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# COMPOSITE APLITE-PEGMATITES OF THE FRANKLIN-SYLVA DISTRICT, NORTH CAROLINA[1]

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Abstract

The Franklin-Sylva district of southern North Carolina contains a number of multiphase, composite, aplite-pegmatite intrusions of tonalitic-granodioritic composition. In several examples it can be demonstrated that the periods of crystallization of the aplite and pegmatite overlapped. The general age sequence of intrusion has been: 1. batholiths of Whiteside tonalite-granodiorite, 2. dikes of aplitic tonalite-granodiorite, 3. dikes of granodioritic-tonalitic pegmatite and 4. dikes of aplitic tonalite-granodiorite. In this district the periods of generation and expulsion of aplitic and pegmatitic fractions overlapped, and the finer and coarser phases of the composite intrusions are not the result of differing intramural conditions during crystallization.

## General Geology

The Franklin-Sylva mica pegmatite district, the second largest in the southeastern United States, both in number of mines and prospects and in total mica production, is chiefly in southwestern North Carolina (Haywood, Jackson, Transylvania, Macon and Clay Counties), with its southeastern part extending southwestward into Rabun County, Georgia (Griffitts *et al.*, 1946; Olson *et al.*, 1946; Heinrich, 1950). The district is underlain chiefly by various regional metamorphic rocks which, in the past, have been lumped into two petrologically simplified mappable units: the Carolina "formation"—dominantly biotitic gneiss, and the Roan "formation"—mainly hornblende gneiss and amphibolite (Keith, 1907A, B). The Carolina gneiss, which is the most widespread unit, actually contains a wide variety of rocks, principally of metasedimentary origin (Heinrich, 1950, 1951) (Table 1). The Roan gneiss is less variable (Table 2). Some of its hornblende gneiss units occur as large lenses or narrow layers in Carolina gneisses which are, in places, garnetiferous against the Roan rocks. Thus at least some of the Roan gneiss bodies probably represent metamorphosed sills and dikes of gabbroic composition.

Post-metamorphic bodies of ultramafic rocks (Table 3) have been intruded into both the Carolina and Roan gneisses. In several places pegmatites cut these ultramafic intrusives. Although unmetamorphosed, some of the sheet-like bodies may have been folded during a Paleozoic (?) period of deformation (Miller, 1953).

The principal igneous rock is the Whiteside tonalite (Keith, 1907B) which occurs in plutons as large as 18 miles (NE-SW) and as wide as 5

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TABLE 1 ROCK TYPES OF THE "CAROLINA GNEISS"

| |
|---|
| *Biotite rocks:* |
| Biotite gneiss and schist |
| Biotite-garnet gneiss |
| Biotite-muscovite gneiss ± garnet |
| Feldspathic biotite gneiss |
| *Quartzose rocks:* |
| Quartz-biotite gneiss ± garnet |
| Garnetiferous quartzite |
| Spinel-bearing quartzite |
| *Kyanite-sillimanite rocks:* |
| Kyanite gneiss ± garnet or staurolite |
| Kyanite-sillimanite gneiss and schist |
| Sillimanite-biotite gneiss and schist ± garnet |
| Sillimanite-muscovite-quartz schist |
| *Garnet (rhodolite) rocks:* |
| Rhodolite-biotite-quartz gneiss ± hypersthene |
| Rhodolite-biotite-sillimanite gneiss |
| *Anthophyllite rocks:* |
| Anthophyllite-rhodolite-quartz gneiss ± sillimanite |
| Anthophyllite-quartz schist |
| Biotite-anthophyllite schist ± sillimanite |
| *Corundum rocks:* |
| Hornblende-corundum gneiss |
| Corundum-garnet gneiss |
| Corundum-kyanite gneiss |
| Chlorite-corundum schist |
| *Carbonate rocks:* |
| Marble |
| Graphitic marble |

miles in the southeastern part of the district. The general dip of the elongate plutons is to the northwest, with most of their consanguineous pegmatites lying to the northwest of the tonalite outcrop areas, i.e., above the hanging wall side of the plutons (see Olson *et al.*, 1946, Pl. 1). Most of the major pegmatites occur in flanking metamorphic rocks, but small, unzoned to indistinctly zoned, muscovite-poor pegmatites are numerous locally in the marginal parts of the Whiteside intrusives.

Dikes or other satellitic bodies of granodiorite-tonalite are not abundant throughout most of the district where pegmatites are common,

TABLE 2. ROCK TYPES OF THE "ROAN GNEISS"

| |
|---|
| Primary |
| Hornblende gneiss and schist ± garnet |
| Amphibolite |
| Granet amphibolite |
| Actinolite schist |
| Secondary |
| Chlorite schist |
| Vermiculite schist |

*i.e.*, at considerable distances from the contact of the Whiteside plutons. Most of these non-pegmatitic dikes are narrow (3 in.–7 ft.) and belong to two main types:

1. Rare porphyritic granodiorite with medium-grained biotite or oligoclase in a finer-grained matrix of orthoclase, oligoclase, quartz, muscovite and biotite.
2. Fine-grained to aphanitic leuco-granodiorite-tonalite, aplitic to slightly gneissiod in texture. It is this rock type that shows varying relations to pegmatites, and it is the purpose of this paper to describe and explore these relationships.

## NATURE OF THE PEGMATITES

Discordant pegmatites are nearly twice as numerous as concordant bodies, and both types commonly intrude rocks of the Carolina gneiss.

