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YAGIITE, A NEW SODIUM-MAGNESIUM ANALOGUE OF OSUMILITE

THEODORE E. BUNCH, *Ames Research Center, NASA, Moffett Field, California 94035*

AND

LOUIS H. FUCHS, *Argonne National Laboratory, Argonne, Illinois 60439.*

ABSTRACT

Yagiite, a new osumilite-type sodium-magnesium-aluminum silicate is found in silicate inclusions of the *Colomera* iron meteorite associated with aluminous titanian diopside, whitlockite, tridymite and plagioclase. The mineral is colorless, uniaxial positive, and weakly pleochroic; refractive indices are $\epsilon = 1.544$, $\omega = 1.536$. Average composition, determined by the electron microprobe, is SiO_2 61.7; Al_2O_3 19.1; Cr_2O_3 0.1; TiO_2 0.8; FeO 2.4; MgO 10.5; MnO 0.2; CaO 0.1; Na_2O 3.7 and K_2O 1.4, sum 100.0 wt. %.

X-ray data show that yagiite is isostructural with osumilite; unit cell dimensions are $a = 10.09 \pm 0.01$ Å, $c = 14.20 \pm 0.03$ Å. Strongest X-ray lines are: 3.228 (100), 5.059 (65), 3.726 (50). Calculated density is 2.70 g/cm^3.

INTRODUCTION

Yagiite[1], (pronounced 'yä-gē-ite), a new osumilite-type mineral with the structural formula $(Na_{1.20}\ K_{0.30})\ (Mg_{2.00})\ (Mg_{0.60}\ Fe_{0.34}\ Ti_{0.10}\ Al_{1.96})\ (Si_{10.22}\ Al_{1.78})\ O_{30}$, has been found in silicate inclusions of the Colomera iron meteorite. X-ray powder data indicate that yagiite is very similar to osumilite, and to two other osumilite-type meteorite minerals, roedderite and merrihueite; there are only minor differences in line spacings and intensities.

The mineral was named for Dr. Kenzo Yagi, Professor of Geology, Hokkaido University, Sapporo, Japan in honor of his contributions to mineralogy and petrology.

Occurrence and optical properties. Yagiite occurs interstitially to small equant grains of aluminous titanian diopside in a small silicate inclusion (0.8 mm in diameter) surrounded by nickel-iron; minor amounts of whitlockite, tridymite and plagioclase are also present. A detailed description of the mineralogy and mineral chemistry of the *Colomera* meteorite is given by Wasserburg *et al.* (1968) and in a paper in preparation by Bunch and others.

In reflected light yagiite has much lower reflectivity than the co-existing pyroxene, approximately equal to that of plagioclase. In transmitted light it shows faint pleochroism (ϵ = colorless, ω = very light blue)

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[1] The name yagiite has been approved by the Commission on New Mineral Names of the International Mineralogical Association.

TABLE 1. SOME PROPERTIES OF YAGIITE AND RELATED OSUMILITE-TYPE MINERALS

	Roedderite[a]	Merrihueite[b]	Osumilite[c]	Yagiite
a (Å)	10.139 ± 0.01	10.16 ± 0.06	10.17	10.09 ± 0.01
c (Å)	14.275 ± 0.01	14.32 ± 0.06	14.34	14.29 ± 0.03
ρ, g/cc (meas.)	2.6	2.87 (calc.)	2.64	2.70 (calc.)
ω	1.537		1.546 (avg.)	1.536
ϵ	1.542	1.559–1.592	1.550 (avg.)	1.544
$\epsilon-\omega$	0.005		0.004	0.008
	colorless	greenish blue	dark blue (pleochroic)	colorless (pleochroic)

[a] Fuchs, *et al.* (1966).
[b] Dodd, *et al.* (1965).
[c] Miyashiro (1956).

and is uniaxial positive. Refractive indices are $\epsilon=1.544\pm0.002$ and $\omega=1.536\pm0.002$. Optical and physical properties of yagiite are compared with those of other osumilite-type minerals in Table 1.

