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CLASSIC MINERAL OCCURRENCES: I. GEOLOGY AND MINERALOGY OF THE RUTHERFORD PEGMATITES, AMELIA, VIRGINIA

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ABSTRACT

The No. 1 and No. 2 Rutherford pegmatites near Amelia, Virginia are widely known for their mineral and gemstone specimens produced incidental to muscovite mining. While major mining took place over 50 years ago, the most recent work in 1957–60 cleared and extended older workings and produced some commercial mica as well as numerous mineral and gemstone specimens. Re-exposure of long-buried portions of both bodies enabled development of new mineralogical and geological information. Both pegmatites consist largely of sodic plagioclase with lesser amounts of microcline-perthite, muscovite, quartz, and other minerals, some of them rare. The following mineral assemblages form distinct zonal units: (a) fine-grained aplitic *border* consisting of plagioclase and garnet, (b) coarse-grained blocky albite-quartz-muscovite *wall zone*, (c) medium- to coarse-grained perthite-quartz-muscovite *outer intermediate zone*, (d) medium- to coarse-grained blocky albite-muscovite-rare mineral *second intermediate zone*, (e) medium-grained massive bladed albite *middle intermediate zone*, (f) medium-grained euhedral cleavelandite *inner intermediate zone*, and, (g) coarse-grained amazonite-quartz-muscovite *core*. These units are arranged symmetrically about a central system of vugs lined by euhedral cleavelandite.

These species were found during the 1957–60 operations: albite, allanite, apatite, bavenite, beryl, biotite, cassiterite, chlorite, columbite, fluorite, galena, herderite, loellingite, manganotantalite, microcline, microlite, monazite, muscovite, pyrite, pyrrhotite, quartz, spessartine, sphene, tourmaline, and zircon. Of these, chlorite, herderite, loellingite, pyrrhotite, and sphene are new for this locality. Studies of the spessartine from the No. 2 pegmatite establish a direct correlation of color to the weight ratio (Fe, Ca)/Mn, with high (Fe, Ca) and low Mn in the dark brownish-red spessartines and vice versa for pale orange spessartines. Changes in composition yield a smooth progression of hues between the two extremes mentioned.

INTRODUCTION

The mineralogically complex Rutherford pegmatites have been described by Lemke *et al.* (1952), who also investigated their geologic setting. However, their examinations were necessarily restricted to fragmentary outcrops of the No. 1 body and to exposures of the No. 2 body to a depth of approximately 70 feet (21 m) beneath the ground surface. Both pegmatites were restudied by the present writer during the period 1958–60, when operations by the Piedmont Mining Company provided open-cut exposures in the No. 1 mine to a depth of about 40 feet (12 m) beneath the surface and in the No. 2 mine to a depth of about 115 feet (35m). From this study it is now possible to describe more fully the internal structure and mineralogy of the No. 2 pegmatite body and, to a lesser extent, that of the No. 1.

The excellent paper by Glass (1935) on the detailed mineralogy of these pegmatites is here supplemented by descriptions of several species new to the locality. Many of the species previously reported were verified by X-ray and optical studies wherever doubt existed as to their identity. Additional information on verified species is also included. Most specimens of this study were collected *in situ* from accessible mine workings. Primary attention is given here to the No. 2 pegmatite which was more actively mined and better exposed.

The Rutherford pegmatites lie within the Keener farm, about 1¼ miles (2 km) north of Amelia, Amelia County, Virginia (Fig. 1). Exploitation of both bodies for commercial mica began in 1873, and systematic mining was carried on intermittently until 1912, when the No. 2 mine was abandoned. Gem-grade amazonite was found in the No. 1 mine sometime prior to 1912, and was recovered from a drift in the central part of the body (J. J. Glass, *pers. comm.*) by the American Gem and Pearl Company of New York City until 1932. In May 1943, E. J. Tyler of Asheville, N. C., reopened the No. 2 mine for a short time to obtain mica. (Lemke *et al.*, 1952). The latest extensive mining was conducted by the Piedmont Mining Company of Amelia, Virginia, under the direction of Warren D. Baltzley of Amelia, beginning in 1957. Initially the old opencut workings of the No. 1 mine were bulldozed to clear rubble and overburden and to expose the collars of two earlier shafts. Work was then shifted to the No. 2 mine which was completely dewatered and largely mucked out. Apparent pinching-off of the pegmatite in the lowest accessible portions of the body discouraged further operations and work was again shifted to the No. 1 where further mucking out and rehabilitation continued until the summer of 1960 when all mining effort ceased.

Geologic Setting

The rock enclosing both pegmatite bodies is a gneiss, pale gray when fresh, that consists essentially of quartz, hornblende, biotite, and plagioclase. It is generally firm and hard except in a friable saprolitized layer, 10–20 feet (3–6 m) thick, that overlies the unaltered rock and merges gradually upward into topsoil. The boundary between fresh gneiss and saprolite is very sharp and approximately planar. Spheroidally-weathered masses of gneiss are absent, and the configuration of the border between saprolite and fresh gneiss suggests that weathering took place along the foliation and was abruptly arrested by resistant layers in the gneiss. The crater-like aspect of the No. 2 mine opencut, shown in profile in Figure 2, is due to slumping of the water-saturated saprolite above the unaltered gneiss; the top margin of unaltered gneiss is shown in Figure 3.

Foliation in the gneiss dips gently to moderately northwestward, but the rock is locally much contorted, especially in the northeastern end of the No. 2 opencut. Many veinlets of quartz-plagioclase-microcline occur in the gneiss; some are concordant with the foliation but most are cross-cutting. The gneiss bordering the pegmatite is largely unaltered where exposed in the upper portions of the opencut wall; here its contacts with the pegmatite are sharp and firmly joined. With depth, the gneiss becomes progressively richer in biotite until this mineral is predominant in a 15–30 cm thickness of rock immediately adjoining the pegmatite. At the

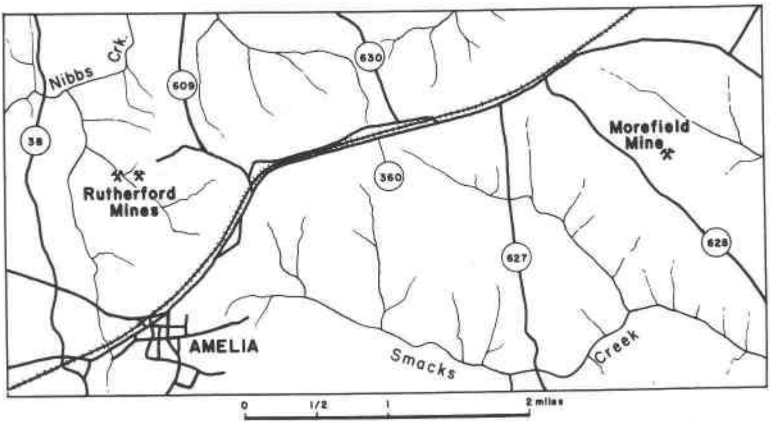

FIG. 1. Location of pegmatites near Amelia, Virginia.

115–foot level (35 m), the micaceous sheath is enriched in fine-grained muscovite near the contact and is cut by numerous fractures that extend into the pegmatite. The fracture surfaces are coated by films of euhedral pyrite. The mica-rich sheath extends from the 115-foot level (35 m) upward to about the 40 foot level along the hanging wall, where it forms slabby masses that are readily detached from the unaltered gneiss. Micaceous rock occurs adjacent to albitic portions of the pegmatite but is absent from parts of the contact zone adjacent to perthite-rich portions.

The Pegmatite Bodies

Both the No. 1 and No. 2 pegmatite bodies are approximately lenticular in shape, but configurations of the outcrops and evidence provided by diamond-drill cores of an earlier exploration by the U. S. Bureau of Mines in 1944 (Lemke *et al.*, 1952) suggest that the No. 1 is proportionately the more elongated. Both bodies strike approximately northeast and dip steeply to the southeast.

The No. 1 body is about 12 feet (3.6 m) thick adjacent to a single-compartment shaft uncovered during bulldozing of the outcrop and asso-

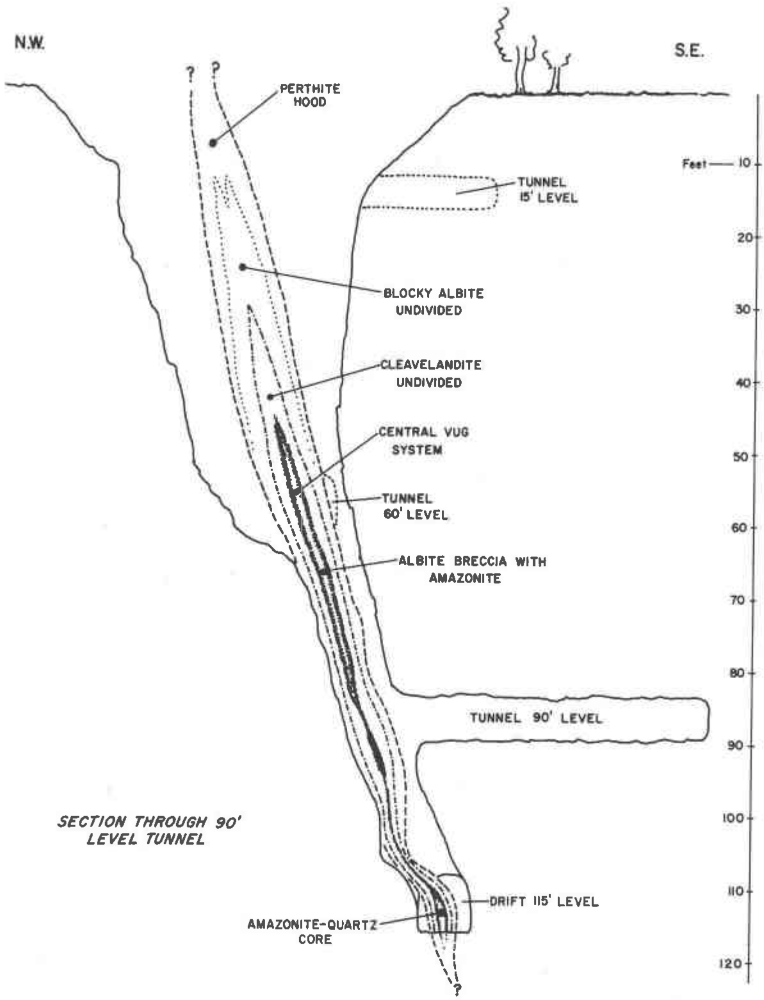

FIG. 2. Restored cross section, Rutherford No. 2 pegmatite.

