Alfred M. Moncla, III. PETROGRAPHY, GEOCHEMISTRY, AND GEOCHRONOLOGY OF THE ROCKY MOUNT BATHOLITH, NORTHEASTERN NORTH CAROLINA PIEDMONT. (Under the direction of Dr. Richard K. Spruill) Department of Geology, April, 1990.

ABSTRACT

The post-metamorphic Rocky Mount batholith (478 km^2) is located along the Fall Line in the northeastern North Carolina Piedmont. Two intrusions comprise the batholith. One intrusion (gray granitoids) with a color index of 5 to 25 is represented by medium-grained microcline megacrystic hornblende biotite granodiorite to biotite granite and rare biotite tonalite and varieties of quartz monzodiorite. Leucocratic (color indexes less than 5), medium-grained equigranular monzogranites (white granites) comprise a second intrusion. Textures within the white granites adjacent to contacts with gray granitoids indicate that the white granite intruded the gray granitoids. Contacts between the white granites and the gray granitoids are straight to irregular. Mineral changes at some of the contacts may indicate some reaction between the two magmas. A third lithology, hornblende biotite tonalite, is found in the northern portions of the batholith. However, relations of these rocks with the others is unknown. These are the most mafic rocks of the batholith and may be a part of the gray granitoids or may represent a third intrusion.

Rocks of the batholith are peraluminous [Al/(Ca+Na+K)

ranges from 1.06 to 1.28] and exhibit typical calcalkaline differentiation trends on an AFM plot and a plot of K_2O-Na_2O-CaO. The batholith is generally more mafic than the late Paleozoic post-metamorphic granitoids defined by Speer and others (1980). Petrograhic data and linear trends exhibited by the gray granitoids on Harker plots indicate that these rocks evolved predominantly by fractional crystallization, possibly in combination with magma mixing or unmixing processes as well. Chemical data indicate that the less siliceous hornblende biotite tonalite from the northern portions of the batholith may be related to the gray granitoids. The white monzogranites are generally homogenous but have great modal, chemical, and textural variability near contacts with the gray granitoids. This variability may be due to both mechanical differentiation and late-stage, water-rich crystallization.

A subsolidus mineral assemblage consisting of chlorite, phengite, and epidote indicates greenschist facies conditions. However, the occurrence of these minerals is not pervasive, and the mineral assemblage may have formed during cooling of the batholith and not during greenschist-grade metamorphism. Strained quartz is the only pervasive deformational texture.

A crystallization age of 345+/-1 Ma is interpreted for the batholith based on Rb-Sr whole-rock data of samples from all three lithologies. The low initial 87Sr/86Sr ratio of 0.70444 indicates a common source of either upper mantle/lower crustal material or rapidly recycled upper crustal material for the batholith. Rb-Sr mineral ages (biotite, 318+/-3 Ma) and K-Ar mineral ages(hornblende, 355+/-8 Ma; biotite, 337+/-8 Ma; and microcline, 202+/-5 Ma) indicate rapid cooling of the batholith.

The Rocky Mount batholith was produced by the approximately contemporaneous crystallization of two (or three) distinct magmas generated from similar sources. Early genetic relationships between the two magmas cannot be determined due to complex evolutionary histories of both intrusions, although chemical data indicate some relationships may exist. The Rocky Mount batholith is older and, based on mineralogical as well as chemical data, more mafic than the late Paleozoic post-metamorphic granitoids (Speer and others, 1980) and may represent the earliest magmatic pulse of the Alleghanian orogeny. The lack of pervasive deformation and metamorphism of the batholith and the relatively old mineral ages suggest that the East Carolina Slate Belt east of the Hollister mylonite zone was not affected by the late Paleozoic tectono-thermal event which conspicuously affected the Raleigh belt.

PETROGRAPHY, GEOCHEMISTRY, AND GEOCHRONOLOGY OF THE ROCKY MOUNT BATHOLITH, NORTHEASTERN NORTH CAROLINA PIEDMONT

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by

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INTRODUCTION

At least thirty syn- and post-metamorphic granitoids crop out in the southern Appalachian Piedmont in a belt trending from Georgia to Virginia. Ages and metamorphic histories of these granitoids have been instrumental in defining the Late Paleozoic orogenic event in the southern Piedmont (Butler and Ragland, 1969; Fullager and Butler, 1979; Snoke and others, 1980; Farrar and others, 1981; Glover and others, 1983; Farrar, 1985a and b; and Russell and others, 1985a, Secor and others, 1986a and b).

The Rocky Mount batholith is located at the eastern edge of the exposed portion of the Eastern Carolina Slate Belt (ECSB), in North Carolina (Figure 1.a). The batholith is covered by Atlantic Coastal Plain strata that thicken from zero to seventy meters southeastward, and exposure of the batholith is limited to outcrops near the western margin of the intrusion along Tar River and Swift Creek and to quarries.

This study is a broad characterization of the petrography, geochemistry, and metamorphic history of the Rocky Mount batholith. It incorporates extensive sampling of quarries, outcrops, and eight new drillcores, petrographic analyses of eighty-five thin-sections, major and trace element analyses of forty whole rocks, analyses of minerals, field descriptions, and K-Ar and Rb-Sr isotopic analyses.

PREVIOUS INVESTIGATIONS

Brief descriptions of granitic rocks in the Rocky Mount area can be found in publications by Watson and Laney (1906), Mundorff (1946), Councill (1954), and Parker (1968). Farrar (1980) first delineated the boundary of the batholith using published drilling logs (Mundorff, 1946), gravity (Department of Defense, 1976) and aeromagnetic (USGS) data. He sampled outcrops along the Tar River and Swift Creek, and a 420 foot core (RM-1) drilled in the center of a -30 milligal Bouguer gravity anomaly. Rock types ranged from biotite monzogranite through biotite hornblende tonalite. Based on petrography and mineral chemistry, Farrar (1980) concluded that the Rocky Mount batholith is more mafic than other post-metamorphic granitoids of the southeastern Appalachian Piedmont.

Sinha (1980) determined a zircon Pb-Pb age of the batholith of 368+/-4 Ma. This age date indicated that the batholith is older than the Late Paleozoic syn- and post-metamorphic plutons of the southeastern Piedmont (Fullager and Butler, 1979). Major element analyses of six whole rock samples from the RM-1 drillcore indicated that the batholith contains < 1% normative corundum and is lower in Na_2O+K_2O and higher in CaO than other post-metamorphic plutons from the southeastern Piedmont. Sinha (1980) called for partial melting of "high-grade rocks" or a substantial basaltic component to produce these chemical characteristics.

Using Farrar's (1980) boundaries, Speer and others

(1984) calculated a surface area of approximately 470 km^2 for the Rocky Mount batholith. They also noted that a well-defined -15 to -20 milligal Bouguer gravity anomaly with respect to the surrounding ECSB indicated a minimum thickness of 5 to 8 km for the batholith. The western boundary of the batholith may be mylonitized as suggested by a linear magnetic high in that area (Speer and others, 1984).

Lawrence and others (1987) produced a Bouguer gravity map of the Rocky Mount area (Figure 1.b). The batholith appears as a gravity "low" occupying the central part of the map and a pattern of alternating "highs and "lows" representing the ECSB metavolcanic and metasediment sequences to the north and west. A well-defined gravity gradient marks the approximate boundary on all but the eastern central side. Modelling is difficult because of heterogenous density distributions within the batholith and country rock. Lawrence and others (1987) calculated that the thickness of the batholith ranges from four to twelve kilometers and suggested that contacts of the batholith with country rock are steep. The approximate boundary of the batholith shown in Figure 1.c is based on reported drilling logs (Mundorff, 1946), outcrops, and modelling of the gravity data by Lawrence and others (1987). The possible eastern extension of the batholith (Figure 1.c) is based solely on gravity data (Lawrence and others, 1987). Surface area of the batholith is estimated at 478 km^2 (591 km^2 if the eastern extension is included).

SAMPLES AND ANALYTICAL TECHNIQUES

Eighty-one samples of the batholith were collected from quarries, outcrops, and drillcores located along the Tar River and Swift Creek drainage basins (Figure 1.c). Rock types found at the various locations are discussed in the Petrography Section. Coordinates of sample locations are listed in Appendix I. Most of the sampling and field observations were performed at the active Nello L. Teer, Rocky Mount Plant quarry (q1) where exposure of the batholith is best. Other sample locations along the Tar River drainage basin include an abandoned and inundated quarry (q2), and two outcrops along the banks of the Tar River. Three outcrops along the banks of Swift Creek and one of its tributaries were sampled. Eight two-inch diameter drillcores were obtained with a drilling rig owned by the Geology Department of East Carolina University. Rocks of the batholith were recovered from two of the drillcores located near Swift Creek (c3 and c4, tonalites) and one located near Tar River (c5, undifferentiated weathered granite). Rocks obtained from the remainder of the drillcores included diabase (c1 and c8) or metamorphic country rock (c2, c6, and c7).

Modal analyses were determined by counting 375+/-50 points on 26 by 46 millimeter petrographic thin sections stained with sodium cobaltinitrite. Chemical compositions of minerals were analyzed using the ARL-9 Spectrometer Microprobe at Virginia Polytechnic and State University.

Concentrations of major and trace elements were analyzed by x-ray fluorescence, atomic absorption, and UV-VIS spectrophotometry at the geochemical laboratory at East Carolina University. Standard curves were based on USGS rock samples. The K-Ar and Rb-Sr age dating was performed respectively at the Laboratory of Isotope Geochemistry , University of Arizona and the University of North Carolina using samples provided by the author.

PETROGRAPHY

The Rocky Mount batholith is comprised of two major and several minor lithologies distinguished on the basis of color, modal variations, contact relations, and texture. Leucocratic granitoids with color indexes less than five range in modal composition from monzogranite to quartz alkali feldspar syenite (Table 1, Figure 2) and are referred to as _white granites_. More mafic rocks (color indexes between five and twenty-five) range in modal composition from rare hornblende biotite tonalite and quartz monzodiorite through biotite tonalite and hornblende biotite granodiorite to biotite granite (Table 1, Figure 2) and are referred to as the _gray granitoids_. Contacts between the white granites and the gray granitoids range from intensely convoluted to straight. Locally, rocks at the contacts have zones (up to 10 cm) of either biotite altered to chlorite, or coarse-grained zones composed chiefly of biotite and potassium feldspar. The white granite exhibits local increases in grain size and igneous foliation defined by modal layering which parallels the contacts. Hornblende biotite tonalites (other tonalites, Table 1, Figure 2) may represent a third major lithology, but the field relations of these rocks with the others are unknown. These rocks are the most mafic rocks of the batholith.

Locations of the various rock types are listed in Table 1 and shown on Figure 1.c. Rocks along the Tar River consist of approximately equal proportions of white granites and gray granitoids with rare occurrences of the hornblende biotite tonalite. Along Swift Creek, hornblende biotite tonalite is the dominant lithology, although gray granitoids and white granites also may be found. The RM-1 drillcore is comprised mainly of the gray granitoids and rare hornblende biotite tonalite and white granites (Farrar, 1980).

White Granites

The white granites are dominantly homogenous, massive, medium-grained monzogranites (Table 1, Figure 2). Less abundant rock types found at contacts with gray granitoids include syenogranites, alkali feldspar granites, and alkali feldspar quartz syenites. White granites may also be pink in color due to either the abundance of potassium feldspar or hematite formed by deuteric alteration. A slight foliation defined by biotite is rare. Plagioclase is anhedral to subhedral (1 to 5 mm), and the potassium feldspar is slightly megacrystic (1 to 7 mm) microperthitic microcline. Pleochroic yellow to brown biotite occurs most commonly as singular crystals (up to 1.5 mm) dispersed throughout the rock and as small (0.2 mm) inclusions in microcline and makes up as much as three percent of the rocks. Quartz (1 to 5 mm) exhibits undulose extinction and local recrystallization. Rarely biotite flakes appear bent and plagioclase grains broken. Magnetite and assemblages of allanite and bastnaesite are common in the granites. However, in the quartz alkali feldspar syenite, clusters of larger magnetite grains (1 cm) and clusters of larger allanite and bastnaesite assemblages (individual grain sizes are 1 to 5 cm) are common. The allanite may be embayed by quartz and fractures in the host rock may be abundant due to decay of radioactive elements within the allanite. Other accessory minerals include titanite, zircon, and apatite.

The white granite changes in texture and mineralogy near some of the contacts with the gray granitoids. In these cases an igneous foliation defined by alignment of minerals and modal layering is developed. Layers range in composition from near normal monzogranite to either plagioclase- or potassium feldspar-rich zones to monomineralogic bands consisting of either potassium feldspar, plagioclase feldspar, or quartz. Maximum thickness of the compositional layers observed is one meter. Grain size and amount of potassium feldspar increases with the degree of mineralogic segregation. Similarly, microcline and plagioclase become more euhedral with increasing grain size. The quartz alkali feldspar syenites may contain either potassium feldspar or albite (Mineralogy Section) and are the coarsest-grained of all the rocks (largest observed potassium feldspar crystals were 20 cm).

Gray Granitoids

The gray granitoids are most commonly comprised of hornblende biotite granodiorite and biotite granite (Table 1, Figure 2). Other rock types include common biotite tonalite and rare hornblende biotite tonalite and quartz monzodiorite. Granodiorite grades into biotite granite over broad areas as potassium feldspar becomes more abundant. Contacts among the other lithologies of the gray granitoids are either concealed from view or are difficult to discern in the field and presumably occur over shorter intervals. Therefore, the inclusion of the biotite tonalites, hornblende biotite tonalite, and quartz monzodiorite as members of the gray granitoids is somewhat tenuous. The gray granitoids are generally medium-grained, equigranular to potassium feldspar megacrystic and locally exhibit an igneous foliation.

