PARAGENESIS OF THE RHODOLITE DEPOSIT, MASONS MOUNTAIN, NORTH CAROLINA

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Abstract

A coarse gneissic rock, which occurs on Masons Mountain, Macon County, North Carolina, and consisted originally of rhodolite and hypersthene, was partly transformed, by metasomatism, into anthophyllite-biotite gneiss. Later solutions, which developed quartz and sillimanite with minor rutile and graphite, accompanied pegmatites that contain quartz, feldspar, biotite, kyanite, staurolite, muscovite, and graphite. Both kyanite and staurolite are apparently pyrogenic in origin. The mineralization appears to have been localized along a fault.

Introduction

The rhodolite garnet localities in Macon County, North Carolina, are about six airline miles north of Franklin, along the flanks of Masons Mountain, a nearly east-west ridge on the east side of the Little Tennessee River. The ridge, which is heavily timbered and covered by brush, has few outcrops, and a deeply weathered mantle obscures the country rock. Most of the rocks underlying the surrounding area are rather uniform in petrology, consisting chiefly of two types, hornblende gneiss (Roan formation) and biotite gneiss (Carolina formation). Kyanitic gneisses are present locally, and corundum gneiss is known from the headwaters of nearby Cowee Creek. Numerous muscovite pegmatites that transect these rocks are related to large intrusives of Whiteside granodiorite-quartz diorite that occur to the southeast in the Highlands-Cashiers area.

The rhodolite variety of garnet was first discovered about 1883 in the gravels of Masons Branch and Cowee Creek together with a rich and unusual suite of detrital minerals: quartz, pyrope, corundum, pleonaste, gahnite, hypersthene, cordierite, kyanite, sillimanite, biotite, hornblende, staurolite, rutile, ilmenite, chromite, zircon, gold, pyrite, chalcopyrite, nickeliferous pyrrhotite, sphalerite, sperrylite, monazite, cyrtolite, and anthophyllite (Hidden and Pratt 1898*A* and 1898*B*, Judd and Hidden 1899, and Henderson, 1931). In the Cowee Creek gravels rhodolite has been found perched on corundum crystals (Judd and Hidden, 1899, 326).

At least three occurrences of the rhodolite in place are known. The first, described by Hidden and Pratt (1898*B*, 468) is one-half mile north of the placer workings near the summit of Masons Mountain. A ledge-like outcrop of rhodolite-biotite rock contains abundant sulfides and traces of sperrylite. A second nearby occurrence was explored by Burnham S. Colburn of Biltmore, North Carolina, in the early 1930s and has been described by Henderson (1931). Here a dike-like mass of rhodolite-anthophyllite (called gedrite) -hypersthene-biotite rock was exposed over a width of 15–20 feet. The anthophyllite from this locality has been restudied by Rabbitt (1948).

Neither of these localities appears to be the one examined by the writer in the spring of 1948, for the rocks found contain abundant sillimanite in addition to the many of the above constituents. This locality is near the west end of the ridge, just east of a newly opened pegmatite quarry (Shepherd vermiculite mine). Pratt (1933) also states that rhodolite was found in gravels "and in the gneissic rocks in several places on this mountain." The writer is indebted to M. V. Denny of the Department of Mineralogy, University of Michigan, for several photographs and to the Department itself for defraying the cost of the thin sections required in this study. E. P. Henderson, of the U. S. National Museum, kindly reviewed the manuscript.

The workings consist of two cuts, of which only the eastern exposes hard rock. This opening, which is ellipsoidal in plan and has a narrow entryway at the southwest end, is 75 feet long in a N. 45°E. direction, 40 feet across, and 60 feet deep at the northeast face. Much of the upper part is in decomposed rock, but fresh gneiss is exposed near the bottom. The gneissic foliation as exposed on the center of the southeast wall strikes N. 65° E. and dips steeply southeast, but in the entryway it strikes N. 70° W. and dips 80° NE. Thus it appears that the mineralized zone has been developed along either a fault or along the fractured axis of a sharply folded syncline that plunges steeply eastward. In view of the continuance of the zone southwestward, it seems more likely that a fault has been the localizing structure. Henderson (1931, 564) states for the Colburn locality " . . . the rhodolite-gedrite rock has been intruded along a fault where there has probably been some displacement." The second cut $30 \times 20 \times 15$ feet in size, adjoins the larger opening at the southwest end; however, no fresh rock is exposed in it.

RHODOLITE ROCKS AND ASSOCIATED ROCKS

The rock types exposed in the cut may be grouped together as follows:

1. Pegmatite and quartz vein material.
2. Rhodolite rocks.
    (*a*) Rhodolite-quartz rock with accessory graphite.
    (*b*) Biotite-rhodolite-quartz gneiss with variable amounts of hypersthene and anthophyllite.
    (*c*) Biotite-rhodolite-sillimanite gneiss with variable amounts of quartz and anthophyllite.
3. Anthophyllite-rhodolite-quartz gneiss with variable amounts of sillimanite and biotite.

