est caractérisée par des feuillets Si_8O_{20}; groupe d'espace *I*422, *a* 7.483(3), *c* 14.893(6) Å. La steacyite correspond à $Th(Na,Ca)_2(K_{1-z}\square_z)Si_8O_{20}$, $z = 0.39$; le minéral avait d'abord été décrit par Perrault & Richard (1973) sous le nom d'ékanite. La steacyite est caractérisée par des groupes distincts Si_8O_{20}, groupe d'espace *P4/mcc*, *a* 7.58(1), *c* 14.77(2) Å, et $Z=2$. Les diagrammes Debye-Scherrer de l'ékanite et de la steacyite montrent des différences. Un silicate de Th–Ca–K a été décrit par Ginzburg *et al.* (1965) sous le nom d'ékanite. On le trouve en Asie centrale. Ce silicate correspond à un $Th(Ca,Na)_2(K_{1-z}\square_z)Si_8O_{20}$, avec *z* entre 0.23 et 0.40. Le groupe d'espace, les dimensions de la maille cristalline et le diagramme de poudre sont identiques à ceux de la steacyite. Ce minéral devrait être désigné sous un autre nom que celui d'ékanite. Ces deux minéraux définiraient une série continue. Le nom honore H.R. Steacy de la Commission géologique du Canada. L'iraqite (Livingstone *et al.* 1976) donne un diagramme de poudre identique à celui de la steacyite; on les présume isostructurales. L'iraqite correspond à $(TR,Th)Ca_2(K_{1-z}\square_z)Si_8O_{20}$, avec $z = 0.47$.

Mots-clés: nom nouveau, steacyite, Ca-Na "ékanite", Saint-Hilaire, "kanaékanite", iraqite, série steacyite – NaCa "ékanite".

Introduction

The name *ekanite* was originally given by Anderson *et al.* (1961) to a metamict mineral corresponding to $ThCa_2Si_8O_{20}$. In recent mineralogical literature (Ginzburg *et al.* 1965, Mokeyeva & Golovastikov 1966, Perrault & Richard 1973, Richard & Perrault 1972), the name has been applied to $Th(Ca,Na)_2(K_{1-z}\square_z)Si_8O_{20}$ and to $Th(Na,Ca)_2(K_{1-z}\square_z)Si_8O_{20}$. Furthermore, the new name *kanaekanite* has been used by Povarennykh (1966) and Povarennykh

& Dusmatov (1970) to designate $Th(Na,Ca)_2(K_{1-x}\square_x)Si_8O_{20}$. The structure of nonmetamict ekanite of composition $ThCa_2Si_8O_{20}$ has recently been solved by Szymański (1981)†.

It is now quite clear, particularly in the light of the crystal-structure work (Szymański 1981, Szymański *et al.* 1982, Mokeyeva & Golovastikov 1966, Richard & Perrault 1972) that the above constitute one distinct mineral species (ekanite), and one distinct mineral *series* between steacyite, $Th(Na,Ca)_2(K_{1-x}\square_x)Si_8O_{20}$ and another *species* (as yet unnamed), $Th(Ca,Na)_2(K_{1-x}\square_x)Si_8O_{20}$.

Original Ekanite and Tombstone Mountains Ekanite

Ekanite is the name proposed by Anderson *et al.* (1961) to designate the green, transparent to translucent mineral from Sri Lanka; chemical composition of this material is given in Table 1, column 2, and the chemical formula is given in Table 2, column 2. Essentially, this material is $ThCa_2Si_8O_{20}$.

Anderson *et al.* (1961) recognized that their natural ekanite was completely metamict and did not give an X-ray-diffraction pattern. However, Dr. R.J. Davis (unpubl. data) obtained a powder pattern on heating the ekanite above 650°C; it is reproduced in Table 3, column 2 (E.J. Fejer, pers. comm., 1980). Anderson *et al.* (1961) concluded that heated ekanite had a body-centred tetragonal cell with *a* 7.46, c 14.96 Å.

Szymański *et al.* (1982) reported on a mineral from the Tombstone Mountains, Yukon Territory, that corresponds to $ThCa_2Si_8O_{20}$. Their microprobe analysis failed to reveal the presence of any K or Na. Difficulties in analyzing this material with the electron microprobe led them to prefer the theoretical composition $ThCa_2Si_8O_{22}$ to the measurements obtained with the microprobe; the microprobe measurements gave a structural formula close to the theoretical composition. This mineral is crystalline, non-metamict ekanite.

