

## STUDY OF HOEGBOMITE

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### ABSTRACT

Hoegbomite occurrences in New York, Virginia, and North Carolina were investigated. The North Carolina locality is a new hoegbomite discovery.

Hoegbomite occurs in emery or hornfels associated with emery. It formed at the expense of an earlier spinel. In North Carolina two varieties of hoegbomite were discovered, hoegbomite *A* and hoegbomite *B*. Hoegbomite *A* appears to be transitional between spinel and hoegbomite *B*. The hoegbomite of the New York emery deposits was formed later than the emery but earlier than the high-temperature quartz veins which represent the last stages of the intrusion that gave rise to the emery.

Some of the properties of hoegbomite are discussed.

### INTRODUCTION

Hoegbomite was first described by Gavelin<sup>1</sup> from Lapland, Sweden, in 1916. The only description of an American occurrence is that by Watson<sup>2</sup> from Virginia in 1925.

In recent years hoegbomite has been reported from a number of localities. Gillson and Kania<sup>3</sup> noted its occurrence in the hornfels of Cortlandt township, New York. De Lapparent<sup>4</sup> reported the discovery of a new mineral which he termed taosite on the island of Samos in the Aegean, but which on further investigation<sup>5</sup> proved to be hoegbomite. Oenay<sup>6</sup> noted hoegbomite in the Turkish emery and Nel<sup>7</sup> in corundum-spinel-chlorite rocks in the corundum fields of eastern Transvaal. Hoegbomite has also been reported from the corundum-rich magnetite ore at Roedstand, Soendmoere, Norway.<sup>8</sup> Sandra<sup>9</sup> discovered hoegbomite in the spilites of Kamerun, West Africa.

<sup>1</sup> Gavelin, A., Ueber Hoegbomit. Ein neues gesteinsbildendes Mineral aus dem Ruotevarre-Gebiet in Lappland: *Bull. Geol. Inst., University of Upsala*, **15**, 289-316 (1916).

<sup>2</sup> Watson, T. L., Hoegbomite from Virginia: *Am. Mineral.*, **10**, 1-9 (1925).

<sup>3</sup> Gillson, J. L., and Kania, J. E. A., Emery deposits near Peekskill, N. Y.: *Econ. Geol.*, **25**, 518 (1930).

<sup>4</sup> De Lapparent, J., Les étapes du métamorphisme des émeris de Samos: *Comptes Rend. Acad. Sci.*, **201**, 154-157 (1935).

<sup>5</sup> De Lapparent, J., Composition minéralogique, structure et origine des émeris de Turquie: *Comptes Rend. Acad. Sci.*, **223**, 227-228 (1946).

<sup>6</sup> Oenay, T. S., Ueber die Smirgelgesteine SW-Anatoliens: *Schweizer. min. pet. Mitt.*, **29**, 387 (1949).

<sup>7</sup> Nel, H. J., Papers on the mineralogy of Southern Africa: *S. Africa Geol. Survey, Mem.* **43**, 1-8 (1949).

<sup>8</sup> Palache, C., Berman, H., & Frondel, C., System of Mineralogy; 7 ed., 1, 723, John Wiley & Sons, New York (1946).

<sup>9</sup> Sandra, A., Sur la présence de hoegbomite dans une spilite du Cameroun: *Comptes Rend. Acad. Sci.*, **230**, 2306-2307 (1950).

In most of these localities hoegbomite occurs as a rare accessory constituent. In several of the above cases its occurrence in a particular area was merely noted by the respective authors and was incidental to the general discussion. This may be the reason why Sandrea who discovered the Kamerun hoegbomite considered it its third reported occurrence whereas eight others had previously become known.

On a ten-day field trip in the crystalline area of Alabama and neighboring Georgia in 1896, Clements<sup>10</sup> collected three samples of hornblende-olivine rock on the road between Lafayette and Oakbowery. Microscopic study showed the rock to be a granular aggregate of hornblende, olivine, pleonaste, and magnetite. Of interest is Clements' observation of the alteration of spinel into a brownish-yellow mineral which he could not identify. He noted: "No such alteration has ever been described for pleonaste in any rock." The mineral he discussed is undoubtedly hoegbomite. His description of that mineral is probably the first on record.