TABLE 3. ROCK TYPES OF THE PERIDOTITE BODIES

| |
|---|
| *Magmatic:* |
| Dunite |
| Troctolite |
| Troctolite-hornblendite |
| Harzburgite |
| Enstatolite |
| Websterite |
| *Metasomatic:* |
| Serpentinite |
| Edenite amphibolite |
| Hornblendite |
| Chlorite rocks |
| Vermiculite rocks |
| Albite-corundum veins |

On the basis of their internal structure those pegmatites that are well exposed may be grouped as follows:

| | % |
|---|---|
| 1. Unzoned | 22 |
| 2. Bi-zonal (border and wall zones) | 6 |
| 3. Poly-zonal (3 to 6 zones) | 69 |
| 4. Composite aplite-pegmatites | 3 |

About 87% of the polyzonal pegmatites have cores of massive quartz; quartz-microcline, microcline and quartz-muscovite cores also occur. Secondary units, such as fracture fillings or replacement bodies are especially rare.

In many of the pegmatites oligoclase exceeds microcline. Thus many pegmatites are granodioritic in composition. Some lack essential microcline; or microcline is entirely absent, and these are tonalitic. Only a small percentage has a truly granitic composition. The accessory species (Heinrich, 1950) are few and not abundant: pyrite, pyrrhotite, chalcopyrite, biotite, garnet, apatite, magnetite and albite; all others are very rare. Conspicuously rare are tourmaline and beryl, minerals which are characteristic accessories of pegmatites of truly granitic composition.

## Aplite-Pegmatite Relations

In addition to several occurrences of simple aplitic dikes (Table 4) i.e. those whose relative ages with respect to pegmatites are indeterminable, there are three age groups of aplites:

1. Those distinctly older than pegmatite. These are transected by pegmatite or occur only as xenolithic blocks within pegmatite.
2. Composite aplite-pegmatite intrusives.
3. Those distinctly younger than pegmatite.

*Pre-pegmatite aplite.* In the middle-level workings of the Iotla-Bowers mine in Macon County are exposed irregular lenses and dikes of aplite which strike N. 30–40° W., dipping at varying angles either NE or SW. These are cut by pegmatite stringers. At the Spruce Ridge and Island Ford mines near Tuckaseegie in Jackson County the aplites and pegmatites show similar relationships.

Table 4. Examples of Aplitic Intrusives not Associated with Pegmatites

1. Road cut near former Gay Post Office on old Sylva highway (formerly U. S. 23). A 6-inch dike along a fault; drag folds in the gneiss border the dike.
2. Oxner mine, Jackson County. A gray aplitic sill near the portal of the lower adit.
3. Ammons mine, north of Sylva, Jackson County. A 2-foot sill follows the foliation of biotite-muscovite gneiss.
4. Diller Bryson mine, north of Sylva, Jackson County. A 6-foot sill strikes NE and dips steeply NW.

At several localities pegmatites that were intruded into gneisses carried up with them angular xenoliths of aplitic tonalite or granodiorite. The Upper Putnam pegmatite in Haywood County elevated xenoliths of aplitic granodiorite, several inches to a foot thick and as long as 10 feet. Part of the pegmatite crystallized at the expense of the finer grained rock, for blades of pegmatitic biotite extend across the contact into aplite for short distances. The occurrences of blocky xenoliths of aplitic granodiorite in the Lower Lyly Knob pegmatite near Franklin in Macon County is shown in Fig. 1.

*Post-pegmatite aplites.* Dikes of granodiorite or tonalite along fractures or faults transect pegmatite at the Putnam (Fig. 2), Sally Reed, Berry and Bee Tree No. 1 mines. At the Bee Tree No. 1 (Transylvania County) the porphyritic tonalite contains oligoclase phenocrysts ($Ab_{76}$) in a fine-grained gneissoid matrix of quartz, oligoclase, biotite, muscovite and accessory apatite, zircon and magnetite.

## Composite Intrusives

The composite intrusives consist of a combination of pegmatite and aplite that appear to be essentially contemporaneous or penecontemporaneous. In most of these, contacts between the two rocks are conformable in general, but may be discordant in detail. The periods of crystallization of the two appear to have overlapped, usually with that of the pegmatite continuing slightly beyond that of the aplite.

*Moss pegmatite.* The Moss composite dike, near Webster in Jackson County, has a core of aplitic tonalite with flanking zones of pegmatite (Figs. 3, 4). Locally thin pegmatitic stringers extend across aplite along 45° shear fractures (Fig. 3). Elsewhere the outer parts of the aplitic core display fracturing developed during reopening of the aplite-biotite gneiss contacts along which the pegmatite was then intruded.

The tonalite consists chiefly of plagioclase (zoned), quartz, biotite and muscovite with accessory apatite, magnetite, garnet, zircon, allanite, pyrrhotite and microcline. Locally microcline becomes essential (20–25%), and in these variants the plagioclase is more sodic. Near contacts with the similarly tonalitic pegmatite, the plagioclase of the aplite is sericitized and replaced by calcite, and its biotite is almost entirely muscovitized. The plagioclases of the two rocks contrast:

| | |
|---|---|
| Pegmatite (younger) | $Ab_{88}$ |
| Aplite (older) | $Ab_{75-82}$ (usual range) |
| | $Ab_{69-84}$ (entire range) |

