NASONITE AND ITS RELATION TO PYROMORPHITE*

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ABSTRACT

Two new analyses of nasonite from Franklin, New Jersey, confirm the formula $Pb_6Ca_4(Si_2O_7)_3Cl_2$. A Weissenberg *x*-ray study gave $a_0 = 10.06$ kX, $c_0 = 13.24$, $a_0 : c_0 = 1 : 1.3161$; space group $C6_3/m$ or $C6_3$; cell contents $Pb_{12}Ca_8(Si_2O_7)_6Cl_4$. The very close analogy in composition and geometry between nasonite and pyromorphite, $Pb_{10}(PO_4)_6Cl_2$, is discussed.

Nasonite, $Pb_6Ca_4(Si_2O_7)_3Cl_2$, has been described from Franklin, New Jersey, by Penfield and Warren[1] and by Palache[2] and from Långban, Sweden, by Aminoff.[3] The mineral is extremely rare and few specimens are extant. Recently small amounts of the mineral have been found at Franklin below the 800 level in pillar 910 south of the Palmer shaft. The nasonite is associated with barysilite ($Pb_3Si_2O_7$), granular datolite, white fibrous prehnite, willemite, axinite, hancockite, garnet, clinohedrite, and manganophyllite. These minerals occur as irregular masses and indistinct veinlets cutting the franklinite-willemite ore and owe their formation to the local introduction of hydrothermal solutions carrying lead, boron and chlorine—all elements notably rare in the normal ore.

The nasonite occurs as white, granular masses with a greasy-adamantine luster. The mineral is not fluorescent. Minute prismatic crystals of the habit shown in Fig. 1 occur projecting into tiny cavities. Two new chemical analyses are cited in Table 1 together with the specific gravity and optical properties as newly measured. The indices of refraction are somewhat higher than those reported by Larsen on the material described by Palache. The analyses conform to the formula $Pb_6Ca_4(Si_2O_7)_3Cl_2$. A small amount of Mn'' substitutes for Pb in the material of analysis 1. The mineral ganomalite, $Pb_6Ca_4(Si_2O_7)_3(OH)_2$, is isostructural with nasonite but the reported analyses of this species[4] and of nasonite show only a slight mutual substitution of Cl and OH.

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[1] Penfield, S. L., and Warren, C. H., *Am. J. Sci.*, **8,** 339 (1899).

[2] Palache, C., *U. S. Geol. Surv., Prof. Paper* **180,** 92 (1935).

[3] Aminoff, G., *Geol. För. Förh.*, **38,** 473 (1916).

[4] Flink, G., *Arkiv Kemi, Min., Geol.*, **6,** no. 21, 16 (1917), and Dana, E. S., *System of Mineralogy*, 6th ed., 422 (1892).

TABLE 1. ANALYSES OF NASONITE

	1	2	3
CaO	10.98	10.92	11.34
MgO	—	0.24	
MnO	2.37	0.63	
PbO	65.96	66.48	67.68
ZnO	0.03	—	
SiO_2	18.32	18.57	18.21
Cl	3.07	3.18	3.58
H_2O+	0.25	0.29	
	100.98	100.31	100.81
O=Cl	0.69	0.72	0.81
Total	100.29	99.59	100.00
G		5.55	
*n*O	1.946 (Na)	1.946 (Na)	
*n*E		1.969	

1. Nasonite. Franklin, N. J. Associated with barysilite. Bauer analysis, 1950.
2. Nasonite. Franklin, N. J. Associated with hancockite, datolite, garnet. Bauer analysis, 1950.
3. $Pb_6Ca_4(Si_2O_7)_3Cl_2$. Theoretical composition.

A Weissenberg *x*-ray study of crystals from the material of analysis 2 gave:

$a_0 = 10.06$ kX $\quad a_0 : c_0 : = 1 : 1.3161$
$c_0 = 13.24$ $\quad a : c = 1 : 1.317$ (Palache; morphology)
Space group $C6_3/m$ or $C6_3$.
Cell contents $Pb_{12}Ca_8(Si_2O_7)_6Cl_4$
Calculated specific gravity 5.63.

The morphological study of Palache showed the mineral to be hexagonal and not tetragonal as originally thought by Penfield and Warren. His crystals were prismatic $\{10\bar{1}0\}$, $\{11\bar{2}0\}$ with $\{10\bar{1}1\}$ as the only terminal form. The present crystals, like those from Långban described by Aminoff, are terminated by a large face of $\{0001\}$. Doubly terminated crystals are not known. The available morphological data does not permit the crystal class to be fixed within the Laue centro-symmetrical group $6/m$ established by *x*-ray study. A decisive test for the presence or absence of piezoelectricity could not be obtained.

