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GEORGECHAOITE $NaKZrSi_3O_9 \cdot 2H_2O$, A NEW MINERAL SPECIES FROM WIND MOUNTAIN, NEW MEXICO

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ABSTRACT

Georgechaoite $NaKZrSi_3O_9 \cdot 2H_2O$ occurs associated with microcline, nepheline, analcime, aegirine, chlorite, catapleiite and monazite in miarolitic cavities in a nepheline syenite at Wind Mountain, Otero County, New Mexico. The crystals are colorless to white, orthorhombic, up to 1 mm long, belong to space group $P2_1nb$, with a 11.836(4), b 12.940(6), c 6.735(4) Å, and show the forms $b\{010\}$, $s\{011\}$, $a\{100\}$, $\bar{a}\{\bar{1}00\}$, $h\{101\}$, $\bar{h}\{\bar{1}01\}$ and $n\{120\}$. Twins $[023]_{180°}$ are observed. Mohs hardness 5, conchoidal fracture, but no cleavage. The density is 2.70(2) g/cm^3 (meas.), 2.689 g/cm^3 (calc.). The optical properties are: biaxial negative, α 1.578(1), β 1.597(1), γ 1.606(1), $2V$ (meas.) 67°, $2V$ (calc) = 68°, $X = a$, $Y = b$, $Z = c$. The X-ray powder-diffraction pattern, very similar to that of gaidonnayite $Na_2ZrSi_3O_9 \cdot 2H_2O$, shows the following strongest nine lines [d in Å(I)(hkl)]: 6.46(73)(020), 5.95(70)(011), 5.83(32)(200,101), 5.67(52)(120), 3.12(100)(112,140), 2.894(19)(122), 2.829(22)(212,240,141), 2.201(21)(103,332,511,412), 2.049(19)(061,052). An electron-microprobe analysis yields the empirical formula $Na_{1.02}K_{0.96}(Zr_{0.99}Ti_{0.01}Fe_{0.01})Si_{3.01}O_9 \cdot 2.14H_2O$. The water content has been confirmed by crystal-structure determination (Ghose & Thakur 1985). The name recognizes Professor George Y. Chao's work on zirconium silicate minerals.

Keywords: georgechaoite, new mineral species, zirconium silicate, Wind Mountain, New Mexico, gaidonnayite.

SOMMAIRE

La georgechaoïte $NaKZrSi_3O_9 \cdot 2H_2O$ et ses satellites, microcline, néphéline, analcime, aegyrine, chlorite, catapléiite et monazite, se trouvent dans les cavités miarolitiques d'une syénite à néphéline à Wind Mountain, dans le comté d'Otero, au Nouveau Mexique. Elle se présente en cristaux orthorhombiques, incolores ou blancs, atteignant au plus un millimètre de long, dont la maille a pour côtés a 11.836(4), b 12.940(6), c 6.735(4) Å, et qui appartiennent au groupe $P2_1nb$. Les formes relevées sont $b\{010\}$, $s\{011\}$, $a\{100\}$, $\bar{a}\{\bar{1}00\}$, $h\{101\}$, $\bar{h}\{\bar{1}01\}$, $n\{120\}$. La macle $[023]_{180°}$ a été reconnue. Dr (Mohs) = 5, fracture conchoïdale, pas de clivage. Ds = 2.70(2) (mes.), 2.689 (calc.). Propriétés optiques: biaxe négative; α 1.578(1), β 1.597(1), γ 1.606(1); $2V = 67°$ (mes.), 68° (calc); $X = a$, $Y = b$, $Z = c$. En diffraction X, le cliché de poudre ressemble à celui de la gaidonnayite $Na_2ZrSi_3O_9 \cdot 2H_2O$ avec, comme raies principales [d en Å(I)(hkl)]: 6.46(73)(020), 5.95(70)(011), 5.83(32)(200,101), 5.67(52)(120), 3.12(100)(112,140), 2.894(19)(122), 2.829(22)(212,240,141), 2.201(21)(103,332,511,412), 2.049(19)(061,052). L'analyse à la sonde de Castaing donne la formule empirique $Na_{1.02}K_{0.96}(Zr_{0.99}Ti_{0.01}Fe_{0.01})Si_{3.01}O_9 \cdot 2.14H_2O$. La teneur en eau est confirmée par la structure cristalline (Ghose & Thakur 1985). Le nom de l'espèce nouvelle reconnaît les travaux du Professeur George Y. Chao sur les silicates de zirconium.

(Traduit par la Rédaction)

Mots-clés: georgechaoïte, nouvelle espèce minérale, silicate de zirconium, Wind Mountain, Nouveau Mexique, gaidonnayite.