Hornblende (1.5 to 3.0 mm) is subhedral to euhedral and is pleochroic: yellow-brown, yellow-green, to blue-green. Grains are commonly twinned, poikiloblastic, and locally color-zoned. Hornblende accounts for up to three and eight modal percent in the biotite granite and granodiorite, respectively. Finer-grained varieties of granodiorite and biotite granite contain more quartz and no hornblende. Granoblastic hornblende also occurs in rare mafic clumps within biotite tonalite. Quartz monzodiorites contain either biotite or euhedral hornblende as the only ferromagnesium mineral. Biotite (up to 3 mm) is pleochroic yellow to brown and occurs as groups of euhedral crystals in mafic clumps. In some cases biotite appears pseudomorphed after hornblende. Biotite is the only ferromagnesium mineral in most biotite tonalites and accounts for as much as twenty-five percent of the rock. Biotite content of the granodiorites and the biotite granites may be as much as fourteen and eleven percent, respectively.

Plagioclase feldspar (2 to 6 mm) is subhedral to anhedral. It locally shows oscillatory zoning in biotite granite and continuous zoning in hornblende biotite granodiorite and biotite tonalite. The minor microperthitic microcline in the biotite tonalite occurs as small (<1 mm) interstitial grains and as inclusions in plagioclase. In quartz monzodiorite microcline also occurs as large (2 cm) poikilitic grains. Microcline ranges in size from 6 mm to megacrysts of up to 4 cm in granodiorite, resulting in a microcline megacrystic texture. Also in the granodiorite are large (3 to 20 cm) pods of microcline crystals. The microcline (7 to 14 mm) in biotite granite is commonly poikiloblastic. Quartz exhibits undulose extinction and is locally recrystallized.

Titanite is the most abundant accessory mineral in the gray granitoids. Titanite occurs as large (1 to 2 mm), twinned, euhedral crystals locally embayed by hornblende, biotite, and quartz, and also as small (1 mm) anhedral poikilitic grains around biotite. It is also interlayered with biotite and occurs as inclusions in hornblende. Apatite is common as inclusions in plagioclase, biotite, and hornblende. Zircon and pyrite also occur as inclusions in the ferromagnesian minerals and zircon is notably larger (0.2 mm) in the hornblende quartz monzodiorite. Allanite is common but not abundant in the gray granitoids.

The RM-1 drillcore (lattitude 36°02.1' and longitude 77° 45.2', Figure 1.c) and two outcrops described by Farrar (1980) are gray granitoids. The 420-foot RM-1 drillcore consists mainly of hornblende biotite granodiorite with minor amounts of hornblende biotite tonalite and biotite granite. The hornblende biotite granodiorite is medium-grained, weakly to moderately foliated, and contains clots (autoliths or xenoliths) with abundant hornblende. Farrar's (1980) granodiorites are similar in texture, and accessory and trace minerals to granodiorites described here. The biotite granite is fine-grained and the hornblende biotite tonalite which is present as an autolith or xenolith is intensely altered. Farrar (1980) also sampled a tonalite containing more hornblende than biotite from the northwestern portion of the batholith and a biotite granite from outcrops along Tar River.

Tonalites at Swift Creek

Equigranular and medium-grained hornblende biotite tonalite is the dominant rock type along Swift Creek (Figure 1.c, Table 1). Petrography and mineralogy of the hornblende biotite tonalite is similar in most respects to other rocks of the gray granitoids. However, hornblende biotite tonalites along Swift Creek contain the greatest amounts (18 to 40%) of ferromagnesian minerals found in the batholith. Plagioclase feldspars in these rocks and in the biotite granites locally show oscillatory zoning.

Igneous foliation is more pronounced in these tonalites. Field relations between the hornblende biotite tonalite and other rocks of the batholith cannot be determined because of the limited exposure of the former. One sample of hornblende biotite tonalite from along the Tar River (q1) is in gradational contact with granodiorite and is therefore part of the gray granitoids. However, other tonalites at this sample location do not contain hornblende and the hornblende present in the sample exhibits a granoblastic texture unlike the subhedral to euhedral hornblendes of the tonalites along Swift Creek. Field relationships of the hornblende biotite tonalite collected at another locality along Tar River (q2) are unknown.

Subsolidus and Joint Mineralization

Subsolidus mineralization is not pervasive and appears to be more common in the white granites than in the more mafic rocks. Epidote is common in all of the rocks. Calcite, white mica, and epidote are present as saussuritization products of plagioclase. Epidote is also found replacing biotite, titanite, and bastnaesite. It commonly forms up to 0.5 mm thick, optically continuos rims on allanite and hornblende and may be twinned along the same plane as the host mineral. Chlorite is found replacing biotite either wholly or interlayered with the biotite; rarely it replaces amphibole. In the white granites the chlorite/biotite assemblage may also be accompanied by white mica. White mica is present mainly as small crystals on plagioclase grains. It is larger where associated with biotite, chlorite, or epidote. White mica is also found filling microcracks in some of the rocks. Other secondary minerals include calcite, hematite, and prehnite(?) filling microcracks in the rocks. Quartz and titanite fill cracks generated by radioactive decay of the allanite in the quartz alkali feldspar syenite. Bulbous and rim myrmekite are abundant in rocks containing appreciable amounts of potassium feldspar.

Pervasive joint sets which dip approximately vertically record brittle deformation which occured much later than crystallization. Sparry calcite is the most common joint coating, followed by epidote which occurs as fine-grained crystals or a dense cryptocrystalline mass, and rare medium-grained siderite. Prismatic quartz rarely occupies voids produced by joint propagation. Also present are curvilinear, subhorizontal fractures possibly produced by stress relief during unloading.

Other Rock Types

The batholith is intruded by aplite, pegmatite, and diabase dikes. Aplite dikes are monzogranites and syenogranites (Appendix II) and were observed in the gray granitoids only. These rocks are fine grained, foliated as defined by biotite, and contain abundant myrmekite imparting an almost granophyric texture to the rock. There is extensive subgrain development of quartz. Unlike the quartz in the granites and more mafic rocks, quartz in these rocks does not exhibit undulose extinction. Accessory and subsolidus minerals include allanite, garnet, magnetite, chlorite, epidote, and clinozoisite (?).

Pegmatites were observed in both gray granitoids and white granites. At one locality a pegmatite in the gray granitoids was truncated by the white granite. Pegmatites contain potassium feldspar, plagioclase, quartz, biotite, allanite, and garnet. Diabase was recovered from cores one and eight.

MINERALOGY

Compositions of nine amphiboles from a gray granitoid from sample location q1 are presented in Table 2. This amphibole is a potassian magnesian hastingsitic hornblende based on ferric/ferrous calculations as presented by the I.M.A. Subcommittee on Amphibole Classification (Leake, 1978). Amphibole from gray granitoids of the RM-1 drillcore analyzed by Farrar (1980) contain less Ca+Na+K and silica than those from gray granitoid of the Nello Teer quarry (Figure 3). Compared to amphiboles from the late Paleozoic granitoids (Speer and others, 1980), all amphiboles of the

Rocky Mount batholith are generally lower in Ca+Na+K and silica (Figure 3). Fe/(Fe+Mg) ratios are similar to those of amphiboles in other post-metamorphic granitoids (Speer and others, 1980).

Analyses of biotites from both the gray granitoids and white granites are presented in Table 3. Figure 4 shows that Fe/(Fe+Mg) ratios of the biotites from the gray granitoids are approximately 0.60 and are comparable to other biotites of the gray granitoids reported by Farrar (1980) and to biotites of the late Paleozoic granitoids (Speer and others, 1980). Biotites from the gray granitoids reported by Farrar (1980), however, do exhibit a wider range in Fe/(Fe+Mg) ratios (0.54 to 0.63). Biotites from white granites (Farrar, 1980) have Fe/(Fe+Mg) ratios of about 0.73, higher than those of biotites of the gray granitoids and the late Paleozoic granitoids (Speer and others, 1980). Biotites from white granites contain more aluminum and less titanium than biotites from the gray granitoids.

Plagioclase composition varies from rare sodic andesine (An_{31}) to common oligoclase (An_{21}) in gray granitoids and from andesine (An_{23}) to albite (An_4) in the white granites (Table 4). Plagioclase in hornblende biotite tonalite is andesine (An_{30}-An_{40}) based on optical determinations (Farrar, 1980). Anorthite content is less for plagioclase from biotite tonalite than from granodiorite. The albite is present in alkali feldspar quartz syenite. Other analyses of plagioclase (Farrar, 1980) are similar. Analyses of potassium feldspar (Table 4) are of the exsolved potassium feldspar portion of the microperthite.

Compositions of allanite and bastnaesite are listed in Table 5 and show high concentrations of cerium, lanthanum, neodymium, and yttrium. A composite analysis of both allanite and bastnaesite yielded 452+/-10 ppm uranium and 1.85+/-0.08 weight % thorium (Benninger, L., University of North Carolina, Chapel Hill, personal communication). Compositions of titanite from hornblende biotite granodiorite and biotite tonalite (gray granitoids) are similar (Table 6). However, iron substitution for titanium is greater for titanite from tonalite than from granodiorite. Apatite from the gray granitoids is a fluorapatite (Table 7).

The white mica is phengitic in composition (Table 8). Substitution of Fe+Mg in the octahedral site ranges from 23 to 27%. Interlayer cations are in a proportion closest to muscovite composition (94 to 98% K) with some substitution of Na(2 to 6%) and minimal substitution of Ca(0 to 1%). Chlorite analyses indicate compositions of brunsvigite and ripidolite (Hey, 1954) in gray granitoids and white granites, respectively (Table 8). Chlorites of gray granitoids from the RM-1 drillcore are ripidolites and brunsvigites (Farrar, 1980). Chlorites of white granites from outcrops along Tar River and the RM-1 drillcore are ripidolites (Farrar, 1980). The Fe/(Fe+Mg) ratio of chlorite is approximately equivalent to that of the mineral it replaces (Farrar, 1980). Compositions of the epidotes range from 16 to 33 mole %

pistacite and from 0.7 to 4.5 mole % piemontite (Table 9). Other reported epidote analyses are similar (Farrar, 1980). Filling cracks in some of the rocks is a larger-grained epidote showing anomolus blue interference colors. Although not analyzed, these epidotes may be of near end member clinozoisite composition.

GEOCHEMISTRY

Major and trace element analyses are presented in Table 10. All rocks of the batholith are peraluminous [Al/(Ca+Na+K) ranges from 1.06 to 1.28] and the gray granitoids are more peraluminous than the white granites. Collectively, the rocks exhibit typical calcalkaline differentiation trends (Figures 5 and 6). Figure 6 shows that the Rocky Mount batholith also contains rocks that are less evolved than those of the late Paleozoic plutons described by Fullager and Butler (1979).

The white granites and gray granitoids exhibit different trends on Harker plots (Figure 7). Regression lines calculated for the gray granitoids are linear for most elements. Ba, Rb, and Sr exhibit the greatest deviation from linear trends whereas Na_2O, K_2O, MnO, and Y exhibit less deviation from linear trends. Regression lines were not calculated for the tonalites of unknown relations and the white granites because of the small sample size and small compositional range, respectively. The tonalites lie near the silica-poor extension of the regression line for most elements. However, relative to the regression line the tonalites contain less MnO, Y, Na_2O, and Rb, and more TiO_2, Fe_2O_3, P_2O_5, CaO, and Sr. Although most of the white granites lie near the silica-rich extension of the regression line, some samples show marked differences in silica as well as the other elements. Greatest variation is observed for Ba and Sr contents of all samples of the white granites.

Chemical analyses of two aplite dikes and diabase recovered from drill core one are presented in Appendix II.

ISOTOPIC DATA

Isotopic data obtained as part of this study include three K-Ar mineral analyses (Table 11), eight whole-rock Rb-Sr and two mineral Rb-Sr analyses (Table 12). A summary of age determinations for samples from the Rocky Mount batholith is presented in Table 13. Whole-rock samples analyzed for Rb and Sr isotopes include three samples each of white granites and gray granitoids from the Nello Teer quarry(q1) and two samples of hornblende biotite tonalite of uncertain relations collected from the two drillcores near Swift Creek. A whole rock isochron using all eight samples yields an age of 345+/-1 Ma which is interpreted as the age of crystallization of the batholith (Fullager and Spruill, 1989). Separate isochrons constructed using only the gray granitoids or the white granites yield similar ages which cannot be distinguished with any degree of certainty (Fullager, P.D., University of North Carolina, Chapel Hill, personal communication). These isotopic data indicate that the gray granitoids and the white granites of the batholith crystallized approximately contemporaneously. The low initial 87Sr/86Sr ratio, 0.7044 (Fullager and Spruill, 1989), suggests a magma source of either upper mantle/lower crustal material or rapidly recycled upper crustal material. The zircon age of 368+/-4 Ma (Sinha, 1980) is approximately 23 Ma older than the presumed age of crystallization. However, zircon ages do not neccessarily reflect the age of the rocks in which they occur (Faure, 1977; Pidgeon and Aftalion, 1978). Zircon may crystallize prior to other minerals in a granitic melt (Poldervaart, 1956; Murthy, 1958) or may be inherited.

Mineral separates analyzed include biotite and plagioclase from a sample of gray granitoid, hornblende from another sample of gray granitoid, and microperthite from a sample of white granite. The Rb-Sr mineral isochron defined by biotite, plagioclase, and the gray granitoid whole rock yields an age of 318+/-3 Ma (Fullager and Spruill, 1989) indicating fairly rapid cooling following crystallization. K-Ar age dates calculated at the University of Arizona for the mineral separates are in a sequence that records cooling of the batholith (hornblende, 355+/-8 Ma > biotite, 337+/-8 Ma > microcline, 202+/-5 Ma). These dates are in general agreement with the Rb-Sr mineral age data.