Nasonite shows an interesting dimensional and chemical relation to the members of the apatite group. A comparison of nasonite and pyromorphite is given in Table 2.

Nasonite is not an isotype of pyromorphite in the sense that $Zr(SiO_4)$ and $Y(PO_4)$ or $CaTi(SiO_4)O$ and $CaMg(AsO_4)F$ are isotypes. In nasonite the Si:O ratio is 2:7 implying the existence of (Si_2O_7) groups, whereas the structure of the members of the apatite group is based on isolated tetrahedral anions (ZO_4), where Z is P^5, As^5 or V^5 ordinarily, and sometimes in part S^6, Si^4 or C^4. The Z:O ratio always appears to be 1:4 in compounds of the apatite structure-type, including the silicatian and sulfatian members such as ellestadite, wilkeite and artificial $Ca_{10}Si_2P_2S_2O_{24}F_2$. The serial substitution of Si^4 for P^5 in apatite-type substances appears from the analytical evidence to be balanced electrostatically by a concomitant serial substitution such as of S^6 for P^5 or of Na^1 for Ca^2 with maintenance of the ratio Z:O = 1:4. The broad similarity between nasonite and pyromorphite presumably follows from a near equivalence

TABLE 2. COMPARISON OF NASONITE AND PYROMORPHITE

	Nasonite	Pyromorphite
Formula	$Pb_6Ca_4(Si_2O_7)_3Cl_2$	$Pb_{10}(PO_4)_6Cl_2$
Space group	$C6_3/m$ or $C6_3$	$C6_3/m$
a_0	10.06 kX	9.95 kX
c_0	13.24	7.31 (x 2=14.62)
$a_0:c_0$	1:1.3161	1:0.735
ρ for $\{h0\bar{h}1\}$	56°40′ $p\{10\bar{1}1\}$	59°32′ $y\{20\bar{2}1\}$
G	5.55	7.04
H	4	$3\frac{1}{2}-4$
nO	1.946 (Na)	2.058 (Na)
nE	1.969	2.048
Sign	+	−

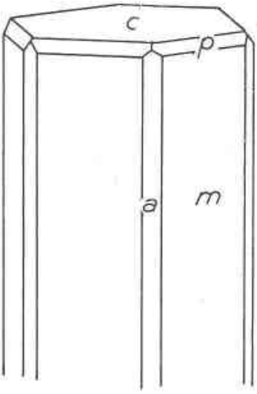

FIG. 1. Nasonite.

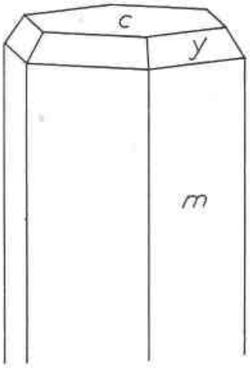

FIG. 2. Pyromorphite.

in the geometrical manner of packing of $3(Si_2O_7)^{-6}=6(PO_4)^{-3}$ with equal numbers of Cl and (Pb, Ca) ions.

The members of the apatite group diverge in symmetry and dimensions even more widely from silicates of the formula-type $A_4''B_6'''(SiO_4)_6$-$(OH)_2$. These silicates comprise the orthorhombic species zoisite and the monoclinic species clinozoisite, epidote, allanite and hancockite, where A is Ca chiefly with minor Pb, Sr, Ce or Mn'' and B is Al chiefly with minor Fe''' or Mn'''. The formulation of the epidote group as nesosilicates, however, may be in error since Ito[5] recently has derived a structure for epidote based on chain-linkages of the (SiO_4) tetrahedra rather than on isolated (SiO_4) groups.

The only other formula-types among nesosilicates that contain a total of 10 cations together with $6(SiO_4)$ groups and $2(OH)$, and hence might afford crystals isotypic with apatite, are the following: $B_8'''C_2'(SiO_4)_6$ $(OH)_2$, $A_2''B_7'''C'(SiO_4)_6(OH)_2$, $A_7''D_3''''(SiO_4)_6(OH)_2$, $A''C_4'D^{5''''}$ $(SiO_4)_6(OH)_2$, $A_4''C_2'D_4''''(SiO_4)_6(OH)_2$, $B_2'''C_4'D_4''''(SiO_4)_6(OH)_2$ and $A_5''B_4'''D''''(SiO_4)_6(OH)_2$. Actual silicates belonging to these formula-types are not known. In any case, it is unlikely that an isotypic relation would exist with silicates containing cations of valence of three or greater since the small size and relatively highly polarizing character of these would result in a coordination different from that of the relatively large divalent cations of the apatite structure-type.

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[5] Ito, T., *Am. Mineral.*, **32,** 309 (1947).