THE HIDDENITE DEPOSIT IN ALEXANDER COUNTY, NORTH CAROLINA

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CONTENTS

INTRODUCTION

In this magazine for August, 1927, S. C. Davidson gave a brief preliminary account of the geological relations of the hiddenite deposit. In the following pages are presented the results of the petrographic study of materials collected in 1926, made principally by Davidson but extended and verified by Goranson. To these have been added crystallographic data, in part based on Goranson's observations, in part on those of Mr. Berman and the senior author. The latter was able to study additional material through the kindness of Mr. B. S. Colburn of Asheville, N. C. This gentleman has assembled in a private museum at Asheville all the numerous specimens taken from the hiddnite mine when reopened in 1926 under the direction of his brother, W. B. Colburn. A careful examination of this interesting collection was made by Palache in 1930 and Mr. Colburn also supplied photographs of some of the matrix specimens of hiddenite and additional crystallographic material for study. We desire to express here our great indebtedness to the Messrs. Colburn for the many favors received at their hands.

The locality of the hiddenite mine has been variously designated at different times. It was first found about 50 years ago on the Warren Farm near Salem Church, Sharpe's Township, Alexander

Co. The name Stony Point later appears for the locality, taken from the nearest village. After the opening of what came to be known as the Emerald and Hiddenite Mine the name of the nearest post office and railroad station was changed to Hiddenite, and this name is still used. The mine is about a mile north of the station which is 15 miles northwest from Statesville.

Hiddenite seems to have been found at only one locality other than that of its original discovery and this was a vein within a short distance, never fully opened. Beryl, quartz and other of its associated minerals are found in many other localities in Alexander County in the near vicinity of the hiddenite mine.

Description of the Country Rock

The rock of the Piedmont region in the vicinity of the deposit is a contorted and profoundly metamorphosed gneiss of Pre-Cambrian age. In hand specimens the grayish rock appears to consist of a fine granular aggregate of quartz, biotite, and garnet, intensely folded and crumpled. The banding is due to alignment of the biotite plates. Microscopically the gneiss consists of an irregular mosaic of quartz, plagioclase and biotite. Garnet, conspicuous in hand specimens, is absent in the thin sections studied. The quartz and plagioclase are intimately interlocked in anhedral grains. The plagioclase, usually easily recognized by the presence of albite twin lamellae, is a calcic andesine. The biotite occurs in ragged, strongly pleochroic plates approximately oriented with their longer diameters in a parallel direction. In all the sections a considerable amount of rounded zircon grains were present, usually enclosed in biotite and giving strong pleochroic halos. Apatite occurs mainly in minute prismatic shapes or rounded cross sections. In one section ragged grains of augite are present, altering about their borders to a green hornblende. The average grain size of the major constituents is about 0.15 millimeters. A rough estimate of the proportion of minerals in thin sections is as follows: Quartz 50 per cent, andesine 15 per cent, biotite 30 per cent, zircon, garnet and apatite 5 per cent. Some pyrite is scattered through the rock near the pegmatites and has been undoubtedly introduced during their formation.

The present mineralogical constitution of the rock indicates that it was initially an argillaceous sandstone, regionally metamorphosed at considerable depth permitting recrystallization and reorientation of mineral grains. The quartz and plagioclase merely recrystallized while the argillaceous material formed mainly biotite and garnet. In brief, the chief evidences for a sedimentary origin of the metamorphosed rock are the high content of quartz and the high content of rounded zircon grains.

Description of the Pegmatites

Observations in the field and the study of hand specimens permit three later stages of mineralization to be distinguished. Prior to at least a portion of the folding, the gneiss was invaded by solutions which resulted in the development of numerous lit-par-lit injections of quartz-feldspar pegmatite. These range from paper-thin veinlets to dikes upwards of a foot in width; in numerous places the feldspar individuals or the dikes as a whole are granulated or drawn out into augen shapes by the folding. Later than this lit-par-lit injection were two periods of pegmatite formation in both of which hiddenite was deposited. The minerals of these three stages are shown in the following table; and will be described in succeeding pages.

Lit-par-lit Pegmatite	Hiddenite Pegmatite	Hiddenite "Cavities"
Quartz	Quartz	Quartz
Andesine	Andesine	Amethyst
Orthoclase	Microcline	Albite
Microcline	Hiddenite	Adularia
Bronzite	Tourmaline	Hiddenite
Tourmaline	Garnet	Holmquistite
Apatite	Dumortierite	Beryl
Pyrite	Sillimanite	Tourmaline
	Zircon	Garnet
	Biotite	Muscovite
	Sericite	Nontronite
	Rutile	Rutile
	Apatite	Apatite
	Pyrite	Monazite
	Calcite	Pyrite
		Arsenopyrite
		Calcite
		Ankerite
		Siderite
		Aragonite

Lit-par-lit Pegmatite Stage. These stringers and lenses are narrow, averaging half an inch in width and were injected along the foliation planes and cross fractures in the gneiss. The earliest injection evidently preceded a large part of the metamorphism of the country rock. In consequence these stringers appear now extremely contorted, resembling the folded migmatites described by Sederholm in Finland.[1] The main constituents of these stringers are fine-grained quartz and andesine with a little orthoclase forming a symplectite texture with the plagioclase. Coarse grained dikes up to a foot in width occur mainly in the fractures cross-cutting the gneissic structure. Microscopically they show coarse grains of quartz, andesine and microcline and around the borders of the large grains, small irregular grains of the same minerals. In one hand specimen a coarse-grained cross-cutting stringer is faulted, the fault plane later intruded by a stringer identical in mineralogical content with the former.