*Tilley pegmatite.* The Tilley pegmatite lies between hanging-wall biotite

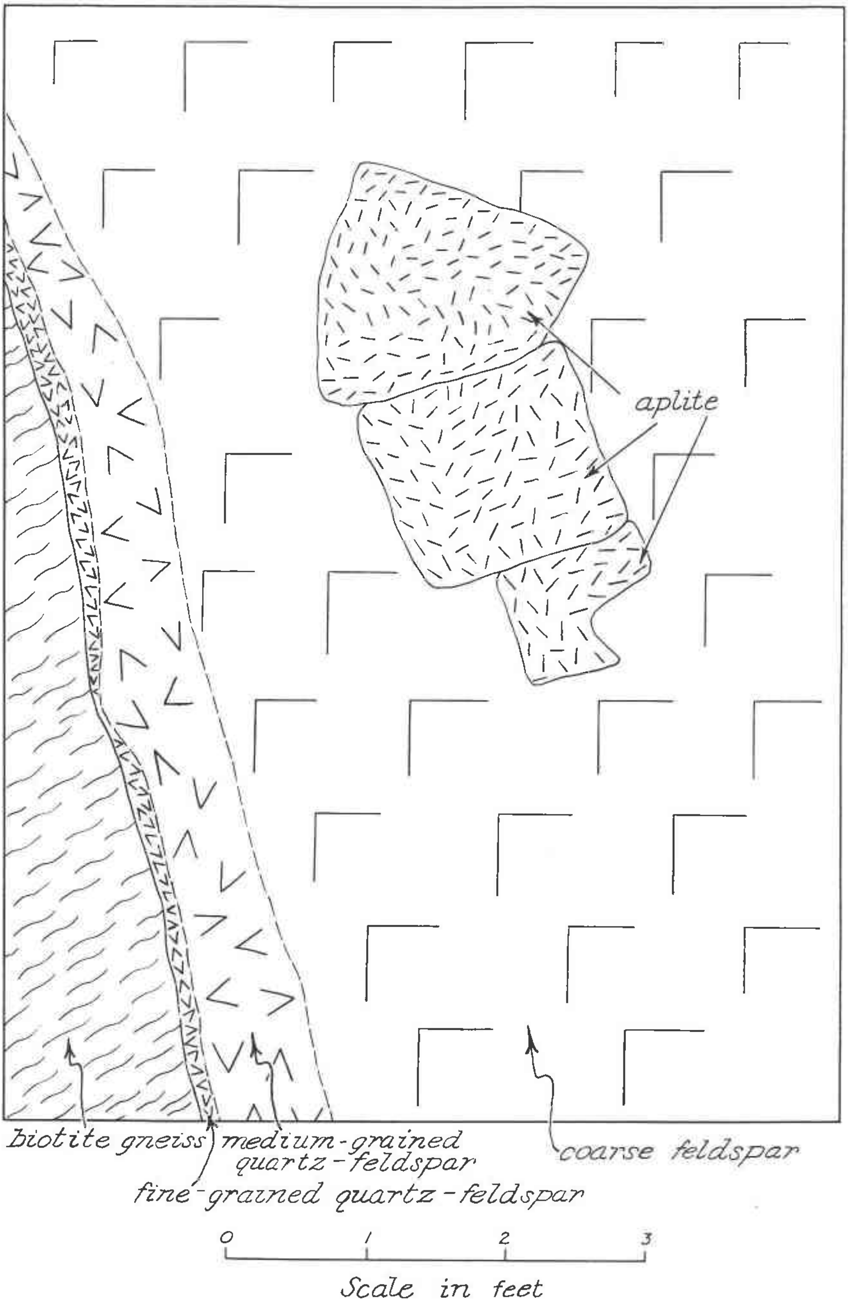


FIG. 1. Xenoliths of aplitic tonalite in the Lower Lyle Knob pegmatite. Franklin-Sylva district, N. C.

