Johachidolite redefined: a calcium aluminum borate

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Abstract

The occurrence of two similar minerals at Jöhachidö, North Korea, may have been responsible for the various compositions suggested for johachidolite. Physical, optical, and X-ray data are reported for a specimen of johachidolite whose composition, $CaAlB_3O_7$, was established by crystal structure analysis of the same specimen by Moore and Araki (1972). This specimen is identical with a second specimen recognized as metatypic by one of the original authors.

Johachidolite was originally described by Iwase and Saito (1942). The chemical analysis led them to assign a complicated formula, $H_6Na_2Ca_3Al_4F_5B_6O_{20}$, which actually does not quite balance. Several authors later proposed new formulas on the basis of the same analysis (Hey, 1962; Davies and Machin, 1968; Kostov, 1968; Strunz, 1970; Povarennykh, 1972). Moore and Araki (1972) solved the structure of a crystal from the U.S. National Museum, (NMNH 105479), from the type locality, Jöhachidö District, Kisshu County, Kankyo Hodu Prefecture, North Korea. This specimen is cataloged by the U.S. National Museum as a gift (given in 1947) from Dr. K. Sakurai, Imperial Science Museum, Tokyo. The structural analysis of a crystal from this specimen led Moore and Araki to assign the formula $CaAlB_3O_7$ to johachidolite. Moore and Araki attribute the results of the original chemical analysis to the probable presence of impurities such as nepheline, fluorite, or villiaumite. However, a question remains as to whether there could have been present originally as much as the 25 weight percent of CaF_2 or NaF that would be required to produce (in part) their results, which are compared in Table 1 with the weight percent oxides calculated for $CaAlB_3O_7$.

Johachidolite was described by Iwase and Saito as having "intense blue fluorescence by the stimulus of ultra-violet radiation" and was illustrated in their paper as showing up prominently in high relief in thin section. It should not, therefore, have been difficult to obtain a relatively pure sample. On the other hand, Iwase and Saito do refer to the presence of a "more opaque, white specimen which is almost similar to johachidolite in appearance, but seems to be lacking in fluorine, and is found in the nephelite block from the same locality." There appears to be a possibility that the two minerals occurred in close association on the original specimen. If that were true, the present $CaAlB_3O_7$ formula would correspond to the designated mineral without fluorine, and johachidolite would be the one with fluorine.

At this point we consulted with Professor Moore who, in turn, asked Dr. Kato, National Science Museum, Tokyo, for help in obtaining a specimen of the type johachidolite. Dr. Kato very kindly made available to Professor Moore a fraction of johachidolite recognized as metatypic with the type material by one of the original authors, Dr. E. Iwase. Dr. Kato reported (written communication, 1973) that a powder pattern of another fraction of the cotypic material could be satisfactorily indexed on the basis of data given by the present authors to Moore and Araki (1972). In the absence of the type specimen (whereabouts unknown), our hypothesis of two minerals cannot be tested, and in the following text we take johachidolite as $CaAlB_3O_7$ with the structure established by Moore and Araki.

We also studied material from NMNH 105479

Table 1. Chemical composition of johachidolite

	1. (wt. %)	2. (wt. %)
SiO_2	0.34	
Al_2O_3	28.34	24.10
Fe_2O_3	0.09	
FeO	--	
MnO	0.23	
CaO	24.77	26.52
Na_2O	8.27	
P_2O_5	0.03	
B_2O_3	24.21	49.38
Cl	--	
F	12.21	
$H_2O(+)$	6.52	
$H_2O(-)$	0.07	
SO_3	--	
	105.08	
$-O = F$	5.14	
Total	99.94	100.00

1. Reproduced from Iwase and Saito (1942); they suggest the formula $H_6Na_2Ca_3Al_4F_5B_6O_{20}$.

2. Data derived from the structural formula $CaAl[B_3O_7]$ (Moore and Araki, 1972).

and, using this specimen, determined the crystallographic data for johachidolite by single-crystal X-ray precession techniques. These data are given in Table 2. The cell constants are slightly different from those reported in Moore and Araki (1972) and result from a further refinement of the powder data that are given in Table 3.

In NMNH 105479, johachidolite is associated with scapolite (dipyre), diopside, albite, nepheline, and phlogopite. The johachidolite occurs as equant anhedral grains up to 1 mm in diameter. Some of the grains have planar surfaces that result from parting

Table 2. Crystallographic data for johachidolite

System orthorhombic, class <u>mmm</u>, space group <u>Cmma</u>

<u>a</u> (Å)	=	7.968(1)*
<u>b</u>	=	11.724(1)
<u>c</u>	=	4.374(1)
<u>a:b:c</u>	=	0.6796:1:0.3731
<u>V</u> (Å³)	=	408.6
<u>Z</u>	=	4 $[CaAl(B_3O_7)]$

Specific gravity (meas)** 3.37(1)   Density (calc) 3.43_7 gcm^{-3}

*USNM specimen no. 105479. Data obtained from refinement of X-ray powder data (Table 3) using a least-squares program of Appleman and Evans (1973). Error in parentheses is one standard deviation.