A third type of pegmatite is composed mainly of andesine and bronzite in fairly coarse grains. The plagioclase has a brownish color and the associated country rock is much higher in ferromagnesian minerals than the usual type. A little black tourmaline and orthoclase is also present.

Usually there is a little apatite associated with the stringers and often a little biotite. Frequently biotite is concentrated slightly along the walls of the stringers. With the exception of the last described stage the mineralogy of the stringers is strikingly similar although a considerable time interval may have elapsed between the first and later stages. The coarse-grained cross-cutting dikes formed near the end of the metamorphism and consequently suffered little deformation. The first impregnations suffered intense deformation culminating in the entire recrystallization of quartz and plagioclase. The later types show only relatively minor stress effects such as anomalous extinction of the mineral grains, bending of the albite twin lamellae and crushing about the borders of the coarse-grained constituents. Mineralogically the chief difference in the later phases is the increased amount of orthoclase and the formation of microcline and considerable pyrite.

A characteristic feature of these stringers is the presence of symplectite, a peculiar vermicular intergrowth of plagioclase and orthoclase. The orthoclase occurs in irregular worm-like forms in the plagioclase, the texture usually confined to the medium sized

[1] Sederholm, H. On Migmatites and Associated Pre-Cambrian Rocks of Southwestern Finland. *Helsingfors*, 1923.

or large grains. The microscopic evidence indicates the texture is due to replacement of the plagioclase by orthoclase and gradations may be traced from plagioclase grains almost free from orthoclase, to orthoclase grains containing corroded islands of andesine. The andesine remnants contain vermicular interpenetrations of orthoclase optically continuous with the outer part. A few grains of plagioclase show blebs of orthoclase arranged along the cleavage planes.

THE HIDDENITE PEGMATITE STAGE. The hiddenite pegmatites mainly parallel the gneissose structure of the country rock and occur in lens-like or dike-like bodies, the latter continuous for some distance. The average width of the bodies is around three inches. The texture of these bodies varies from fine to relatively coarse, the larger crystals generally surrounded by an enclosing hull of sugary, grained material. These bodies have sharp contacts towards the country rock and along the walls is usually a considerable concentration of biotite. Wall-rock alteration is on the whole lacking, except for a few large grains of apatite near the contacts with the country rock which may be due to metasomatic processes.

Microscopically the coarse-grained feldspar resolves into microcline with its characteristic grid structure surrounded on its borders by a fine-grained mosaic of microcline and quartz. The larger grains of microcline have numerous inclusions of small oval-shaped grains of plagioclase oriented with their longest axes in a definite parallel direction. The intergrowth may be termed a "Guttate Perthite," similar to that described by Barth[2] in the Adirondack feldspars. The average size of the blebs is .008 millimeters in width and .060 millimeters in length, the larger blebs confined to the border of the grains and decreasing in size towards the centre but increasing in numbers. The plane of the long axis of the blebs appears to be in the azimuth of the B-vibration direction of the microcline and the blebs are thus probably localized along the intersection of the (010) and (001) cleavages. The smaller surrounding grains of microcline are entirely free from these inclusions. The large grains of microcline show strain shadows.

Quartz is present in a moderate amount in the pegmatites, in large grains and minute fragments about the borders of the larger grains with microcline. The large grains of quartz show strain

[2] Barth, Tom F. W. Mineralogy of the Adirondack Feldspars. *Am. Mineral.*, Vol. **15**, 1930, p. 130.

effects while the smaller appear to be unstressed. The quartz does not tend to develop crystallographic boundaries.

Andesine ($Ab_{60}An_{40}$) is present in subordinate amounts, in large and small grains. The large grains especially show decided strain shadows. The grain boundaries are rounded and suggest corrosion by the other constituents.

Brownish red garnet, of the variety spessartite, occurs in slightly distorted rhombic dodecahedrons. Their average cross section is about one inch. Poikilitically included in the garnets are a variety of minerals, quartz, green and blue tourmaline, dumortierite, microcline, sillimanite, biotite with included zircons and chlorite, all in small quantity. The dumortierite occurs in a bundle of finely fibrous needles with its diagnostic pleochroism—cobalt blue along the length of the fibers. The biotite inclusions are partly altered to chlorite.

Hiddenite occurs in these pegmatites in moderate amounts embedded in microcline or quartz. It has an olive green color and is prismatic in habit with excellent cleavages at about 90°. The crystals reach a length of about one-quarter inch. In thin section the hiddenite appears partly altered along its cleavages to chlorite and replaced around its borders by calcite. Small elongated crystals of black rutile are often included in the hiddenite.

Blue, green and black tourmaline occur, the blue and light green found only in small amounts in thin section. The blue tourmaline is present as inclusions in garnet and as small rounded grains in quartz. The light green variety has a similar occurrence. Well-shaped crystals of black tourmaline are present in hand specimens; the prisms are striated and truncated by steep rhombohedral faces. The refractive indices are much lower than those of schorlite ($\omega = 1.652$). It is probably a magnesium tourmaline with very little iron. The black tourmaline appears to cut across crystals of hiddenite.

Biotite occurs as concentrations along the walls of the pegmatite; as inclusions in garnet, and as flakes in the pegmatite. Rounded zircon grains are often present in the flakes resembling those in the biotite found in the country rock. Thus the indications are that all the biotite associated with the pegmatites has been derived from the country rock and exists as unreplaced residuals of the latter.

Some pyrite and calcite are present in the pegmatite, appearing to fill either interstitial spaces or to replace some of the pegmatite minerals. Both may thus belong to the later cavity mineralization when they were deposited abundantly.