DISCUSSION

Nature of the Batholith

The gray granitoids (possibly including the tonalites along Swift Creek) and the white granites represent two (or three) major lithologies which comprise the composite Rocky Mount batholith. Both lithologies exhibit broad ranges in modal and chemical composition which, along with mineral chemistry and bulk compositional evolution, differ between the two lithologies. Abrupt contacts between the two lithologies indicate that the various lithologies represent at least two separate intrusions. Mineral changes at some contacts indicate some reaction between the two magmas. Crystallization ages for both phases are the same, indicating approximately contemporaneous emplacement of the two magmas. Changes in texture and composition within the white granites near some of the contacts indicate that the white granite intruded the gray granitoids. Chemical trends exhibited by the gray granitoids and the white granites indicate different processes of magmatic evolution.

Magmatic Evolution

Gray Granitoids

The gray granitoids exhibit petrographic and mineralogic features which indicate several processes of magmatic evolution dominated by fractional crystallization. Zoned plagioclase and hornblende, apparent pseudomorphic textures of biotite after hornblende, granoblastic hornblende and variable amounts of tetrahedral aluminum in the hornblende all indicate changing magma compositions due to fractional crystallization. The variable amounts and size of microcline megacrysts and pods of microcline grains may represent remnants of assimilation or incipient segregation associated with magma mixing or unmixing.

Whole-rock chemical trends indicate various mechanisms of magmatic evolution for the gray granitoids as well. Linear trends exhibited by most major elements on the Harker plots (Figure 7) may indicate either magma mixing (Langmuir and others, 1978) or unmixing (White and Chappell, 1977). However, nonlinear trends exhibited by Na_2O, K_2O, and the trace elements indicate processes other than mixing. Fractional crystallization and partial melting may also produce linear trends depending on the range in composition observed and distribution coefficients of the elements (Wall and others, 1987). Langmuir and others (1978) suggest that inconsistent positioning of individual samples between two theoretical end members on element-element plots preclude mixing as the prime mechanism for magma evolution. Concentrations of Sr and Rb are variable, but general trends are consistent with fractional crystallization and not partial melting (Robb, 1983). The great variability in Ba concentrations indicate changing bulk distribution coefficients for the element during magma evolution (Hanson, 1978) predominated by fractional crystallization.

Although grouped with the gray granitoids, consanguinity of the biotite tonalites and rare quartz monzodiorites and hornblende biotite tonalites located along Tar River with the gray granitoids is conjectural. These rocks are grouped with the gray granitoids based on similarities in texture and mineralogy. However, plagioclases from these rocks contain a lower anorthite content than those from the other gray granitoids. Compared to other rocks of the gray granitoids, these rocks also are different in the following respects: lower K_2O, Ba, and slightly lower Sr; higher Na_2O, Al_2O_3, and MnO; and variable P_2O_5 contents. These rocks may have been emplaced as a separate magma or may represent the earliest crystallization products of the gray granitoid magma. Complicating factors for a genetic connection, however, include lower Ba and Sr concentrations in these rocks compared to the gray granitoids. Ba and Sr should decrease from earlier-formed lithologies (presumably biotite tonalites and quartz monzodiorites) to the later-formed lithologies (other gray granitoids) based on the mineralogy of the rocks and estimated bulk distribution coefficients (Tindle and Pearce, 1981). The trace element data may indicate, therefore, that the biotite tonalites and quartz monzodiorites represent a separate intrusion whose contacts with the gray granitoids are ill-defined, or that they crystallized earlier, after which the gray granitoid magma evolved under different conditions or by other mechanisms.

Tonalites at Swift Creek

The more mafic hornblende biotite tonalites located along Swift Creek show greater major and trace element affinities for the biotite tonalites, rare quartz monzodiorites, and especially for the rare hornblende biotite tonalites found along the Tar River than for the gray granitoids. The evolutionary history of these rocks may parallel those of the biotite tonalites and quartz monzodiorites.

White Granites

The white granites are predominantly massive, medium-grained monzogranites which are modally and chemically homogenous except near contacts with the gray granitoids (Figure 8). The coarse grain size of the alkali feldspar quartz syenite indicates that these rocks crystallized during late-stage, water-rich conditions and are the latest of the white granites to have crystallized. Consequently, the trend of magmatic evolution for the white granites involves a decrease in silica and evolution of the magma towards a composition of potassium feldspar with lesser quartz, albite, rare-earth minerals, and magnetite.

Other white granites including monzogranites and syenogranites collected near contacts with the gray granitoids (and/or exhibiting textural variations) vary widely in chemical composition (Figure 8). Many of these rocks exhibit modal layering paralleling contacts with the gray granitoids which may have been produced by mechanical flow differentiation during final emplacement of the white granite magma.

Behavior of trace elements in the white granites is variable. Concentrations of Rb parallel those of K_2O and both are greatest for the alkali feldspar quartz syenites, indicating that these rocks are the most evolved of the white granites. White granites (monzogranites and syenogranites) exhibiting textural variations or located near contacts may represent the earliest crystallization products of the white granite magma. Ba and Sr concentrations are greater in these rocks than in the homogenous monzogranites located away from contacts. Ba and Sr concentrations should decrease with increasing fractional crystallization in granites (Robb, 1983).

Other Rocks

Two generations of pegmatites are inferred. An early pegmatite intruding the gray granitoids is truncated by the white granite. Later pegmatites cross-cut both white and gray granitoids. Two samples of aplite dikes observed only in the gray granitoid are chemically similar to the white granites (Appendix II). However, concentration of Ba is anomolously high for one of the samples.

Batholith

Compared to the magmatic evolution of the white granites, the magmatic evolution of the gray granitoids is complex. The white granites are relatively homogenous with much of the variation attributable to late stage magma evolution or mechanical differentiation near contacts with the gray granitoids. The gray granitoids represent a broad range in modal and chemical composition, and evidence indicates fractional crystallization, and possibly magma mixing and unmixing. Based on these different evolutionary trends, mineralogy, contact relations, and concordant, whole-rock Rb-Sr age data for the various lithologies it is interpreted that the white granite and gray granitoids were emplaced approximately contemporaneously as separate magmas. Trace element trends within each major lithology are complex, and cannot be used to assess whether the two intrusions are related by fractionation processes. However, the same low initial 87Sr/86Sr ratio suggests that the two magmas originated from similar sources. Alternatively, the two magmas may have originated from a single parent magma which subsequently evolved by fractional crystallization or unmixing.

Later History

The subsolidus mineral assemblage suggests greenschist facies conditions. However, the occurrence of subsolidus minerals in rocks of the batholith is not pervasive. Therefore, subsolidus mineralization formed during cooling following crystallization and the batholith was not subsequently involved in greenschist-grade metamorphism.

Ductile deformation features are not common within the batholith. Biotite foliation is rare and in most cases is primary. Other rare features such as kinked biotite flakes, broken plagioclase grains, and local recrystallization of quartz are isolated and may be either primary or secondary features. Microcracks filled with various minerals are rare and are more abundant in the granites than in the gray granitoids. The only pervasive deformational feature is quartz with undulatory extinction.

The interpreted crystallization age of the batholith, 345+/-1 Ma, is older than other post-metamorphic plutons of the southern Piedmont (Fullager and Butler, 1979). The Rocky Mount batholith may record the earliest and most mafic pulse of the Alleghanian orogeny or may represent an earlier event altogether. The batholith cooled rapidly as indicated by Rb-Sr and K-Ar age dates on biotite of 318+/-3 and 337+/-8 Ma, respectively. The lack of significant deformation and regional metamorphism of the batholith, combined with age dates for other plutons (Mauger and others, 1983; Russell and others, 1985) indicates that the ECSB east of the Hollister mylonite zone was not affected by the late Paleozoic thermal and deformational events documented in other areas of the southern Piedmont (Farrar, 1985a; Dallmeyer and others, 1986; Secor and others, 1986a and b).

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FIGURES

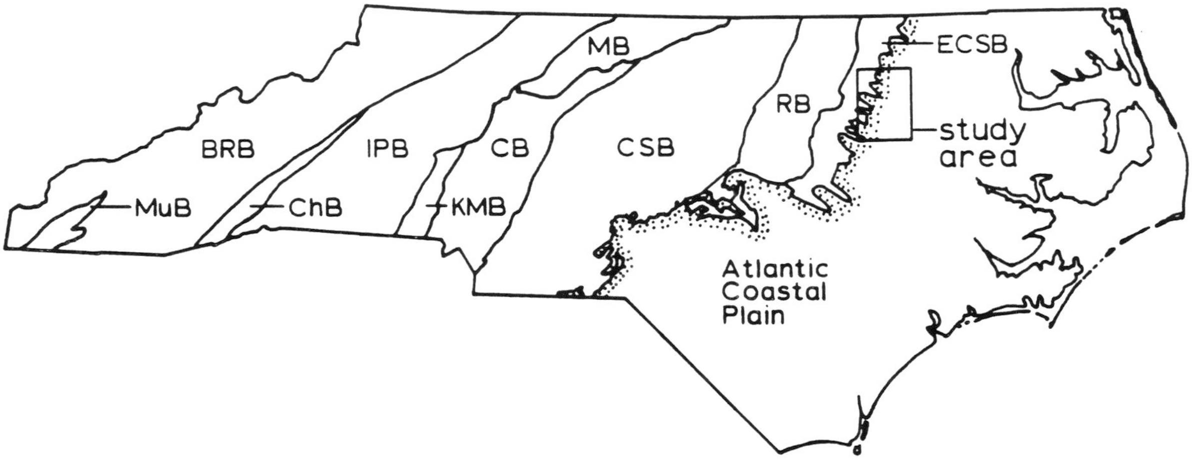

Figure 1.a. Location of study area. ECSB = East Carolina Slate belt, RB = Raleigh belt, CSB = Carolina Slate belt, CB = Charlotte belt, MB = Milton belt, KBM = Kings Mountain belt, IPB = Inner Piedmont belt, ChB = Chauga belt, BRB = Blue Ridge belt, MuB = Murphy belt.

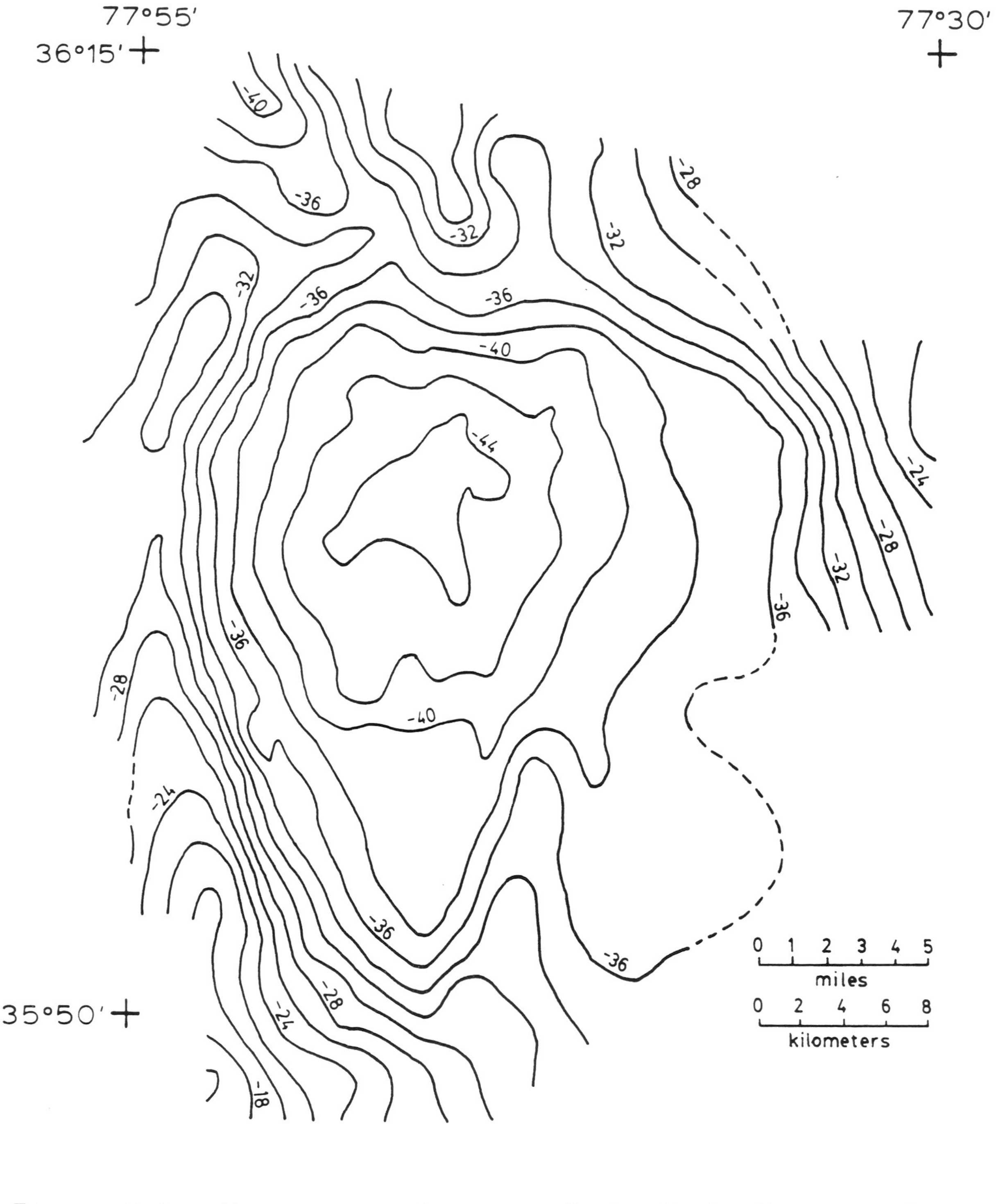

Figure 1.b. Bouguer gravity map of the Rocky Mount region. Modified from Lawrence and others (1987). Contour interval is two milligals.