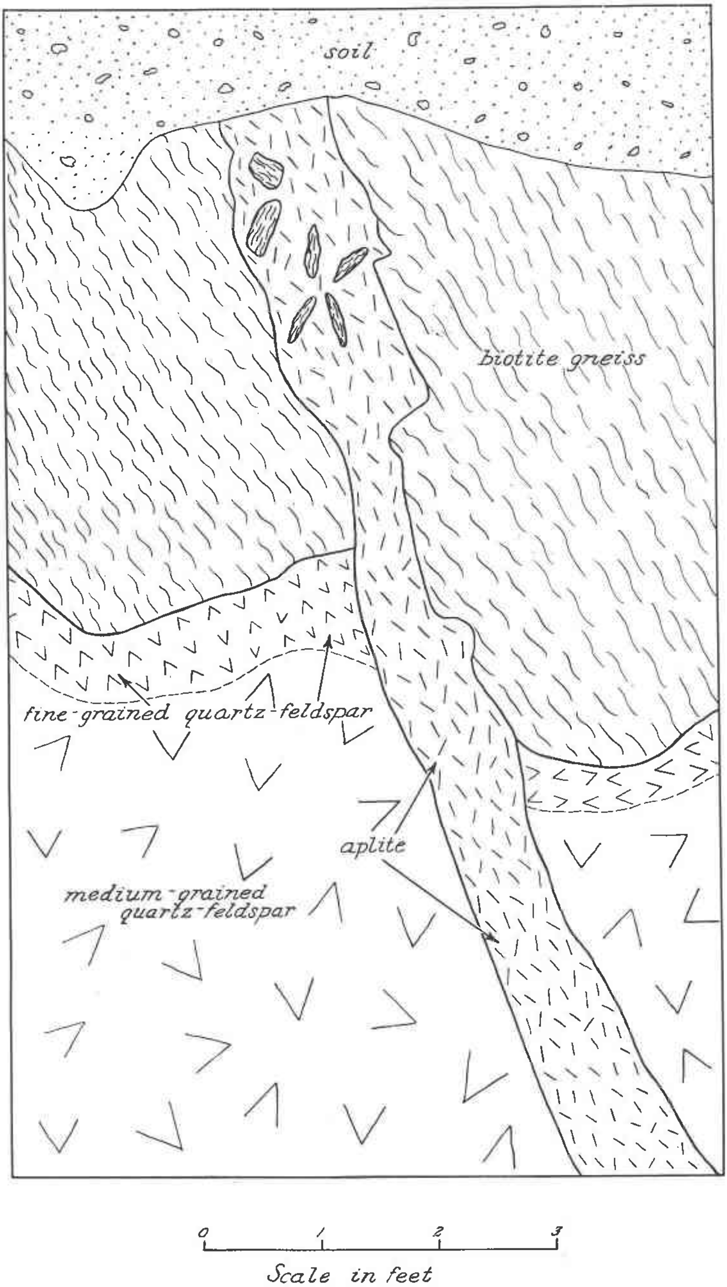


FIG. 2. Dike of granodiorite aplite cutting Putnam pegmatite along a fault. Franklin-Sylva district, N. C.

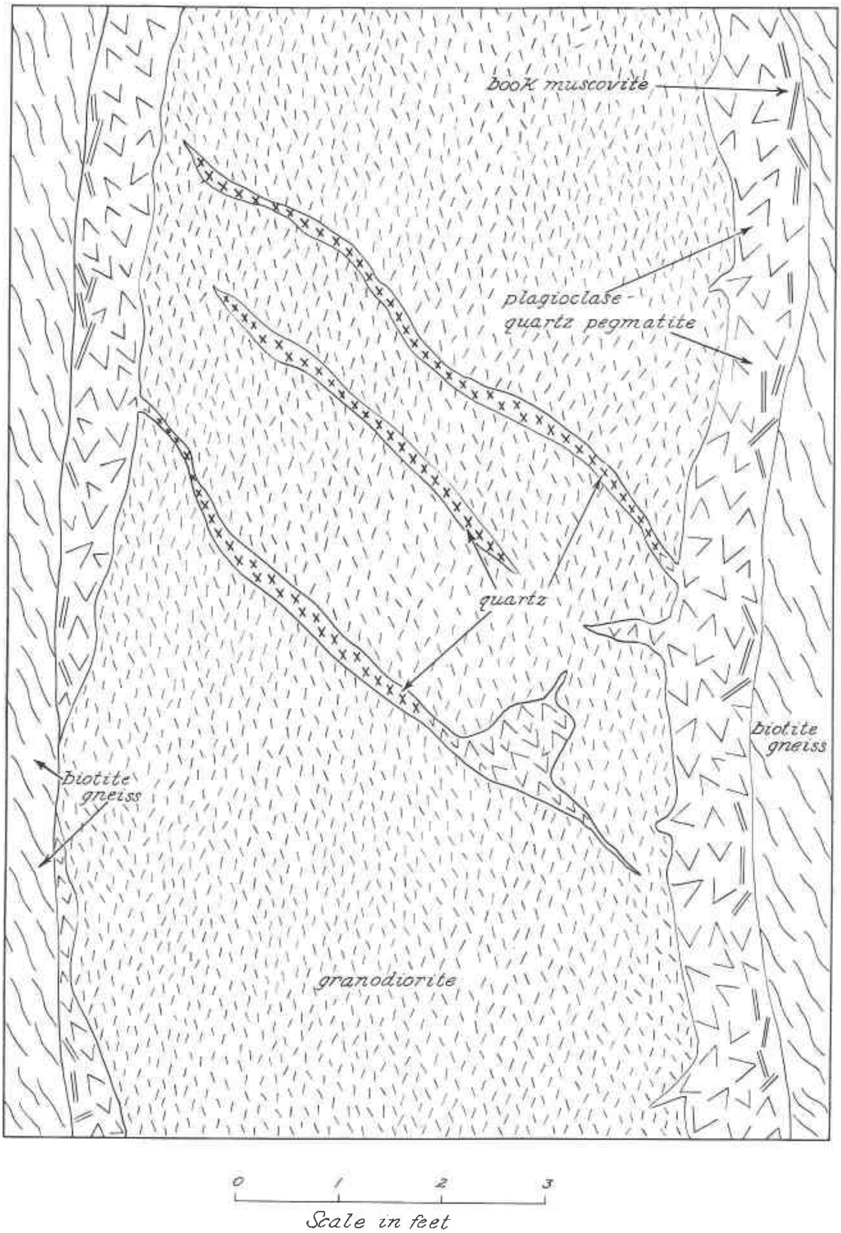


FIG. 3. Pegmatite stringers transecting granodiorite in composite pegmatite-aplite intrusive. Moss mine, Franklin-Sylva district, N. C.