INTRODUCTION

The Wind Mountain laccolith crops out over 4.3 km^2 in southern Otero County, New Mexico, about 3 km north of the Texas - New Mexico border. It is one of about 20 small shallow intrusive bodies of syenite, nepheline syenite, phonolite and trachyte that were emplaced as discordant sheets, sills and laccoliths in Permian and Cretaceous sediments in the early Eocene (Barker *et al.* 1977).

Two other zirconium silicates, eudialyte and catapleiite, had previously been reported as rock-

forming minerals in the nepheline syenites. Georgechaoite was found on the south side of Wind Mountain (Lat. 32°1′29″N, Long. 105°27′51″E) in June 1982 by Robert M. Boggs. The mineral is named for Professor George Y. Chao, of Carleton University in Ottawa, in recognition of his work on zirconium silicates. The mineral has been accepted, and the name, pronounced *jorj-chow-ite,* approved by the IMA Commission on New Minerals and Minerals Names prior to publication. Type material has been deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C. (NMNH #161902).

Occurrence

Georgechaoite occurs in miarolitic cavities up to 2 cm in diameter, in an analcime nepheline syenite on the south side of Wind Mountain. About a dozen specimens with scattered crystals were found in two places, for a total of about 50 mg of material. It is likely that further material will be found with additional field-work. Associated minerals in the miarolitic cavities include microcline, nepheline, aegirine, catapleiite, monazite and a chlorite. Other minerals found in the cavities but not associated with georgechaoite include natrolite and chabazite.

The sequence of formation in the miarolitic cavities, determined by observations with a stereomicroscope, is as follows: microcline (earliest), nepheline, analcime, aegerine, chlorite, catapleiite, monazite and georgechaoite (latest).

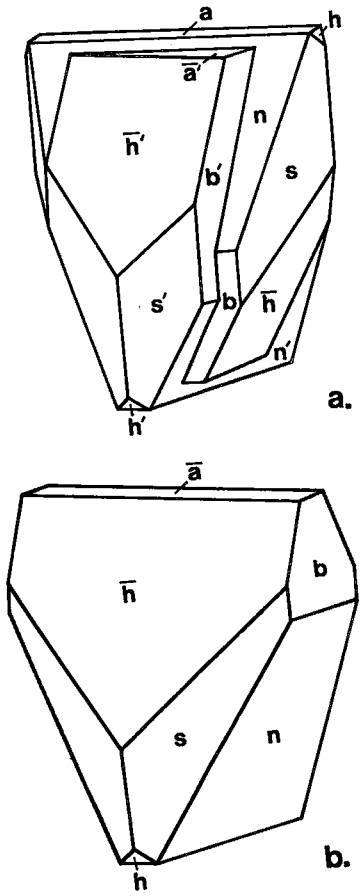

FIG. 1. Drawings of twinned (a) and untwinned (b) crystals of georgechaoite. Forms shown are $a\{100\}$, $\bar{a}\{\bar{1}00\}$, $b\{010\}$, $h\{101\}$, $\bar{h}\{\bar{1}01\}$, $s\{011\}$ and $n\{120\}$.

Physical Properties, Habit and Twinning

Georgechaoite crystals are colorless to white and range in size from about 0.25 to 1.0 mm. Most of the crystals form interpenetration twins by a half-turn about [023] as shown in Figure 1a. The twin law was deduced from measurements carried out on a two-circle optical goniometer. The resulting twin has the *a* axis of the two individuals parallel and the *b* axis of one individual at a 14° angle to the *c* axis of the second individual and *vice versa.* This differs from the twin law reported by Chao & Watkinson (1974) for gaidonnayite from Mont St. Hilaire, Quebec. Their twin law, a half-turn about [012], would result in a twin with the *b* and *c* axes of the two individuals at an angle of about 2.5° instead of the 14° observed in georgechaoite. It is most likely that the twin laws are the same in the two species in view of their isostructural nature. If the twinned crystals from Mont St. Hilaire had not been measured it would have been easy to miss the actual angular relationship, and thus the actual twin-law, since on simple visual examination the georgechaoite twins appear to have the *b* and *c* axes of the two individuals approximately parallel to one another.

Both the twinned crystals and rare untwinned crystals (Fig. 1b) show form development indicative of their polar *2mm* symmetry with unequal development of upper and lower forms. Forms present (measured with a two-circle goniometer) are $b\{010\}$, $s\{011\}$, $a\{100\}$, $\bar{a}\{\bar{1}00\}$, $h\{101\}$, $\bar{h}\{\bar{1}01\}$, $n\{120\}$.