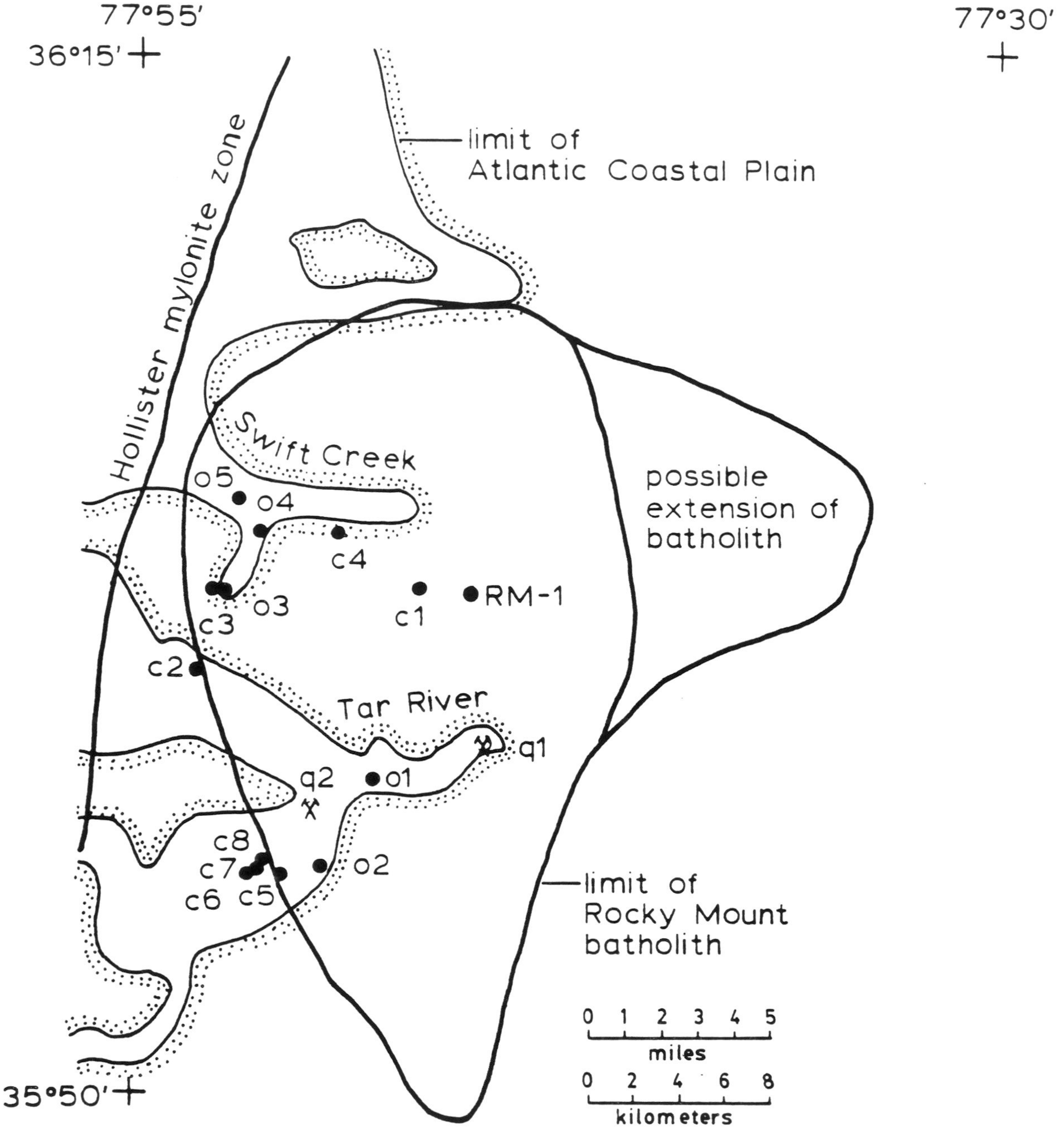

Figure 1.c. Map of the Rocky Mount batholith and sample locations. Boundary of batholith is based on outcrops, published drilling logs (Mundorff, 1946), and gravity data (Lawrence and others, 1987). Possible extension of batholith based on gravity data only. Trace of limit of Atlantic Coastal Plain and Hollister mylonite zone from Kite and Stoddard (1984) and Farrar (1985a). q=quarry, o=outcrop, and c=drill core. RM-1 is the location of the drill core described by Farrar (1980).

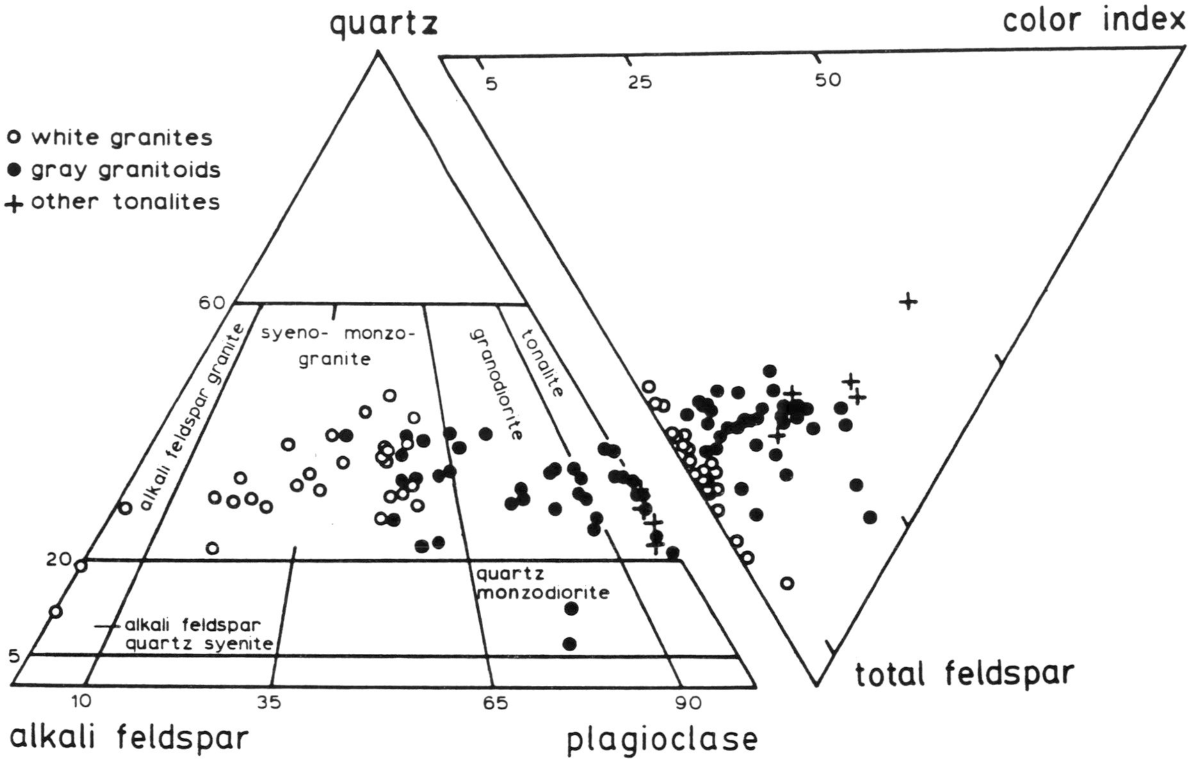

Figure 2. Modal distribution of quartz-alkali feldspar-plagioclase and quartz-total feldspar-color index in the Rocky Mount batholith. I.U.G.S. subcommission on the Systematics of Igneous Rocks classification (Streckeisen, 1976).

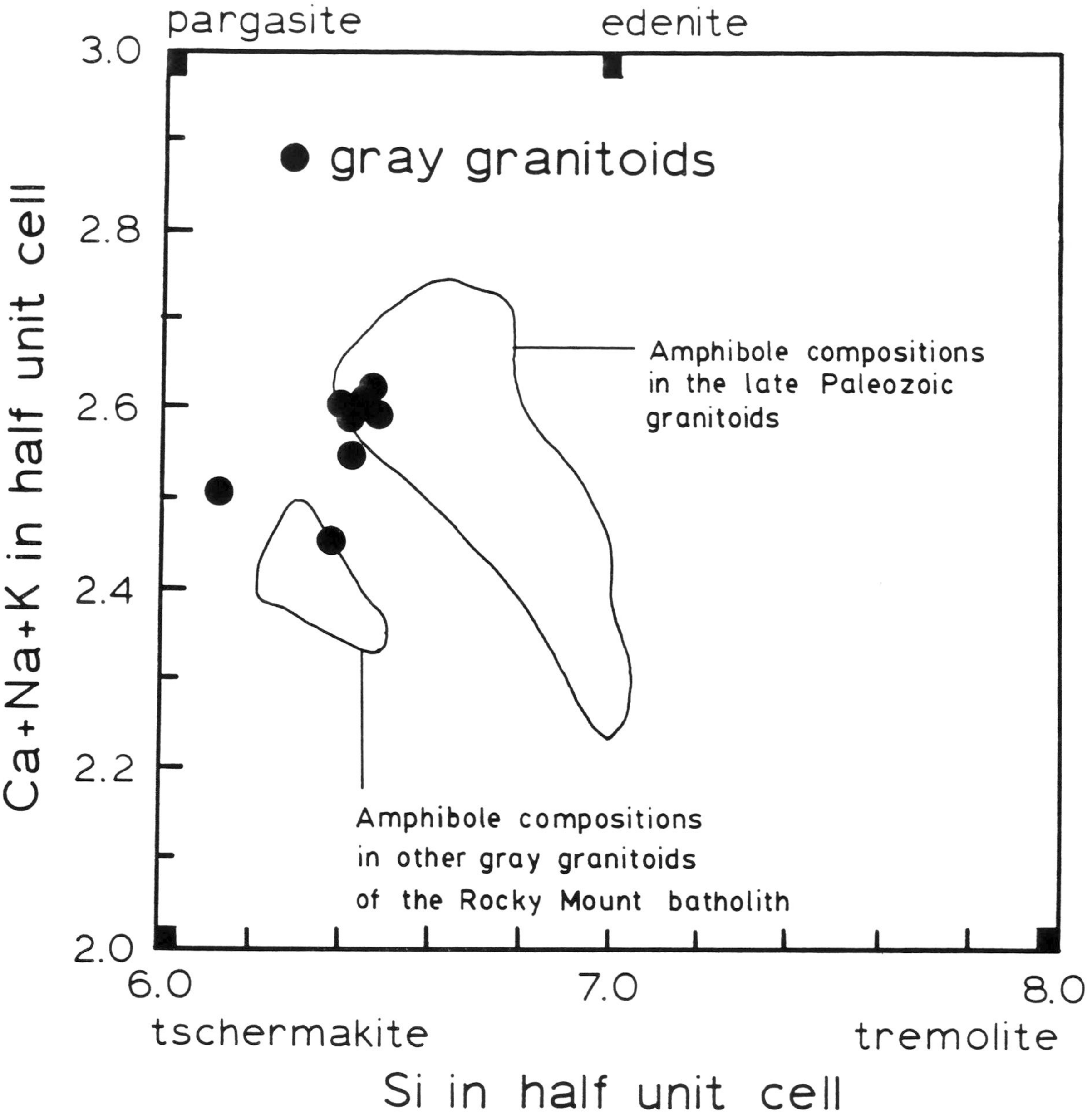

Figure 3. Plot of Si against Ca+Na+K in the half unit cell for amphiboles from the Rocky Mount batholith. Compositional fields of amphiboles from the late Paleozoic granitoids and from other gray granitoids of the Rocky Mount batholith are from Speer and others (1980) and Farrar (1980), respectively.