ciated caved opencut workings. Next to the shaft is a remnant of coarse-grained perthite-muscovite-quartz pegmatite, but to the southwest, past the exposed opencut workings, the body tapers to about 2 feet (0.6 m) and consists of albite-quartz-muscovite pegmatite. Dump material suggests that deeper portions of the body yielded coarse-grained amazonite-quartz-cleavelandite and vuggy cleavelandite-quartz pegmatite. Except for the meager information contained in Lemke *et al.*, (1952), nothing more is known of the dimensions and extent of this body. The No. 2 body is emplaced along an irregular fracture in the gneiss, cross-cutting the foliation. It reaches a maximum thickness of about 15 feet (4.5 m) near the northeastern end of the opencut, where it divides as shown in Figure 3, tapering to an undetermined thickness beyond the limits of the opposite end of the opencut. Although much of the opencut floor is obscured, downward convergence of the walls suggests that the approximately parabaloid keel lies about 60 feet (18 m) below the arch and plunges to about 120 feet (36.5 m) at the northeastern end of the opencut. Available evidence strongly suggests that this body is largely mined out.

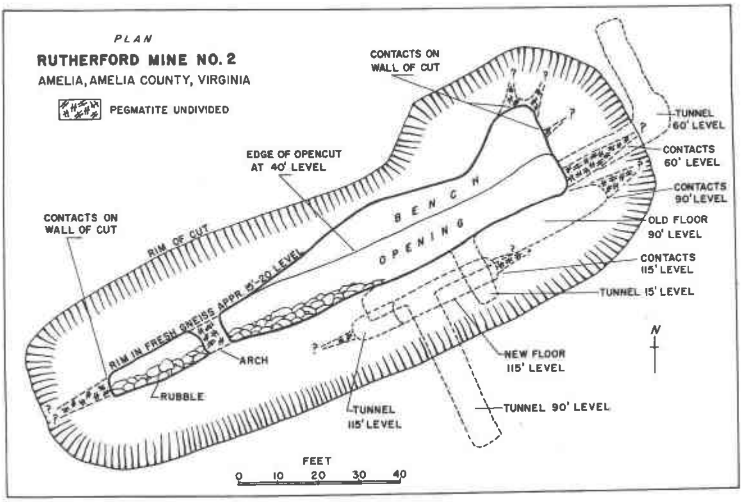

FIG. 3. Map of Rutherford No. 2 mine.

Gneiss and Pegmatite Brecciation

An interesting feature of the No. 2 body is the presence of gneiss brecciation in the northeast portion immediately above and below the 60-foot (18 m) tunnel. The disturbance of the gneiss has been attributed by Lemke *et al.*, (1952) to injection of the pegmatite along a discordant fracture, with the upper branches of pegmatite controlled to some extent by the layering of the gneiss. The xenoliths lend credence to this view, inasmuch as they appear to be slab-like sections that split away from the enclosing gneiss along foliation partings. One of the larger slabs, measuring about 4×2×1 ft. (1.2×0.6×0.3 m), apparently had fallen from the hanging wall and lodged in an approximately horizontal attitude in the pegmatite chamber. It was completely enclosed by albite, with some portions encrusted by euhedral cleavelandite and muscovite; only the interior of the slab was fresh, the periphery being altered to a depth of several inches, with the outermost portions consisting of a fine-grained mixture of albite, quartz, muscovite mica, and a dark green mineral of byssolitic character. Unfortunately, this dark green mineral was not immediately identified and specimens are now lacking to establish its identity. However, notes made during mining indicate that it may be an amphibole byssolite derived from the ferromagnesian minerals of the gneiss xenoliths. The abundance of quartz upon the dumps, discolored by what appears to be the same mineral, suggests that considerable pegmatite elsewhere in the body formerly contained xenoliths of gneiss.

Brecciation of the gneiss may have been due in part to faulting, as suggested by a difference of about 5 feet (1.5 m) in elevation between the opposite rims of unaltered gneiss along the margins of the opencut. Just below the gneiss breccia, at about the 75-foot (23 m) level, is another breccia consisting of slabs and angular fragments of albite with some amazonite, which fill central spaces in the pegmatite body and are jumbled together as if they were dump material. These slabs and blocks were originally attached to the walls of a large vug. The appearance of this portion of the body is shown in the sketch of Figure 4. The breccia fragments are cemented together along points of contact by shallow overgrowths of euhedral cleavelandite that clearly postdate the inward collapse of the vug walls. On the other hand, the intrusion of earlier units of pegmatite into brecciated gneiss, the thick overgrowths of cleavelandite upon gneiss xenoliths that are completely enclosed in albite, and the dissemination of the byssolitic material within quartz crystals indicate that the detachment of gneiss slabs took place considerably before the formation of euhedral cleavelandite. Thus the disturbances that led to the detachment of gneiss slabs and the detachment of albite vug-wall sections appear to have been unrelated events.

Pegmatite Zones

The No. 2 pegmatite body is distinctly and symmetrically zoned and is composed almost entirely of albite which is enveloped in its upper portions by a hood-like unit of microcline perthite. At the 115-foot (35 m) level occurs a small core unit composed of amazonite and quartz. The mineralogical units that appear to mark distinct genetic events in the development of this body are identified below according to the terminology of Cameron *et al.*, (1949).

Border—Aplite; fine-grained, in places faintly streaked with bands of very small red garnet crystals; present only in patches along the footwall.

Wall—Blocky, anhedral albite, quartz, and muscovite, with allanite and apatite; medium- to coarse-grained; present in a large patch on the footwall.

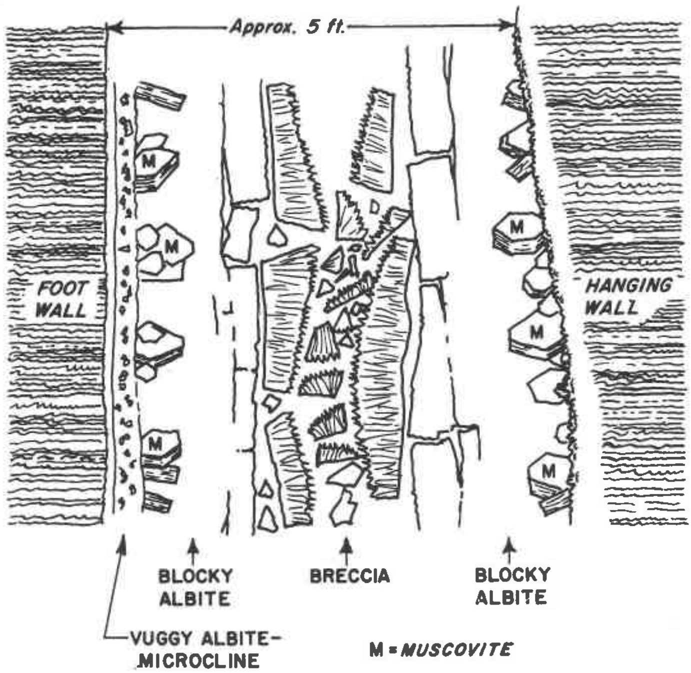

FIG. 4. Breccia filling in Rutherford No. 2 pegmatite, 75-ft (23 m) level.

Intermediate (*Outer*)—Perthite-quartz-muscovite hood, with allanite and fluorite; medium- to coarse-grained; concentrated in the upper part of the body with downward-tapering extensions along the walls.

Intermediate (*Second*)—Blocky anhedral albite and muscovite, with columbite, apatite, microlite, spessartine, monazite, and zircon; medium- to coarse- grained; well developed in many parts of the body.

Intermediate (*Middle*)—Massive, bladed albite with some microlite, muscovite, quartz, cassiterite, and spessartine; medium-grained; well developed in the northeastern part of the body.

Intermediate (*Inner*)—Euhedral cleavelandite, with muscovite, spessartine, microlite, cassiterite, and manganotantalite; medium-grained; well developed in the northeastern part of the body.

Core—Amazonite and quartz, with muscovite, spessartine, galena, and apatite; coarse-grained; well developed only at the 115-foot (35 m) level in the northeastern half of the opencut.

Hood unit. The hood or *outer intermediate unit* consists mainly of medium- to coarse-grained anhedral to euhedral microcline perthite, the smaller grains predominating in exposures near the northeastern extremity of the body and the coarser ones near the central area and extending to the arch shown in Figure 3. The perthite color ranges from very pale brown to pale brownish-pink. In the arch exposure, interstitial quartz is grayish and much fractured near the borders of the pegmatite body, but transparent and smoky in hue nearer the center of the arch. Masses of transparent dark brownish-red fluorite as much as 7 cm in diameter occur with the smoky quartz. Hard, dark brown muscovite crystals are enclosed by the hood unit, reaching diameters of 7–12 cm in the arch and as much as 25 cm in the remnants of the hood unit attached to the hanging wall slightly northeast of the arch. No rare element minerals were noted in the arch, although Lemke *et al.*, (1952) reported allanite, as flattened crystals to 15 cm in maximum length, from perthite-rich pegmatite in the northeastern end of the opencut.