In the course of this study three hoegbomite localities were investigated along the Appalachian belt. They include a new hoegbomite locality in Macon County, North Carolina, the hoegbomite occurrence of Pittsylvania County, Virginia, previously described by Watson,<sup>11</sup> and a Westchester County, New York occurrence. Hoegbomite from Westchester County, New York, has been reported in the hornfels adjoining the emery deposits of Emery Hill by Gillson and Kania<sup>12</sup> but its mode of occurrence has not been described. In this study hoegbomite was noted in both the emery and hornfels of Emery Hill and on the south slope of Salt Hill. The Alabama occurrence could not be rediscovered as the descriptions of Clements were not sufficiently detailed.

#### NEW YORK OCCURRENCE

Hoegbomite occurs as a very rare accessory mineral in the emery deposits and hornfels of Cortlandt township, Westchester County, New York. Cortlandt township is located to the south and southeast of the town of Peekskill, about 35 miles north of New York City. Two hoegbomite occurrences were noted, one at Emery Hill, the other on the south slope of Salt Hill.<sup>13</sup>

The Cortlandt emery is a corundum, titaniferous magnetite, spinel (pleonaste) aggregate that occurs in norite. The relative proportions of

<sup>10</sup> Clements, J. M., Notes on the microscopical character of certain rocks from northeast Alabama: *Geol. Survey of Alabama*, **5**, 156-157 (1896).

<sup>11</sup> Watson, T. L., *op. cit.* (1925).

<sup>12</sup> Gillson, J. L., and Kania, J. E. A., *op. cit.* (1930).

<sup>13</sup> For index map see Friedman, G. M., The sapphirine occurrence of Cortlandt, New York: *Am. Mineral.*, **37**, 244-249 (1952).

the constituent minerals vary. Hoegbomite was noted in the rock in which spinel was abundant and corundum scant. Sillimanite, cordierite, kyanite, magnetite, garnet, and sapphirine make up the hornfels.

The hoegbomite crystals are very small and must be studied with high power magnification. The length of the largest crystals does not exceed 0.04 mm., their width does not exceed 0.02 mm. They are pleochroic;  $\omega$  = moderate brown,  $\epsilon$  = moderate yellowish brown,  $\omega > \epsilon$ . The mineral is uniaxial negative.

Hoegbomite is a replacement product of spinel. The stages in the replacement of spinel can be traced. It usually formed around the margin of the spinel grains, the rest of the original crystal is typical spinel. Tabular plates which resemble biotite usually show the strongest pleochroism. They also occur along the margin of spinel grains. Many of the spinel grains are slightly fractured and tabular hoegbomite replaced the spinel between the fracture and the margin of the original spinel grain. The major difference in the composition between hoegbomite and spinel is that hoegbomite contains titanium. Titanium must have therefore been introduced subsequent to spinel formation.

Quartz veins that have cut the emery are bounded along their entire margin by reaction rims of garnet. The quartz is nowhere in direct contact with spinel. The reaction between spinel and quartz gave rise to garnet and sillimanite or to sapphirine, and occasionally to cordierite.<sup>14</sup> Quartz veins are surrounded by garnet, garnet in turn by sillimanite. Sapphirine was formed at the expense of the spinel farthest from the quartz vein. These quartz veins have cut the emery after the replacement of spinel by hoegbomite. This is evident from the following: it has been shown<sup>15</sup> that spinel and quartz are incompatible. Hoegbomite on the other hand is stable in the presence of free silica. Wherever quartz reacted with a spinel grain that was partially replaced by hoegbomite the spinel part was transformed into sapphirine, unless garnet or cordierite formed. The original grain is therefore, partially sapphirine and partially hoegbomite. As the quartz veins represent the last stages of the intrusion that was responsible for the formation of the emery, of which the spinel is a major constituent, the titanium emanations that gave rise to the hoegbomite can be deduced as being later than the formation of the spinel, but earlier than the high-temperature quartz veins.

#### VIRGINIA OCCURRENCE

The Virginia hoegbomite occurs in the emery deposits of Whittles, which are located in the north-central part of Pittsylvania County,

<sup>14</sup> Friedman, G. M., The sapphirine occurrence of Cortlandt, New York: *Am. Mineral.* 37, 244-249 (1952).