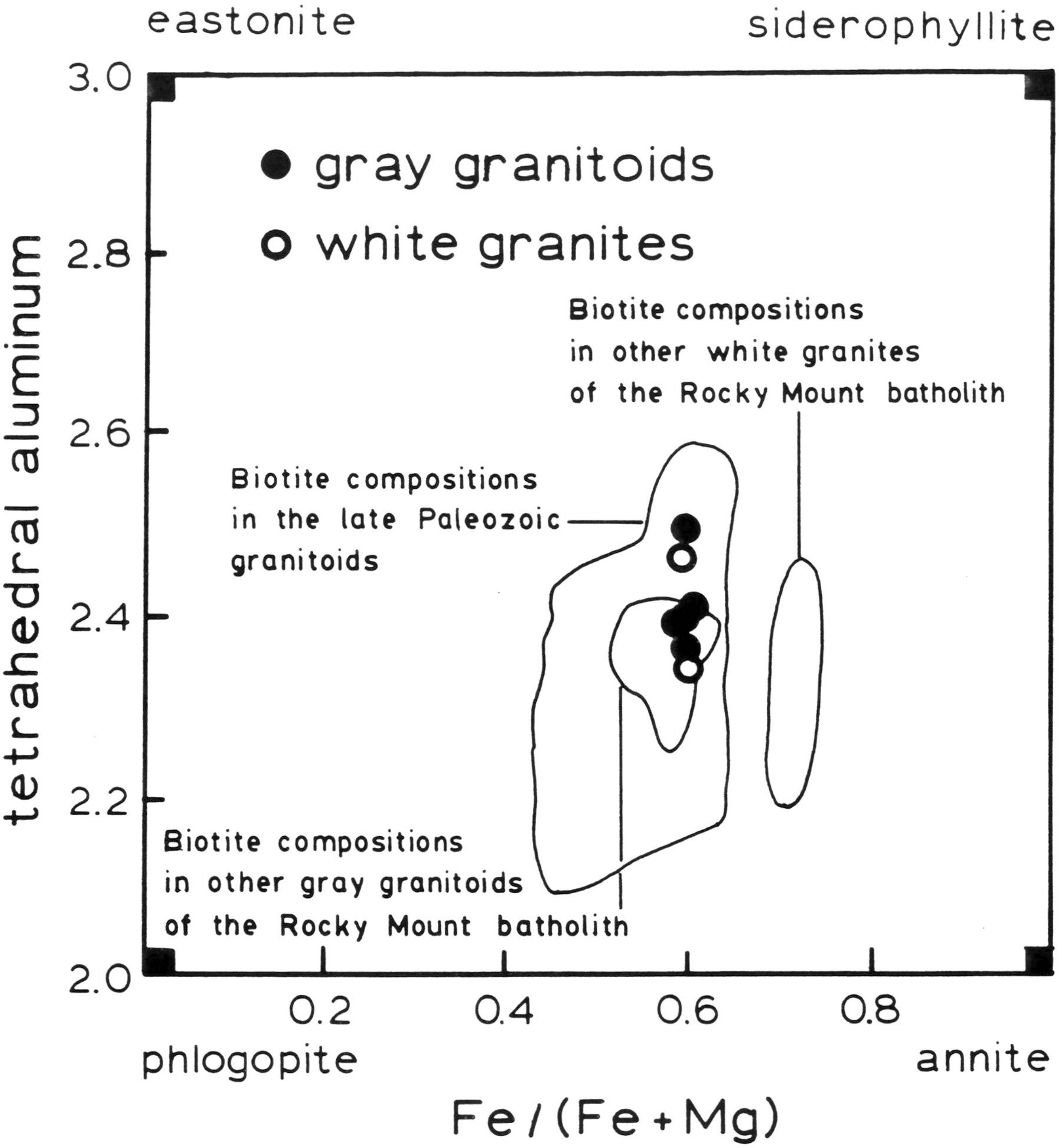

Figure 4. Compositions of biotite from the Rocky Mount batholith projected onto the phlogopite-annite-eastonite-siderophyllite field. Compositional fields of biotites from the late Paleozoic granitoids and from other rocks of the Rocky Mount batholith are from Speer and others (1980) and Farrar (1980), respectively.

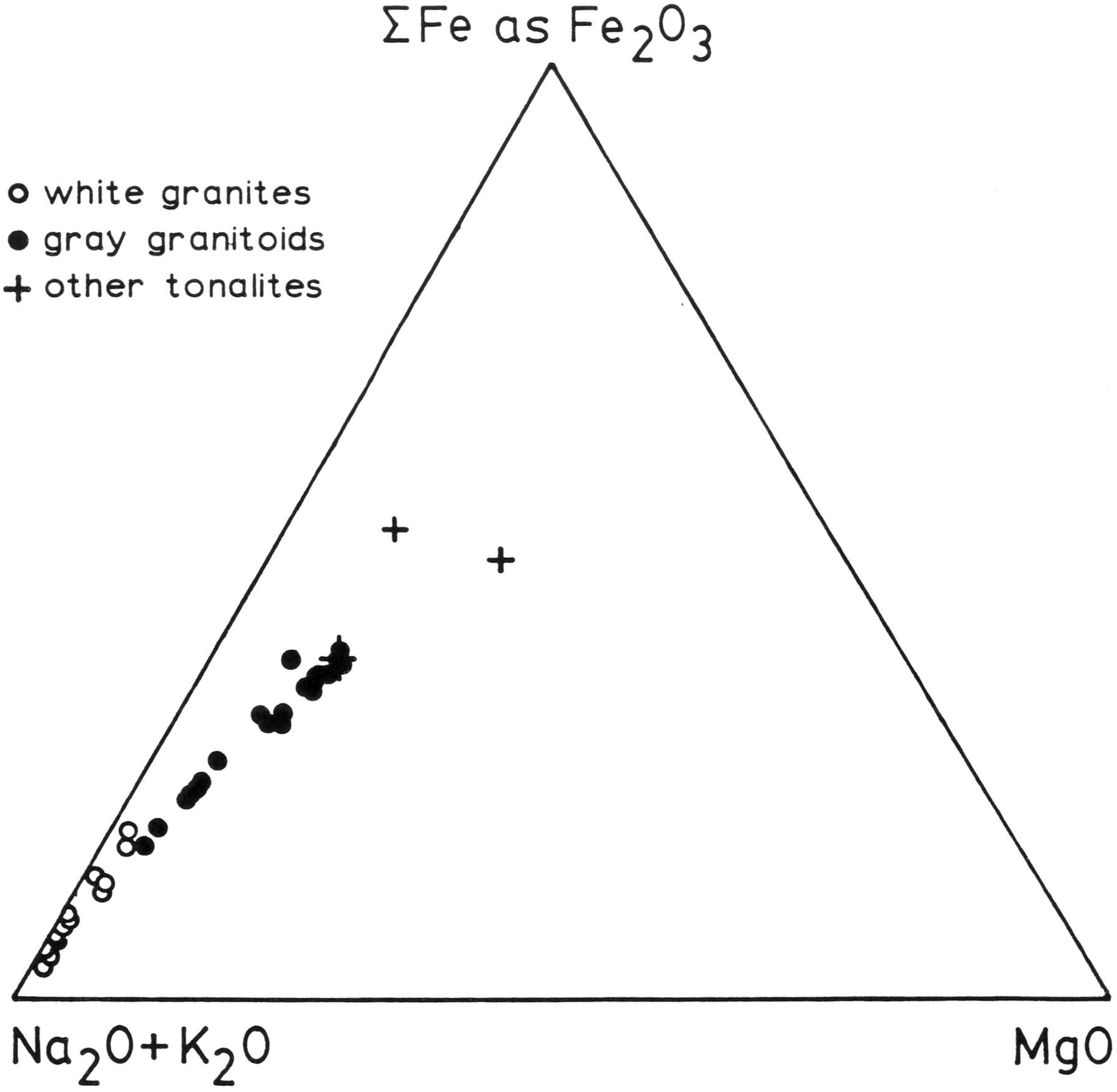

Figure 5. AFM diagram of the Rocky Mount batholith.

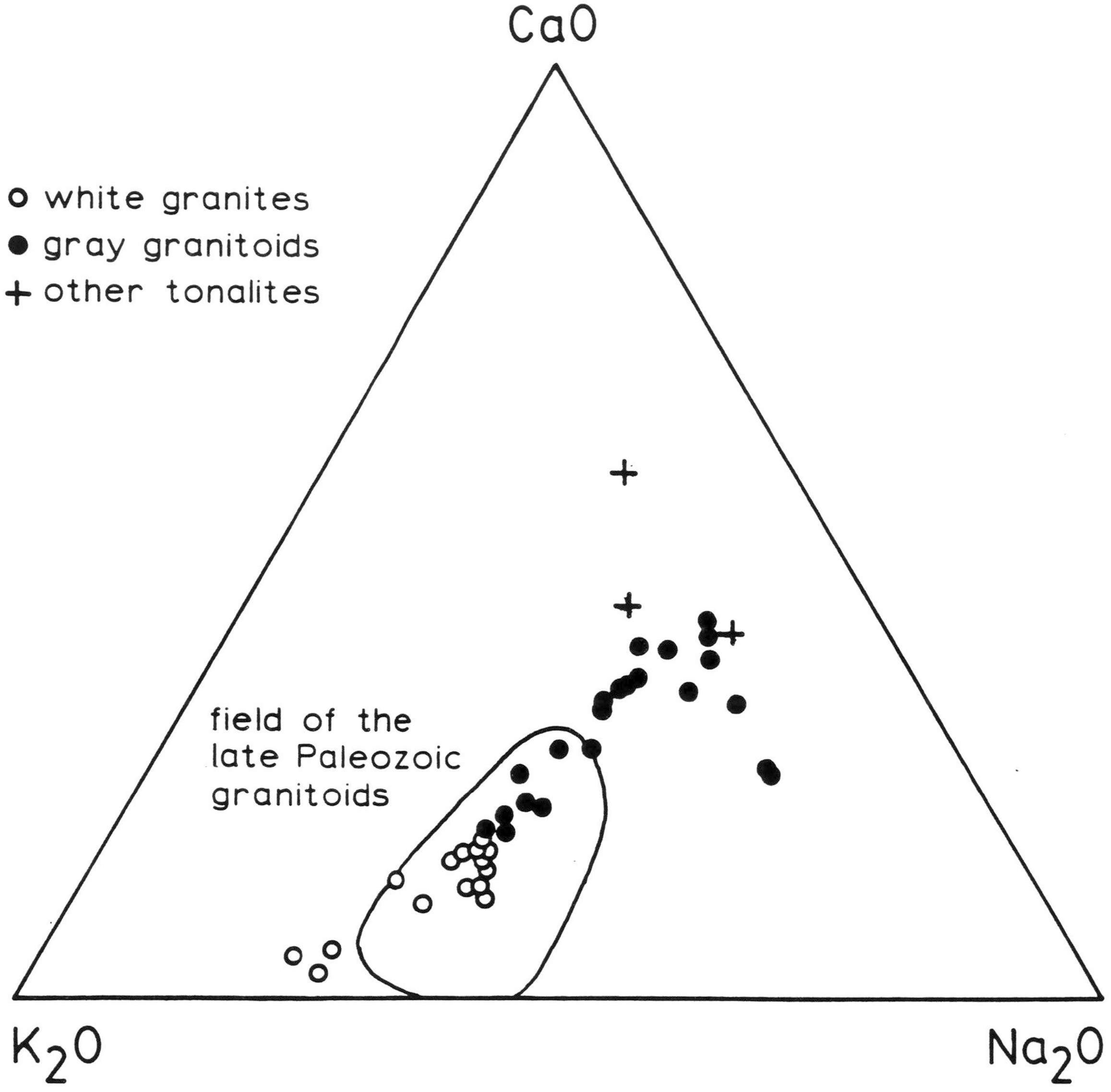

Figure 6. K_2O-Na_2O-CaO diagram of the Rocky Mount batholith. Field of the late Paleozoic granitoids from Fullager and Butler (1979).

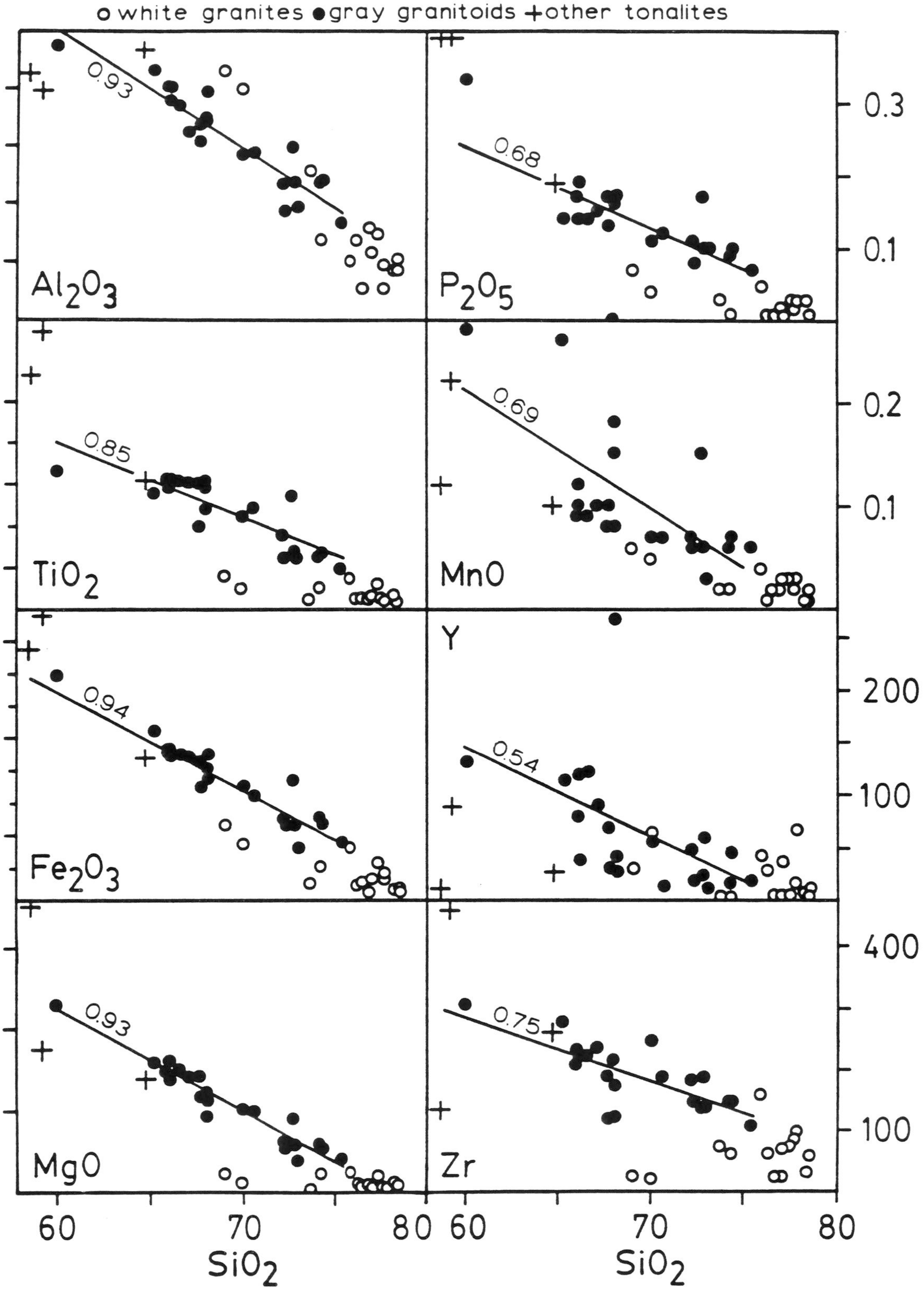

Figure 7.a. Harker diagrams of the Rocky Mount batholith. Oxides in weight percent and trace elements in parts per million. Regression lines calculated for gray granitoids only. Correlation coefficients are presented as absolute values adjacent to the regression lines.