4. Anthophyllite-quartz gneiss.
5. Biotite-anthophyllite gneiss with variable amounts of sillimanite.

These rocks are only the main types present and represent a somewhat arbitrary grouping, for the varieties intergrade over short distances. The texture is commonly coarsely gneissic and the foliation is due largely to mineralogical banding, although rocks rich in anthophyllite (type 4) are somewhat schistose in structure, with well oriented amphibole blades. The outstanding features of the exposures are the mineralogical variability and the heterogeneous distribution of the rock varieties. Pods, lenses, and irregular segregations of the various rock types are common, and contacts between units are gradational.

The most conspicuous rocks are those containing abundant rhodolite. Coarse rhodolite-quartz aggregates occur as ragged, pod-like masses, as much as 6–8 inches long, in somewhat finer-grained biotite-rhodolite-quartz gneiss. Some of the pods contain as much as 60–70% garnet, in a subordinate interstitial network of quartz. The rhodolite shows its distinctive rose-lavender color and is clear but fractured. Irregularly rounded grains, $\frac{3}{4}$ inch or less in diameter, were observed. According to Pratt (1933) the largest piece of gem rhodolite ever found weighed $43\frac{1}{2}$ carats, and the largest cut stone weighed $13\frac{3}{8}$ carats. Between the garnet grains and the quartz are brilliant, $\frac{1}{8}$ inch spangles of graphite. Clumps of dark reddish brown biotite flakes and a few ragged crystals of olive green hypersthene, one-half inch long, also occur in the segregations.

The matrix in which the pods are set is somewhat less coarse-grained, contains less garnet, and ranges from strongly gneissic to granoblastic in texture. It varies in composition from biotite-garnet gneiss with hypersthene, quartz, and graphite through biotite-anthophyllite-garnet gneiss, to anthophyllite-biotite gneiss with minor garnet. Some of the anthophyllite occurs as blades more or less normal to the contacts of the garnet-rich pods. Sillimanite becomes abundant locally as tufts and sinuous films of white fibers, $\frac{1}{2}$ inch long.

Thin sections of these rocks yield detailed textural evidence on the mineral paragensis. Garnet, colorless in the thin slices, forms large ragged poikiloblastic grains enclosing quartz, biotite, and anthophyllite. Quartz is the most abundant of the inclusions, which are commonly confined to central parts of the garnet grains. This quartz, in contrast to the more abundant late quartz, shows no strain or flamboyant structure. Minute seams of chlorite replace garnet.

Several types of veins cut broken garnets. Anthophyllite appears in monomineralic veins as the earliest of the transecting minerals. The pale golden brown amphibole, which commonly forms coarse subhedral prismatic blades, is unoriented to rather well-oriented. Rocks in which anthophyllite predominates contain garnet only as very small, strongly corroded specks.

A second generation of veins contains biotite, quartz, and a few ragged anthophyllite relicts. In general biotite is later than anthophyllite, for the mica follows grain boundaries of the amphibole and corrodes adjoining blades. It also replaces anthophyllite along cleavages. Most of the quartz of the veinlets crystallized after biotite. This is shown by the restriction of biotite to the margins of some veins, i.e., against garnet, whereas quartz occupies the central parts. The marginal mica flakes have feathery contacts against the quartz.

Both the anthophyllite and biotite veins in garnets are abruptly transected, in some places at right angles, by veinlets and streaks of sillimanite or of quartz and sillimanite. Disseminated sillimanite prefers to replace biotite. In the banded gneisses sillimanite is confined to the biotite layers and does not occur in anthophyllite-rich parts. It forms fringes of small fibers around the margins of biotite flakes or lies along biotite-anthophyllite grain contacts. Aggregates of sillimanite prisms contain relict shreds of biotite. Sillimanite commonly forms euhedral crystals or crystal groups, coarse-grained and poorly oriented. Most of it is associated with abundant quartz in quartz-sillimanite bands and lenses in which coarse euhedral grains of rutile are locally abundant. Rutile also forms vein-like structures across and within garnet and along anthophyllite cleavages and grain margins.

Other quartz-sillimanite bands contain parallel graphite flakes as well as rutile, and some graphite also has been developed along anthophyllite cleavages. The quartz of these layers usually shows conspicuous flamboyant structure, wavy extinction, a good orientation and minutely sutured contacts. It resembles vein quartz that has been somewhat metamorphosed. At least some of the sillimanite is later than quartz, for "trains" of small sillimanite crystals follow zones of fracturing in granulated quartz. In general, rocks that contain abundant quartz also contain much sillimanite but very little biotite.