Excellent exposures of the hood in the northeastern end of the opencut, in the arch, and in places along both walls of the opencut indicate that this unit formed a sheath over the upper portion of the albitic pegmatite units, tapering downward on both sides until it disappeared at about the 50-foot (15 m) level (Figure 2). The boundary between the perthite unit and the contiguous blocky albite unit is marked by a transition zone consisting of albite interstitial to perthite crystals in the upper portion of the pegmatite body, but consisting only of scattered perthite euhedrons in albite along the lower margins of the hood. Although the hood is now largely removed, it may have extended completely along the outcrop as suggested by the considerable quantity of perthite still to be found in the shallow dumps near the southeastern end of the arch.

Albitic units. Whereas the hood unit appears to be mineralogically homogeneous, the plagioclase-rich portions of the pegmatite body contain three distinct types of albite with substantially different mineral associates. The first type, which is closest to the walls, consists of medium- to coarse-grained albite, forming blocky anhedral crystals. On the basis of its associated minerals which are indicative of two formational events it is apportioned between the *wall unit* and the *second intermediate unit.* The next type of albite, a compact bladed cleavelandite, overlies the blocky albite along a boundary marked by an abrupt transition from blocky crystals to bladed crystals. This cleavelandite is assigned to the *middle intermediate unit.* The third type of albite, containing an abundance of small angular vugs, consists of loosely interlocked glassy cleavelandite crystals. This unit overlies the compact bladed cleavelandite and forms linings in the large central vugs of the pegmatite body. It is assigned to the *inner intermediate unit.*

Blocky albite units. The wall unit consists primarily of blocky crystals of white albite, dark brown muscovite crystals, prismatic crystals of allanite as much as 35 cm long, translucent, faintly pinkish-gray, and much fractured anhedral quartz, and blebs of white apatite 2.5 cm or less in diameter. The allanite crystals tend to lie normal to the walls; the smaller ones are relatively clean and completely enclosed in blocky albite, whereas the larger and longer ones generally are sheathed at their extremities by scaly masses of greenish muscovite. These two minerals, muscovite and allanite, are common to both the blocky albite pegmatite and the perthite pegmatite of the hood. While all of the muscovite in the perthite zone appears to be of the same type, the muscovite of the blocky albite pegmatite occurs in two types: the smaller books closest to the walls are the hard, brown kind, but the larger books, which are oriented with their basal faces approximately normal to the walls, extend considerably farther into the pegmatite body and are characterized by numerous cleavage splits and overgrowths of clear, pale green muscovite. Figure 4 shows a cross-section of the body at the 75-foot (23 m) level, where the muscovite books along the walls are similar to those occurring in the perthite hood at higher levels. The pegmatite here contains few accessory minerals.

The blocky albite pegmatite at the 95 foot (29 m) level, comprising the second intermediate unit, and sketched in Figure 5, contains split muscovite books with overgrowths of green muscovite and associated crystals of microlite, columbite, zircon, monazite, blebs of white apatite, and minutely-fractured spessartine crystals which crumble into sand-like fragments when released from their matrix. The larger muscovite books commonly contain lace-like interlaminations of small clear quartz crystals. Similar mineralization was found to extend to the lowest depths reached by the Piedmont Company.

While there are no apparent differences in the character of the blocky albites assigned to the wall and second intermediate zones, except one of increasing grain size toward the center of the body, there are striking differences in the mineralogical associates indicative of a pronounced change in the composition of the pegmatite residuum during formation of the blocky albite. In the earlier blocky albite occur hard, dark brown muscovite euhedrons and allanite euhedrons identical to those found in the hood perthite, but rare minerals are absent. On the other hand, the later blocky albite contains the rare species but not the allanite, except where crystals of the latter were so large that they remained exposed during the formation of later blocky albite as did many larger books of muscovite. Both the exposed allanite and muscovite crystals then received overgrowths of the green muscovite characteristic of the later blocky albite, the allanite becoming covered by scaly green muscovite and the dark brown muscovite developing outer zones of green muscovite.

The earlier blocky albite rock of the wall zone forms a sheath-like envelope similar in shape to the hood unit and positioned just beneath it. Like the hood unit, it is thickest in the upper part of the pegmatite body and tapers downward along both walls. The similarities in mineralization in this unit and in the hood unit suggest that both formed nearly contemporaneously, with the hood perthite crystals separating and growing mainly in the upper part of the pegmatite chamber and the early blocky albite forming below.

The later blocky albite rock, now characterized by a much different associate mineralization and the presence of green muscovite, is similar in configuration to the early blocky albite unit and is positioned immediately beneath it. However, the rare mineral associates observed within it near the northeastern end of the opencut are confined to the portions be-

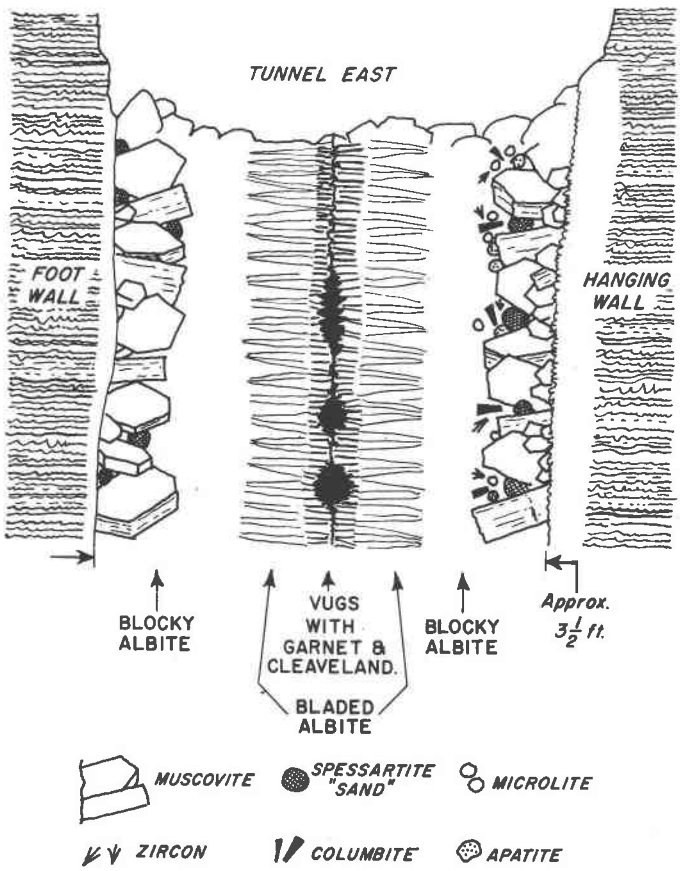

FIG. 5. Detailed cross section, Rutherford No. 2 pegmatite.

low about the 80-foot (24 m) level and are abundant only on the hanging wall. The similarities in shape and relative positions of the hood and blocky albite units are indicated in Figure 2.

The mineralogical relationships thus far noted suggest the following sequence of pegmatite crystallization:

(a) Crystallization of a thin, discontinuous aplitic border zone along the walls.

(b) Beginning of dark brown muscovite crystallization and allanite crystallization.

(c) Formation of earliest blocky albite enclosing the smaller brown muscovite books and smaller allanite crystals, accompanied in places by formation of very pale pinkish-gray quartz enclosing apatite; continued crystallization of muscovite and allanite.

(d) Formation of hood perthite, which encloses some allanite crystals and small to large books of hard, brown muscovite; allanite crystallization ceases.

(e) Formation of green muscovite on exposed crystals of muscovite and allanite, and crystallization of rare accessory minerals enclosed in blocky albite.

(f) Formation of hood perthite ceases and interstices fill with dark brownish-red fluorite and transparent smoky quartz.

(g) Blocky albite continues to form but now encloses only small segregations of green muscovite, some spessartine, and very minor quantities of rare minerals.

The mineralization of each of the three units so far discussed is in consonance with observations of Russian pegmatites, as summarized by Ginzburg (1960) who presents some details on mineral assemblages to be expected in the several major stages of granitic pegmatite development. Of interest here are the stages Ca-Na (plagioclase)→K (microcline)→Li (spodumene) [absent in the Rutherford pegmatites]→Na (albite)→late K (muscovite). According to Ginzburg, lepidolitization and greisenization are still later stages, but evidence of these was not found in the Rutherford No. 2 pegmatite. The above stages are idealizations of course, and actual development in any pegmatite is dependent upon the chemistry of the original magmatic supply. In the Rutherford No. 2 pegmatite, almost all the plagioclase is albite, indicating either the absence of substantial quantities of Ca in the original supply, fixing of Ca in other minerals, or migration of Ca into the surrounding gneiss. Only a little Ca is represented by other minerals such as apatite and microlite in the pegmatite, and Ca-minerals appear to be absent from the alteration halo in the surrounding gneiss which consists mainly of micas and quartz; thus it seems likely that the original magmatic supply was deficient in this element and that, from the beginning, the No. 2 pegmatite was characterized by abundant Na, little Ca, and an abundance of K as represented by K-perthite and the large quantities of muscovite.

Early formation of the blocky albite as a whole is consistent, according to Ginzburg's criteria, with the presence of minerals that he considers to be typical of the Ca-Na (plagioclase) stage, namely, allanite, apatite, rare earth phosphates (monazite), niobates-tantalates (columbite), microlite, and zircon, all of which are present in the blocky albite units in the Rutherford No. 2 pegmatite. The later K (microcline) stage is represented by the perthite hood unit, with mineralogy much simpler than that of the blocky albite unit. In addition to the muscovite, quartz, and fluorite already mentioned, the hood unit apparently contained considerable quantities of beryl. However, very little beryl was found *in situ* during the Piedmont Company's operations.