HIDDENITE "CAVITIES." From the mineralogical point of view the greatest interest in this deposit surrounds the "cavities" or pockets which were found in great number. These vary in size from minute druses to openings several feet in diameter. They vary widely in mineral contents but most of them contain either hiddenite or beryl or both. They are generally exceedingly sharply defined against the enclosing gneiss, occupying shear planes transverse to the foliation, the contained minerals being implanted directly upon the walls. In fact these cavities remind one very strongly of the Alpine clefts in form, structure and the habit and nature of the contained minerals. Some are however less sharply delineated and are surrounded by zones of bleached or altered gneiss; here it is quite clear that solutions have been active and these cavities may well be the result of destructive attack on parts of earlier formed pegmatites. If so, there was later a renewal of deposition in them for they are lined with free-standing crystals of a variety of minerals.

It is these cavities that have yielded all the most interesting crystallized minerals for which the deposit is well known. In the following pages these minerals will be described as found in our specimens, with only casual attention to earlier descriptions.

Quartz. The most abundant mineral in these cavities is quartz, which very often forms the first coating of the walls, other minerals being implanted upon it. The form may be simple or of the utmost complexity as shown in the figures in *Dana's System*, page 185, which are derived from the descriptions of Von Rath (11). In the Colburn collection are several hundred small crystals obtained from the recent working. The vast majority are quite simple in form. A number however show trapezohedral forms and several show rounded etch faces close to the basal pinacoid in position as shown in figures by Hidden (4) and Miers (13). These have not been studied in detail. In the crystals in our possession there are no unusual forms but a few show delicate hair-fine inclusions of rutile. It was from one of these cavities of unusual size, found at the beginning of the mining here, that Hidden found the finest crystals of emerald, and hundreds of quartz crystals of great beauty with large liquid inclusions. The largest crystal weighed about 25 pounds. The largest "water-bubble" was some $2\frac{1}{2}$ inches in length. Hidden (2) gives a vivid account of the extraction of these crystals from the red clay which quite filled the pocket; and of the total destruction of the whole find while still exposed near the mine when the chill of a frosty night caused them to explode to a mass of shapeless fragments by the expansion of the frozen liquid inclusions. The same writer (14) recorded the interesting observations that the complexity of the form was greater when the number of crystals in the cavity was small and that the prevailing form when hiddenite was present was the steep rhombohedron $(30\bar{3}1)$.

Amethyst. In a few narrow crevices the quartz shows two or more generations. The earlier crystals are clear and colorless, of a slender habit. Many of them have been etched about the summits to produce a flattened surface upon which are implanted a later

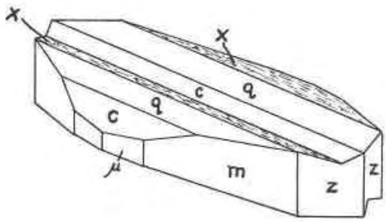

Fig. 1. Adularia, Hiddenite, N. C.

parallel growth of faintly amethystine quartz. As this quartz has a stouter habit the groups suggest a "scepter-quartz" on a very small scale. Occasionally the second generation shows the same etching faces and a third generation of striated crystals deposited upon their tips giving a curious steeple-shaped summit to the whole.

Feldspars. Albite was found as distinct crystals and in crystalline masses surrounding some vugs. The crystals are clear or milky, twinned on the albite law, and show the common forms and habit of this mineral.

Orthoclase in the habit of adularia was found in isolated crystals and twin groups attached to quartz in a few pockets.

The crystals are unusual both in habit and in the presence of some of the rarer forms reported on adularia. The measurements established the presence of the following forms: $c(001)$, $b(010)$, $a(100)$. $\zeta(210)$, $\mu(310)$, $m(110)$, $z(130)$, $\Delta(501)$, $q(\bar{2}03)$, $x(\bar{1}01)$, $n(021)$, $e(111)$ and $o(\bar{1}11)$. Of these forms a, ζ, μ, Δ, and e are extremely rare on feldspars even of the adularia variety. Figure 1.

shows the curious tabular habit of most of the simple crystals with deeply groved surface; these tables are often attached by an edge. The second figure shows a less typical combination for the locality. On most crystals, faces like *e* and *n* are represented only by rounded surfaces of solution in striking contrast to which is the brilliancy of the prism zone faces.

The determination of the uncommon forms is based on the following measurements:

		Measured		Calculated		No. of Faces
		φ	ρ	φ	ρ	
ζ	210	73° 49′	90° 00′	73° 31′	90° 00′	1
μ	310	78 32	90 00	78 44	90 00	5
Δ	501	90 00	79 45	90 00	79 06	2
e	111	68 39	56 50	68 44	56 52	1

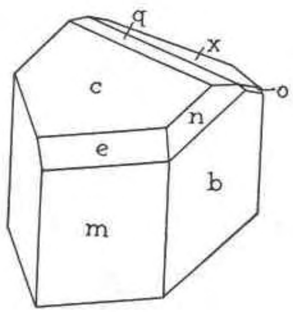

Fig. 2. Adularia.

Most of the adularia crystals are, however, complexly twinned. The twinning is commonly on the Baveno law and is repeated, as is so commonly the case with the Swiss adularia, to develop fourlings; the axis of elongation of the group is the *a* axis and the group is a square prism bounded by four faces of the basal pinacoid. The rounding of the terminal faces of these twin groups was so pronounced that it proved impossible to measure them but their nature was easily established. Regular fourlings of the type described were not so common however as pairs or triplets, all twinned on the Baveno law and with every sort of irregularity of mutual development. The glassy lustre of these crystals, the brilliance of the prism-zone faces when visible, and the variety of habit united to give them an appearance quite unlike any feldspar known to the writers.