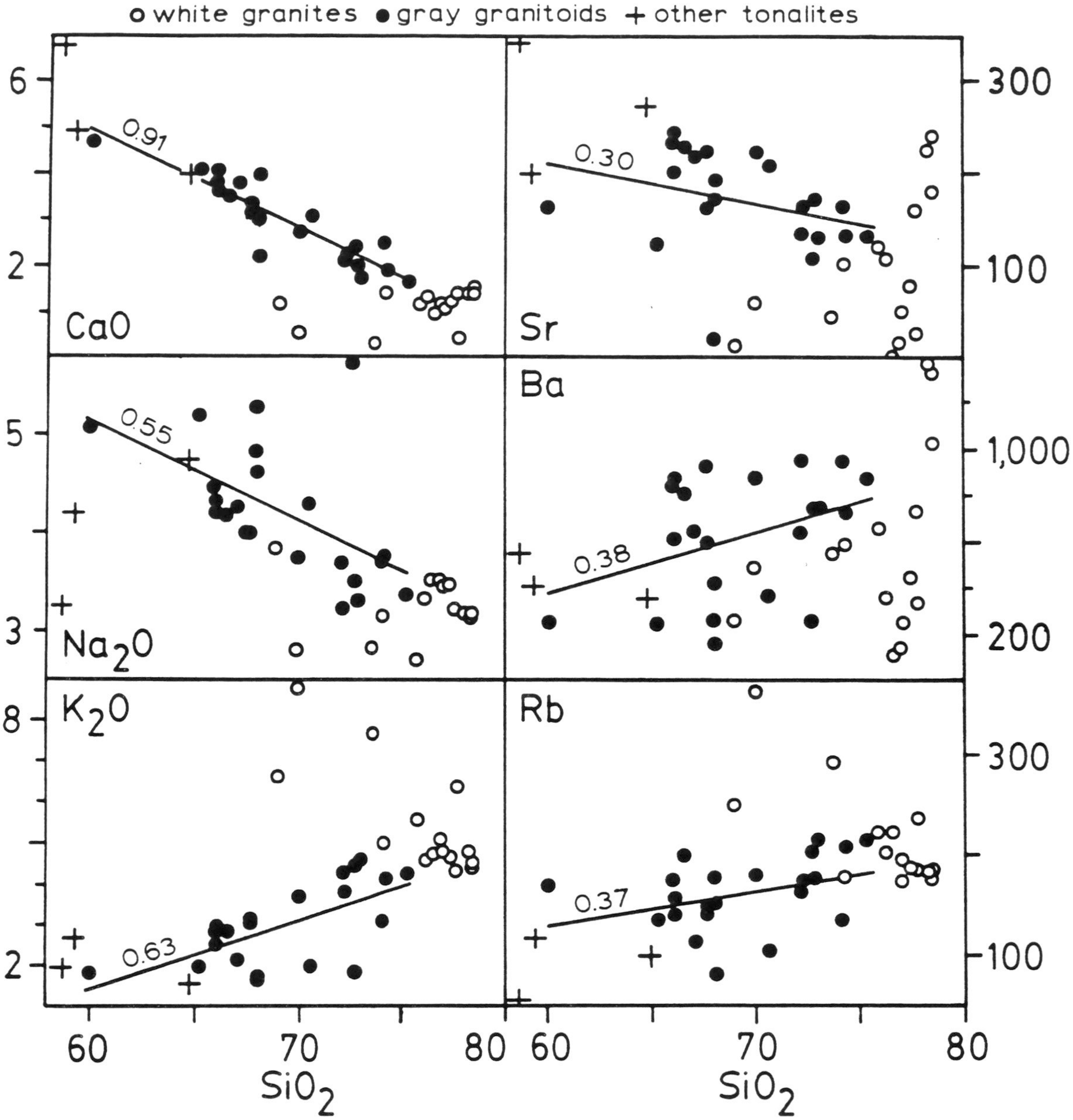

Figure 7.b. Harker diagrams of the Rocky Mount batholith. Oxides in weight percent and trace elements in parts per million. Regression lines calculated for gray granitoids only. Correlation coefficients are presented as absolute values adjacent to the regression lines.

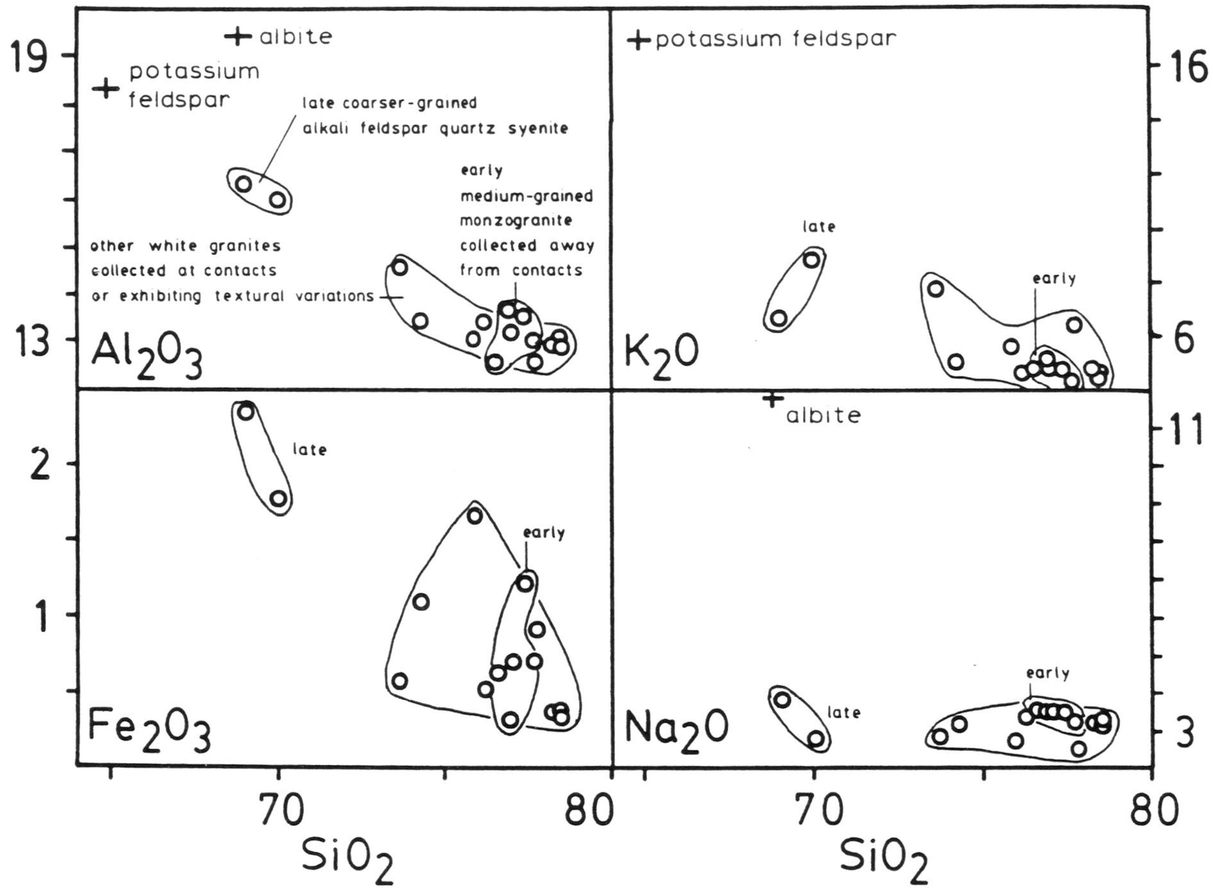

Figure 8. Selected Harker diagrams of the white granites of the Rocky Mount batholith. Oxides in weight percent. Crosses indicate mineral compositions.

TABLES

TABLE 1A. MODAL DATA OF GRAY GRANITOIDS AND OTHER TONALITES

Sample	Location	Quar	K-Fel	Plag	Biot	Hnbl	Acc	Sub
I. Hornblende biotite tonalite of uncertain relations								
21(1)	q2	24.3	0.3	60.3	10.1	4.3		0.7
42	o3	18.4	0.3	52.1	21.4	3.3		4.2
48	o4	25.2	0.5	54.4	5.4	12.6	1.6	0.3
52	c3	17.0		39.6	22.3	17.5	1.7	1.9
53(1)	c4	16.0	1.5	53.2	20.8	4.7	2.9	0.3
II. Gray granitoids								
A. Tonalite								
3(1)	q1	17.6	1.0	55.5	18.5	6.9(2)	0.3	0.2
10	q1	22.7	0.6	57.6	16.3		0.3	2.5
16b	q2	27.9	tr	58.2	12.5			1.4
45	q2	24.1	0.5	55.8	19.6	tr		
62	q1	28.0	1.8	55.0	15.2			
64	q1	32.6	1.1	53.3	12.8		0.3	0.3
67	q1	29.6	1.0	58.8	10.3			0.2
I	q1	16.0	0.4	58.9	24.7			0.4
VIII	q1	30.0		50.8	19.0	tr		0.3
X	q1	25.0	0.7	57.2	16.6		0.2	0.5
B. Quartz monzodiorite								
60	q1	9.8	14.4	54.9	0.2	19.6	0.9	1.0
IV	q1	5.5	17.0	56.9	20.6			
C. Granodiorite								
1(1)	q1	24.2	14.9	44.1	9.4	6.6	0.7	
4b	q1	24.8	7.0	49.8	12.7	4.4	1.3	0.3
14	q1	19.9	7.2	52.5	13.5	5.6	0.8	0.3
20	q2	31.1	6.1	53.5	8.1	0.3	0.3	0.3
22	q2	26.0	14.2	48.3	7.8	2.6	0.3	0.9
26	q2	34.5	18.7	38.6			1.0	7.3(3)
29	q2	28.7	5.9	52.6	8.5	2.6	0.5	1.2
31	q2	22.8	6.9	57.2	7.4	4.5	0.9	0.5
39(1)	q1	25.3	12.6	43.7	9.3	7.9	1.0	0.2
44	o1	37.2	19.0	36.7	7.1			
46	o1	29.8	9.2	49.6	10.6			0.9
58	q1	35.5	14.0	39.7	8.7			2.1
70	q1	28.0	7.6	46.2	11.8	3.1	1.1	2.2
71	q1	22.0	9.8	46.7	13.8	5.4	1.1	0.9
XII	q1	23.8	6.0	50.0	13.8	4.8	1.0	0.8
D. Biotite granite								
7	q1	35.8	24.7	31.6	4.5			3.8
23	q2	35.8	22.7	34.0	6.5		0.3	0.6
25	q2	24.5	33.2	36.0	3.9		0.3	1.5
27	q2	37.8	33.2	24.7	3.6			0.7
30	q2	31.6	21.5	39.9	4.9	1.2	1.2	
33	q2	34.2	27.0	32.3	6.2			0.2
43	o2	31.0	27.4	35.9	5.1			0.6
50	o5	20.8	31.3	42.2	5.0		0.3	0.2
61	q1	29.6	27.1	31.4	10.6	1.0	0.6	
74	o1	32.0	24.4	39.6	4.1			
XIII	q1	19.9	26.5	40.5	9.0	3.3	0.2	0.5

mineral percentages by volume

Acc = accessory minerals including titanite, pyrite, apatite, zircon, and allanite

Sub = subsolidus minerals including chlorite, epidote, white mica, calcite, and hematite

(1) averaged from more than one slide

(2) granoblastic hornblende in a rare mafic clump

(3) 7.3 modal % chlorite

TABLE 1B. MODAL DATA OF THE WHITE GRANITES

Sample	Location	Quar	K-Fel	Plag	Biot	Acc	Sub
III. White granites							
A. Massive, medium-grained monzogranites collected away from contacts with gray granitoids							
6	q1	37.1	30.3	31.4	0.7		0.5
11	q1	28.6	30.6	40.1	0.2	0.8	0.5
35	q2	35.1	30.6	32.4	1.0		0.9
36	q1	29.9	31.2	37.3	0.5	0.3	0.8
59	q1	44.8	25.4	28.1	0.6		1.1
63	q1	41.4	23.8	32.7	1.4		0.7
65	q1	29.1	32.6	34.9	1.4	0.9	1.2
75	q1	30.6	28.6	37.0	2.9		0.8
VI	q1	38.3	27.2	34.2	0.6		
VII	q1	37.0	29.8	32.1			1.1
B. Samples either collected at a contact with gray granitoids or exhibiting textural variations							
1. monzogranites							
5(1)	q1	35.8	32.0	30.8	0.1		1.4
16a	q2	33.6	42.1	23.0	0.7	0.3	0.3
34	q2	36.1	29.9	31.1	1.3	0.2	1.1
40	q1	34.9	36.6	26.8	0.3		1.4
41	o3	37.8	35.3	22.8	2.2		1.9
69	q1	42.9	30.0	26.6			1.0
II	q1	30.9	42.7	25.9		0.5	0.5
IX	q1	26.4	36.6	36.3			0.6
2. syenogranites							
9	q1	28.7	54.4	15.3			0.8
12	q1	29.8	57.6	12.6			
13	q1	32.2	52.4	14.6			0.8
24	q1	31.2	44.4	22.2	1.3	0.3	0.5
28	q2	27.7	50.2	19.5	2.0	0.2	0.3
66	q1	29.4	52.3	17.3		0.2	0.7
68	q1	37.8	42.7	18.4	0.8		0.2
XI	q1	21.5	61.0	16.4			0.8
3. alkali feldspar granite							
Meta-1	q1	20.1	50.2	1.2		27.7(2)	1.0
4. alkali feldspar quartz syenite							
72	q1	11.5	52.0	32.2	1.8	1.7(3)	0.8
73	q1	18.8	tr	80.2(4)			0.7

mineral percentages by volume

Acc = accessory minerals including magnetite, pyrite, titanite, allanite, zircon, apatite, and garnet

