

ARMENITE, A WATER-BEARING BARIUM-CALCIUM-ALUMOSILICATE

BY

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WITH 4 FIGURES IN THE TEXT

Introduction: This mineral was originally found by cand. min. O. A. Corneliussen in 1877. He was aware of being confronted with something exceptional, but eventually he arrived at the conclusion that it was an epidote with an unusual habit, and labelled it "Epidote?". — While working on the Kongsberg-minerals, I found it in the collections of the university and made it subject to a more thorough examination. It is known only in a single specimen found in the Armen Mine at Kongsberg, and after that mine I have named it *armenite*.

Armenite is colourless or green and translucent to dull. The crystals are pseudo-hexagonal, with long prismatic habit and poorly developed terminal faces. They may attain a size of $1\frac{1}{2} \times \frac{1}{2}$ cm.

Chemical properties.

Tiny fragments of these crystals carefully examined for purity were chemically analyzed; the analysis was made by stud. mag. scient. Lars Lund, whom I want to thank for his excellent assistance. The purity of the precipitates was optic spectrographically controlled and the amount of strontium determined by civ. eng. A. Kvalheim, to whom I am also indebted. 0,5 gr. was used for the main analysis, and 0,5 gr. for the determination of alkalis. The composition is as follows:

	A	B
SiO ₂	46,18 %	7690
Al ₂ O ₃	27,52 -	2692
BaO	12,37 -	829
SrO	0,04 -	4
CaO	9,99 -	1781
Na ₂ O	0,16 -	26
K ₂ O	0,13 -	14
H ₂ O +	3,41 -	1893
H ₂ O —	0,11 -	
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	99,91 %	

A; weight percents, B; corresponding molecular proportions.



Fig. 1. Armenite crystals. The two upper crystals have small axinites on the prism faces. Photo by Unn Hofseth.

According to this the gross formula is (A):



directly from the analysis



and after subtraction of alkalis:



The gross formula may also be (B):



directly from the analysis:



and after subtraction of alkalis:



We see that formula A is in better accordance with the analysis, whereas B agrees with the formula type

(earth alkali) $\text{Al}_2\text{Si}_8\text{O}_{10} \cdot n\text{H}_2\text{O}$, a well-known type.

Physical properties.

As already mentioned armenite is pseudo-hexagonal with long prismatic development. The angles between the prism faces were measured on three crystals. They were all about 60° , ranging from $59^\circ 37'$ to $60^\circ 45'$ with an average deviation of $11'$.

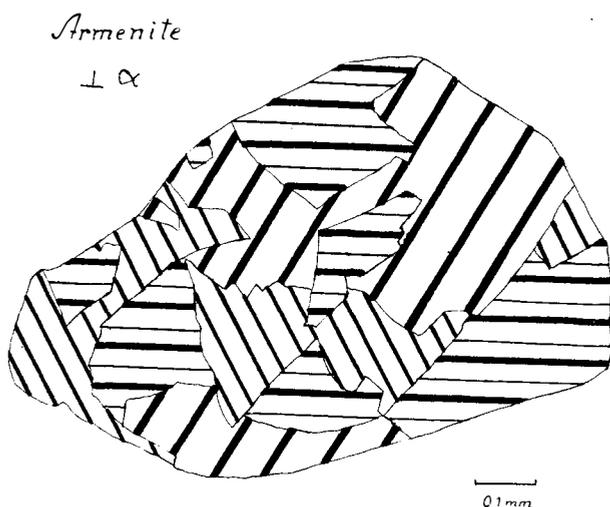


Fig. 2. Penetration twin of armenite, showing three individuals making an angle of 120° with each other.

The variation showed no regularity, and the deviations are most probably due to numerous vicinal faces that interfered with the measurements. The terminal faces were strongly corroded and therefore not measurable.