Tourmaline (schorl) was formerly found upon the dumps (Lemke *et al.*, 1952), but none was noted *in situ* during the recent mining except for a few small sprays of acicular crystals enclosed in muscovite books. Presumably the large crystals reported earlier occurred in the perthite hood unit. The allanite reported in the perthite-rich pegmatite at the northeast end of the opencut by Lemke *et al.*, (1952) as crystals similar to those observed in the early blocky albite tends to confirm the view that nearly simultaneous development of the perthite hood unit and the earlier blocky albite unit took place. The early commencement of muscovite crystallization in the No. 2 pegmatite, and its extensive development along practically all wall areas, may have influenced the duration and development of the K (microcline) stage by removing potassium and silica from the pegmatite material, thus favoring the continuation of sodic plagioclase mineralization.

Cleavelandite units. The next development within the No. 2 pegmatite is marked by the second major type of albite, the medium-grained, massive cleavelandite that uniformly overlies the blocky albite wherever these two units can be observed together (Fig. 5). Accessory minerals in this unit resemble those of the blocky albite unit, but with important differences that warrant calling this unit the *middle intermediate zone.* This unit contains no brown muscovite but does contain small quantities of transparent pale green muscovite and lesser quantities of pale pink muscovite. The green muscovite appears to be identical with that formed upon the much larger crystals of brown muscovite enclosed in blocky albite. Spessartine is not abundant but tends to form larger crystals than those noted in the friable spessartine aggregates of the late blocky albite. Microlite, which occurs sparingly, is dissimilar to the microlite of the late blocky albite; in the latter the crystals are opaque, dark olive to dark brown in color, and radioactive, while in the massive bladed cleavelandite they are non-radioactive (Glass, 1935), less fractured, reddish- to yellowish-brown in color, and commonly transparent upon corners and edges. The crystals display less flat faces, and display rounded edges with minute vicinal overgrowths. Aggregates of small cassiterite crystals occur sparingly. No allanite, monazite, or columbite were observed in this unit. From the position of this unit and the differences in albite and accessory mineralization, it represents a transitional stage between the blocky albite and the euhedral cleavelandite which lines the vugs along the central portions of the body.

The last albite mineralization formed a distinctive unit, termed the *inner intermediate zone*, that overlies the massive cleavelandite of the previous generation. This final layer lines the long central vugs of the pegmatite body and ranges from 7–30 cm in thickness (Fig. 5). It consists entirely of euhedral cleavelandite with much space between the blades, thus constituting a reticulated mass of sharply terminated glassy crystals. The associated minerals are quartz, green muscovite, amazonite, and spessartine, with very minor quantities of microlite, manganotantalite, cassiterite, apatite, galena, loellingite, tourmaline, chlorite, herderite, bavenite, sphene and pyrite. Only muscovite, spessartine, microlite, cassiterite, and manganotantalite are enclosed wholly or in part by the cleavelandite and thus are nearly contemporaneous with that mineral; the other species occur upon the cleavelandite and are therefore younger.

Amazonite-quartz core. The youngest major unit in the No. 2 pegmatite is a discontinuous core consisting of pale green amazonite and quartz. It was found in place only in a short drift headed southwestward from the base of the Piedmont Company's workings at the 115-foot (35 m) level in the No. 2 opencut. Here it formed a pod about 2 m long and 40 cm thick, filling completely the space between wall linings of euhedral cleavelandite. Margins of the pod consisted of abundant pale green muscovite books, some of which were 20 cm in diameter, with pink tabular apatite crystals, a mass of blue apatite with a white fibrous outer layer, an ovoid mass of galena, and some broken crystals of very pale orange spessartine.

The amazonite in this core unit was very pale in color and was marked by the white albite streaks typical of much of the material from both this deposit and the No. 1 pegmatite. Corrosion of the amazonite was apparent in all specimens removed from this pod but was more pronounced a short distance away, where the amazonite was found only as ragged fragments lying loose in narrow vugs between euhedral crystals of cleavelandite. The open space at this point connects with the much wider vug openings at higher levels. These vugs are more or less continuous up to the 60-foot (18 m) level, where the width of the vug opening is between 0.3–0.6 m, as shown in Figure 2. The breccia in the central space of the pegmatite body consists largely of slabs and angular fragments of euhedral cleavelandite and some massive bladed cleavelandite with corroded blocks of amazonite (Fig. 4). Near the 75-foot (23 m) level a crude euhedral crystal of amazonite about 25 cm in diameter was found, much corroded and coated with white fibrous bavenite. Breccia fragments, in various stages of corrosion, were uncovered within the central vug system from this level down to the 90 foot (27 m) level. Below this, the amazonite is less corroded and is free of coating material. At the 90 foot (27 m) level some small chips of amazonite were found cemented together by pyrite and pyrite replacing tabular crystals of pyrrhotite.

These relationships show that the last major episode in the No. 2 body was the formation of a discontinuous amazonite-quartz core. This was followed by minor stages in which the core was largely removed by solution and the constituents redistributed. The abundant green muscovite found in the inner parts of the pegmatite may represent fixing of the potassium liberated from the amazonite, while the final glassy terminals on cleavelandite blades may represent plagioclase material made available through the dissolution of amazonite. The notable concentration of quartz crystals at the upper end of the vug system probably represents silica obtained in part from the dissolution of core quartz. This final, post-core activity appears to coincide with the Na (albite) stage of Ginzburg (1960), and probably merges into the late K (muscovite) stage described by him. Some concluding hydrothermal activity is evidenced by the presence of such minerals as herderite, bavenite, chlorite, and pyrite, the last forming considerable masses in some of the smaller lower-level vugs where it cements fragments of spessartine, albite, muscovite, and quartz, and has infiltrated numerous cracks throughout the pegmatite and in the surrounding gneiss.

To summarize, the final stages of pegmatite crystallization appear to have been as follows:

(h) Formation of compact bladed cleavelandite with minor quantities of green and pink muscovite, spessartine, translucent to transparent microlite, and cassiterite.

(i) Formation of translucent to transparent cleavelandite that lines the central vugs of the pegmatite body, along with green muscovite, large transparent spessartine crystals, translucent to transparent microlite, cassiterite, and manganotantalite.

(j) Continued formation of green muscovite with spessartine, apatite, and galena.
(k) Formation of the amazonite-quartz core.
(l) Partial dissolution of the core and formation of fibrous tourmaline, chlorite, sphene, colorless apatite, quartz, herderite, loellingite, bavenite, and pyrite.

The Rutherford No. 1 Pegmatite

Several mineralogical units of the No. 1 pegmatite are similar to those of the No. 2 and were identified *in situ* during the work of the Piedmont Company. A well-developed perthite hood unit was found in the uppermost portion of the body next to the single-compartment shaft. It consisted primarily of very pale brown euhedral crystals of perthite, large, hard, sharp-edged crystals of brown muscovite, and pale gray, shattered, interstitial quartz. The grain size ranges from medium to very coarse. No smoky quartz, fluorite, or allanite were found in this unit.

Exposed about 20 feet (6 m) southwest of the hood unit, and beyond a debris-covered area, is blocky albite-quartz-muscovite pegmatite. This incompletely exposed unit ranges from coarse- to medium-grained, the grain size diminishing away from the perthite unit. The quartz ranges from gray, shattered material to colorless and smoky material of considerable translucency. No rare minerals were noted as accessories, nor any xenoliths of gneiss. Dump material, probably discarded during the last underground operations in 1932 by American Gem and Pearl Company, contains masses of reticulated cleavelandite without the perfect euhedral development exhibited by similar specimens from the No. 2 mine. Many of these masses contain transparent to milky or smoky quartz, green muscovite, and amazonite that fill interstices between cleavelandite blades. Collectors have obtained good examples of microlite from this material. Amazonite fragments from the same dumps are considerably deeper in color than amazonite from the No. 2 pegmatite, and are harder and less corroded; the whitish coating noted on many of the fragments from the No. 2 pegmatite is absent here. In many specimens the amazonite covers and encloses cleavelandite, generally in association with green muscovite and colorless, smoky, or milky quartz.

Both rock exposures and specimens collected from the dumps indicate fundamental similarities between the No. 1 and No. 2 pegmatites. The perthite hood of the No. 1 seems to have been considerably smaller than that of the No. 2, but much of it may have been removed by erosion. The blocky albite unit of the No. 1 does not contain the variety of minerals noted in the corresponding unit of the No. 2, but such minerals occur in the No. 2 well below the perthite hood unit and similarly could occur in the lower parts of the No. 1 body. Unfortunately, these parts were inaccessible during the period of observations upon which this paper is based. Even the amazonite-quartz core unit of the No. 2 pegmatite appears to have its counterpart in the No. 1, but the latter is apparently much larger in volume, and probably less extensively corroded. It is also probable that the very large central vug and smaller ancillary vugs of the No. 2 body do not have their counterparts in the No. 1 body. The record of amazonite production and the evidence presented by specimens found upon the dumps of the No. 1 suggest that the central vug system of the No. 1 is filled more or less completely by the amazonite-quartz core unit. Both pegmatites must have been very closely related in their origin and age.

Mineralogy

The mineralogy of the Rutherford and Morefield pegmatites was last treated in detail by Glass (1935) who listed 27 confirmed species from the Rutherford No. 1 and No. 2 pegmatites. Another mineral, bavenite, was subsequently described by Fleischer and Switzer (1953), and recently, an unusual filiform tourmaline was described by Mitchell (1964). Five species new to the Rutherford pegmatites—chlorite, herderite, loellingite, pyrrhotite, and sphene—are noted for the first time, along with remarks on unusual specimens of previously described species. Unless stated otherwise, descriptions apply to specimens from the No. 2 pegmatite.