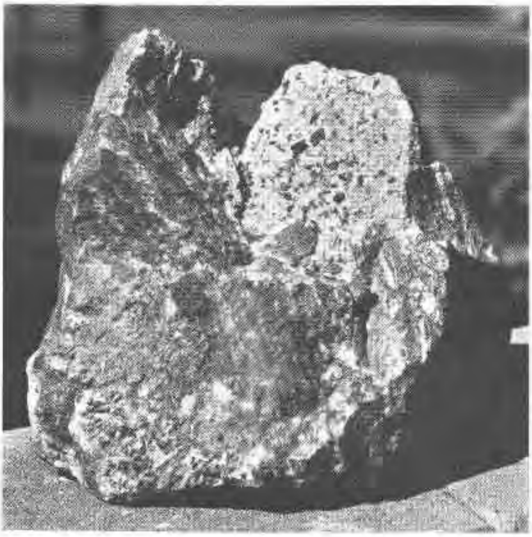

PLATE I. Hiddenite, North Carolina.

PLATE II. Hiddenite, North Carolina.

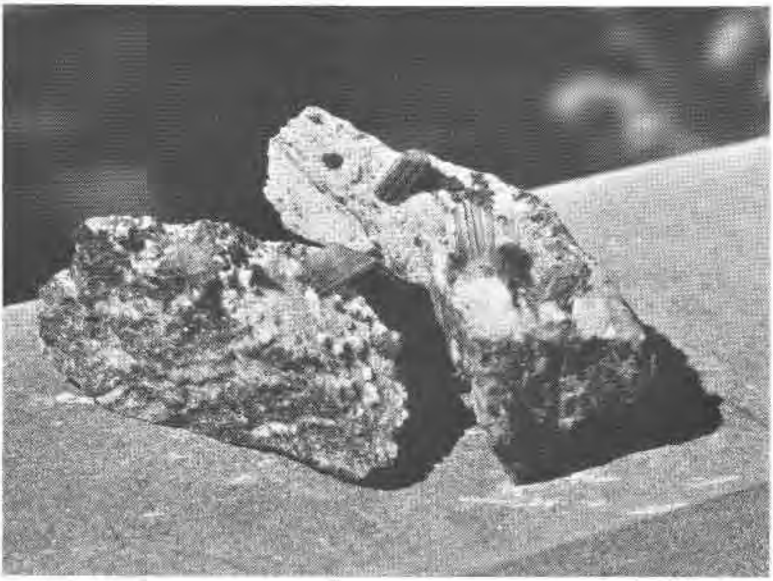

PLATE III. Hiddenite. North Carolina.

Hiddenite. In the cavities hiddenite occurs in a great variety of habits. The commonest type, characteristic of all the earlier mined gem crystals is prismatic, with a square or more or less octagonal cross section. Such crystals are deeply etched on every surface, the terminal faces especially being reduced to uneven curved surfaces. Such crystals are illustrated in *Dana's System*, p. 367, taken from Hidden (8). The colored illustration on Plate V of Kunz *Gems of North America* is also of this type. This crystal, now in the Collection of Harvard University, is, like many of the gem quality, twinned on the orthopinacoid. In Mr. Colburn's operation of the quarry, but one cavity was found containing gem material. In it were some 20 good-sized crystals of good green color but not for the most part clear enough for cutting. In addition were many slivers and last remnants of solution which

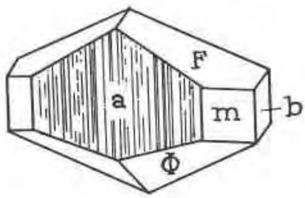

Fig. 3. Hiddenite, Hiddenite, N. C.

take the form of slender spicules or needles. Most of the cavities opened in 1926 where hiddenite occurred were sharply angular or pipe-like with attached crystals standing directly on the wall rock. The photographs reproduced herewith in Plates I-III show such cavities and their hiddenite crystals. These are flattened plates parallel to the orthopinacoid (100), are not twinned for the most part, and are dark green in color. They are always coated with gray nontronite which readily scales off showing sometimes very rough, sometimes smooth but dull faces beneath.

A modification of this habit is shown in figure 3. The prism planes are much reduced, pyramids and clinodome making the terminations. The greatest dimension of such crystals is in the direction of the *b* axis. A marked feature of both these types is the deeply grooved striation of the orthopinacoid due to oscillatory combination with the prism. This shows particularly well in the photograph, Plate III.

In a few cavities were found several small hiddenites of clear green color whose general proportions are shown in figure 4. In these the prism zone was quite unattacked by etching agents, the faces being brilliantly reflecting and not striated. Most of the terminal planes, however, were dull but by attaching glass plates with

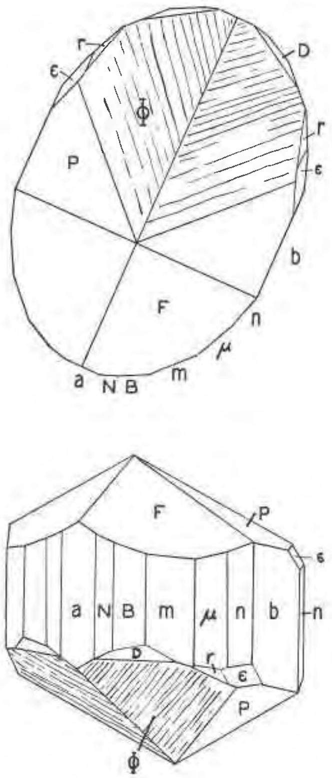

Fig. 4. Hiddenite, North Carolina.

glycerine, measurements were obtained sufficiently accurate to permit their identification. The form ϕ was deeply striated in direction of the intersection with p. The forms determined, most of them shown in the drawing, were as follows:

$a(100)$	$\mu(120)$	$\phi(\bar{3}12)$
$b(010)$	$n(130)$	$D(\bar{4}21)$
$N(310)$	$z(150)$	$r(\bar{2}21)$
$B(210)$	$F(011)$	$\epsilon(\bar{2}41)$
$m(110)$	$p(\bar{1}11)$	$t(\bar{4}81)$

Of these forms, the two prisms $N(310)$ and $B(210)$ are new to spodumene. They were found repeatedly and gave faultless signals on the goniometer.