Ekanite from the Tombstone Mountains has space group *I*422 with *a* 7.483(3), *c* 14.893(6) Å, *Z*=2. These data agree well with the "heated ekanite" data of Dr. R.J. Davis, as do the powder patterns of the two materials (Table 3, col. 1 and 2).

TABLE 1. CHEMICAL COMPOSITION OF EAKNITE, AN UNNAMED Th-Ca-K SILICATE, STEACYITE AND IRAQITE

	EKANITE Th-Ca silicate		UNNAMED Th-Ca-K silicate		STEACYITE Th-Na-K silicate		IRAQITE RE-Ca-K silicate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
SiO_2	56.10%	55.6%	54.60%	54.50%	52.18	57.92	51.7
Al_2O_3		Tr	1.48				0.77
ThO_2	30.81	27.6	23.74	26.47	26.74	28.03	9.54
UO_2		2.1	0.58	1.46	2.47		0.65
Fe_2O_3		0.5	0.10	0.17	0.18		0.10
PbO		0.8				0.07	0.35
RE_2O_3			2.39	0.36		0.47	15.06
ZrO_2							0.17
CuO							0.07
CaO	13.09	13.7	10.44	7.54	6.00	4.92	10.73
MnO		Tr	0.02			1.64	
SrO			0.03				
RE_2O_3							
MgO		Tr				0.17	0.02
Na_2O			2.63	3.51	3.53	3.36	0.27
K_2O			3.30	4.08	4.10	3.42	2.76
H_2O^+			0.32	1.02	4.40		4.41
F			0.26				0.07
	100.00	100.3	99.89	99.11	99.60	100.00	96.67
		F = 0	0.11			impurities	2.54
			99.78				99.21

(1) Theoretical $ThCa_2Si_8O_{20}$. Tombstone Mountains material is very close to this. Szymański et al. (1982).
(2) Sri Lanka. Anderson et al. (1961).
(3) Central Asia: specimen 65185 of Ginzburg et al. (1965).
(4) Central Asia: specimen 65630 of Ginzburg et al. (1965).
(5) Central Asia: specimen 65186 of Ginzburg et al. (1965).
(6) St-Hilaire, Quebec, Canada: Perrault & Richard (1973).
(7) Iraqite: Livingstone et al. (1976).

TABLE 2. CHEMICAL FORMULAE FOR EKANITE, AN UNNAMED Th-Ca-K SILICATE, STEACYITE AND IRAQITE.

	EKANITE Th-Ca silicate		UNNAMED Th-Ca-K silicate		STEACYITE Th-Na-K silicate		IRAQITE RE-Ca-K silicate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
A							
Th^{4+}	1.00	0.90	0.77	0.89	0.94	0.88	0.33
U^{4+}		0.06	0.02	0.05	0.08		0.02
Fe^{3+}		0.05	0.01	0.02	0.02		0.01
Pb^{2+}		0.03				0.01	0.01
RE^{3+}			0.12	0.02		0.03	0.67
Zr^{4+}							0.01
Cu^{2+}							0.01
B							
Ca^{2+}	2.00	2.11	1.59	1.18	0.98	0.73	1.75
Mn^{2+}						0.19	
Na^+			0.72	1.00	1.05	0.90	0.08
RE^{3+}							0.17
Mg^{2+}						0.03	
C							
K^+	0.	0.	0.60	0.77	0.80	0.61	0.53
Vacancies	1.00	1.00	0.40	0.23	0.20	0.39	0.47
Σ	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Si							
Si^{4+}	8.00	8.00	7.75	8.00	8.00	8.00	8.00
Al^{3+}			0.25				
O							
O^{2-}	20.00	20.13	19.53	20.00	19.98	19.52	20.07
Charges Σ+	40.00	40.27	39.05	40.01	39.95	39.04	40.14
Σ-	40.00	40.26	39.06	40.00	39.96	39.04	40.14

(1) (2) (3) (4) (5) (6) (7), see bottom of Table 1.

Th–Ca–K Silicate and Th–Na–K Silicate

A Th–Ca–K silicate (Ginzburg *et al.* 1965)

†There is a minor typographical error in this abstract: six lines from the bottom, Si_4O_{20} should read Si_8O_{20}.

