STRUCTURAL RELATIONS, ORIGIN AND EMPLACEMENT OF GRANITIC ROCKS IN THE CEDAR ROCK COMPLEX, GEORGIA PIEDMONT

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ENVIRONMENTAL PROTECTION DIVISION
GEORGIA GEOLOGIC SURVEY

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Cover: Outcrop of High Falls Granite at High Falls State Park, northwestern Monroe County, Georgia.

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STRUCTURAL RELATIONS, ORIGIN AND EMPLACEMENT OF GRANITIC ROCKS IN THE CEDAR ROCK COMPLEX, GEORGIA PIEDMONT

by

Robert L. Atkins and Jerry A. Lineback

ABSTRACT

The Cedar Rock Complex of the Georgia Piedmont consists of granite and granite gneiss surrounded by the metamorphic rocks of the Georgiabama thrust stack. Zones of weakness in the metamorphic rock, induced by tensional forces, acted as conduits and allowed granitic magma to intrude into the low-pressure apical portions of northeast and northwest trending folds in the metamorphic rocks, forming sheet-like plutons.

The Cedar Rock Complex, from oldest to youngest, consists of the Odessadale Granite Gneiss, the High Falls Granite, the Hollonville Granite and the Gay Granite. The Odessadale Granite Gneiss is part of a thrust sheet emplaced in the Georgiabama thrust stack while stacking took place during the early Paleozoic. The consistent orientation of gneissic banding in the Odessadale with the regional structural fabric indicates that the Odessadale was metamorphosed. Mineralogy and chemistry suggest a sedimentary origin for the Odessadale. The High Falls Granite intruded the Zebulon thrust sheet of the Georgiabama thrust stack as a concordant sheet-like pluton after the emplacement of the Odessadale Granite Gneiss also during the early Paleozoic. The Hollonville Granite intruded the Georgiabama thrust stack as sheet-like plutons during the late Paleozoic, after the Georgiabama thrust stack was assembled. The Gay Granite intruded the Hollonville as dikes and sills shortly after the Hollonville was emplaced.

INTRODUCTION

The Cedar Rock Complex is an assemblage of four lithologically distinct and mappable granitic rock units. From oldest to youngest, these are the Odessadale Granite Gneiss, the High Falls Granite, the Hollonville Granite, and the Gay Granite. The Odessadale Granite Gneiss has been metamorphosed and may be sedimentary in origin. The three granites contain structural features indicating magmatic emplacement.

These granitic rocks crop out together in discrete areas surrounded by non-granitic metamorphic rocks of the Georgiabama thrust stack in the western part of the Piedmont Physiographic Province of Georgia. The area of outcrop of the Cedar Rock Complex lies between the towns of High Falls and LaGrange, Georgia (between 32^{o} 52.5' and 33^{o} 20' N and 84^{o} and 84^{o} 57' 30" W (plate 1). The Complex is exposed at the surface in nine Georgia counties: Troup, Meriwether, Pike, Spalding, Butts, Fayette, Upson, Monroe, and Lamar. The Cedar Rock Complex has been mapped over 880 km^2 in parts of 18 U. S. Geological Survey 7 .5 minute topographic quadrangles (plate 1).

The purpose of this study is to: 1) describe the structural features of the granites and the granite gneiss of the Cedar Rock Complex; 2) interpret the nature and origin of the structural features of these rocks; 3) determine the mechanism of formation or emplacement of each granitic unit; 4) describe the deformational history of the Complex; and 5) relate these granitic rocks to the tectonostratigraphy of the Georgiabama thrust stack.

Methods of Investigation

Field mapping of the Cedar Rock Complex and measurement of the orientation of planar and linear structural features were carried out by Atkins between 1980 and 1986 (plates 2 and 3). Tectonostratigraphic units and geologic structures in the surrounding metamorphic terrane of the Georgiabama thrust stack were mapped earlier by Higgins and Atkins (unpublished data). Seventy-three thin sections of the granitic rocks of the Cedar Rock Complex and 32 thin sections of the surrounding metamorphic rocks were examined to quantify lithologic distinctions. Twenty samples from the granitic rocks of the Cedar Rock Complex were analyzed for major oxides by atomic absorption spectrophotometry in the United States Geological Survey laboratories in Reston, Virginia (plate 1).