<sup>15</sup> Friedman, G. M., *op. cit.*

about 20 miles north of Danville and 40 miles south of Lynchburg. As the Virginia hoegbomite has previously been described by Watson a detailed discussion is not necessary. The replacement features merely will be described.

The Virginia emery consists of corundum, spinel (of composition near hercynite), and titaniferous magnetite. The relative proportions of these

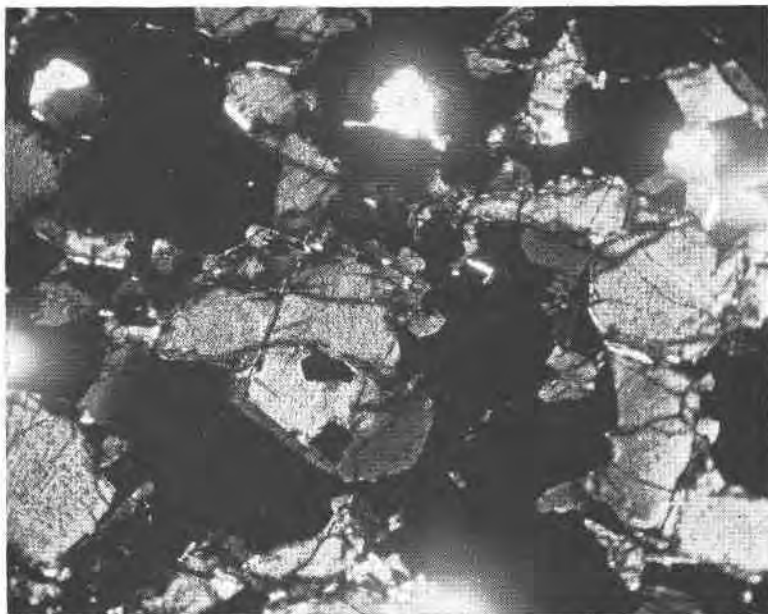


FIG. 1. Photomicrograph of Virginia emery showing hoegbomite. Hoegbomite (dark borders) rimming spinel (large grains). Prismatic hoegbomite (near left margin), magnetite (opaque).  $\times 56$  (W. B. Hall, photo).

three constituents vary widely, in some of the thin sections spinel was not observed and corundum was abundant, in others the reverse held true. Hoegbomite is invariably associated with spinel, or occurs in slides containing spinel relicts in which the spinel has almost been totally replaced by hoegbomite. The emery deposits, as at Cortlandt, New York, are associated with a basic rock, a gabbro.

That hoegbomite formed at the expense of earlier spinel is evident from the observation that spinel grains are mantled with hoegbomite and replacement nuclei of hoegbomite occur in some of the spinel grains. In some samples it can be noted that hoegbomite crystals have merely replaced the outer margin of spinel grains and entirely replaced only small spinel grains that were partially enclosed in magnetite. In other sections hoegbomite grains are molded on small remnants of spinel and corroded

spinel relicts are enclosed in the hoegbomite. Again, in a third type of section only occasional corroded spinel relicts are noted in hoegbomite, the bulk of the slide being made up of hoegbomite, magnetite, and corundum.

Measurement of the grain sizes of the hoegbomite differ substantially from the figures given by Watson. The largest crystals he observed<sup>16</sup> did not exceed 0.03 mm. in length and 0.01 mm. in width, while the corresponding measurements made in this study were 1 mm. and 0.3 mm., respectively. Many of the hoegbomite grains have entirely replaced spinel grains and consequently assumed the dimensions of the former.