TABLE 3. DEBYE-SCHERRER PATTERNS FOR EKANITE, AN UNNAMED Th-Ca-K SILICATE, STEACYITE AND IRAQITE

EKANITE Th-Ca silicate (1)		(2)		hkl	Th-Ca-K silicate (3) (4) (5)		STEACYITE Th-Na-K silicate (6)		IRAQITE RE-Ca-K silicate (7)		hkl
d	I/Io	d	I/Io		d	I/Io	d	I/Io	d	I/Io	
							7.60	14	7.62	30	100
7.45	58	7.5	60	002	7.32	90	7.42	11	7.36	80	002
6.70	73	6.72	60	101							
							5.37	15	5.36	15	110
					5.22	90	5.30	45	5.28	100	102
4.31	14			112							112
4.14	100	4.13	100	103	4.21	20					
									3.40	60	210
					3.36	100	3.38	100	3.38	80	202
3.343	96	3.30	100	202	3.30	60	3.32	55	3.31	100	104,211
3.265	65	3.22	100	211							
3.044	13			114	3.06	20	3.07	12	3.08	12	212
2.766	23	2.77	40	213,105							
							2.67	10	2.69	15	220
2.642	54	2.63	80	220,204	2.64	90	2.64	41	2.64	100	204
					2.51	60	2.51	14	2.53	20	300,222
2.494	18	2.485	20	222,006							
2.460	22	2.44	20	301							
2.254	14	2.25	30	312,116	2.16	10					312
2.225	22	2.22	30	303,215							
2.157	22	2.15	40	224			2.16	19	2.17	40	224,313
2.060	17	2.045	30	206,321			2.07	10	2.06	15	320,304,321
									2.03	15	206
					2.011	60	2.00	26	2.01	4	322,314
1.996	20	1.990	30	314	1.992	10			1.989	15	216
1.913	20	1.910	30	323,305							
									1.900	15	400
					1.887	50					
1.868	17	1.870	40	400,008							
									1.837	12	410,402
					1.824	70	1.821	20	1.830	12	234,411
1.810	19	1.805	60	402,226					1.811	12	226
1.796	26	1.797	60	411,217							
					1.784	30					330,412
1.758	11	1.755	10	118,332							
1.702	19	1.696	40	413,325	1.693	50			1.702	10	420
1.671	15	1.663	40	420,404							
					1.648	60	1.643	14			402,414
1.632	12	1.623	60	422	1.625	50			1.618	12	218
					1.543	40					
					1.530	40					
I422					P4/mcc						
a 7.483 (3)		7.46			7.58		7.58		7.61		
c 14.893 (6)		14.96			14.82		14.77		14.72		

(1) → (7): see Table 1. Powder patterns of (3), (4) and (5) are reportedly identical.

and Th–Na–K silicate (Perrault & Richard 1973) were originally described as ekanite. X-ray-diffraction and chemical data on these minerals are quite complete. The Th–Ca–K silicate corresponds to $Th(Ca,Na)_2(K_{1-z}\square_z)Si_8O_{20}$ (Table 1, columns 3 and 4; Table 2, columns 3 and 4). It is characterized by preponderance of Ca^{2+} in the *B* sites of the structure; in addition, K^+ is prevalent in the *C* position although there are important vacancies (*z* in the range 0.23 to 0.40).

The Th–Na–K silicate corresponds to $Th(Na,Ca)_2(K_{1-z}\square_z)Si_8O_{20}$ (Table 1, columns 5 and 6; Table 2, columns 5 and 6). It is characterized by preponderance of Na^+ in the *B* sites; in addition, K^+ is prevalent in the *C* position although there are important vacancies (*z* in the range 0.20 to 0.30). This mineral has now been renamed *steacyite*. The space group for both minerals is identical, as are Debye-Scherrer diagrams; cell-size variations are within the estimated standard deviation. These data are *P4/mcc*, a 7.58(1), *c* 14.77(2) Å, *Z*=2.