Previous Studies

Watson (1902) conducted the first detailed geologic investigation of granites in Georgia, published many petrographic descriptions and subdivided Georgia granites into two textural types: gneissic and massive. He concluded that the gneissic granites, like the Odessadale, are older than the massive granites. Hewett and Crickmay (1937) described the Snelson granite in the northern part of the Warm Springs quadrangle, which we include in the Odessadale Granite Gneiss. The Snelson granite contains a persistent foliation which is folded on a small scale. The Snelson granite is described as having the form of a series of coalescing lenses that occupy the trough and flanks of a broad synform (Crickmay, 1952). Herrmann (1954) described the flow structures and petrology of the Stone Mountain Granite and the migmatitic Lithonia Gneiss that are similar to the Cedar Rock Complex (plate 1).

Fullager and Butler (1976) concluded that the Sparta Complex in the eastern Georgia Piedmont consists of rocks of two different radiometric ages (550 and 300 m.y.)(plate 1). The granites of the Sparta Complex have a wide variety of textures, ranging from coarse-grained and porphyritic to fine-grained and massive, as do the Cedar Rock granites.

Other recent studies of Piedmont granites that assisted in understanding the Cedar Rock Complex include Size and Covert (1985) and Covert (1986), who described the petrology, structure, and petrogenesis of the migmatized Lithonia Gneiss. Sinha and Higgins (1987) concluded that the Yellow Dirt Gneiss and Hightower Granite, located in the Piedmont north of the Brevard fault in Georgia, were localized along thrust sheets of the Georgiabama thrust stack. These granitic rocks show evidence of decompressional melting and localization along structural discontinuities. Grant and others (1980) concluded that the Stone Mountain granitic magma formed as a result of anatexis and intruded previously folded metamorphic rocks as a flattened ellipsoidal magma mass. The magma movement was controlled by earlier structures. The Mount Arabia migmatite in the Lithonia Gneiss represents small-scale incipient melting due to water being unavailable for larger scale melting.

The Piedmont of the southern Appalachians is a multiply deformed terrane of metasedimentary, metavolcanic, metaplutonic, and plutonic rocks. The complex geology of the southern Appalachians has given rise to several structural interpretations. The reader is referred to Hatcher (1972, 1978), Hatcher and Odom (1980), Williams and Hatcher (1982, 1983), Cook and others (1979, 1981), Secor and others (1986), Zen (1981), Rodgers (1982) and Higgins and others (1988) for details of the various theories.

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GRANITIC ROCKS

Lithology of Granites

Granites are granular igneous rocks containing predominantly alkali feldspar and quartz. Orthoclase, microcline and plagioclase are the common feldspar minerals. Plagioclase is typically oligoclase with some andesine and albite. Biotite, muscovite, amphibole and pyroxene are common accessory minerals. Sericite is a frequent alteration product. The silica content of granites generally ranges between 65 and 75 percent and they typically contain between 5 and 30 percent quartz. Petrographic analyses of the granitic units making up the Cedar Rock Complex show that all samples analyzed, except for a single sample of the Odessadale Granite Gneiss, fall within the composition range of granite as defined by Streckeisen (1973)(fig. 1; table 1).

Granites are formed by the partial melting of older sedimentary rocks, igneous rocks and/or metamorphic rocks. Granites can also be the result of ultrametamorphism by which melt, and residual xenolithic and xenocrystic material derived from parent rock, move *en masse* to the site of crystallization (White and Chappell, 1977).

Granite gneiss is a metamorphic rock with a granitic composition that has planar or contorted banding. Granite gneiss may form by the metamorphism of an older igneous rock but may also form by partial melting of a host rock resulting in a mixed rock containing both igneous and metamorphic minerals, a process called migmatization. The igneous component in a migmatite may occur parallel to or cut across compositional layering in the host rock.

Internal Sturctures of Granites

The movement of a partially crystallized granitic magma may orient elongate minerals, such as prismatic K-feldspar or platy minerals such as mica, in the