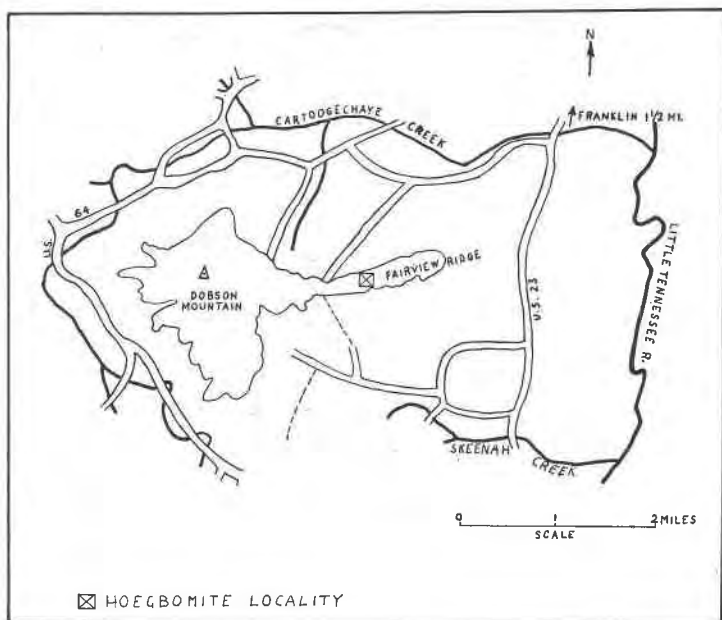


FIG. 2. Index map of the Dobson Mountain-Fairview Ridge tract, North Carolina, showing location of hoegbomite occurrence.

#### NORTH CAROLINA OCCURRENCE

The North Carolina hoegbomite occurs in the emery deposits of Macon County. The hoegbomite locality can be reached from Franklin by following Highway 23 south for about five miles, then turning west before crossing Skenah Creek. About two miles west of Highway 23 a northward trending road leads to the top of the Fairview Ridge where the emery deposits are located.

<sup>16</sup> Watson, T. L., *op. cit.* (1925).

The North Carolina emery is very similar in composition to the New York and Virginia emery. Its chief mineral constituents are corundum, spinel (of composition near pleonaste), and titaniferous magnetite. Hoegbomite is common. Because of the deep weathering it was not possible to establish with certainty the nature of the rock in which the emery occurs. Outcrops of Roan gneiss, which in this area is of dioritic composition, were noted near emery occurrences.



FIG. 3. Photomicrograph of North Carolina emery showing hoegbomite. V-shaped mineral in center is hoegbomite *A* passing marginally into hoegbomite *B* (dark rim). Prismatic hoegbomite *B* in upper right. Corundum (white), magnetite (black, opaque). The rest of section is made up of spinel (example lower right and lower left) and hoegbomite (example top center, right margin).  $\times 34$ . (W. B. Hall, photo.)

In hand specimen the hoegbomite cannot be distinguished from the associated iron oxides and spinel. Like these it is of black color. However, after the rock is crushed and examined with the aid of a binocular microscope, even without immersion into refractive index liquids, the brown color of the mineral becomes apparent. The grains have a metallic luster. Most of the hoegbomite crystals are anhedral, some, however, are of prismatic form. They are on the average larger than those from the Virginia locality. The largest grains exceed 1 mm. in length and are about 0.4 mm. in width. The cleavage is micaceous and well developed.

TABLE 1. OPTICAL PROPERTIES OF HOEGROMITE

	Virginia	North Carolina		Transvaal		Kamerun	Turkey	Samos	Sweden (Lapland)
		A	B	A	B				
Pleochroism									
$\omega$	dark brown	pale pink	deep brown	reddish brown	dark sepia brown	yellow	dark brown	brownish red	dark golden brown
$\epsilon$	light golden brown to nearly colorless	light yellow pink to nearly colorless	moderate brown	pale golden brown	light sepia brown	yellow brown	light brown to yellow brown	yellow	light golden brown
Refractive Index									
$\omega$	1.848	1.840-1.845	1.852	1.820	1.848	>1.845 <1.850	between 1.82+1.85	~1.78	1.853 ±0.003
$\epsilon$	1.817	1.815 ±0.005	1.804	1.800	1.823	~1.804	~1.815		1.803 ±0.003
Absorption	$\omega > \epsilon$	$\omega > \epsilon$	$\omega > \epsilon$	$\omega > \epsilon$	$\omega > \epsilon$	$\omega > \epsilon$	$\omega > \epsilon$	$\omega > \epsilon$	$\omega > \epsilon$
$\omega - \epsilon$	0.031	0.020-0.035	0.048	0.020	0.025	0.047-0.048	0.032	0.035	0.050

Two varieties of hoegbomite can be distinguished. These differ somewhat in their optical properties. Nel,<sup>17</sup> in his study of the Transvaal hoegbomite likewise noted two varieties and referred to these as hoegbomite *A* and hoegbomite *B*. This nomenclature will be adopted in this study.