Rounded zircons occur in garnet, anthophyllite, biotite, and quartz. Hypersthene is closely associated with coarse garnet and forms large ragged grains replaced by biotite and anthophyllite.

All these highly variable rock types are cut by veinlets of quartz, sillimanite, and quartz-sillimanite. Some of the quartz veins are three inches thick and contain specks of magnetite. Fibers of white sillimanite, $\frac{1}{4}$ inch long, also are plastered against the sides of fractures cutting across the gneissic structure.

Near the entryway, a pegmatite zone, four feet thick, consists of three stringers that coalesce upward into a two-foot sill along the foliation of the gneisses. Mottled blue to white kyanite blades, 0.1×0.3 inch in size, are scattered throughout the central parts of the sill. Quartz, kaolinized feldspar, and biotite flakes partly altered to vermiculite also are present. The kyanite blades are randomly oriented; a few are curved. Locally clusters of tightly interlocking, generally parallel blades form fist-sized masses.

From the above relationships it is apparent that the rhodolite-bearing rocks and their associates have undergone several transformations. Amongst the earliest minerals that remain are rhodolite and hypersthene. The unstrained quartz and the zircon probably antedate some of the garnet, for they appear as inclusions in the central parts of the rhodolite. Much anthophyllite appears to have formed at the expense of garnet. It veins that mineral, and anthophyllite-rich rocks contain only small rhodolite relicts. The chemical compositions of the rhodolite and anthophyllite are very similar (Henderson, 1931), except that the anthophyllite has a lower FeO content. It seems likely that rhodolite and hypersthene were metasomatically transformed into anthophyllite and biotite. This change requires chiefly the subtraction of iron and silicon and the addition of hydroxyl and aluminum.

The second stage was marked by the introduction of solutions that became increasingly rich in silicon and replaced much of the earlier rock substance with quartz, minor rutile, and a trace of graphite. During the final phases aluminum was introduced and sillimanite was formed, mainly at the expense of biotite. These later stages coincided with the intrusion of the kyanite pegmatites and the formation of the quartz veins.

KYANITE-STAUROLITE PEGMATITE

About 200 feet southwest of the rhodolite occurrence a new bulldozer cut (Shepherd mine) has been dug to mine vermiculite. The cut, which is 200×300 feet in plan and about 40 feet deep at the face, is largely in decomposed biotite gneiss. Near the bottom of the face a zone of pegmatite dikes trends N. 30° W. and dips 45° NE. Eight dikes, ranging in thickness from one to four feet, are exposed over a 20-foot width. The country rock, a dark fine-grained biotite gneiss containing a few grains of pink garnet, has been converted to a granoblastic aggregate of fine-grained vermiculite, around and between the pegmatites.

Exposures of some of the pegmatites show no kyanite, but other dikes are locally rich in the mineral. The chief constituents are clear to milky quartz and kaolinized white feldspar. Pegmatites with abundant kyanite contain more quartz than feldspar. Some dikes have small core pods of massive white quartz or of "burr rock"—massive quartz studded with

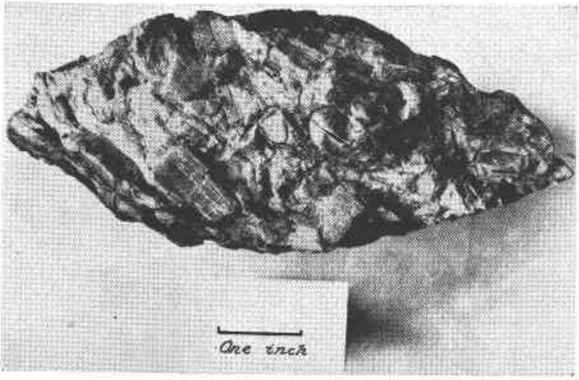

FIG. 1. Kyanite pegmatite from Shepherd mine, Masons Mountain, North Carolina. The warped strip in the right central part of the specimen is biotite. Other blades are kyanite in quartz-kaolinized feldspar matrix.

small, subparallel muscovite books. Biotite plates several inches across are not uncommon. Locally a dark reddish brown mineral occurs rather abundantly in pods as long as two inches. In the field it was thought to be garnet, but microscopic examination shows it is staurolite. Further search of the specimens revealed a perfect staurolite crystal, one-half inch across with the typical flattened, eight-sided cross section and brilliant prism faces. Reexamination of kyanite pegmatite from the rhodolite cut (described above) also disclosed several minute staurolite grains. Indices and pleochroism of the staurolite are:

$\alpha=1.739$, pale yellow
$\beta=1.744$, pale orange
$\gamma=1.749$, golden orange

Most of the staurolite is unusually free of inclusions or alteration, but a few grains show typical quartz-inclusion structure.