From the viewpoint of the collector, the most rewarding units in the No. 2 deposit are blocky albite wherever it is discolored gray, and to a lesser extent, compact, bladed cleavelandite. The perthite of the hood is practically barren of rare or unusual species. The euhedral cleavelandite provides excellent specimens and corroded fragments of associated spessartine, but seldom furnishes rare minerals. However, bavenite commonly occurs in the spaces between the cleavelandite blades of this last unit and is worth looking for. The grayish discoloration of the blocky albite appears to have been caused by proximity to radioactive species which it encloses, the intensity of discoloration rapidly diminishing away from such inclusions. Discoloration of the albite is common about crystals of zircon, monazite, and microlite. It therefore pays to examine all discolored albite very carefully for crystals of these species. In places, the compact bladed cleavelandite encloses excellent microlite crystals, cassiterite in small masses, and, within small vugs, crystals of spessartine, green and pink muscovite euhedrons, fibrous tourmaline, and rarely, manganotantalite. Spessartine is eagerly sought by vistors to the mines where the best specimens are associated with the euhedral cleavelandite linings of the large central vugs. Unfortunately it is seldom attached to the cleavelandite and ordinarily falls away during mining to join the many small bits of mineral debris which are thrown upon the dumps to settle downwards between the larger masses of pegmatite or gneiss. Spessartine has been most consistently recovered from the dumps by sifting finer material through wiremesh screens.

Also of interest to collectors are grains of blocky albite which commonly display beautiful pale blue reflections (peristerism). This material enjoys some vogue as a gem stone although the quality of the material and the intensity of the effect do not compare favorably with the moonstones of Ceylon or Burma. On the other hand, the gem-quality amazonite from the Amelia localities (Rutherford and Morefield pegmatites) enjoys a world-wide reputation because of the intensity and beauty of its color and the size of fracture-free pieces. That from the No. 1 pegmatite is much superior to the amazonite from the No. 2 pegmatite. Most of the amazonite from the latter pegmatite occurs as white-coated corroded grains which require fracturing or sawing to reveal the quality of the material within. Small fragments of excellent amazonite are still obtained from the dumps of the No. 1 mine but few are found over 2 cm in diameter. It is possible that substantial quantities remain within the No. 1 pegmatite but no information is available as to quantities in sight when the American Gem and Pearl Company ceased mining for amazonite in 1932.

Albite. The principal variety of albite forms white to slightly yellowish blocky anhedrons which range from less than 2 cm to as much as 25 cm in diameter. The grains are twin-composites of several large individual crystals each of which ranges in thickness from one to several centimeters. The twinning composition plane is {010}. Fresh fracture surfaces display widely spaced twinning striae. Many grains contain central areas displaying pale blue peristerism but this effect seldom is obvious except upon freshly fractured surfaces. The exterior zones of such grains consist of opaque white albite while the peristerite cores are translucent and slightly yellowish in color. As has been noted on peristerites from other localities, the blue reflections appear through the cleavage plane *b* {010}. Recent analyses of albite from the Rutherford pegmatites (Deer *et al.*, 1963) indicate that the An content is below the peristerite range of An_1-An_{25}, as shown below:

Mole %	7. (1952)	8. (1938)	9. (1961)
Ab	98.0	98.0	98.5
An	0.3	0.4	0.7
Or	1.7	1.6	0.8

Probably the material selected for these analyses was the clear, glassy euhedral cleavelandite which megascopically appears most attractive for accurate analytical results as compared to the cloudy material of the blocky albite. However, it is the latter which commonly displays peristerism and not the cleavelandite. To check the composition of the Amelia peristerite, a typical sample from the No. 2 mine was examined under the electron probe and yielded the following results:

CaO =	1.4 Wt %	Ab	91.3 Mole %
K_2O =	0.4	An	6.6
Al_2O_3 =	21.0	Or	2.1
SiO_2 =	31.1		

Thus the peristerite does contain more An than shown for the published analyses above, sufficient to place it in the accepted peristerite range of An_{1-25}.

Within the blocky albite are associated muscovite, quartz, allanite, spessartine, columbite, apatite, microlite, monazite, zircon, and pyrite. Most of these species are closely associated in clusters of crystals between the larger books of muscovite (Fig. 5). The microlite, allanite, zircon, and monazite are radioactive. They are enclosed by albite which is discolored from pale to dark gray, the darkest grays appearing adjacent to the radioactive species. The albite is friable immediately next to such inclusions but becomes firmer farther away. The blue peristerism of the albite is unaffected by the radioactivity.

The spessartine in the blocky albite is mainly in the form of spherical masses composed of numerous small, loosely coherent to incoherent grains, which crumble readily into a sand when scraped with a finger-nail; the walls of the openings left within the albite by removal of the garnet display rough planes recognizable as those of the trapezohedron n {211}. Apparently the spessartine formed in single crystals that were minutely fratured after enclosure by albite; a similar fracturing also occurs in the columbite and microlite enclosed in the blocky albite but these tend to cohere better.

The massive bladed albite unit consists of tightly interlocked curved blades of cleavelandite, ranging from 7 to 20 cm in length. They are white in color but in places are faintly blue or green. The rock is brittle and falls apart with moderate blows of the hammer. This unit contains scattered crystals of green muscovite, microlite, cassiterite, pyrite, and spessartine within small vugs which again appear to be impressions of spessartine euhedrons. The microlite and cassiterite are confined to a narrow zone bordering the euhedral cleavelandite unit which lines the central vugs. The muscovite commonly forms perfect books of small size within small vugs in this zone, some of the mica being pale yellow-green in hue and some very pale purple or very pale purplish-pink. The microlite is usually translucent or transparent along edges of crystals.

The euhedral cleavelandite lining the central vugs is famous among mineralogists and collectors for the perfection of the bladed crystals which range from white to colorless or faintly tinged with green or blue. The terminals of the crystals are usually sharp, glossy in luster, and transparent. The crystal blades are invariably twin-composites flattened on *b* {010}, which plane is also the twinning composition plane. Each blade usually consists of three to five individuals, but of these only the pair forming the broad *b* (010) faces are large while the remaining individuals appear as much thinner platy individuals sandwiched between them. The preferred orientation of the crystals with respect to the vug walls is with the *b* (010) faces perpendicular. The growth is most rapid along the *a* [100] and *c* [001] directions, resulting in reticulated masses with deep angular spaces between the criss-crossed blades (Figure 6). Commonly these masses develop cracks along their bases as shown in Figure 4 and are therefore easily pried loose in the form of slabs covered completely upon their vug-wall sides with excellent terminated crystals. One such specimen recovered during the Piedmont Mining Company operations measured about 60 cm square and was about 25 cm thick. The largest twinned crystals in this slab could be traced from the base of the specimen to the vug-wall surface. The exposed portion of the blade measured about 15 cm in length and about 2.5 cm in thickness. Most crystals are much smaller, averaging about 5 cm in breadth and about 6 mm thick although their roots may extend to as much as 15 cm in depth. Associates of the cleavelandite include muscovite, commonly in sharp euhedrons of pale green color, quartz crystals, which, however, are uncommon except in the gneiss breccia area in the upper portion of the central vug system, gem grade spessartine masses, cottony masses of minute bavenite crystals, fibrous tourmaline and occasionally small microlite crystals which form at the roots of the cleavelandite blades.

An unusual assemblage of minerals was noted in a narrow vug lined with euhedral cleavelandite at the 90-foot (27 m) level in the northeastern end of the No. 2 mine. Here were found etched masses of spessartine, massive and euhedral pyrite, detached blades of cleavelandite, very small doubly-terminated quartz crystals, very small prisms of colorless apatite, pyrrhotite partly replaced by pyrite, corroded fragments of amazonite, small prisms of loellingite, microscopic sphene crystals, fibrous tourmaline, herderite crystals, chlorite, and muscovite. Most of the contents of the vug were loose but some portions were cemented together with massive pyrite which appeared to be the last-formed mineral.

Allanite. Elongated prismatic crystals of black allanite are common in some portions of the blocky albite against the footwall of the No. 2 opencut and, according to Lemke *et al.*, (1952), also occur in the hood perthite at the upper northeastern end of the opencut. Some allanite in the blocky albite unit is enclosed in scaly masses of greenish muscovite and gray granular quartz. Both the albite and quartz next to the allanite crystals are discolored, presumably because of radiation damage. The forms are

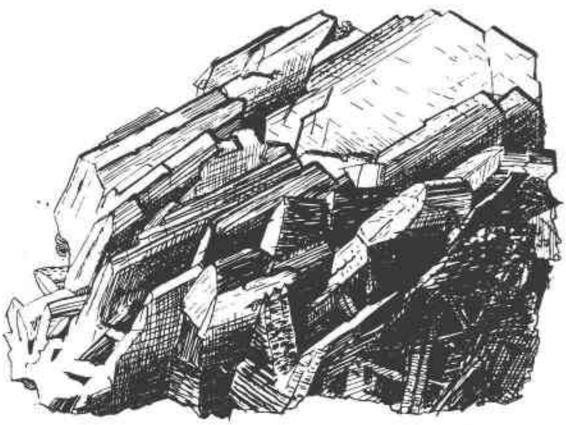

FIG. 6. Cleavelandite from Amelia.

rough faces in the zone parallel to the *b*-axis, furnishing crystals which resemble two-edged swords in cross-section. The blades are commonly about 7 cm in length but one individual was noted which was 35 cm long and about 2.5 cm in width. The crystals are extremely friable and it is nearly impossible to remove them whole from matrix.