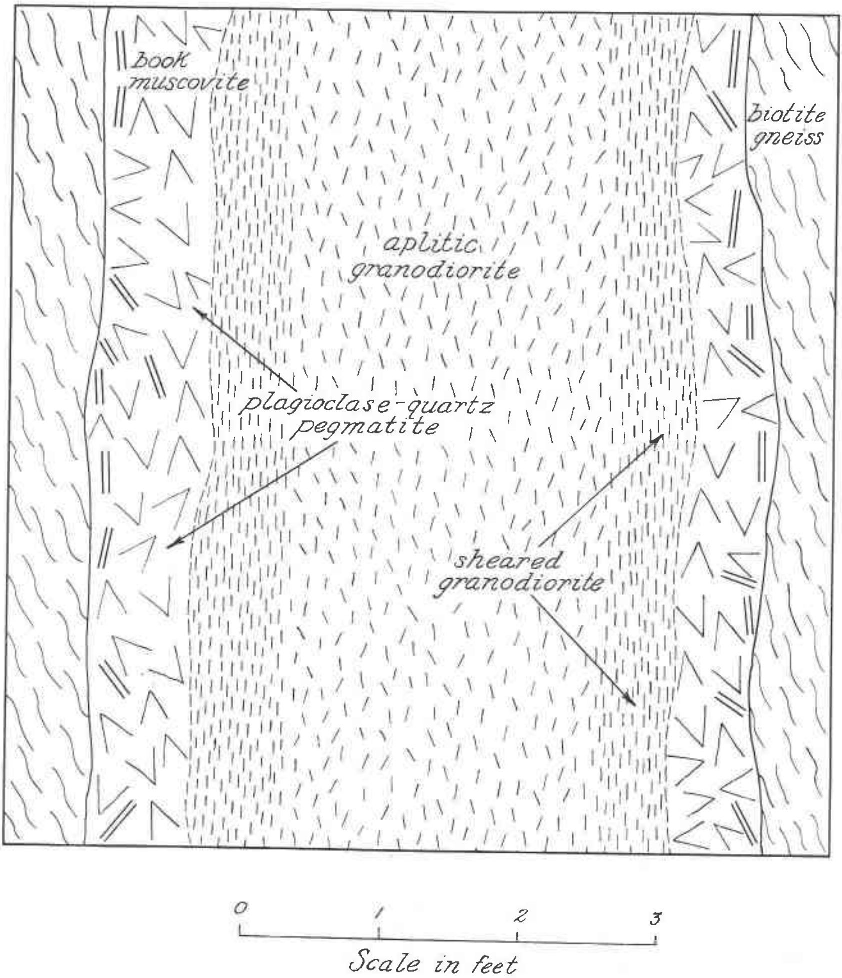


FIG. 4. Composite pegmatite-aplite. Moss mine, Franklin-Sylva district, N. C.

gneiss and footwall aplitic tonalite (Fig. 5). Clusters of books of muscovite that lie mainly along the pegmatite footwall appear to have grown into the tonalite. The tonalite contains quartz, plagioclase ($Ab_{78-83}$), biotite, muscovite and accessory apatite, zircon and magnetite. Microcline, which is usually accessory, may be essential locally. Muscovite replaces some of the biotite; the rest may be chloritized. The plagioclase is slightly sericitized, traces of calcite also are present. The plagioclase of the tonalitic pegmatite is slightly more sodic ($Ab_{85}$) than that of the aplite.

*McCrary pegmatite.* The McCrary composite intrusive, near Sealy, Macon County, has, like the Moss, a central unit of aplitic texture flanked by zones of pegmatite. The periods of crystallization of the two appear to have overlapped. Each of the marginal, mirror-image pegmatite units is itself zoned with a border zone of fine-grained quartz-oligoclase rock, a poorly defined zone of book muscovite and an interior zone of coarse oligoclase with some microcline (Fig. 6). The oligoclase crystals

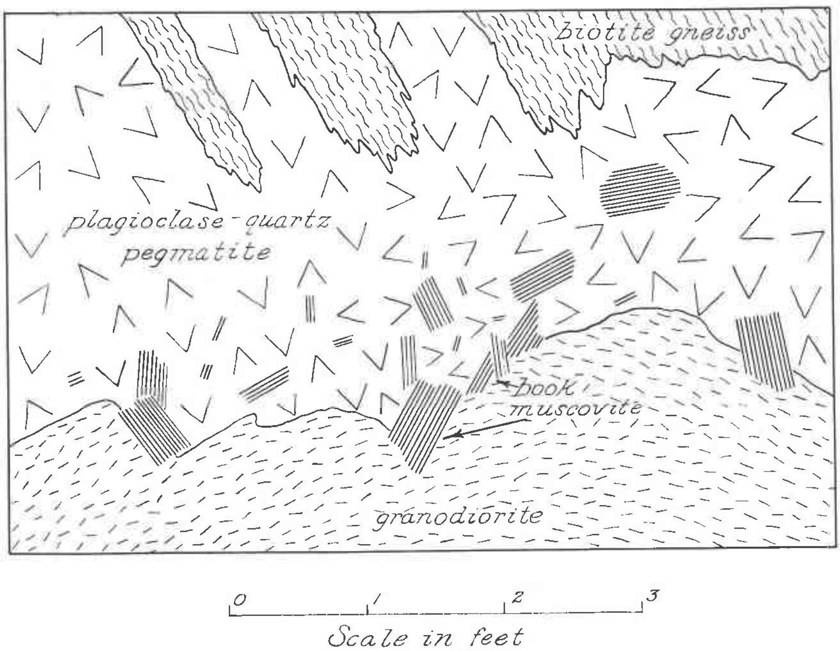


FIG. 5. Pegmatite localized along gneiss-granodiorite contact. Tilley Mine, Franklin-Sylva district, N. C. Note partial replacement of granodiorite by large muscovite crystals.

project euhedrally into the "core" of aplitic tonalite. These euhedra are sheathed by accumulations of fine flakes of biotite. These relationships are interpreted as follows:

1. Intrusion of tonalitic pegmatite magma.
2. Crystallization of border and wall (mica) zones of the pegmatite.
3. Beginning of crystallization of the oligoclase-rich intermediate zones.
4. Flushing out of remaining central, probably highly siliceous, pegmatite fluid which normally might have crystallized as a quartz core.
5. Injection of tonalitic aplitic magma