Measured ϕ	Calculated ϕ
(310) 70° 38′ Av. of 6	70° 37′
(210) 62 08 Av. of 3	62 10

It is worthy of remark that the crystal constants of spodumene rest upon most unsatisfactory observations. The axial ratio of

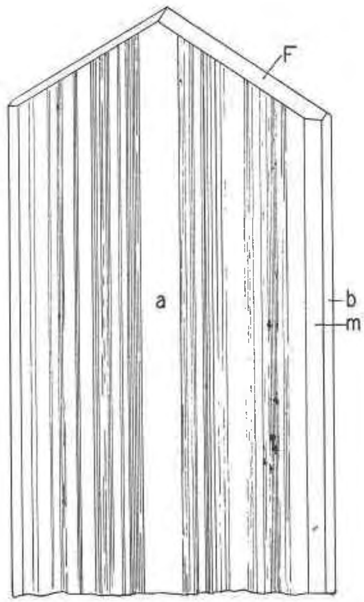

Fig. 5. Hiddenite, North Carolina.

Dana's System is based on contact measurements; that used in Goldschmidt, Winkletabellen and Atlas, is taken from Vom Rath (10) who had to attach glass plates to crystal faces in order to secure readings. We examined hundreds of crystals of hiddenite in this research in the hope of finding any with satisfactory terminal faces but in no case successfully. Such readings as were obtained agreed fairly well with the angular values based on Vom Rath's axes.

Another extreme type of habit is shown in figure 5. which is a thin plate parallel to the orthopinacoid and twinned on that plane so that it presents perfect orthorhombic symmetry.

Holmquisitite. This rare lithium-amphibole was first described by Osann[3] from the Island of Utö in Sweden. It is found in a metamorphic schist near the contact of a lithium pegmatite. In the Hiddenite Mine it was found in and around a single cavity, notable for its considerable content of gem hiddenite. In the gneiss it is visible as a bluish band amidst the feldspathic areas and in thin section appears as ragged grains and fibres replacing the original quartz and feldspar. In one fragment of the cavity lining, the holmquistite was found in fairly stout prisms of measureable size and quality. They are bounded by the prism (110) and orthopinacoid (100). The prism angle is 54°39′, the result of two independant and satisfactory readings. The prism angle measured by Osann on Utö holmquistite is given as 55°48′. This was probably made on a cleavage fragment and the divergence of the two values may be due to poor readings.

The optical properties as determined by Goranson are as follows: $\alpha = 1.625$; $\beta = 1.645$; $\gamma = 1.654$.

Pleochroism, X = light yellow; Y = violet; Z = purplish violet. $Z \wedge c$ = parallel or almost so. Dispersion weak. $\rho > v$. $2V = 51°$ (determined on the Fedorow stage).

Material for analysis was secured by crushing some of the bands richest in holmquistite and concentrating the mineral by magnet and heavy solution. It was believed that the final sample obtained still contained about 5 per cent of dark inclusions, probably magnetite. The specific gravity of the powder is 3.111, determined by the pycnometer. The following analysis (2) was made by Earl V. Shannon in the laboratory of the U. S. National Museum. With it for comparison is that of Osann (1).

Holmquistite from the North Carolina locality is composed largely of the lithia member of the amphibole group[4] and a minor amount of a deficient silica member commonly found in basic rocks.[5] The formula deduced from the analysis is:

[3] Osann, A. Ueber Holmquistit, einen Lithionglaucophan von der Insel Utö, *Sitzb. der Heidelberger Akad. Wiss.*, **1913**, Abh. 23, 1–16.

[4] This member is the lithia equivalent of the glaucophane member proposed by W. Kunitz, *Neues Jahrb.*, *Beil. Bd.* **LX**, *Abt. A*, 1929, S. 171–250.

[5] Priv. communication. H. Berman, A study of the amphiboles not yet completed indicates the presence of this type of amphibole in the more basic rocks.

$3Li_2(Mg, Fe)_3Al_2Si_8O_{22}(OH)_2$
$1Ca_2(Mg, Fe)_3Al_2(Al_2Si_6)O_{22}(OH)_2$
with Mg:Fe=2:1 and Li:Na=4:1.