Crystal Structures

The crystal structures of ekanite from the Tombstone Mountains and that of steacyite are illustrated in the following paper (Figs. 2 and 4, Szymański *et al.* 1982). The two structures differ in two important features: 1) the manner of arrangement of SiO_4 tetrahedra: the ekanite from the Tombstone Mountains shows a puckered sheet arrangement of SiO_4 tetrahedra of composition Si_8O_{20} (Fig. 2 in Szymański *et al.* 1982), whereas steacyite from Saint-Hilaire shows independent discrete Si_8O_{20} units (pseudocubic arrangement of tetrahedra: Fig. 2 in Richard & Perrault 1972, Fig. 4 in Szymański *et al.* 1982). 2) the potassium site; the potential potassium site in the ekanite from the Tombstone Mountains is completely vacant, whereas in the Saint-Hilaire steacyite, it is more than 50% occupied.

These two differences are obviously linked: the presence of K^+ at (0,0,½) in steacyite annuls any possibility of bridging bonds between adjacent Si_8O_{20} groups and favors the closure of Si–O bonds into a cubic arrangement of tetrahedra. The complete absence of K^+ favors a sheet-like organization of Si_8O_{20} in ekanite. We consider that these major structural differences are justification for different mineral names.

Iraqite

The mineral *iraqite* (Livingstone *et al.* 1976), discovered in granites from northern Iraq, has a Debye-Scherrer pattern identical with those of Th–Ca–K silicate and steacyite. It has a space group *P4/mcc*, *a* 7.61(1), *c* 14.77(2) Å, *Z*=2. Rare-earth elements are preponderant in the *A* sites. Chemical composition and powder pattern are given in Tables 1, 2 and 3, column 7. Ca^{2+} is preponderant in the *B* sites and K^+ is prevalent in the *C* position, although there are important vacancies (*z*=0.47).

Total Valence Charges

Ekanite presents balanced valence charges when perfectly stoichiometric with 40 positive charges and 40 negative charges. Both Sri Lanka ekanite and Tombstone Mountains ekanite very nearly approach perfect stoichiometry (Table 2, col. 1 and 2).

There is no chemical formula with balanced valence charges and full occupancy of each atomic position by one single element for steacyite; $ThNa_2KSi_8O_{20}$ yields 39+ and 40–. Partial occupancy of the *C* sites and substitution of Na^+ by Ca^{2+} in the *B* sites are necessary for valence charge-balance. In the Saint-Hilaire steacyite, occupancies are 0.92 for *A*, 1.85 for *B* and 0.61 for *C* (Table 2, col. 6); Na^+ is prevalent in the *B* sites (0.90) but Ca^{2+} is important (0.73). In the central Asia steacyite, occupancies are 1.04 for *A*, 2.03 for *B* and 0.80 for *C*; Na^+ just slightly exceeds Ca^{2+} (1.05 *versus* 0.98; Table 2, col. 5).

Similarly, there is no chemical formula with balanced valence charges and full occupancy of each atomic position by one single element for the Th–Ca–K silicate from central Asia; $ThCa_2KSi_8O_{20}$ yields 41+ and 40–. Partial occupancy of the *C* sites and substitution of Ca^{2+} by Na^+ in the *B* sites are necessary for valence charge-balance. Principal compensation for the more calcic members would seem to come predominantly through partial occupancy of *C* (0.60 in the central Asia material, Table 2, col. 3).

Charge balance is attained in $ThCaNaKSi_8O_{20}$. This formula requires strict equality between Ca^{2+} and Na^+ and full occupancy of all sites. Crystal-structure analysis does not support this formula; Ca^{2+} and Na^+ occupy the same sites, and partial occupancies, especially in the K position, are more general than exceptional.

Name

The name *steacyite* honors Mr. Harold R. Steacy, curator of the National Mineral Collection housed at the Geological Survey of Canada, in recognition of his life-long studies of Canadian radioactive minerals and their occurrences. Type material has been deposited with the Collection principale de l'Ecole polytechnique de Montréal (E.P. 12480) and cotype material, with the National Mineral Collection at the Geological Survey of Canada (61529).

NOMENCLATURE

The name *steacyite* as defined in this text has been approved by the IMA Commission on New Minerals and Mineral Names. Usage of the name *kanaekanite* should be discouraged; it implicitly relates *steacyite* and the other Th–Ca–K silicate, as yet unnamed, to ekanite. Structural analysis shows this to be incorrect. A new name should be proposed for the Th–Ca–K silicate from central Asia: we would certainly favor the usage of the name *steacyite* with a suitable chemical prefix.

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