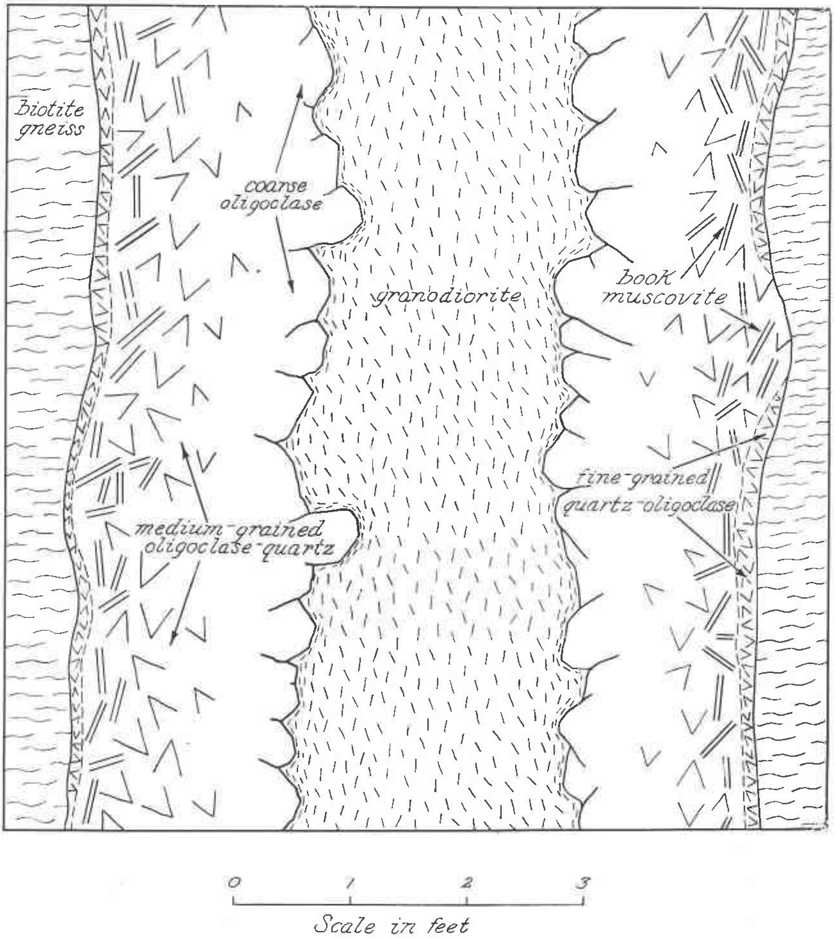


FIG. 6. Composite pegmatite-aplite. McCrary pegmatite, Franklin-Sylva district, N. C.

6. Continued growth of the intermediate zone oligoclase crystals into the feldspathic tonalitic fluid with crystallization of biotite representing rejection of iron and magnesium-rich material by the encroaching plagioclase.

The slightly younger age of some of the aplite also is attested to by local thin stringers of aplite that not only transect the pegmatite but continue outward as sills into the biotite gneiss wall rock.

The zoned plagioclase of the aplite ranges from $Ab_{65}$ to $Ab_{83}$, whereas that of the pegmatite has the composition $Ab_{88-93}$.

*Wolf Creek pegmatite.* The Wolf Creek pegmatite dike in Jackson County contains large pods and lenses of granitic rock. Against these pods books of pegmatitic muscovite have crystallized in a comb-structure pattern.

*Big Ridge pegmatite.* The Big Ridge pegmatite near Waynesville in Haywood County has been one of the largest and principal mica-producing mines[1] of the United States (Olson *et al.*, 1946). It is also one of the most unusual pegmatites of the world in structure. Its form is that of an irregular, elongate, inverted bowl (Fig. 7) which occupies the contact between generally overlying (or outer) biotite gneiss and the top of an underlying stock of aplitic tonalite. The only other pegmatite of similar structural localization known to the writer is the Stockscheider of Geyer-Greifenstein and Aue in Saxony (Stelzner, 1865; Vogt, 1931). This four meter-thick granitic pegmatite, locally accompanied by aplite, is, like the Big Ridge, a "skull cap" that fits over the top of a granite stock, with mica schist forming the outer, hanging-wall rock.

Part of the Big Ridge pegmatite is asymmetrically zoned (Fig. 8). Adjacent to the hanging-wall gneiss is a thin, chilled-margin border zone of fine-grained oligoclase-quartz rock. The main or central unit is a medium-grained intergrowth of oligoclase, quartz, biotite and minor muscovite. Microcline is present but locally and in subordinate amounts, and in a few places short quartz core pods appear. Against the tonalite are concentrated large books of muscovite (18 inches max.) and biotite which, together with crystals of oligoclase and apatite, extend into the finer-grained rock. Some of the large mica crystals appear to be entirely within tonalite which they replaced. Along this footwall mica-rich zone the pegmatite locally grades into tonalite by means of a gradual decrease in grain size, a reduction in the amount of quartz, and an increase in biotite over muscovite. It is noteworthy that both the Big Ridge and the Stockscheider have sharp contacts with their metamorphic outer wall rock and, at least locally, gradational contacts with their inner granitoids.

Small inclusions of tonalite also occur locally in the Big Ridge pegmatite. These are characterized by having most of their biotite replaced by muscovite and their plagioclase by sericite and calcite. In a few places very thin dikes of aplitic tonalite transect the pegmatite. These are usually so fine-grained that they appear aphanitic ("felsite").