The refractive indices of armenite are rather low. Using the immersion method, in several crystals, I found $\alpha = 1,551$ and $\beta = 1,559$. It was quite impossible to find any section $\perp \alpha$ or $\perp \beta$, so γ could not be measured directly. The cleavage $\perp \gamma$ is obviously very marked, and, as earlier suggested by me (Norsk geologisk tidsskrift 19, p. 312), a cleavage $\perp \alpha$ is probably non-existent. Then I had a thin section $\perp \alpha$ made, and with Berek's compensator I measured $\gamma \div \beta = 0,0034$.

Based on these measurements I state:

$$\alpha = 1,551 \pm 0,002$$

$$\beta = 1,559 \pm 0,002$$

$$\gamma = 1,562 \pm 0,002$$

In several crystals the axial angle was measured with the universal stage, and the following values were found: $61,5^\circ$, 61° , 61° , 60° , 60° , $60^\circ 59'$, consequently $2V \div = 60^\circ \pm 2^\circ$. Computed from the indices, one finds $2V \div = 63^\circ$, in good agreement with the measured values.

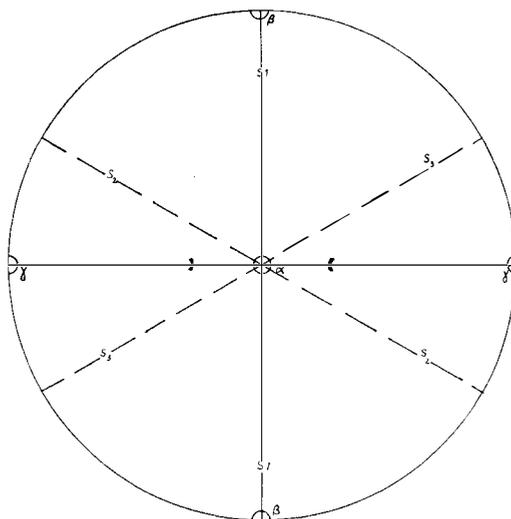


Fig. 3. Stereographic projection: S_1S_1 perfect cleavage. S_2S_2 and S_3S_3 indicates directions of less perfect cleavage.

Microscope examinations of the thin sections showed the pseudohexagonal crystals to be penetration twins composed of three optically biaxial individuals making an angle of 120° with each other (Fig. 2). Each individual possesses three tauto-zonale cleavage planes, one perfect (Fig. 3, S_1S_1) and two distinct ones (Fig. 3, S_2S_2 and S_3S_3). The angles between them are all 120° , and the zone axis is parallel to the pseudohexagonal axis, corresponding to the optical direction α ; the best cleavage lies in the α - β -plane. (Fig. 3.) It is natural therefore to select the α - β -plane as one fundamental face and the zone axis (= pseudohexagonal axis, = direction α), as one crystallographic axis. Thus armenite would seem to be rhombic.

A probable explanation of these phenomena is that armenite is truly hexagonal at high temperatures, and on cooling, changes to a rhombic (?) low temperature modification.

Whether armenite on heating will become uniaxial, is not known.

The hardness of the mineral is between 7 and 8; the specific gravity was determined with a Westphal balance and heavy solutions. $D = 2,76$.