X-ray data. An X-ray powder pattern of yagiite was obtained using a Norelco powder camera, diameter of 11.45 cm with Ni-filtered CuKα_1,α_2 radiation. The pattern was indexed on a hexagonal unit cell with $a=10.09\pm0.01$ Å and $c=14.29\pm0.03$ Å. Calculated X-ray density ($Z=2$) is 2.70 g/cm^3. X-ray data for yagiite are compared with those for osumilite, roedderite and merrihueite in Table 2. Yagiite is isostructural with other osumilite-type minerals as indicated by the similar X-ray powder patterns and unit cell parameters. Differences in line spacings and intensities for yagiite compared to osumilite and roedderite are minor, but show more marked variations compared to merrihueite.

Chemistry. Analyses were carried out with an ARL-EMX electron microprobe using wet-chemically analyzed mineral standards similar in composition to yagiite. Corrections were made for drift, deadtime, background, mass absorption and fluorescence. No atomic number corrections were made because of standard-sample similarity. To minimize volatilization of alkalis during analyses a low sample current (0.02 microampere), short counting time (10 seconds) and an accelerating voltage of 15 kV were used. Sample grains of the type osumilite (Sakkabira, Japan) were analyzed simultaneously with yagiite for comparative purposes. Results of these analyses along with published electron microprobe analyses of roedderite and merrihueite are listed in Table 3.

It is apparent that yagiite is most similar in composition to osumilite

TABLE 2. X-RAY POWDER DIFFRACTION DATA

	Merrihueite *Mezo-Madaras*		Roedderite *Indarch*		Osumilite Sakkabira, Japan		Yagiite *Colomera*	
hkil	*I*	*d*(Å)	*I*	*d*(Å)	*I*	*d*(Å)	*I*	*d*(Å)
$10\bar{1}0$			10	8.827	30	8.827	5	8.73
0002	80	7.13	50	7.126	70	7.126	30	7.12
$10\bar{1}2$	10	5.50	10	5.532	60	5.532	15	5.529
$11\bar{2}0$	30	5.03	80	5.062	70	5.091	65	5.059
$20\bar{2}0$	5	4.40	90	4.383	60	4.392	15	4.368
$11\bar{2}2$	10	4.13	80	4.129	80	4.129	20	4.127
$20\bar{2}2$	100	3.73	90	3.729	80	3.745	50	3.726
0004	5	3.60	80	3.567	60	3.567	25	3.565
$12\bar{3}0, 10\bar{1}4\}$	5	3.33	30	3.295	60	3.300	15	3.299
$12\bar{3}1$	90	3.23	100	3.229	100	3.225	100	3.228
$12\bar{3}2$	10	3.01	10	3.006	40	3.006	20	2.990
$11\bar{2}4$			10	2.940				
$30\bar{3}0$	60	2.92	90	2.916	90	2.916	40	2.909
$20\bar{2}4$	100	2.774	90	2.761	90	2.770	50	2.765
$12\bar{3}3$			30	2.717	30	2.721	10	2.716
$22\bar{4}0$			60	2.531	40	2.536	15	2.523
$21\bar{3}4, 13\bar{4}0\}$			10	2.432	20	2.432	5	2.428
$13\bar{4}1$			10	2.393	40	2.388	5	2.390
$13\bar{4}3, 11\bar{2}6\}$			40	2.168	30	2.168	10	2.159
$20\bar{2}6, 40\bar{4}2\}$	10	2.097	30	2.099	10	2.096	5	2.090
			10	2.067	10	2.069		
$13\bar{4}4, 23\bar{5}0\}$	20	2.010	50	2.012	50	2.014	30	2.003
$41\bar{5}1$			40	1.897	10	1.918	10	1.890
$23\bar{5}3, 13\bar{4}5$ $30\bar{3}6, 41\bar{5}2\}$			40	1.852	50	1.853	25	1.846

in that it has aluminum as a major component, whereas merrihueite and roedderite are low in aluminum. Yagiite contains more MgO and Na_2O, and less Al_2O_3, FeO and K_2O than osumilite. It should be pointed out that the original wet-chemical analysis reported by Miyashiro (1956) is probably in error owing to contamination by cordierite or other minerals that coexist with osumilite. Electron microprobe analyses of the two other known osumilite occurrences (Obsidian Cliffs, Oregon and Monte Arci, Sardinia) (Bunch and Olsen, in preparation) are very similar to our microprobe analysis of Sakkabira osumilite and indicate a narrow compositional range. Osumilite in these three known occurrences has crystallized in cavities of rhyolites in association with either fayalite or ferrohypersthene and at least one iron oxide (hematite or magnetite). In contrast, yagiite has crystallized in a magnesium-rich environment with aluminous titani-