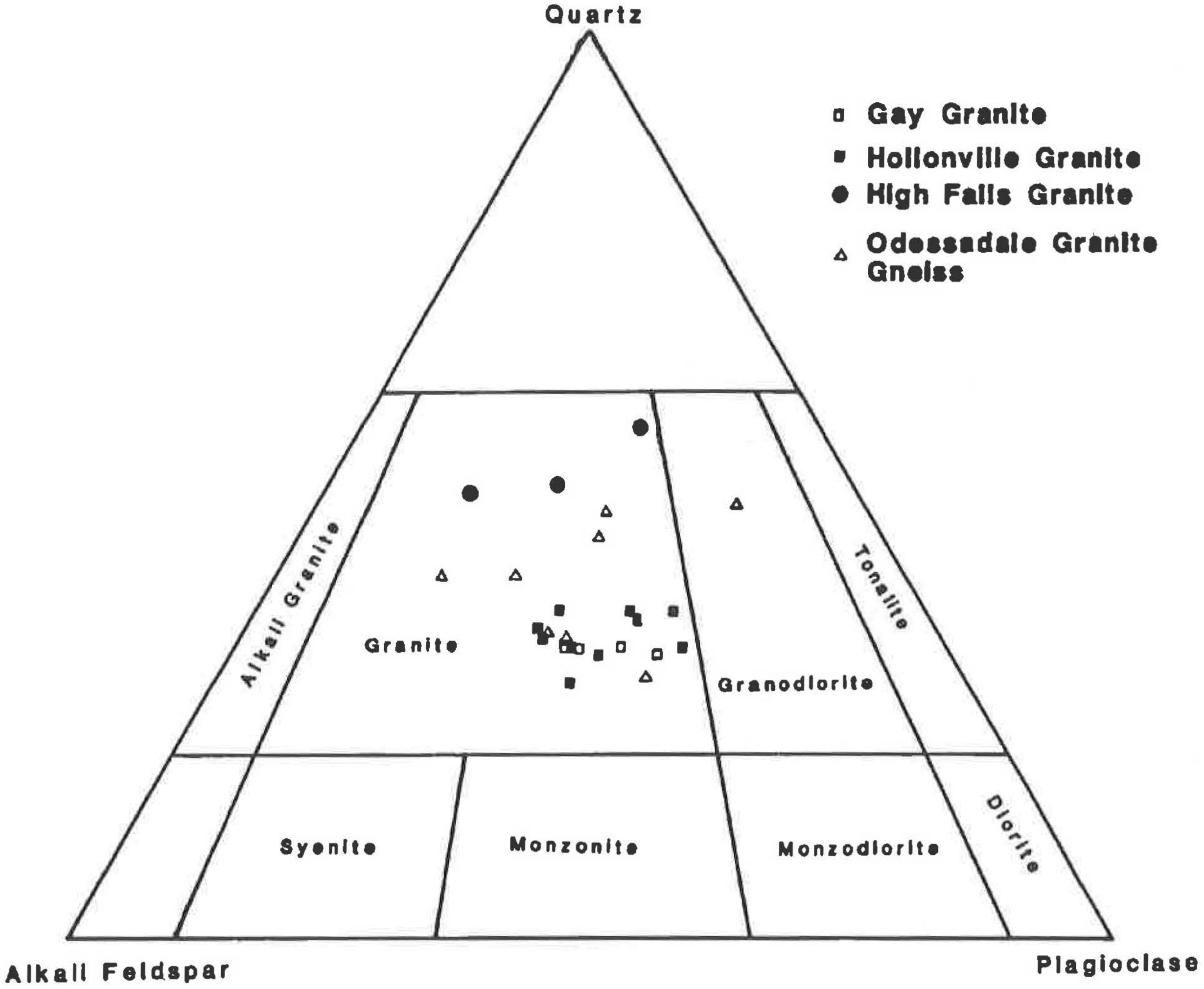


Figure 1. Triangular plot of the relative percentages of modal quartz, alkali feldspar and plagioclase for the granitic rocks of the Cedar Rock Complex (Table 1). Classification from Streckeisen (1973).

TABLE 1

Average modal mineral abundance of granite and granite gneiss units in the Cedar Rock Complex.

Modal Mineral	Odessadale n=8 percent (sd)	Hollonville n=10 percent (sd)	High Falls n=3 percent (sd)	Gay n=4 percent (sd)
Plagiclase	27.6 (7.1)	30.5 (3.9)	16.9 (6.4)	32.6 (3.8)
Microcline	29.3 (9.9)	29.1 (5.8)	22.4 (7.1)	29.1 (3.5)
Quartz	37.0 (7.6)	29.9 (2.3)	42.5 (4.6)	28.3 (0.6)
Biotite	3.7 (3.1)	5.3 (4.3)	8.3 (3.1)	4.9 (1.5)
Muscovite	0.9 (0.9)	3.6 (2.9)	7.7 (8.0)	2.9 (0.8)
Epidote	0.3	0.4	0.1	0.2
Myrmekite	0.6	0.6	1.3	1.4
Garnet	0.1	tr.	0.8	tr.
Chlorite	0.3	0.1	--	0.3
Opaques	0.4	tr.	0.3	tr.
Apatite	tr.	tr.	--	0.2
Sphene	tr.	--	--	--
Zircon	tr.	tr.	tr.	tr.
Totals	100.2	99.5	100.3	99.9