Hoegbomite *A* is weakly pleochroic,  $\omega$  = pale pink,  $\epsilon$  = light yellow pink to nearly colorless; absorption  $\omega > \epsilon$ . In contrast to hoegbomite *B* the interference colors of hoegbomite *A* are not masked by the color of the mineral. The indices of refraction<sup>18</sup> are variable;  $\omega = 1.840\text{--}1.845$ ,  $\epsilon = 1.815 \pm 0.005$ . Double refraction:  $\omega - \epsilon = 0.020\text{--}0.035$ .

Hoegbomite *B* likewise is pleochroic,  $\omega$  = deep brown,  $\epsilon$  = moderate brown; absorption  $\omega > \epsilon$ . Hoegbomite *B* closely resembles the Virginia and New York hoegbomite, its brown color, however, is much deeper than that of those localities. Because of the deep brown color the interference colors of many grains are masked. The indices of refraction<sup>19</sup> are  $\omega = 1.852$ ,  $\epsilon = 1.804$ ; double refraction:  $\omega - \epsilon = 0.048$ .

Both varieties of hoegbomite are uniaxial negative. Hoegbomite *B* shows a greater absorption than hoegbomite *A*.

The North Carolina like the New York and Virginia hoegbomite was formed by replacement of spinel. Spinel grains are mantled with hoegbomite and replacement nuclei of hoegbomite occur in spinel grains. Many hoegbomite *B* grains pass marginally into hoegbomite *A* and these in turn into spinel. Hoegbomite *A* appears to be transitional between spinel and hoegbomite *B*.

#### COMPARATIVE TABLE OF OPTICAL PROPERTIES

For comparative purposes a table of the optical properties of hoegbomite has been compiled.

#### ASSOCIATION

The minerals that are immediately associated with the hoegbomite of the ten reported localities are noted in the table below.

At the New York, Virginia, North Carolina, Alabama, Lapland, and Samos localities hoegbomite is intimately associated with spinel and magnetite, corundum is abundant in most cases. Spinel has been reported from all the localities except Turkey.<sup>20</sup> The magnetite-spinel rocks in which the hoegbomite of the American localities occurs is associated with basic rocks.

<sup>17</sup> Nel, H. J., *op. cit.* (1949).

<sup>18</sup> Determined by Jewell J. Glass of the U. S. Geol. Survey.

<sup>19</sup> Determined by Jewell J. Glass of the U. S. Geol. Survey.

<sup>20</sup> No information has been available to the author on the Norwegian occurrence.



TABLE 2. MINERALS ASSOCIATED WITH HOEGBOMITE

	New York	Virginia	North Carolina	Alabama	Lapland	Norway	Samos	Turkey	Kamerun	Transvaal
Spinel	—	—	—	—	—	No Information	—	—	—	—
Corundum	—	—	—	—	—	—	—	—	—	—
Magnetite	—	—	—	—	—	—	—	—	—	—
Pyroxene	—	—	—	—	—	—	—	—	—	—
Diaspore	—	—	—	—	—	—	—	—	—	—
Chlorite	—	—	—	—	—	—	—	—	—	—
Chloritoid	—	—	—	—	—	—	—	—	—	—
Gibbsite	—	—	—	—	—	—	—	—	—	—

## DISCUSSION OF ORIGIN

Gavelin and Watson believed that hoegbomite was essentially a primary mineral but that some hoegbomite was formed by replacement of spinel. Examination of hoegbomite from New York, Virginia, and North Carolina indicates a secondary origin. The mineral appears to have formed at the expense of spinel. Hoegbomite *B* appears to be the ultimate product.

Nel ascribes the following formula to hoegbomite  $(\text{Fe}, \text{Mg})_6(\text{Al}, \text{Fe})_{16}\text{TiO}_{32}$ . The composition of pleonaste spinel is  $(\text{Mg}, \text{Fe})\text{Al}_2\text{O}_4$ . If the formula of the spinel is written  $(\text{Mg}, \text{Fe})_8\text{Al}_{16}\text{O}_{32}$  it becomes apparent that the hoegbomite was formed from the spinel by the isomorphous substitution of Ti for 2(Mg, Fe) and  $\text{Fe}^3$  for Al ions.

As shown at the New York locality the Ti emanations which reacted with the spinel to form the hoegbomite were later than the formation of the spinel-magnetite-corundum rock, but earlier than the high temperature quartz veins which represent the last stages of the intrusion that gave rise to that rock.

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