**Measured by the immersion method in a Clerici solution. Iwase and Saito (1942) say "slightly smaller than 3.4"; their Table II lists 5.4, presumably a misprint.

Table 3. X-ray powder diffraction data for johachidolite

	Calculated*		Observed**	
hkl	$d_{h\,k\,l}$		$d_{h\,k\,l}$ (Å)	I
020	5.862		5.88	8
001	4.374		4.377	11
200	3.984		3.989	17
111	3.645		3.643	9
021	3.506		3.506	18
220	3.295		3.296	17
201	2.946		2.944	14
040	2.931		2.931	11
131	2.737		---	---
221	2.632		2.632	100
041	2.435		2.434	25
240	2.361		2.361	14
311	2.229		2.230	16
002	2.187		---	---
241	2.078		---	---
112	2.076		2.075	15
022	2.049		2.049	6
151	2.000		2.001	25
400	1.992		---	---
331	1.963		1.964	49
060	1.954		---	---
202	1.917		1.915	4
420	1.886		1.887	14
132	1.856		---	---
222	1.822		1.820	27
401	1.813		1.814	17
061	1.784		---	---
260	1.754		1.754	21
042	1.753		---	---
421	1.732		---	---
312	1.671		---	---
440	1.648		1.647	10
351	1.631		---	---
261	1.628		1.629	14
242	1.604		---	---
332	1.550		1.550	6
441	1.542		1.542	11
171	1.535		---	---
511	1.485		---	---
402	1.473		1.473	16
080	1.466		---	---
003	1.458		1.458	10
062	1.457		---	---
422	1.428		1.428	4
113	1.424		---	---
023	1.415		---	---
531	1.398		1.398	5
460	1.395		1.396	5
081	1.390		---	---
203	1.369		1.369	6
223	1.333		1.334	7
442	1.316		1.316	9
043	1.306		1.306	6
620	1.295		1.295	5
601	1.271		---	---
313	1.271		1.271	5
621	1.242		1.242	9
333	1.215		1.215	5
640	1.210		1.210	4

Plus 17 additional lines all with I > 10

* All calculated spacings listed for $d_{hkl} > 1.380$ Å. Indices from least-squares analysis of <u>X</u>-ray powder data using the digital computer program of Appleman and Evans (1973).

** U.S. National Museum Specimen No. 105479. <u>X</u>-ray diffractometer conditions are: Cu/Ni radiation λ $CuK\alpha_1 = 1.54051$ Å; silicon used as internal standard; scanned at $\frac{1}{4}°$ per minute from 3–80° 2θ.

Table 4. Optical properties of johachidolite

	Present study*	Iwase and Saito (1942)**
	Biaxial positive	Biaxial negative
α	1.712(2)	1.715
β	1.717(1)	1.720
γ	1.726(1)	1.729
$2V_\alpha$	70(2)°	72° (calc)
Orientation	X = a	
	Y = c	
	Z = b	
Dispersion	r > v, strong	r > v, strong
Birefringence	0.014	
Nonpleochroic		

*USNM specimen no. 105479. Indices measured with Na light and $2V_\alpha$ with a spindle stage.

**Determined by the immersion method. The indices are not consistent with the optic sign given.

on {201} and/or from growing against the idiomorphic crystals of albite, thus giving the appearance of being subidiomorphic. The mineral has no cleavage, in accordance with the even distribution of bond strengths in three dimensions throughout the structure. There is a subconchoidal fracture. Johachidolite is resistant to crushing, and its hardness is 7-1/2 on Mohs' scale (Iwase and Saito give 6.5–7). It is colorless and transparent; some grains are semitransparent and whitish. The luster is vitreous. It fluoresces under short-wave ultraviolet light a pale (rather than intense) blue and has weak phosphorescence. The specific gravity observed is in good agreement with the calculated density (Table 2). The optical properties are given in Table 4 and compared with those of Iwase and Saito (1942).

Chemically, johachidolite is insoluble or very slightly soluble in strong acids (HF, HCl, aqua regia) or in hot strong alkaline solutions. When heated, it begins to fuse at about yellow heat, but does not give off water, and retains its birefringence at this point. At red heat, it readily fuses to a clear hard glass with $n = 1.584 \pm 0.002$ and a specific gravity of slightly less than 2.7. The fused glass is very slowly soluble in cold 1:1 HCl and is nonfluorescent.

Electron-microprobe analyses of the metatype specimens (by Dr. Eugene E. Foord) show major Ca and Al only; there is no more than tenths of a percent of Na and a trace of Cl. No fluorine was detected. These results confirm the formula assigned by Moore and Araki. This redefinition of johachidolite as $CaAlB_3O_7$ has been approved by the I.M.A. Commission on New Minerals and Mineral Names.

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