Apatite. Four varieties occur in the No. 2 pegmatite as follows: white to very pale pink opaque blebs enclosed in albite and quartz, small perfect hexagonal colorless prisms in vugs in cleavelandite, small tabular pink crystals (recovered from one vug adjacent to a microcline-quartz core remnant in the drift at the 115-foot (35 m) level, and nearby, massive dark blue apatite. The blebby variety easily escapes notice because it is similar in diaphaneity, texture and color to the blocky albite and a whitish quartz which commonly enclose it. It is somewhat more conspicuous in quartz principally because it is whiter in hue. When the quartz or the albite have been discolored by radioactivity, the apatite stands out in strong contrast because it remains white. This variety of apatite is associated with allanite, muscovite, microlite, zircon, columbite, and other species in the blocky albite units. The small prismatic euhedrons which occur in cleavelandite vugs are mostly transparent, somewhat greasy in luster, and commonly display excellent faces of the forms $m\{10\bar{1}0\}$ and $c\{0001\}$; other forms are $x\{10\bar{1}1\}$, $r\{10\bar{1}2\}$, $s\{11\bar{2}1\}$ and $y\{20\bar{2}1\}$. Faces of x, r, and s are rough. The prisms are colorless but some appear slightly brownish or greenish in hue due to inclusions of brown tourmaline or a green fibrous mineral which may be an amphibole. A good cleavage is easily developed parallel to $c\{0001\}$. The largest crystal found measured about 2 cm in length and about 3 mm in diameter; most are much smaller with transparency and sharpness and smoothness of faces improving with decreasing size. The tabular pink crystals are compressed along the c-axis and are bounded by rough faces with considerable rounding of edges. They display narrow faces of $m\{10\bar{1}0\}$ and rough, somewhat curved faces of $c\{0001\}$ which are covered with numerous minute growth hillocks. These crystals are only translucent and occasionally display a weak chatoyancy from minute tubes parallel to the c-axis. A similar chatoyancy, but caused by so many tubes as to render the surface white, was observed in the single mass of dark blue apatite found near the pink tabular crystals. This mass, measuring about 5 cm in diameter, displayed a few rude crystal faces and was found adjacent to galena and partly imbedded in large pale green muscovite crystals.

Bavenite. This mineral, rare in pegmatite deposits elsewhere in the world, is abundant in the No. 2 pegmatite, particularly in the albite breccia in the eastern end of the opencut at about the 75-foot (23 m) level, and below this to the 90-foot (27 m) level. It commonly occurs in fibrous cottony masses which coat breccia blocks, in places to a thickness of 3 mm. Mostly the masses are loosely felted aggregates of slender blades but some crystals form radiate aggregates which bear a striking resemblance to the bavenite shown in the photograph of Figure 1 of Schaller and Fairchild (1932), which figure portrays bavenite in a vug in an altered beryl crystal from Mesa Grande, California. The finest Rutherford examples, as tufts of terminated crystals, occur in the spaces between blades of euhedral cleavelandite. An unusual occurrence was discovered in the short drift headed northeast at the northeastern end of the opencut at the 90-foot (27 m) level where an ovoid cavity in massive bladed cleavelandite, measuring $40 \times 35 \times 25$ cm, was found to be solidly filled with cottony bavenite. The water-saturated material superficially resembled a pure white clay but lacked the weight and slippery feel of clay. Handfuls of the bavenite could be squeezed to expel much of the water; the remainder, when allowed to dry, somewhat resembled in lightness and texture the meerschaum of Turkey.

The first identification of bavenite from the Rutherford No. 2 pegmatite was made by Fleischer and Switzer (1953) on fibrous aggregates from within a small vug in cleavelandite. In view of the recent comment by Mitchell (1964) to the effect that much bavenite might be misidentified filiform tourmaline, a sample of the material collected in 1959 from the brecciated albite zone was re-examined by X ray and confirmed as bavenite. Under the microscope the crystals within the felted masses clearly display the flattened habit depicted by Schaller and Fairchild (1932). The X-ray diffractometer produced peaks corresponding closely to those found by Fleischer and Switzer (1953). Extraneous peaks could not be identified as belonging either to bertrandite, which has been identified in association with bavenite (Fleischer & Switzer, 1953), or to tourmaline.

Bertrandite. Recently Mr. Rudolph J. Bland, Jr. of Richmond, Va. found a section of an altered beryl crystal of approximately 10 cm in length and 7 cm in diameter upon the dumps of the No. 2 mine near the southeast end of the opencut. Several areas of the specimen contained small cavities lined with colorless, transparent, stubby, prismatic crystals of orthorhombic aspect which do not exceed about 1 mm in length. A sample of the latter mineral was X rayed and determined to be bertrandite. Several beryl peaks were identified in the diffractometer trace which supports the view that bertrandite is an alteration product of beryl.

Beryl. Early mining uncovered considerable beryl as rough prismatic crystals up to 15 cm in diameter. Similar crystals, though not as large, were found upon the dumps attached to perthite. They are hexagonal in cross-section, rough-surfaced, often partly coated with small flakes of silvery mica, and opaque to slightly translucent in interior portions. The color is typically pale grayish-green. The only specimen found *in situ* was a translucent brownish-yellow mass of about 7 cm in diameter which was almost completely enclosed in scaly brown mica and came from a place adjacent to the gneiss at the 90-foot (27 m) level in the northeastern end of the No. 2 pegmatite.

Biotite. Brownish-black biotite is abundant in the gneiss adjacent to the

the pegmatite in the lower levels of the No. 2 mine but none was observed in the pegmatite itself.

Cassiterite. This species occurs as black to very dark blackish-brown masses, covered, in part, with numerous shining vicinal faces. It is most commonly enclosed in the massive bladed cleavelandite from which specimens to 2 cm in diameter were recovered. Very small euhedrons of dark brown color occur in cavities in the euhedral cleavelandite. All crystals are twinned in the Zinnwald mode shown on p. 575 of Dana's *System* (Palache *et al.* 1944). Optical constants were determined by J. J. Glass (pers. comm.) as follows: $\omega=1.997$, $\epsilon=2.09$, $\epsilon-\omega=0.093$; uniaxial.

Chlorite. This species forms grayish-green spheroidal aggregates measuring about 1.5 mm in diameter which are implanted upon other minerals in vugs in the euhedral cleavelandite. It also occurs as films in fractures in albite and as coatings upon spessartine masses. It is commonly mixed with pyrolusite, and spessartine and cleavelandite fragments, and with pyrite in the small veinlets emplaced along fractures in blocky albite and cleavelandite units in the lowest levels of the No. 2 opencut.

Columbite. Simple tabular crystals are fairly abundant in the discolored blocky albite where they are associated with microlite, zircon, monazite, apatite, muscovite, spessartine and pyrite. Most crystals are dull gray on their exterior surfaces but dead black upon fresh fracture surfaces. They can seldom be removed or exposed without crumbling. The largest crystal recovered measured $4\times4\times2$ cm.

Fergusonite. The zircon crystals reported later in this paper bear a strong resemblance in habit, color, radioactivity effects, and fracture to fergusonite crystals and at first were mistaken for them. It is possible that the fergusonite of Fontaine (1883) may have been zircon.

Fluorite. Dark brownish-red, pale green, and colorless masses of transparent fluorite have been found upon the dumps but only the red variety was found *in situ.* It occurs in mono- and poly-crystalline masses measuring up to 7 cm in diameter in the arch near the southwestern end of the No. 2 opencut. The associates of the pale green and colorless masses, all of which appear to be corroded upon their exteriors, suggest that this variety occurs in the central cleavelandite vugs. Both varieties are strongly thermoluminescent after moderate heating as described by Kunz (1884).

Galena. Only one specimen was uncovered and that a rough ovoid mass, about 7 cm long, found partly imbedded in a large pale green muscovite book adjacent to the amazonite-quartz core in the floor of the drift at the 115-foot (35 m) level. The galena mass was partly coated with pyrite crystals and contained pyrite-filled cracks.

Herderite. This uncommon granitic pegmatite phosphate-mineral is reported for the first time from the Amelia pegmatites. The specimens consist of 3 mm-long aggregates of bladed crystals which form sheaves reminiscent of stilbite. The central, narrowed portions of the sheaves are approximately square in cross-section. A sketch of a typical aggregate appears in Figure 7. The exteriors of aggregates are pale brown and opaque while the interiors are transparent yellow but appear black because of many microscopic inclusions of an unidentified mineral. Fracture surfaces are greasy in luster. The identity of the herderite was established by Switzer (pers. comm.) by means of an X-ray powder pattern. J. J. Glass (pers. comm.) identified pyrite inclusions in the herderite. A later X-ray diffractometer trace, taken from carefully selected, inclusion-free material, provided numerous herderite peaks and also some extraneous peaks which, however, could not be identified as belonging to pyrite. Similar extraneous reflections were noted by Switzer (pers. comm.) but these also could not be identified.

Loellingite. Small prismatic crystals of typical habit not over 3 mm in length occur very sparingly in vugs in cleavelandite associated with apatite, pyrite, pyrrhotite, spessertine, sphene, tourmaline, and amazonite.

Manganotantalite. This species has been previously reported from Amelia by Lee and Wherry (1919). A bladed aggregate of crystals, measuring $7 \times 7 \times 5$ cm, was found in dump material and appears to be manganotantalite. It consists of many thin, bladed crystals grown approximately parallel but diverging slightly from the base to the terminations. The faces are sharp and polished and the color is dead black. Thin edges and splinters are transparent and display a deep red hue which suggests manganotantalite rather than columbite. The perfection of development further suggests that this aggregate grew upon euhedral cleavelandite within one of the central vugs.