In general the interpretation here presented fits the analysis fairly well. The low value for the calculated water may be ac-

ANALYSES OF HOLMQUISITITE

	1 Per cent	2 Per cent	3 Mol. Ratios		4 Found	5 Calculated	6 Per cent	
SiO_2	60.45	55.48	.9201	Si	7.4	7.5	56.13	SiO_2
TiO_2	trace	.64	.0080					
Al_2O_3	7.70	14.64	.1432					
				Al	2.5	2.5	15.86	Al_2O_3
Fe_2O_3	9.68	1.80	.0113					
FeO	4.38	10.36	.1442					
MnO	—	trace		Mg	3.0	3.0	18.92	{MgO, FeO}
MgO	12.12	9.40	.2331					
CaO	—	1.32	.0235	Ca	0.2	0.5	3.48	CaO
Na_2O	1.12	.66	.0106}	Na				
K_2O	0.54	.74	.0079}		0.3}	1.5	3.38	{Na_2O, Li_2O}
Li_2O	2.13	2.40	.0803	Li	1.3}			
H_2O-	0.09}							
H_2O+	2.28}	3.16*	.1754	H	2.8	2.0	2.23	H_2O
F	0.43	trace						
Sum	100.92	100.60					100.00	
less O=F	0.18							
	100.74							

1. Analysis of Holmquistite from Utö, Sweden. Osann, analyst.
2. Analysis of Holmquistite from North Carolina. E. V. Shannon, analyst.
3. Molecular ratios of Column 2.
4. The number of cations present for 24 oxygen atoms. For method of computation see H. Berman, *Am. Min.*, 14, 11, 1929, p. 389.
5. Calculated atomic composition from formula:

$$Ca_2(Mg,Fe)_3\ Al_2(Al_2Si_6)O_{22}(OH)_2 \cdot 3Li_2(Mg,Fe)_3Al_2Si_8O_{22}(OH)_2.$$

6. Percentage composition calculated from column 5.

* The sample was insufficient to make a direct determination of water so that this constitutent had to be taken by loss on ignition corrected for oxidation of ferrous iron. The fluorine likewise could not be determined, but judged from the qualitative test it is not present in important amount. E. V. Shannon.

counted for by the fact that insufficient material for a direct determination was not available. (See note following analysis).

The analysis of holmquistite from Utö, treated in the same manner as the North Carolina analysis yielded the formula $Li_2Mg_3Al_2Si_8O_{22}(OH, F)_2$ which is the same as the North Carolina formula with no deficient silica member.

Beryl. This is, next to quartz, the most widespread mineral of the North Carolina pegmatites. It is generally pale blue-green or blue but at Hiddenite some of the crystals found were so deep a green as to be properly termed emerald. Here were found, very early in the working of the mine the two crystals now in the American Museum of Natural History which are well illustrated in Kunz, *Gems of North America.* The larger was $8\frac{1}{2}$ inches long and slender. The green coloring is confined to a deeply pigmented superficial layer. Like most of the larger crystals of beryl found in the region, these are of simple prismatic form with basal termination. Smaller crystals are exceedingly complex. Hidden and Washington (14) figured such a one and our figure 6 shows nearly the same combination but more complex, drawn with the actual development of the numerous faces. The forms shown are: $c(0001)$, $m(10\bar{1}0)$, $a(11\bar{2}0)$, $p(10\bar{1}1)$, $n(20\bar{2}1)$, $d(33\bar{6}4)$, $s(11\bar{2}1)$, $\nu(51\bar{6}1)$, $n(31\bar{4}1)$, $v(21\bar{3}1)$. This crystal was attached to the wall of a tiny pocket and is about $\frac{1}{2}$ inch in length. It is pale green in color. Other crystals in our collection show deep solution figures especially on the prism planes, the lenticular pits horizontally placed and so closely spaced as to entirely destroy the original surface. Other crystals show solution cracks filled with silver-white plates of muscovite. Part of the surface of the crystals is covered by small plates of muscovite and a fine greyish chloritic mineral. Calcite, quartz and pyrite crystals have grown on the beryl crystals. A few crystals altered entirely to fine-grained mica are in the collection.

Tourmaline. In the cavities tourmaline is found occasionally in black crystals, brown in thin section. There is no indication that lithium entered into their composition to any extent. They are slender attached needles with simple rhombohedral terminations at the free end.

Garnet. Garnet is rare in the cavities. It is a honey-yellow spessartite variety in small, poorly developed crystals.

Muscovite. Muscovite is generally present, often abundant and

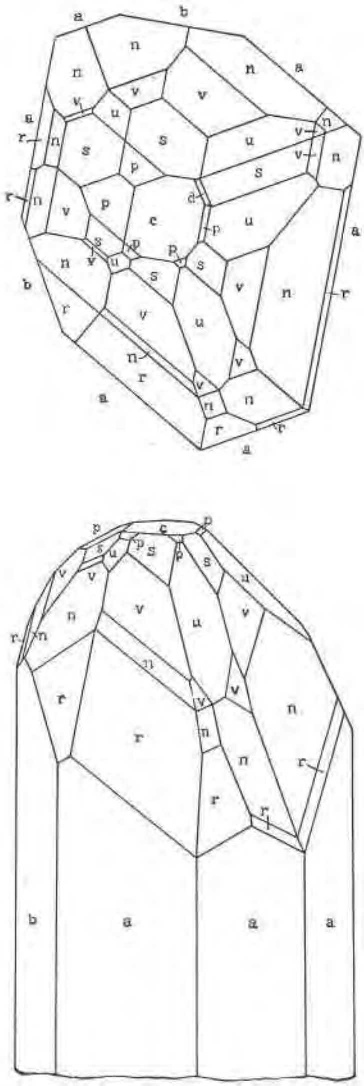

Fig. 6. Beryl, Hiddenite, N. C.

well crystallized. The crystals are often attached edgewise to the cavity and reach an inch or more in diameter. The commonest variety is a silvery mica with dusty bronzy exterior. The crystals are very thin basal plates with sharp hexagonal outline. Clarke (16) has analyzed this muscovite and finds it a normal one. In one cavity the muscovite is light green in color and bears on its surface tiny crystals of rutile, apatite, and monazite.