The crystals have a Mohs hardness of 5 and conchoidal fracture. There is no indication of cleavage. The measured density of 2.70(2) g/cm^3 using heavy-liquid techniques is in good agreement with the calculated value of 2.689 g/cm^3. Georgechaoite is colorless in thin fragments and shows no pleochroism. Georgechaoite is biaxial negative, and the indices of refraction measured with a universal stage, using white light and a plot on a Hartman dispersion net, are α 1.578(1), β 1.597(1), γ 1.606(1), $2V$ (meas.) 67°, $2V$ (calc.) = 68°. The optical orientation is $X = a$, $Y = b$, $Z = c$. Georgechaoite shows no fluorescence in either long- or short-wave ultraviolet light.

Applying the Gladstone–Dale relationship with the constants of Mandarino (1981) and the observed

composition gives a K_C of 0.2185. The measured indices of refraction and density give a K_P of 0.2199. This gives a value of the compatibility expression $1-(K_C/K_P)$ of −0.0064, which indicates superior compatibility between density, indices of refraction and chemical composition.

X-Ray Crystallography

Georgechaoite is orthorhombic, space group $P2_1nb$, with a 11.836(4), b 12.940(6), and c 6.735(4) Å. The cell dimensions were refined from data obtained on a single-crystal diffractometer (Ghose & Thakur 1985). The orientation with the two-fold axis along a was chosen to correspond with the orientation used for the isostructural mineral *gaidonnayite* (Chao & Watkinson 1974). The X-ray powder-diffraction data, obtained on a Philips diffractometer using Cu$K\alpha$ radiation (λ 1.54178 Å) with annealed synthetic CaF_2 (a 5.459 Å) as an internal standard, are given in Table 1. The data are compared with those for gaidonnayite. Gaidonnayite has a slightly smaller unit-cell, with a 11.740(3), b

TABLE 1. COMPARISON OF X-RAY POWDER-DIFFRACTION DATA FOR GEORGECHAOITE AND GAIDONNAYITE

Gaidonnayite*				Georgechaoite				Gaidonnayite*				Georgechaoite			
hkl	d_{calc}	d_{obs}	I	hkl	d_{calc}	d_{obs}	I	hkl	d_{calc}	d_{obs}	I	hkl	d_{calc}	d_{obs}	I
020	6.410	6.42	30	020	6.470	6.46	73					123	2.088	2.089	8
011	5.931	5.93	80	011	5.974	5.95	70	441	2.095	2.056	5	441	2.077		
200	5.865	5.84	80	200	5.918	5.83	32	213	2.057			213	2.072	2.067	6
101	5.812			101	5.857							351	2.060		
120	5.625	5.63	50	120	5.677	5.67	52								
								061	2.035	2.037	20	061	2.054	2.049	19
111	5.293	5.28	10					052	2.035			052	2.052		
021	4.628	4.64	10	021	4.666	4.52	6	260	2.008			260	2.026		
220	4.328	4.31	30	220	4.367	4.34	16			2.005	10	161	2.024	2.023	13
121	4.305			121	4.341			152	2.005			152	2.022		
211	4.166	4.17	15												
								600	1.955	1.950	10				
221	3.634	3.618	20B	221	3.664	3.63	14	133	1.949			133	1.964		
031	3.601			031	3.632							303	1.951	1.951	8
131	3.443	3.441	30	131	3.472	3.45	14	261	1.923	1.921	30	261	1.940		
301	3.377	3.376	5					252	1.923						
320	3.339	3.337	5												
								512	1.900	1.897	10				
012	3.236	3.224	5	012	3.259	3.24	16	360	1.875						
040	3.205			040	3.235			233	1.873	1.875	10				
112	3.120	3.124	100	112	3.142	3.12	100	620	1.871						
140	3.092	3.094	80	140	3.121										
321	2.987	2.990	5					611	1.857						
								451	1.855	1.854	5	451	1.871		
400	2.934	2.931	40	400	2.959	2.950	14	323	1.854			323	1.868	1.866	10
122	2.875	2.873	20	122	2.896	2.894	19					522	1.855		
212	2.834	2.831	30	212	2.855										
240	2.813	2.806	30	240	2.839	2.829	22	361	1.806						
141	2.806			141	2.831			352	1.805	1.804	5				
								621	1.801						
331	2.649	2.647	20					062	1.801						
222	2.647			222	2.667			413	1.758	1.758	10				
				031	2.657	2.656	8								
				411	2.652			460	1.727	1.725	5				
								004	1.673			004	1.684		
241	2.593	2.594	20	241	2.616	2.604	8	461	1.673			153	1.678	1.675	16
132	2.570	2.564	5	132	2.590	2.576	5	452	1.672	1.670	30	343	1.671		
312	2.494	2.488	10	312	2.513			640	1.670			014	1.670		
340	2.479							153	1.666						
232	2.403	2.403	10	232	2.422	2.417	10			1.637	40				
				051	2.416					1.617	5				
431	2.274	2.269	5							1.606	5				
251	2.217	2.217	5							1.591	5				
501	2.215									1.545	20				
013	2.197	2.195	20							1.512	5				
103	2.191			103	2.206					1.488	5				
				332	2.202	2.201	21			1.471	5				
				511	2.201					1.450	5				
				412	2.191					1.409	10				
440	2.164	2.161	5	440	2.183					1.376	5				
113	2.159			113	2.174	2.164	8			1.287	5				
				242	2.170										
060	2.137	2.135	5	060	2.157	2.151	16								
160	2.102	2.102	10	160	2.122	2.119	11								
				023	2.121										