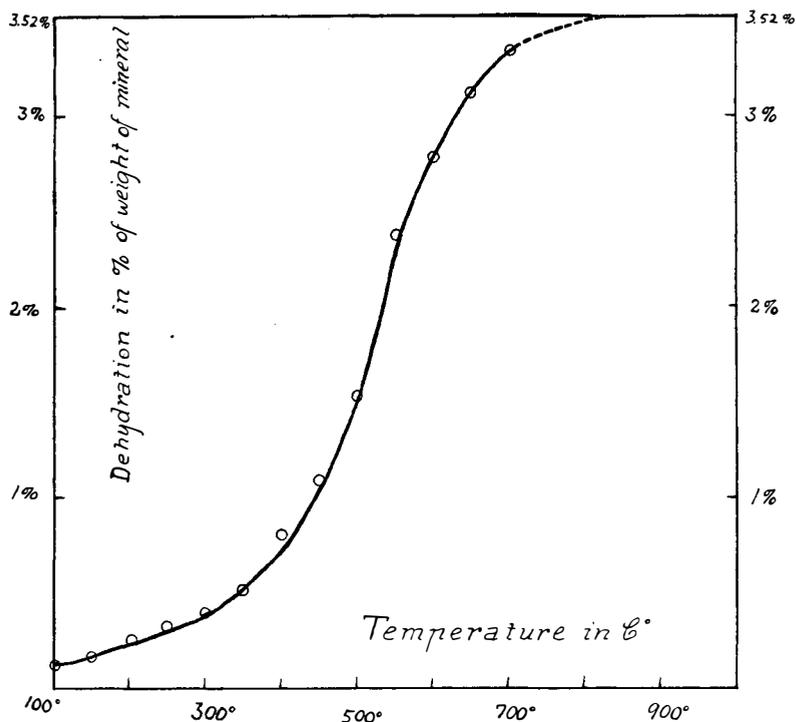


Fig. 4. Dehydration curve of armenite.

Discussion.

The systematic position of armenite is still uncertain. A first guess would be that a water-bearing earth-alkali-alumina-silicate should be a zeolite. To decide this, the hydration was examined. It was done as follows: 1.4 gr. armenite was powdered and heated for several hours at 105 C° to get rid of the hygroscopic water, then ½ hour at 150 C° and weighed, then ½ hour at 200 C° and weighed, and so on for every 50th degree. The resulting curve (Fig. 4) appears to be quite different from that of zeolites. It resembles the dehydration curve of sericite (Baker, James M., University of Toronto Studies, Geol. Ser. 40, p. 103). An important feature is that the greater part of water is expelled between 450° and 600°. The curve thus demonstrates that the water is not zeolitic.

Melting does not take place at a temperature available in a crucible over a teclu burner.

Armenite shows strong resemblance to milarite. Both exhibit hexagonal habit and are composed of rhombic (?) segments. The data are as follows:

	Armenite	Milarite
Cryst. syst.	Rhomb. (?) and hex.	Rhomb. and hex.
Formula	$\text{BaCa}_2\text{Al}_6\text{Si}_9\text{O}_{80} \cdot 2\text{H}_2\text{O}$	$\text{KCa}_2\text{Be}_2\text{AlSi}_{12}\text{O}_{80} \cdot \frac{1}{2}\text{H}_2\text{O}$
n	1,56	1,53
H	7,5	6
D	2,76	2,6

To show the supposed isomorphism we may write the formulae



We see that in armenite the bivalent Ba (1,43 Å) replaces the univalent K (1,33 Å), and, in order to satisfy the valences, at the same time silica (0,39 Å) in the complex silica-oxygen-anion of armenite is replaced by alumina (0,57 Å) and in milarite by beryllium (0,34 Å).

In order to ascertain the systematic position and prove the possible relation to milarite, an x-ray investigation must be carried out.

Paragenesis.

The specimen examined shows, besides armenite, the following minerals: axinite, pyrrhotite, quartz, and calcite.

Armenite is first deposited, with the pseudohexagonal base nearly perpendicular to the wall of the vein. On armenite grow clear little crystals of axinite and quartz, and at last the vein is filled with calcite.

Pyrrhotite occurs in well developed crystals which have later been corroded. Also these seem to be younger than armenite.

Armenite is probably the oldest mineral in the paragenesis.

Acknowledgements. The experimental part of the present paper was done while I was connected with the Mineralogisk Institutt, whose director, professor Tom. F. W. Barth, as well as professor V. M. Goldschmidt, director of the Mineralogisk Museum, kindly placed the facilities of both institutions at my disposal.

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Norges geologiske undersøkelse,

Oslo, in November 1940.