Sub = subsolidus minerals including chlorite, epidote, white mica, calcite, and titanite

(1) averaged from more than one slide

(2) 27.7 modal % of the metamict allanite-bastnaesite assemblage

(3) 1.7 modal % magnetite

(4) plagioclase is albite

TABLE 2. COMPOSITIONS OF AMPHIBOLES IN GRAY GRANITOIDS

	[				sample # 3				]
SiO2	41.600	39.965	40.660	42.376	42.285	43.101	42.243	43.310	42.007
Al2O3	9.952	13.561	12.282	10.629	9.826	10.018	10.051	10.481	9.612
FeO*	22.984	21.650	20.680	22.413	22.767	22.757	22.454	22.252	22.875
MgO	7.438	6.748	6.443	7.462	7.668	7.771	7.580	8.271	7.426
K2O	1.277	1.280	1.281	1.310	1.320	1.308	1.261	1.258	1.310
Na2O	1.394	1.437	1.375	1.441	1.434	1.527	1.431	1.466	1.365
CaO	11.546	10.932	10.444	11.617	11.651	11.598	11.625	11.680	11.680
TiO2	0.975	0.934	1.007	1.018	0.996	1.056	1.007	1.190	0.914
MnO	0.665	0.595	0.553	0.595	0.681	0.650	0.694	0.691	0.580
P2O5			0.026						
ZnO			0.092						
Cr2O3			0.025						
NiO			0.057						
Rb2O			0.002						
SrO			0.066						
BaO			0.075						
F			0.254						
Cl			0.095						
Total	97.831	97.102	95.417	98.861	98.628	99.786	98.346	100.599	97.769
-O=F+Cl			0.129						
Total			95.289						

oxide and element percentages by weight
*total iron as FeO

TABLE 3. BIOTITE COMPOSITIONS

	Gray Granitoids					White Granites	
	[sample # 1]		[sample # 3]			[sample # 5]	
SiO_2	36.188	37.087	35.795	36.164	36.046	35.639	36.736
Al_2O_3	15.210	15.771	15.834	15.615	14.892	17.013	16.504
FeO*	22.563	22.168	22.797	22.804	22.987	21.998	21.829
MgO	8.497	8.277	8.652	8.154	9.028	8.344	8.024
K_2O	8.910	8.474	7.194	7.624	9.281	7.377	7.705
Na_2O	0.153	0.446	1.497	1.272	0.093	0.114	0.113
CaO	0.064	0.078	0.116	0.093	0.069	0.095	0.131
TiO_2	3.204	3.537	3.262	3.008	2.573	2.514	2.672
MnO	0.740	0.753	0.453	0.489	0.463	0.795	0.891
Total	95.529	96.591	95.600	95.223	95.432	93.889	94.605

oxide percentages by weight
*total iron as FeO

TABLE 4. FELDSPAR COMPOSITIONS

SiO2	Al2O3	FeO*	MgO	K2O	Na2O	CaO	TiO2	MnO	Total	Or	Ab	An
I. Gray granitoids												
A. sample # 1												
61.054	22.577	0.090	0.009	0.274	8.203	4.507	0.000	0.002	96.716	1.660	75.410	22.930
60.489	23.526	0.105	0.010	0.313	7.993	4.235	0.000	0.000	96.671	1.930	75.880	22.190
62.992	24.177	0.066	0.005	0.216	9.056	4.501	0.000	0.000	101.013	1.210	77.540	21.250
62.966	24.260	0.061	0.013	0.239	8.959	4.612	0.000	0.000	101.110	1.310	76.790	21.900
62.602	23.627	0.092	0.017	0.152	8.420	4.586	0.000	0.003	99.499	0.950	76.160	22.900
B. sample # 3												
65.054	19.111	0.057	0.076	15.244	0.474	0.108	0.018	0.045	100.187	94.990	4.470	0.530
61.831	23.625	0.126	0.031	0.236	7.958	6.060	0.039	0.011	99.917	1.320	69.430	29.250
61.992	24.686	0.068	0.026	0.211	8.420	5.859	0.007	0.000	101.269	1.200	71.390	27.420
62.909	23.250	0.141	0.000	0.217	8.742	4.982	0.005	0.000	100.246	1.200	75.130	23.670
60.859	24.600	0.063	0.047	0.125	8.065	6.539	0.000	0.000	100.298	0.690	68.580	30.730
63.414	23.903	0.062	0.008	0.205	8.945	5.135	0.006	0.000	101.678	1.090	75.070	23.830
II. White Granites												
A. sample # 5												
63.299	19.177	0.090	0.037	14.510	0.557	0.063	0.000	0.000	97.733	94.150	5.530	0.330
62.858	18.886	0.061	0.033	14.730	0.471	0.022	0.000	0.010	97.071	95.280	4.610	0.110
60.450	25.052	0.110	0.000	0.058	9.127	4.728	0.000	0.020	99.545	0.290	77.530	22.180
63.026	24.041	0.064	0.023	0.137	9.664	4.061	0.000	0.000	101.016	0.780	80.510	18.710
61.574	23.748	0.014	0.015	0.088	10.103	3.745	0.000	0.001	99.288	0.470	82.640	16.890
63.567	23.903	0.055	0.039	0.062	9.933	2.970	0.000	0.000	100.529	0.300	85.530	14.170
63.402	22.159	0.145	0.006	0.058	10.266	2.399	0.000	0.037	98.472	0.300	88.310	11.400
B. sample # Meta-1												
64.690	19.073	0.059	0.043	16.078	0.508	0.032	0.016	0.046	100.545	95.250	4.550	0.200
64.717	19.054	0.073	0.019	15.699	0.470	0.007	0.010	0.048	100.097	95.640	4.360	0.000
64.538	19.740	0.020	0.000	0.046	11.217	0.881	0.000	0.034	96.476	0.290	95.560	4.150

*total iron as FeO

oxide percentages by weight

Or, Ab, and An = percent orthoclase, albite, and anorthite, respectively

TABLE 5. ALLANITE AND BASTNAESITE COMPOSITIONS

	ALLANITE COMPOSITIONS										BASTNAESITE COMPOSITIONS					
	Gray Granitoids [sample # 1]	[White Granites sample # Meta-1								]	[White Granites sample # Meta-1					]
SiO2	33.815	29.540	29.695	33.285	32.090	31.684	31.323	35.645	34.395	40.786	4.179	1.080	0.692	2.358	2.480	2.081
Al2O3	17.371	13.646	13.820	16.276	15.014	15.806	16.085	14.862	14.470	16.500	4.603	19.835	12.918	18.584	6.340	2.621
FeO*	13.628	14.108	14.161	13.954	13.441	14.651	14.606	5.905	8.205	5.698	14.800	0.903	3.432	9.578	7.322	6.156
MgO	0.319	0.789	0.715	0.581	0.419	0.836	0.851	0.367	0.376	0.431	0.499	0.116	0.249	0.217	0.285	0.323
K2O	0.043	0.062	0.069	0.064	0.054	0.071	0.072	0.533	0.544	1.043	0.177	0.111	0.103	0.161	0.146	0.125
Na2O	0.065	0.100	0.100	0.053	0.167	0.029	0.087	0.167	0.496	0.739	0.109	0.044	0.130	0.064	0.005	0.000
CaO	16.763	9.060	8.817	11.827	11.183	9.109	9.349	3.964	4.344	3.811	5.961	5.928	5.735	6.374	6.748	9.002
TiO2	0.341	0.960	0.943		0.758				1.034		0.388	0.476	0.402			
MnO	0.814	2.164	2.230	1.556	1.537	2.344	1.982	0.597	0.855	0.522	0.329	0.290	0.310	0.005	0.000	0.000
P2O5				0.000	0.001	0.000	0.028	0.013	0.016	0.000				0.132	0.010	0.000
ZnO					0.000				0.000							
Cr2O3					0.111				0.147							
NiO					0.234				0.208							
Rb2O					0.000				0.000							
SrO				0.892	0.260	0.603	0.582	0.789	0.053	0.841				0.467	0.821	0.918
BaO				0.219	0.107	0.000	0.010	0.113	0.296	0.186				0.007	0.000	0.181
La2O3				4.045		4.505	4.628	4.026		2.629				8.642	10.622	10.642
Ce2O3				8.697		11.281	11.351	10.023		6.852				19.059	23.437	23.174
Nd2O3				3.545		4.474	4.215	3.713		2.745				7.548	8.361	8.969
Y2O3				1.244		0.940	0.997	0.969		1.060				2.515	2.559	4.192
UO2				0.047		0.065	0.085	0.122		0.122				0.047	0.026	0.114
SO3				0.000		0.000	0.012	0.025		0.000				0.187	0.138	0.171
F				0.228	0.265	0.264	0.213	0.627	0.696	0.406				5.094	6.388	7.617
Cl				0.000	0.005	0.014	0.009	0.016	0.000	0.033				0.033	0.032	0.055
Total	83.159	70.429	70.550	96.513	75.646	96.676	96.485	82.476	66.135	84.404	31.045	28.783	23.971	81.072	75.720	76.341
-O=F+Cl				0.096	0.113	0.114	0.092	0.268	0.293	0.178				2.152	2.697	3.219
Total				96.417	75.533	96.562	96.393	82.208	65.842	84.226				78.920	73.023	73.122

oxide and element percentages by weight
*total iron as FeO

TABLE 6. COMPOSITIONS OF TITANITE IN GRAY GRANITOIDS

	[sample # 1]			[sample # 3]
SiO_2	30.140	28.878	29.398	30.993
Al_2O_3	2.144	2.035	2.106	2.209
FeO*	2.144	2.028	1.928	1.538
MgO	0.116	0.076	0.092	0.095
K_2O	0.029	0.030	0.032	0.027
Na_2O	0.066	0.024	0.048	0.015
CaO	26.679	25.576	25.618	29.324
TiO_2	34.022	35.655	35.938	35.768
MnO	0.376	0.323	0.297	0.128
Total	95.716	94.625	95.457	100.097

oxide percentages by weight
*total iron as FeO

TABLE 7. COMPOSITION OF APATITE IN GRAY GRANITOIDS

	[sample # 3]
SiO_2	0.469
Al_2O_3	0.110
FeO*	0.537
MgO	0.089
K_2O	0.061
Na_2O	0.034
CaO	52.829
TiO_2	0.044
MnO	0.104
P_2O_5	38.225
ZnO	0.092
Cr_2O_3	0.019
NiO	0.048
Rb_2O	0.000
SrO	0.000
BaO	0.058
F	3.805
Cl	0.020
Total	96.544
-O=F+Cl	1.607
Total	94.937

oxide and element percentages by weight

*total iron as FeO

TABLE 8. WHITE MICA AND CHLORITE COMPOSITIONS

	WHITE MICA COMPOSITIONS						CHLORITE COMPOSITIONS		
	White Granites						Gray Granitoids	White Granites	
	[sample # 5]			[sample # Meta-1]			[sample # 1]	[sample # 5]	
SiO2	44.622	43.512	45.315	45.520	47.115	45.981	26.333	23.351	23.545
Al2O3	27.231	28.477	27.107	27.818	28.045	27.232	19.498	20.813	21.171
FeO*	5.153	5.258	6.127	5.418	5.544	6.099	26.159	31.786	31.864
MgO	1.618	1.508	1.879	1.675	1.718	1.787	10.571	7.097	6.880
K2O	9.729	9.402	10.165	8.689	8.312	8.911	0.792	0.023	0.035
Na2O	0.248	0.365	0.257	0.139	0.132	0.138	0.510	0.356	0.366
CaO	0.022	0.090	0.016	0.121	0.050	0.008	0.414	0.171	0.133
TiO2	0.403	0.600	0.745	0.305	0.400	0.501	0.690	0.058	0.025
MnO	0.140	0.137	0.172	0.124	0.147	0.156	1.265	1.364	1.409
Total	89.166	89.349	91.783	89.809	91.463	90.813	86.232	85.019	85.428

oxide percentages by weight
*total iron as FeO

TABLE 9. EPIDOTE COMPOSITIONS

	Gray Granitoids			White Granites		
	[sample # 1]	[sample # 3]		[sample # 5]		[sample # Meta-1]
SiO2	33.815	46.806	45.859	37.940	38.504	32.090
Al2O3	17.371	18.896	18.931	24.809	23.358	15.014
FeO*	13.629	10.169	10.270	7.185	9.966	13.441
MgO	0.319	0.098	0.054	0.052	0.045	0.419
K2O	0.043	0.045	0.026	0.041	0.016	0.054
Na2O	0.065	0.000	0.013	0.029	0.036	0.167
CaO	16.763	20.057	20.228	23.100	23.124	11.183
TiO2	0.341	0.559	0.351	0.031	0.010	0.758
MnO	0.814	0.259	0.240	0.353	0.685	1.537
P2O5			0.014			0.001
ZnO			0.015			0.000
Cr2O3			0.051			0.111
NiO			0.071			0.234
Rb2O			0.000			0.000
SrO			0.032			0.260
BaO			0.060			0.107
F			0.000			0.265
Cl			0.002			0.005
Total	83.160	96.889	96.217	93.540	95.744	75.646
-O=F+Cl			0.000			0.113
Total			96.217			75.533