Microcline. Very pale brownish-pink to very pale brown microcline occurs in the perthite of the hood unit. Euhedrons of microcline-perthite to

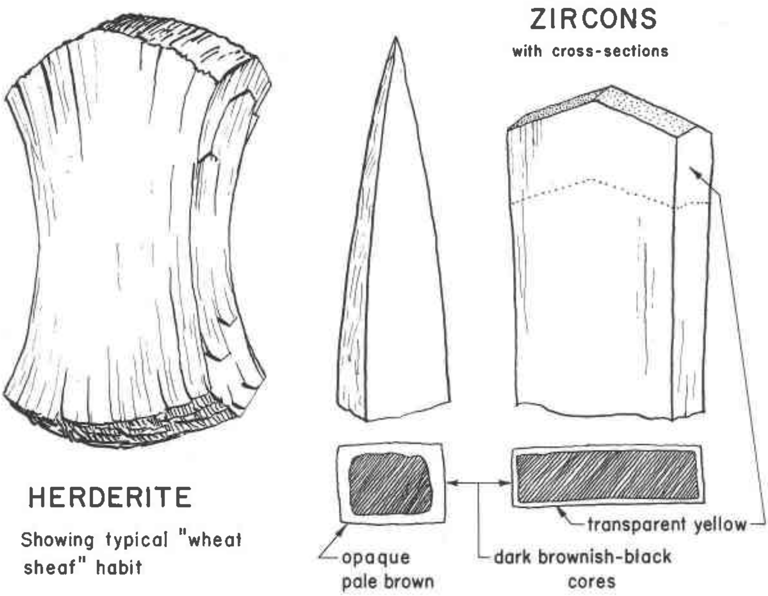

FIG. 7. Form of herderite and zircon at Amelia.

about 25 cm in length occur in the arch near the southwestern end of the opencut in the No. 2 mine and somewhat larger euhedrons occur in the hood remnant in the opencut of the No. 1 mine. The amazonite of the No. 2 pegmatite is generally much paler in hue than that of the No. 1 and usually occurs in corroded crystal fragments and blocks, many of which are white upon the exteriors. Some of the more severely corroded pieces contain small cavities which may have resulted from the selective dissolution of albite. An unusual variety of amazonite from the No. 2 pegmatite is pale greenish-blue, highly translucent within layers parallel to the principal cleavage plane *c* {001}, and cleaves readily to yield thin flakes which sometimes reach 7 cm in diameter. The largest amazonite specimen obtained from the No. 2 pegmatite during recent mining was a partly euhedral mass measuring $30\times 20\times 15$ cm. The amazonite from the No. 1 pegmatite is regarded as among the finest gem-grade amazonite found anywhere. Its color ranges from pale to intense green to bluish-green. Most material displays white veinlets of albite in the typical "plaid" pattern; other material is nearly free of visible albite but is much less abundant than the first type mentioned. A notable feature of much of the No. 1 amazonite is its occurrence in fracture-free anhedrons to about 25–30 cm in diameter which feature made this material even more attractive to lapidaries. The principal production of amazonite by the American Gem and Pearl Company was shipped to the gem-cutting center of Idar-Oberstein in Germany.

Microlite. This species, generally rare elsewhere, proved to be abundant in the blocky albite of the No. 2 pegmatite. It was also found sparingly in the massive bladed albite and in the euhedral cleavelandite. The largest number of crystals found in the blocky albite were ball-like euhedrons as much as 25 mm in diameter, occurring singly or in clusters associated with columbite, zircon, monazite, apatite, greenish muscovite and spessartine between large books of brown muscovite (Figure 5). Many crystals display large faces of the octahedron $o\ \{111\}$, but major modifications by $a\{100\}$, $n\{211\}$, and $d\{110\}$, on most crystals contribute to the ball-like habit mentioned. The crystals in the cleavelandite units tend to be primarily octahedral in habit with only slight modification by other forms. These crystals are far less sharp than those from the blocky albite, most of the faces and corners being roughened or rounded by growth hillocks. Another feature of these crystals is their far greater translucency as compared to those from the blocky albite. In some crystals, the translucency passes into complete transparency along crystal edges. The color of both varieties is also markedly different, the microlite from the blocky albite being dull brown to greenish-brown, while the microlite from the cleavelandite units tends to be reddish-brown to brownish-yellow. A detailed discussion of these varieties is furnished by Glass (1935). One of the most remarkable specimens of microlite recovered during the operations of the Piedmont Mining Company was a 7-gram rectangular fragment of a larger crystal from which was cut a flawless step-cut gem of 3.66 carats. The depth and quality of color strongly resemble brownish almandite. This gem is now in the collection of the U. S. National Museum. It was so different in appearance from the usual microlite that its identity was checked by X ray (Switzer, pers. comm. 1959). Clear gem quality microlite from Amelia was previously reported by Hidden (1885) but the absence of additional specimens for many years afterward cast some doubt on the existence of such material; this find verifies that such transparent microlite did occur.

Monazite. This mineral has been previously reported in large crystals (Fontaine, 1883) but recent mining only produced crystals not over about 1 cm in diameter from the blocky albite of the No. 2 pegmatite. The crystals are sharped-edged euhedrons, somewhat tabular in habit, with prominent faces of $a\{100\}$, $m\{110\}$, and $x\{\bar{1}01\}$, and small faces of $e\{011\}$. The faces are dull in luster and pale brown in hue; exterior material is opaque but the interiors of the crystals consist of ovoid areas of fractured translucent monazite of pale brownish-pink hue. The latter material was examined by J. J. Glass (pers. comm.) who provided the following optical data: $\alpha = 1.785$, $\gamma = 1.835$; biaxial positive, extinction angle ca. 12°. Dark inclusions in the pink cores appeared to be monazite also; these are isotropic with $n \pm 2.00$. The monazite is usually associated with crystals of columbite, microlite and zircon.

Muscovite. On the basis of different habits, colors, and positions within the pegmatite, two distinct varieties of muscovite occur. The first, and by far the most abundant, is the dark brown muscovite which occurs in the earlier units of the pegmatite body in small to large crystals of thick tabular habit. The later units contain the second variety, which is pale green in hue and, rarely, pale pink muscovite which forms very thin tabular crystals. Sericitic varieties are described in detail by Glass (1935) and will not be treated here. The larger books of brown mica, some exceeding 30 cm in diameter, provided the commercial mica for which both Rutherford pegmatites were originally mined. The largest crystals recently recovered from the No. 2 pegmatite did not exceed 25 cm in diameter and about 15 cm in thickness. The finest crystals occurred in the perthite hood and in the earlier blocky albite. These were sharp-edged, hard, free of inclusions and splits, and of uniform brown coloration. Large crystals enveloped in later blocky albite were overgrown by zones of green muscovite with concurrent development of fringed edges upon the individual sheets, somewhat like those observed upon some lepidolite crystals. Many were split after formation because inclusions of quartz within them are common, usually in the form of delicate lace-like growths consisting of numerous flattened euhedrons of microscopic size. Other splits without inclusions were also common, while many of the books, when extracted from the enclosing rock, fell apart into a number of plates.

The later muscovite is predominantly pale yellow-green in hue and remarkably transparent along both the *c*-axis and lateral axes directions. Faint color zoning is evident in some crystals, with interior zones being somewhat darker in hue than outer zones. The pale pink or pale purple-ish-pink subvariety is found in small vugs in late blocky albite and in the massive cleavelandite. The best specimens of green muscovite were found in cavities in the gneiss breccia filling in the upper end of the northeastern extremity of the No. 2 opencut where the euhedrons were partly imbedded in cleavelandite. Similar specimens occurred in vugs adjacent to the amazonite-quartz core at the 115-foot (35 m) level, where, additionally, some euhedrons of 15 cm in diameter and about 5 cm in thickness were found. Very small flake-like euhedrons also occur throughout the central vug system where they grow as sprays between blades of euhedral cleavelandite or are partly enclosed within them.

Pyrite. This species is a late but widespread constituent of the No. 2 pegmatite below the 75-foot (23 m) level. It is increasingly abundant with depth until at the lowest levels, it heavily coats cracks and fissures in the pegmatite and adjacent gneiss with sparkling druses consisting of cubic crystals not over 3 mm in diameter. Thinner films were found in fractured crystals of microlite, monazite, columbite, and other species in other units of the pegmatite. Perfectly developed cube euhedrons, some with slight octahedral modifications, occur in the central vugs of the euhedral cleavelandite unit. Massive granular pyrite also fills some of the smaller vugs and cements together fragments of cleavelandite, spessartine, quartz and apatite. While the larger crystals appear to be confined to the lowest portions of the pegmatite, smaller crystals, some microscopic in size, and attached to crystals of bavenite and acicular tourmaline, occur between blades of cleavelandite in the albite breccia at the 75-foot (23 m) level.

Pyrrhotite. Several small vugs in the euhedral cleavelandite unit provided wafer-like crystals of pyrrhotite completely coated by drusy pyrite and largely replaced by that mineral. The largest crystal measured about 2 cm in diameter and about 3 mm thick. Broken crystals contain granular cores of grayish-green material which resembles pyrrhotite. Larger crystals readily adhere to a magnet but small crystals do not. The broken crystals quickly develop a white efflorescence upon fresh fracture surfaces which suggests the presence of pyrrhotite. An X-ray diffractometer trace of magnetically separated material showed several peaks of pyrite and other peaks which may belong to pyrrhotite but the results were inconclusive.