* Chao & Watkinson (1974); d in Å.

12.820(3), and c 6.691(1) Å and the same space-group. The powder patterns are very similar except that owing to its larger unit-cell, georgechaoite has slightly larger d-values.

Chemical Composition

Several crystals were embedded in epoxy, ground and polished, and coated with approximately 200 Å of carbon. Analyses were made with a combination of wavelength-dispersion and energy-dispersion techniques on an ARL electron microprobe equipped with a Tracor Northern energy-dispersion analyzer. Analysis conditions consisted of an acceleration voltage of 15 kV, a sample current of 10 nA, and a spot size of 30 μm to avoid volatilization of the alkalis. The following standards were used: zektzerite for Na, Si and Zr, rutile for Ti, hematite for Fe, and potassium feldspar for K. An EDS spectrum shows no other elements with atomic number greater than 11; F was shown to be absent with the wavelength-dispersion spectrometer. Owing to the lack of sufficient material, water was determined by difference and by analogy with gaidonnayite. The water content has been confirmed by a complete structural refinement (Ghose & Thakur 1985). The crystals show little compositional variation from core to rim. An average of several compositions is shown in Table 2 along with the ideal composition for $NaKZrSi_3O_9 \cdot 2H_2O$. This gives an empirical formula of $Na_{1.02}K_{0.96}(Zn_{0.99}Ti_{0.01}Fe_{0.01})Si_{3.01}O_9 \cdot 2.14H_2O$, which approximates the ideal formula given above.

Relationship to Gaidonnayite and Na-K Ordering

When the initial compositional and X-ray powder-diffraction data became available, we suspected that georgechaoite was an Na–K ordered mineral isostructural with gaidonnayite (Chao 1973), because of 1) the consistent 1:1 ratio of Na and K, and 2) the fact that gaidonnayite has two crystallographically distinct Na sites (Chao 1985). This view was confirmed by a complete crystal-structure determination, which is reported in the following paper by Ghose & Thakur (1985). Georgechaoite does not show a superstructure with respect to gaidonnayite, even though it is an ordered structure. This is due to the fact that the two sites of Na in gaidonnayite are crystallographically distinct; thus the ordering of K in one of these sites does not produce a superstructure.

Gaidonnayite from Narsarsuk, Greenland, originally described as α-catapleiite by Gordon (1924), was analyzed by Mandarino & Sturman (1978) and found to contain a significant amount of potassium. These compositions are not characterized by a 1:1 ratio of Na and K; however, those crystals in which K exceeds Na in the K site (numbers 11 to 14) probably have the ordered structure of georgechaoite.

TABLE 2. CHEMICAL COMPOSITION OF GEORGECHAOITE

	Ideal $NaKZrSi_3O_9 \cdot 2H_2O$	Weight percent	Number of cations	Number of oxygens	On basis of 9 oxygens
SiO_2	43.17 %	43.18	0.7186	1.4372	3.01
ZrO_2	29.51	29.03	0.2356	0.4712	0.99
TiO_2	-	0.11	0.0014	0.0028	0.01
FeO	-	0.15	0.0021	0.0021	0.01
Na_2O	7.42	7.54	0.2433	0.1217	1.02
K_2O	11.28	10.75	0.2282	0.1141	0.96
H_2O	8.63	(9.21)*	1.0225	0.5112**	2.14†
sum	100.01	90.76*		2.1489	

* H_2O by difference. Sum does not include H_2O. ** Sum of oxygen atoms does not include oxygen atoms in H_2O. † From H_2O by difference.

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