oxide and element percentages by weight
*total iron as FeO

TABLE 10A. WHOLE-ROCK CHEMICAL DATA OF THE GRAY GRANITOIDS AND OTHER TONALITES

Sample	Location	SiO2	Al2O3	Fe2O3*	MgO	K2O	Na2O	CaO	TiO2	MnO	P2O5	Ba	Rb	Sr	Y	Zr	LOI	H2O	Total
I. Hornblende biotite tonalite of uncertain relations																			
21	q2	64.77	16.68	4.34	1.40	1.52	4.74	3.98	0.62	0.10	0.19	352	101	273	26	259	0.77	0.04	99.25
52	c3	58.68	16.26	7.75	3.52	1.88	3.26	6.78	1.13	0.12	0.39	555	51	346	11	133	0.87	0.06	100.81
53	c4	59.30	15.98	8.78	1.75	2.65	4.19	4.90	1.34	0.22	0.39	402	119	201	88	457	0.51	0.03	100.17
II. Gray granitoids																			
A. Tonalite																			
3	q1	60.07	16.73	6.96	2.30	1.84	5.07	4.68	0.67	0.27	0.33	245	170	162	131	307	0.60	0.06	99.68
62	q1	68.04	15.45	4.08	1.24	1.71	4.82	3.01	0.61	0.15	0.16	257	178	171	40	216	0.42	0.06	99.84
64	q1	72.75	14.98	3.71	0.92	1.85	5.73	2.41	0.55	0.15	0.17	249	204	109	24	138	0.38	0.04	103.71
67	q1	68.08	15.43	4.48	0.94	1.69	5.26	2.19	0.59	0.18	0.00	158	152	19	266	125	0.37	0.05	99.33
B. Hornblende quartz monzodiorite																			
60	q1	65.28	16.31	5.26	1.59	1.99	5.18	4.08	0.56	0.26	0.14	244	135	122	113	278	0.44	0.05	101.23
C. Granodiorite																			
1	q1	66.02	16.03	4.60	1.45	2.82	4.44	3.80	0.63	0.09	0.17	838	176	232	79	209	0.36	0.02	100.58
14	q1	66.61	15.70	4.52	1.51	2.83	4.16	3.49	0.62	0.09	0.14	803	200	227	122	222	0.45	0.10	100.38
20	q2	70.63	14.89	3.24	1.00	2.00	4.28	3.08	0.49	0.07	0.12	361	106	208	14	188	0.49	0.05	100.43
22	q2	67.71	15.08	3.48	1.18	3.11	3.98	3.17	0.40	0.10	0.13	590	149	163	30	120	0.41	0.07	98.93
29	q2	68.09	15.95	3.75	1.13	1.71	4.61	3.96	0.48	0.08	0.17	414	82	192	27	175	0.43	0.01	100.46
31	q2	66.10	16.03	4.64	1.61	2.52	4.19	4.05	0.63	0.10	0.14	608	157	243	39	231	0.53	0.01	100.68
39	q1	66.10	15.78	4.48	1.41	2.96	4.31	3.61	0.59	0.12	0.19	865	141	201	118	221	0.53	0.02	100.25
58	q1	74.19	14.38	2.59	0.60	3.12	3.72	2.49	0.26	0.06	0.09	945	136	165	17	148	0.49	0.04	102.17
70	q1	67.11	15.23	4.44	1.42	2.14	4.25	3.77	0.61	0.10	0.15	639	114	217	90	235	0.58	0.02	99.95
71	q1	67.68	15.37	4.31	1.43	3.14	3.98	3.33	0.61	0.08	0.17	921	143	223	68	189	0.47	0.06	100.78
D. Biotite granite																			
7	q1	75.36	13.69	1.82	0.42	4.26	3.36	1.64	0.20	0.06	0.07	873	216	133	18	109	0.60	0.08	101.69
23	q2	72.30	13.88	2.37	0.56	3.83	3.22	2.23	0.25	0.06	0.08	949	175	165	20	148	0.40	0.02	99.35
25	q2	72.84	14.38	2.33	0.59	4.50	3.50	1.98	0.28	0.06	0.10	740	177	172	59	188	0.45	0.07	101.21
30	q2	72.21	14.35	2.48	0.63	4.30	3.69	2.09	0.36	0.07	0.11	638	164	135	48	183	0.53	0.08	101.02
33	q2	73.02	13.96	1.65	0.40	4.59	3.30	1.72	0.25	0.03	0.10	745	216	131	12	139	0.59	0.06	99.79
61	q1	70.04	14.85	3.54	1.03	3.70	3.73	2.71	0.45	0.07	0.11	870	181	223	56	246	0.29	0.07	100.75
74	o1	74.37	14.41	2.38	0.56	4.14	3.76	1.89	0.27	0.07	0.10	722	209	133	45	147	0.38	0.02	102.48

*total iron as Fe2O3
LOI = loss on ignition
oxides and LOI in weight percent; trace elements in parts per million

TABLE 10B. WHOLE ROCK CHEMICAL DATA OF THE WHITE GRANITES

Sample	Location	SiO2	Al2O3	Fe2O3*	MgO	K2O	Na2O	CaO	TiO2	MnO	P2O5	Ba	Rb	Sr	Y	Zr	LOI	H2O	Total
III. White granites																			
A. Massive, medium-grained monzogranites collected away from contacts with gray granitoids																			
6	q1	77.71	13.00	0.72	0.08	4.36	3.22	1.42	0.06	0.02	0.02	734	188	162	17	91	0.17	0.02	100.92
59	q1	76.99	13.64	0.32	0.10	5.13	3.51	1.16	0.06	0.02	0.02	147	176	19	<10	28	0.45	0.07	101.51
63	q1	77.08	13.20	0.71	0.08	4.82	3.48	1.11	0.07	0.03	<0.02	255	198	53	37	74	0.20	0.03	100.87
65	q1	76.62	12.59	0.63	0.08	4.78	3.53	0.99	0.06	0.02	<0.02	119	225	3	<10	28	0.35	0.03	99.72
75	q1	77.44	13.53	1.22	0.22	4.72	3.49	1.25	0.13	0.03	0.03	446	190	81	<10	79	0.31	0.10	102.55
B. Samples either collected at a contact with gray granitoids or exhibiting textural variations																			
1. monzogranites																			
5	q1	78.52	12.92	0.34	0.11	4.48	3.15	1.43	0.05	0.02	<0.02	1030	180	182	<10	62	0.21	0.04	101.42
34	q2	74.28	13.42	1.10	0.25	5.05	3.16	1.42	0.11	0.02	<0.02	594	180	105	<10	66	0.36	0.03	99.29
40	q1	76.26	13.42	0.52	0.09	4.64	3.34	1.34	0.06	0.01	<0.02	361	204	110	29	66	0.23	0.01	100.00
69	q1	78.34	12.91	0.38	0.14	4.82	3.19	1.44	0.08	0.01	0.03	1382	186	227	<10	34	0.32	0.04	101.88
2. syenogranites																			
13	q1	73.68	14.60	0.58	0.06	7.72	2.84	0.32	0.06	0.02	0.03	554	294	46	<10	78	0.26	0.04	100.31
24	q2	75.92	13.06	1.67	0.27	5.60	2.72	1.20	0.16	0.04	0.05	662	225	123	43	162	0.43	0.06	101.30
66	q1	77.80	12.59	0.92	0.05	6.42	2.51	0.47	0.05	0.03	0.03	336	239	29	68	98	0.26	0.03	101.24
68	q1	78.52	13.11	0.38	0.11	4.54	3.20	1.55	0.05	0.01	<0.02	1338	188	242	11	63	0.35	0.03	102.03
3. alkali feldspar granite (no samples analyzed)																			
4. alkali feldspar quartz syenite																			
72	q1	69.02	16.31	2.35	0.24	6.66	3.84	1.17	0.17	0.06	0.07	258	252	13	31	29	0.63	0.07	100.65
73	q1	70.00	16.01	1.79	0.13	8.82	2.81	0.55	0.11	0.05	0.04	486	365	61	65	24	0.36	0.06	100.83

*total iron as Fe2O3
LOI = loss on ignition
oxides and LOI in weight percent; trace elements in parts per million

TABLE 11. K-Ar ISOTOPIC DATA

	Gray Granitoids		White Granite
	Hornblende [sample # 39]	Biotite [sample # 15]	Microcline [sample # 40]
potassium (% by weight)	1.204	7.529	12.58
	1.192	7.555	12.46
	1.182	7.529	12.44
mean	1.193	7.538	12.49
radiogenic argon (pm/g)	816.6	4864	4623
	814.8	4842	4630
	813.5	4841	
	817.4		
mean	815.6	4849	4626
atmospheric argon (%)	1.2	0.9	0.8
	0.2	1.1	1.0
	0.1	0.9	
	0.5		
mean	0.4	0.9	0.9
date +/- error (Ma)	355+/-8	337+/-8	202+/-5

pm/g = picomoles/gram
Analyses performed by the Isotope Geochemistry Laboratory, University of Arizona (sample #'s UAKA 86-18 through 20).

TABLE 12. Rb-Sr ISOTOPIC DATA

sample #	Rb(ppm)	Sr(ppm)	86Sr/88Sr	87Sr/86Sr	87Rb/86Sr
I. Hornblende biotite tonalite of uncertain relations					
52	82.6	353.20	0.11956	0.70785	0.677
53	144.5	211.20	0.11890	0.71424	1.982
II. Gray granitoids					
1	205.8	240.40	0.11958	0.71653	2.479
3	205.5	173.10	0.11937	0.72160	3.439
15	162.1	139.90	0.11892	0.72073	3.358
III. White granites					
59	180.3	34.69	0.11967	0.77931	15.150
63	191.1	48.33	0.11971	0.76058	11.500
65	228.0	20.22	0.11932	0.86761	33.130
IV. Minerals from sample # 15					
biotite	1167.8	7.71	0.11917	3.17299	543.900
plagioclase	11.3	130.10	0.11954	0.70701	0.250

Analyses performed by Fullager, P.D., 1988, University of North Carolina, Chapel Hill

TABLE 13. AGE DETERMINATIONS OF THE ROCKY MOUNT BATHOLITH

Sample	Method	Reference	Date(Ma)
zircon(1)	207Pb-206Pb	2	368+/-4
hornblende(1)	K-Ar	1	355+/-8
whole-rock(8)	Rb-Sr	3	345+/-1
biotite(1)	K-Ar	1	337+/-8
biotite(1)	Rb-Sr	3	318+/-2
microcline(1)	K-Ar	1	202+/-5

number in parentheses is the number of samples analyzed

references:
1 = this report
2 = Sinha (1980)
3 = Fullager and Spruill (1989)

APPENDICES

APPENDIX I. COORDINATES OF SAMPLE LOCATIONS

Location	Latitude	Longitude
I. Quarries		
q1	35°58’25.0"	77°44’51.1"
q2	35°56’44.7"	77°50’05.7"
II. Outcrops		
o1	35°57’40.0"	77°48’10.5"
o2	35°55’33.0"	77°49’49.5"
o3	36°02’09.9"	77°52’40.0"
o4	36°03’36.9"	77°51’30.2"
o5	36°04’25.9"	77°52’11.4"
III. Drill core		
c1	36°02’18.5"	77°46’48.1"
c2	36°00’13.3"	77°53’18.8"
c3	36°02’10.6"	77°52’53.2"
c4	36°03’29.7"	77°49’11.4"
c5	35°55’15.2"	77°50’57.6"
c6	35°55’15.2"	77°51’42.2"
c7	35°55’23.1"	77°51’21.9"
c8	35°55’36.9"	77°51’23.5"

APPENDIX II.A. MODAL DATA OF THE APLITE DIKES

Sample	Location	Quar	K-Fel	Plag	Biot	Acc	Sub
18	q2	37.3	32.0	28.0	1.0	tr	1.7
32	q2	36.0	38.5	17.3	2.2	tr	6.0

mineral percentages by volume

Acc = accessory minerals including allanite, garnet, magnetite
Sub = subsolidus minerals including chlorite, epidote, and white mica

APPENDIX II.B. WHOLE ROCK CHEMICAL DATA OF APLITE DIKES AND DIABASE

Sample	Location	SiO2	Al2O3	Fe2O3*	MgO	K2O	Na2O	CaO	TiO2	MnO	P2O5	Ba	Rb	Sr	Y	Zr	LOI	H2O	Total
I. Aplite dikes																			
18	q2	75.18	13.61	1.04	0.12	4.81	3.44	1.19	0.08	0.04	0.03	698	273	66	<10	62	0.19	0.02	99.86
32	q2	76.44	13.06	0.98	0.15	5.67	2.62	0.93	0.09	0.03	<0.02	2144	253	179	22	78	0.41	0.07	100.72
II. Diabase																			
55	c1	49.25	16.50	10.72	7.28	0.54	1.85	10.29	0.48	0.18	0.06	297	0	147	14	45	1.35	2.07	100.62

*total iron as Fe2O3
LOI = loss on ignition
oxides and LOI in weight percent; trace elements in parts per million