Nontronite. Under this name may be described the coatings and alteration products which are often found in the cavities especially associated with hiddenite. Crystals of this substance rarely failed to show at least part of their surface coated with a dark green film or crust, beneath which the faces were always rough or etched. It may be removed with more or less ease, sometimes scaling off in millimeter thick crusts but is clearly a product of alteration. In some cases the whole crystal has been altered and complete pseudomorphs are found. This material has been called hisingerite in previous descriptions as by Clarke (16). Optically it agrees best with nontronite. No special study was made by us of this material.

Rutile. This is a mineral of widespread occurrence in the Hiddenite Mine pockets and is remarkable for the brilliance and beauty of its crystals as well as for an extraordinary range of habit. The majority of the crystals are slender needles, deeply furrowed in the prism zone, with simple terminations. These are untwinned, reach an inch or more in length, and are always attached to the cavity walls or to earlier minerals. Twin groups of an infinite variety are also to be seen, twinned on both laws, twin plane *e*(101) or *v*(301), both sometimes present in the same group. Vom Rath (10) figures a simple contact twin on *v*. The complexity of form is notable and the abundance of crystals with large development of the base is unusual. In the same hand specimen may be seen crystals of slender habit and others with prisms reduced to mere lines so the crystals are pyramidal; others are flattened parallel to a pair of prism faces so that they have exactly the appearance of thin brookite crystals. Again the network of twinned needles takes on the sagenite form. Hair-fine needles are included in quartz not rarely. The forms observed by us in a very incomplete study of these interesting crystals were as follows: Known forms: *c*(001), *a*(100), *m*(110), *x*(410), *h*(210), *r*(320), *e*(101), *s*(111), *E*(117), α(227), β(112), *Z*(321), and *t*(313), and the new forms *D*(118), *F*(115), *H*(229), and *L*(131)

The three forms *D*, *F*, and *H* were all found on the twin crystal shown in figure 7. It will be noted that these new forms are part of a highly differentiated zone between *c* and *s* which contains also *F*, α, and β. Compare with this figure that of Hidden and Wash-

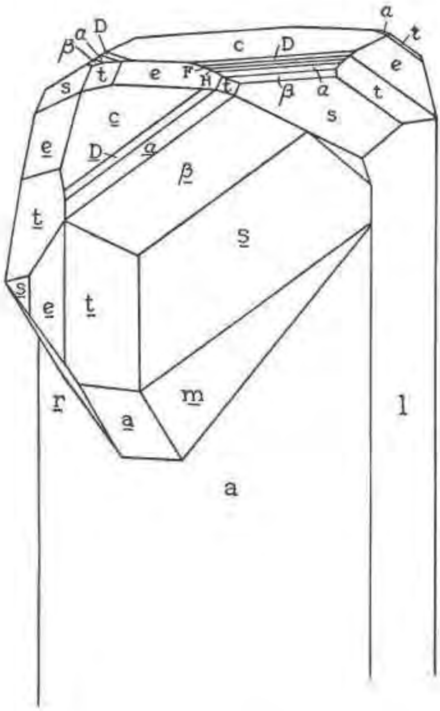

FIG. 7. Rutile, twinned on (031). Hiddenite, N. C.

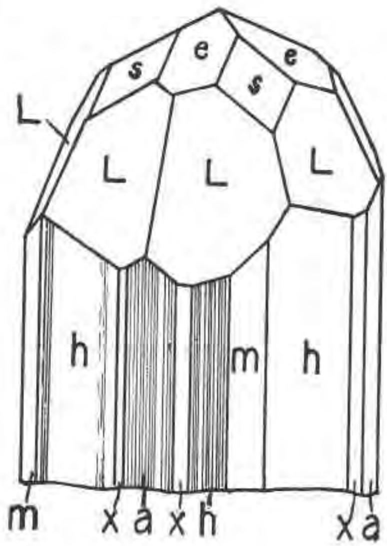

FIG. 8. Rutile, Hiddenite, N. C.

ington (14) reproduced in *Dana's System*, p. 237. The form *L* was found on every crystal measured and is dominant on the type shown in figure 8, equant with *z* in figure 9.

	Calculated		Measured		No. of faces
	ϕ	ρ	ϕ	ρ	
D(118)	45°00′	6°30′	45°00′	6°38′	4
F(115)	45 00	10 19	45 00	10 16	2
H(229)	45 00	11 27	45 00	11 25	2
L(311)	18 26	63 51	18 26	63 51	7

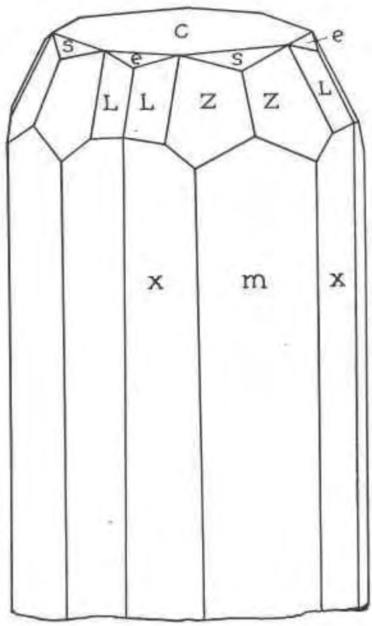

FIG. 9. Rutile, Hiddenite, N. C.

Monazite. Monazite is not rare in North Carolina pegmatites and has been frequently described. None of the published figures, however, actually refer to specimens from the Hiddenite Mine. It was found in our specimens in tiny, clear, honey-yellow crystals embedded in albite or calcite, or attached to cavity walls. The forms identified are shown in figure 10: *a*(100), *b*(010), *c*(001), *e*(011), *ω*(101), *n*(111), *v*($\bar{1}$11), *s*(121), and *o*($\bar{1}$21). The habit is either as shown in figure 10 or prismatic parallel to the edge of the pyramid ($\bar{1}$11).