Kyanite, in blades as much as three inches long and an inch wide, varies from pale blue to deep blue. Some of the smaller blades show a tendency toward subparallel orientation, but the larger are randomly arranged (Fig. 1). Others are curved and broken. Kyanite developed after biotite, for some blades bisect the

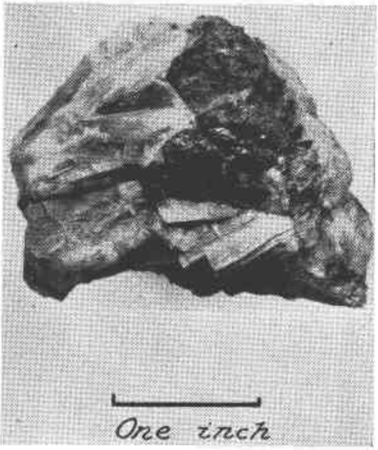

FIG. 2. Anhedral staurolite (dark) molded between kyanite blades, Shepherd pegamite, Masons Mountain, North Carolina.

large mica plates. Staurolite, which crystallized after kyanite, is molded against the latter (Fig. 2) and sends off thin stringers into kyanite blades. Some staurolite has been granulated.

Small spangles of graphite are disseminated through parts of the pegmatites. Scattered vugs, ¼ inch across, are stained by manganese and iron oxides and may have formed through destruction of some of the kaolinized feldspar.

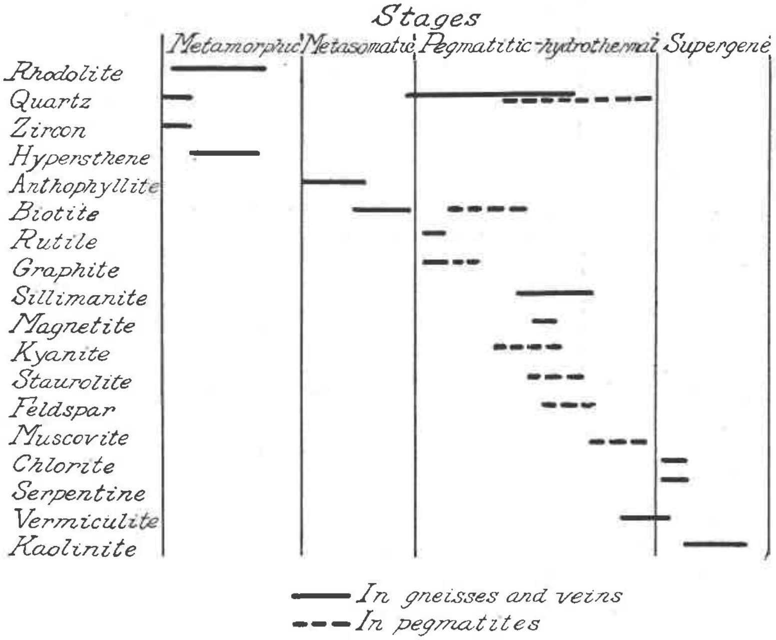

FIG. 3. Schematic diagram showing paragenetic sequence of the minerals of the rhodolite deposits and associated pegmatites, Masons Mountain, North Carolina.

CONCLUSION

This deposit represents one of the few recorded occurrence of coarse staurolite as an important pegmatitic constituent. A few other examples of staurolite in pegmatites are known (for example, Laubman and Steinmetz, 1920, Scholz, 1925 and Frondel, 1940), but the mineral appears to be either xenocrystic or metamorphic in origin. The writer has also recently found staurolite in kyanite-quartz veins in a kyanite-staurolite schist in the pre-Beltian Cherry Creek Series along Cherry Creek, Madison County, Montana. This occurrence may be analogous to that cited by Chapman (1946), who describes quartz veins, some with staurolite and others with staurolite concentrations in the immediate wall rock, in staurolite schist of the Littleton formation in west-central New Hampshire.

If any country rock material was assimilated by the Shepherd pegmatites, the process took place at depth before the pegmatite magma was intruded up to its position of crystallization, for the wall rocks are staurolite-free. There is no doubt that these dikes represent the southwestern continuation of the pegmatite zone exposed in the entryway to the rhodolite cut. Probably the aluminous pegmatites and the solutions that produced the quartz-sillimanite mineralization had their origins in a common source. It is interesting to note that kyanite crystallized in the pegmatites and sillimanite formed in the wall rocks, yet conditions of pressure and temperature could not have been radically different. The complete paragenetic sequence of the minerals in the gneisses as well as those in the pegmatites is shown in figure 3.

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