Quartz. Milky, smoky, and slightly pink, massive quartz occur in the perthite and blocky albite units of the No. 2 pegmatite. Some massive milky quartz is discolored to pale gray when it is adjacent to radioactive species as allanite, microlite and zircon. Quartz discolored by greenish inclusions occurs in vugs in euhedral cleavelandite in the northeastern end of the No. 2 pegmatite opencut. Some crystals collected here measure 20 cm in length and 7 cm in diameter. Inclusions of the unidentified greenish mineral previously mentioned are abundant in outer zones of the crystals but the interiors are free of flaws or inclusions and commonly smoky in hue. In many examples, the crystals grew after the cleavelandite and some of the muscovite because they deeply enclose cleavelandite but only enclose small crystals of muscovite in their outermost zones.

Minute transparent colorless quartz crystals form very thin lace-like aggregates in splits in larger mica books in the lower portions of the blocky albite unit. Some of the aggregates reach 7 cm in diameter. The crystals composing them are grown chiefly along the *c*-axis direction and are flattened along a pair of opposite prism faces. Similar, but unflattened crystals, usually doubly-terminated, occur sparingly in small vugs in the euhedral cleavelandite of the lower portions of the pegmatite. Several specimens of pale gray chalcedony reaching diameters of as much as 10 cm and partly enclosing scales of silvery mica and small blades of cleavelandite, were found on the dumps of the No. 2 mine but none of this material was noted in place.

Spessartine. The spessartine from the No. 2 mine has long been known for the large size of its gemmy crystals, some of which reach 7 cm in diameter, but most specimens contain only small areas which are sufficiently free of inclusions to afford flawless faceted gems. The largest number of specimens consist of irregular single-crystal masses typically covered with numerous parallel striations and lozenge-shaped pits or elevations as shown in the sketch of Figure 8. The angles between the straight striations correspond to those between edges of the dodecahedron $d\{110\}$. Some euhedrons were found during mining, notably small trapezohedra of dark brownish-red color in the blocky albite unit, and fragments of a larger, pale orange crystal displaying faces of $d\{110\}$ and the trapezohedron $n\{211\}$. This crystal was found in a vug in cleavelandite at the lowest level of the No. 2 mine. Most of the gem-grade spessartine occurs in the smaller vugs of the cleavelandite unit along the central portion of the pegmatite as shown in the sketch of Figure 5. Here were found ball-like aggregates of crystals, the largest of which measured 15 cm in diameter and consisted of numerous interlocked crystals which taken together weighed 4 kg after the tenacious coatings of chlorite were removed from the individual crystals. It is characteristic of such aggregates that the crystals next to the periphery possess pale orange zones while those in the interior of the aggregate do not. Further, the exterior crystals are orange-zoned only adjacent to the periphery of the aggregate itself. The general shape and color-zoning suggest that each ball-like aggregate was originally a single crystal which fractured late in its growth after it had accumulated an outer zone of orange-colored material. Subsequent solution of all exposed surfaces resulted in each fragment becoming covered with the markings described above. The chlorite may be a reaction product of the de-

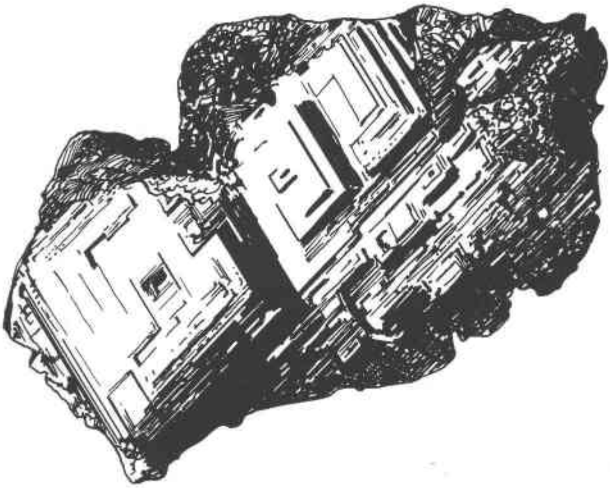

FIG. 8. Gem spessartine.

composition of the spessartine. It is entirely possible that fracturing of spessartine crystals occurred even more extensively than the evidence of the larger aggregates would suggest. Most spessartine specimens contain numerous veils of single and two-phase inclusions which are considered to be evidence of "healing" of fractures by the deposition of material within crack openings (Roedder, 1962). Many small fragments, in the size range of 3 to 12 mm, and of various hues, occur in the loose material within vugs in the cleavelandite and probably represent larger crystals which were fractured and scattered to such an extent that the individual fragments could not coalesce into larger masses. Significantly, the largest aggregates recovered during recent mining in the No. 2 pegmatite were found enclosed more or less firmly in cleavelandite (Figure 5), suggesting that the fracture fragments were physically restrained from movement and thus able to "heal" into the larger fragments typical of this mode of occurrence.

The color of spessartine is commonly assumed to reflect the proportion of manganese to iron in its composition, the dark brownish-red hues indicating higher iron and the orange hues indicating higher manganese. Recent investigations of the properties of garnets, and summaries of previous work, provide data on the correlation of specific gravity and refractive index to composition but do not provide parallel correlations of color (Fleischer, 1937; Skinner, 1956; Stockwell, 1927). In order to determine if a correlation between color and Mn/Fe in Rutherford No. 2 spessartine does exist, a series of 50 samples of various hues, selected from a lot of about half a kilogram of small fragments and crystals taken from the cleavelandite vug system of the pegmatite, were investigated by electron microprobe (Sinkankas & Reid, 1966). A preliminary scan for elements showed the presence of Si, Al, Mn, Fe, and Ca; a specific search for Mg and Cr failed to show quantities within the normal detection limits of the microprobe, or, less than 0.3 weight percent. The samples were visually graded to provide a smooth transition from the darkest brownish-red hue to the palest yellow-orange hue and imbedded in that order in a single sample holder. With a few minor exceptions among the darker-hued specimens which were more difficult to color-grade, the proportion of iron fell steadily and manganese rose equally steadily from the reddish-brown end of the sequence to the orange end. Calcium apparently accompanies iron because its quantity falls steadily in proportion to iron. This relationship is expressed below in approximate end-member mole-percents of spessartine, almandite, and grossular:

		n(Na)	Spessartine	Almandite	Grossular
Dark brown-red	(Fe-rich)	1.809	50	43	7
Pale orange	(Mn-rich)	1.795	95	3	2

A plot of the values for the fifty specimens shows a remarkably smooth transition and there appears to be no question that the hues of the spessartine from the Rutherford No. 2 pegmatite directly reflect the relative proportions of (Fe, Ca)/Mn. Variation in color is also accompanied by a proportional change in refractive index as indicated above.

Sphene. Colorless sphene forms spherical aggregates about 1.5 mm in diameter in small vugs in the cleavelandite unit in the lower portions of the pegmatite. Associates are apatite, cleavelandite, chlorite, quartz, muscovite, herderite, spessartine and pyrite. The identity of the sphene was established optically by J. J. Glass (pers. comm.).

Topaz. A small section of a specimen of massive white topaz recently found by Mr. Rudolph J. Bland, Jr. was kindly supplied for examination and X-ray identification. It was found at the extreme east side of the No. 1 mine dump adjacent to an earthen dam which is located near the No. 1 opencut, and contained white single crystals of topaz to 1 cm in diameter imbedded in fine-grained greenish sericite with small quantities of violet sericite and bluish cleavelandite (Bland, pers. comm.).

Tourmaline. Euhedrons of this species were found sparingly as black flattened crystals of small size forming sprays in some muscovite books. The muscovite encloses them completely and they have not grown along later splits in the books as has been previously noted in the case of quartz. Tourmaline was also identified as minute acicular transparent euhedrons of dark brown color within colorless apatite crystals from which it was readily isolated by dissolving the apatite in hydrochloric acid. Nearly colorless fibers occur in vugs in cleavelandite and some specimens consist of matted filiform fibers which resemble some of the bavenite, as reported by Mitchell (1964).

Zircon. Metamict zircon crystals are relatively common in the blocky albite associated with microlite, columbite, apatite, muscovite, pyrite, and spessartine. Very small prismatic individuals, less than 1.5 mm thick, and not more than 1.5 cm in length, occur in radiate sprays. The forms are $m\{110\}$ and $p\{111\}$ and the crystals are commonly flattened along a pair of $m(110)$ faces (Figure 7). The crystals are lustrous and dark brown in color except in narrow zones near the terminations where the mineral becomes transparent and pale brownish-yellow in hue (Figure 7). A partial analysis furnished by J. J. Glass (pers. comm.) shows that this variety contains 54 percent ZrO_2, 28 percent SiO_2, with some of the remainder 0.11 percent U_3O_8, 0.40 per cent TbO_2, and yttrium rare earths.

A second variety of zircon forms larger crystals which grow as isolated prismatic individuals ranging from 1.5 to 6 mm thick and up to 4 cm long (Figure 7). The exterior zones consist of pale brown earthy material with a dull luster but the cores are very dark brown to nearly black pitch-like material. In broken crystals the cores display an excellent conchoidal fracture surface with resinous luster. This variety is described by M. E. Mrose (pers. comm.) as follows: "Brown prismatic crystals . . . were studied by X-ray powder and single-crystal diffraction methods. The crystals, originally suspected of being fergusonite, gave metamict powder patterns; but precession patterns were obtained indicating a zircon-type mineral with the following cell data: tetragonal, $I4_1/amd$; $a=6.60\pm0.01$A, $c=6.02\pm0.01$A. This data coupled with X-ray fluorescence analysis (H. Rose) shows the material to be an Fe-rich zircon. The crystal habit, which is unusual for zircon, consists of the forms $m\{110\}$ and $e\{011\}$; with large (110) and $(\bar{1}\bar{1}0)$ and small (110) and $(\bar{1}10)$. In some specimens (101) is very large while the other second-order pyramids are narrow, giving a monoclinic appearance to the crystals."

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