Apatite. Apatite is a very minor constituent of these cavities. Crystals of dull greenish white color and simple form were observed on one cavity wall. Hidden and Washington (14) published a figure reproduced in *Dana's System*, pp. 763 and 764, of a very complex apatite crystal. In one of our vug specimens minute water clear crystals were seen implanted on green muscovite which proved when measured to be almost identical with the published figure.

Pyrite. Pyrite in brilliant cubeoctahedrons is widely distributed in the cavities. It is seen implanted on rutile, quartz, beryl, hiddenite and muscovite. It offers no points of particular interest. To some extent, it has invaded the wall rock in granular masses.

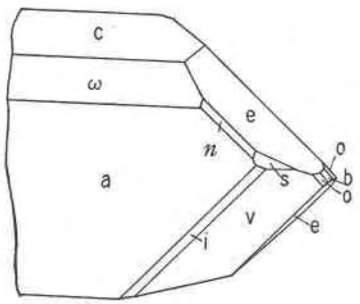

FIG. 10. Monazite, Hiddenite, N. C.

Arsenopyrite. Arsenopyrite is a rare constituent, first found by dissolving from a few cavities the calcite filling. The minute, perfect, and very brilliant crystals, having been completely embedded in calcite, are doubly terminated. They show the complex development of figure 11 the forms present being: *m*(110), *e*(101), *ρ*(015), *q*(013), *s*(012), *l*(011), *v*(212), *o*(112), *A*(532) and *B*(514). It is interesting to note that the last three forms *o*, *A*, and *B* have also been found on arsenopyrite formed in calcite at Franklin, N. J. They were first reported by Palache[6] but not figured. The present figure might perfectly well serve for the Franklin crystals.

Carbonates. Three types of carbonate are present, calcite, ankerite, and siderite. Of the three, calcite is the most abundant and may be divided in age relationship into two types, optically into two, and crystallographically into three. The earliest formed cal-

[6] Palache, Charles. Contribution to the Mineralogy of Franklin Furnace, N. J., *Am. Jour. Sci.*, **29**, 1910, 177.

cite is in flattened rhomb-shaped crystals grouped in fan-like aggregates. It has a dull white color and its indices are higher than ordinary calcite ($\omega=1.667$). It reacts as normal calcite with cold hydrochloric acid. The later calcite forms in two crystal types which agree optically ($\omega=1.658$), one in hexagonal tablet-like individuals showing only the forms *c*(0001) and *m*(10$\bar{1}$0); the third type is in normal unit rhombohedrons. The ankerite ($\omega=$

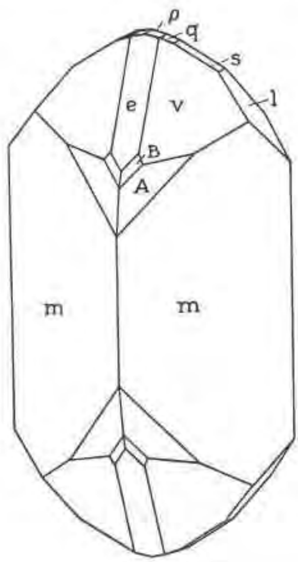

FIG. 11. Arsenopyrite, Hiddenite, N. C.

1.703) is in iron-oxide-coated rhombohedral crystals associated with the flat rhomb calcite, the latter usually growing over the ankerite crystals. Dolomite, early reported from the hiddenite cavities, is probably ankerite. A crystal of clean-cut rhombohedral form showing base and twin striae parallel to (0001) and to (01$\bar{1}$2) was tested and gave an index ($\omega=1.702$) too high for dolomite.

Siderite. Siderite was found on one specimen in the form of yellow, rough rhombohedrons and crusts of reddish color. Both were late formations in cavities and were identified by much higher index of refraction.

Aragonite. White needles of aragonite were found in one or two cavities. The crystals could not be measured.

Genesis

From a study of the hand specimens a tentative genetic history is proposed.

1. Metamorphism of the argillaceous sandstone.

2. Injection of the first migmatitic lit-par-lit stringers.

3. Renewed metamorphism followed by folding and recrystallization of the stringers.

4. Shearing of the country rock with the formation of transverse fractures.

5. Injection of the later stages of lit-par-lit stringers, followed by some movement.

6. Formation of the pegmatitic stringers along the foliation planes of the rock.

7. Slight shearing causing the separation of former incipient cross fractures.

8. Formation of the vug and cavity minerals.

The paragenetic sequence in the pegmatites is not definite. A small quantity of andesine followed by microcline and quartz was first to crystallize. Garnet, hiddenite, and tourmaline then followed with a later formation of quartz in vein-like bodies. The entire pegmatite was then subjected to slight movement resulting in granulation about the borders of the larger grains, especially microcline and quartz. The garnet was slightly distorted, the hiddenite and tourmaline show very little strain effects. The remaining pegmatite minerals are present in inconsequential amounts and their sequence is not evident. The formation of the vugs in the pegmatites then occurred through some change in the parent source; solution occurring instead of deposition. The highly irregular shape of the cavities supports this mode of origin of the cavities. Pyrite and calcite were probably introduced during the cavity stages.

Following the pegmatites, the mineralization of the vugs and openings took place. A more definite sequence was ascertained as here the minerals often grow on one another. The following sequence appeared universal in the cavities: quartz, hiddenite and beryl, mica, albite, siderite and flat rhomb calcite, quartz, monazite and rutile, adularia, pyrite, calcite, followed by corrosion of practically all the minerals and some oxidation of pyrite to limonite.

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