The mineralogy of the tonalite of the stock is very uniform: Quartz, oligoclase, biotite and muscovite are essential; the accessories include apatite, zircon, magnetite, epidote, microcline; sericite, calcite and chlorite are secondary. The post-pegmatite tonalite is very similar except

[1] Between 1922–1944, 436,000 pounds of sheet mica and 807,000 pounds of punch mica were obtained from this deposit.

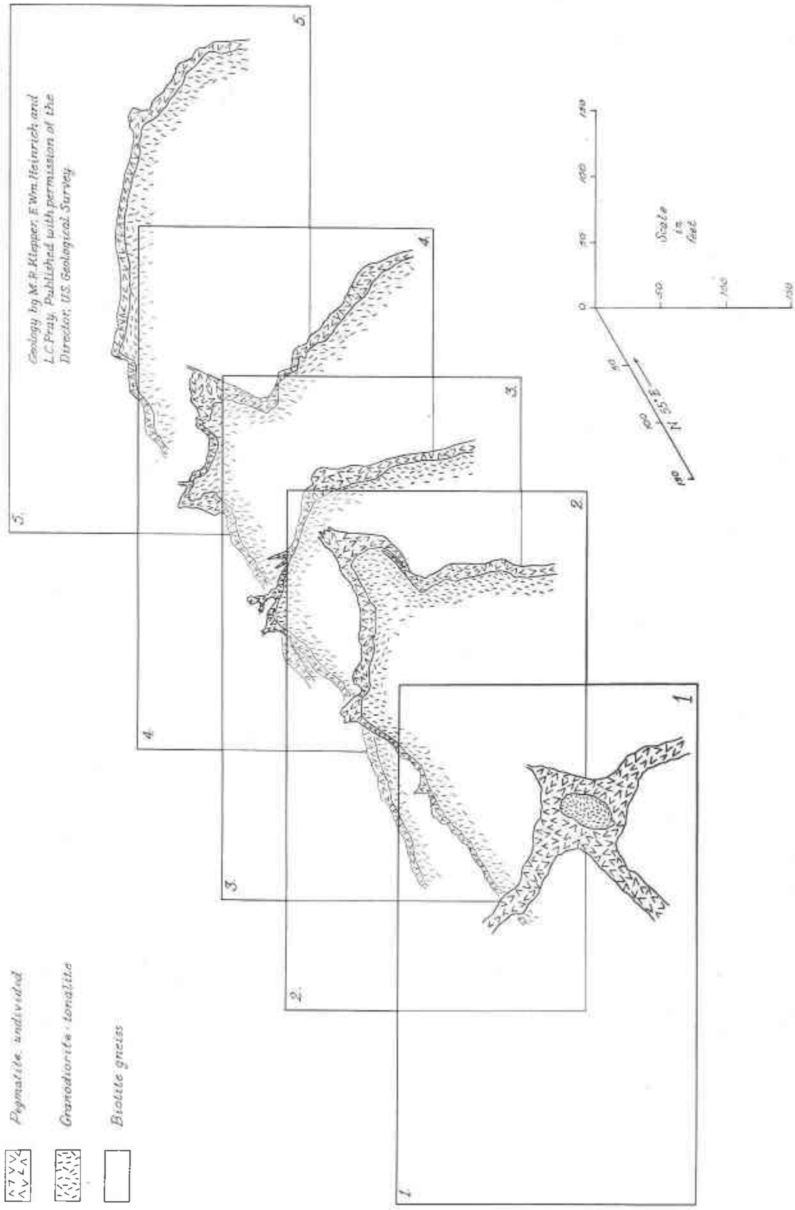


FIG. 7. Transparent-plate diagram in isometric projection of the Big Ridge pegmatite, Franklin-Sylva district, N. C.

that muscovite is more abundant and microcline appears to be entirely absent.

The plagioclases of the three tonalitic rocks have the compositions:

| | |
|---|---|
| Tonalite of the stock | $Ab_{76-78}$ |
| Pegmatite | $Ab_{77}$ |
| Post-pegmatite aphanitic tonalite | $Ab_{81-86}$ |