TABLE 3. ELECTRON MICROPROBE ANALYSIS OF OSUMILITE-TYPE MINERALS

	Yagiite *Colomera*	Osumilite Sakkabira, Japan	Roedderite[a] *Indarch*	Merrihueite[b] *Mezo-Madaras*
SiO_2	61.7	61.6	71.0	61.8
Al_2O_3	19.1	21.4	0.4	0.2
Cr_2O_3	0.1	<0.02	—	—
TiO_2	0.8	0.1	—	—
FeO	2.4	8.6	2.0	23.7
MnO	0.2	0.8	—	0.5
MgO	10.5	3.7	19.5	4.4
CaO	0.1	0.1	—	0.3
Na_2O	3.7	1.0	4.0	2.0
K_2O	1.4	2.9	3.3	3.8
Total	100.0	100.2	100.2	96.7

Structural Formulas for Osumilite-Type Minerals

Coordination	XII	VI	IV	IV	
Basic Formula[c]	(Alk or Me)	Me_2	Me_3	$(Si, Al)_{12}$	O_{30}
Osumilite					
Sakkabira	$(K, Na, Ca)_{0.98}$	$(Fe, Mg)_{2.00}$	$(Mg, Al, Mn)_{2.95}$	$(Si, Al)_{12}$	O_{30}
Yagiite					
Colomera	$(Na, K)_{1.50}$	$Mg_{2.00}$	$(Mg, Fe, Al, Ti)_{3.00}$	$(Si, Al)_{12}$	O_{30}
Roedderite[a]					
Indarch	$(Na, K)_{1.99}$	$Mg_{2.00}$	$(Mg, Fe)_{3.13}$	Si_{12}	O_{30}
Merrihueite[b]					
Mezo-Madaros	$(K, Na)_{1.72}$	$Fe_{2.00}$	$(Fe, Mg)_{3.20}$	Si_{12}	O_{30}

[a] Fuchs, *et al.* (1966).

[b] Dodd, *et al.* (1965).

[c] Schreyer and Schairer (1962).

an diopside. These environmental differences are reflected in the relative amounts of MgO and FeO in yagiite and osumilite. Similarly, roedderite, the sodium magnesium analogue of merrihueite, coexists with the magnesium-rich minerals enstatite and clinoenstatite (Fuchs *et al.*, 1966), while merrihueite is associated with a more iron-rich mineral, "fayalitic olivine" (Dodd *et al.* 1965).

On the basis of thirty oxygens per unit cell the analyses in Table 3 can be recast into structural formulas that clearly show the complex solid solution that is possible for osumilite-type minerals. At least two substitutional pairs (K–Na; Fe–Mg) are possible for these minerals, and a complete solution series probably exists between the aluminum-poor members, merrihueite and roedderite, by mutual substitutions of K and Na, and Fe and Mg, and from both minerals to the aluminum-rich member osumilite. The basic formula (Table 3) shows that the 12-coordinated positions are occupied by alkalis, but alkalis are not necessarily essential in forming the structure, as Schreyer and Schairer (1962) have suggested. A further complication is indicated by the possibility that vacancy sites exist in the 12-coordinated positions. The formula should contain 2.0 alkali atoms; osumilite, however, contains only one, yagiite 1.5 and merrihueite 1.7. In addition, Olsen (1967) has shown that roedderite can have as many as 0.5 alkali atoms in excess of the empirical formula, and that these are probably "stuffed" into the structure. The 6-coordinated positions for yagiite and roedderite are occupied by magnesium, whereas iron is the predominant cation in this position for osumilite and merrihueite. Both yagiite and osumilite have nearly two atoms of aluminum in the 4-coordinated sites. Roedderite and merrihueite have very small amounts of aluminum that can be considered nonessential.

We propose that yagiite be restricted to that part of the solid solution region with $Na > K$, $Mg > Fe$ and $Si/Al < 7$ (atomic ratio) and that osumilite be redefined as that part of the solid solution region with $K > Na$, $Fe > Mg$ and $Si/Al < 7$ (atomic ratio). This would define that part of the osumilite-type mineral system involving the substitutions discussed above, with roedderite being the sodium magnesium analogue of merrihueite, and yagiite the sodium magnesium analogue of osumilite.

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