## Sequence of Igneous Rocks

From the general field relationships in the district and particularly

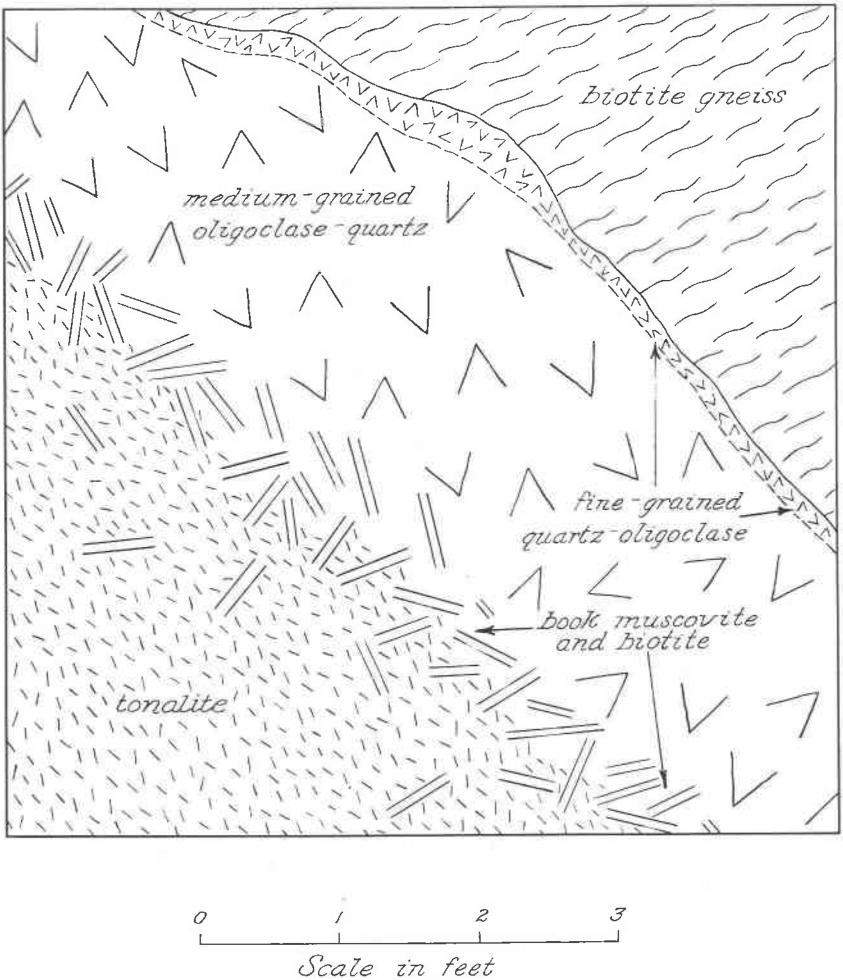


Fig. 8. Asymmetric zonal structure of the Big Ridge pegmatite, Franklin-Sylva district, N.C.

from the relationships at the selected deposits described above, the sequence of intrusive rocks in the Franklin-Sylva district has been:

1. Main batholiths of Whiteside tonalite-granodiorite,
2. Pre-pegmatite aplitic tonalite-granodiorite,
3. Pegmatite, chiefly granodioritic, some tonalitic,
4. Post-pegmatite aplitic granodiorite, tonalite, muscovite tonalite and porphyritic tonalite.

In some cases the crystallization periods of pegmatite and aplite overlapped.

## Discussion

The various problems of aplite-pegmatite relationships have been summarized by Jahns (1955). Bodies of pegmatite-aplite " . . . representing single injections of magma followed by segregation during crystallization" have been scrutinized in detail by Jahns and Tuttle (1963) who conclude that " . . . the pegmatite is ascribed to crystallization of magma saturated in volatile constituents and the aplite to rapid crystallization of magma during escape of such constituents."

The composite aplite-pegmatites of the Franklin-Sylva district differ from those studied by Jahns and Tuttle (1963) in these respects:

1. Neither is granitic and neither has a bulk composition that falls in the thermal valley of petrogeny's residua system.
2. The bodies are multiphase intrusions, not the result of intramural processes that succeeded a single intrusion, albeit the time interval between injections in some examples appears to have been short indeed.
3. In the Franklin-Sylva composite intrusions the pegmatitic phase either has plagioclase of the same composition as the aplitic phase or slightly more sodic plagioclase, irrespective of which is the older. In only one case, the Big Ridge, a few minute dikes of aphanitic tonalite contain a plagioclase more sodic than that of the pegmatite they transect.

We are concerned here therefore with the closely timed appearance of two types of material of essentially identical composition (as we find them now), intruded at the same levels under identical conditions, and derived from the same source. Yet they differ spectacularly and abruptly in grain size.

In only one other respect are the two different, and that is in their effect upon their walls. Pegmatite wall rocks show various types of mineral transformations and metasomatic effects. One of these is muscovitization produced in xenoliths of aplite included in the pegmatite. No exomorphic effects occur around aplites, either in gneissic or pegmatitic wall rocks.

It can be concluded that if these aplites, like those of Jahns and Tuttle (1963) are indeed " . . . quenched rocks . . . the result of a 'pressure quench'," owing to the escape of volatiles and a responsive rise in the liquidus temperature with "crystallization in flood," then the escape of volatiles did not occur at the place of intrusion and therefore not shortly before "crystallization in flood." In contrast the coarser pegmatites *do* show effects that demonstrate the escape of volatiles *in situ*. This is not to argue that the mechanism proposed by Jahns and Tuttle (1963) is invalid for the type of pegmatite-aplites they describe, but rather that it is not applicable in this case.

For the Franklin-Sylva composite aplite-pegmatites, whose intrusions were related in time, it can be postulated that the period of generation of and expulsion of pegmatitic magma overlapped with the terminal stages of intrusion of normal tonalitic magma.

Composite, multi-phase intrusions of aplite-pegmatite are certainly not rare (see, for example, Vogt, 1931[1]; Preiswerk, 1931; Jahns and Tuttle, 1963). In several districts alternating intrusions of aplite and pegmatite have been found. In the Kimberley mine of South Africa, for example, the sequence deciphered by Schwarz (1914) is:

1. Pegmatite
2. Aplite
3. Pegmatite
4. Aplite

Nor is a variable time relationship of pegmatite formation to granite emplacement unknown. Cornwall pegmatites of three different time relationships have been found by Hosking (1952): 1. Pegmatites formed before granite emplacement. 2. Pegmatites formed during granite emplacement. 3. Pegmatites formed after consolidation of granite. Some of the intrusions of the last category are themselves composite aplite-pegmatite bodies.

## Acknowledgments

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[1] Recently restudied by Reitan (1965) who concludes the pegmatites originated through secondary recrystallization of associated aplite.

tional Grant No. 39. Mr. Richard W. Vian assisted in the petrographic examinations. The U. S. Geological Survey gave permission to publish Fig. 7, which is the product of joint mapping by M. R. Klepper, L. C. Pray and the writer.

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