(sd) = standard deviation

tr. = mineral was identified in the petrographic description but were not counted in the modal analysis.

plane of movement, imparting a primary flow banding or foliation to the rock. Tabular biotite clots (schlieren) and elongate xenoliths also are excellent flow plane markers in granites. Another way to identify a flow plane is by a change in the percentage of minerals present across that plane or boundary (Marre, 1986). A more subtle flow lineation can be delineated by mapping the orientation of spatially separated crystals of prismatic or elongate minerals. The flow structures preserved in a granite can be used to develop a model for the emplacement of the pluton (Pitcher and Berger, 1972; Marre, 1986).

TECTONOSTRATIGRAPHY AND STRUCTURE OF THE METAMORPHIC ROCKS ADJACENT TO THE CEDAR ROCK COMPLEX

Tectonostratigraphy

A regional structural and tectonostratigraphic interpretation of the Southern Appalachian Orogen was developed by Higgins and others (1984, 1986, 1988). According to this model, the Orogen formed as a series of stacked thrust sheets (fig. 2). Thrusting took place more or less continuously from about the Middle Ordovician through the Permian. Moving and stacking of the thrust sheets generated folding, metamorphism and plutonism. Thrust sheets with different deformational and metamorphic histories are juxtaposed within the thrust stacks. Each of the three major thrust stacks in Georgia contain several thrust-fault bounded sheets of rock (fig. 2). The stacking order of the thrust faults determines the stratigraphy and the stacked units do not necessarily represent a younging upward sedimentary sequence. Each thrust sheet in a thrust stack is defined on the basis of its characteristic lithologies, its stratigraphic position in the thrust stack and its bounding thrust faults (fig. 2).

The granitic rocks of the Cedar Rock Complex are enclosed by the metamorphic rocks of the Georgiabama thrust stack. The metamorphic rocks of each thrust sheet making up the Georgiabama thrust stack in the central and western parts of the Georgia Piedmont are described from the bottom to the top of the stack (fig. 2).

Bill Arp Thrust Sheet

The lowermost tectonostratigraphic unit in the Georgiabama thrust stack is the Bill Arp thrust sheet (fig. 2). It structurally overlies the relatively less metamorphosed Paleozoic sedimentary rocks of the Rome-Kingston thrust stack that underlies the Valley and Ridge Physiographic Province of northwestern Georgia. The Bill Arp thrust sheet is composed of the Great Smoky Group which in turn consists of the Ola and Kalves Creek formations. The Ola Formation is a quartz-biotite-muscovite-sillimanite graphite schist that locally contains thin layers of biotite-garnet schist, biotite schist and biotite-plagioclase gneiss. The Kalves Creek Formation is a yellow weathering sillimanite-graphite schist that contains thin (less than 1 m) layers of biotite-garnet schist, biotite schist and/or biotite-plagioclase gneiss.

Zebulon Thrust Sheet

The Zebulon thrust sheet structurally overlies the Bill Arp thrust sheet and consists of the Senoia Member and undifferentiated Zebulon Formation (fig. 2). These units are composed of interlayered, generally pink to purple weathering schists (commonly with abundant aluminosilicate minerals and garnet), ocher weathering hornblende-plagioclase amphibolites and lesser amounts of a wide variety of biotite-plagioclase gneisses. The upper part of the Zebulon Formation contains thin beds of gondite and magnetite-bearing gondite.

Clairmont Thrust Sheet

The Clairmont thrust sheet is structurally above the Zebulon thrust sheet (fig. 2). The Clairmont is a complex polykinematic, polytectonic melange. It consists of fragments, chips, blocks and slabs of amphibolite, light-gray granofels, metagranite and quartzite in a multiply deformed light to dark gray biotite-plagioclase gneiss matrix. The gneiss also contains autoclastic chips, blocks and slabs.

Wahoo Creek Thrust Sheet

The Wahoo Creek thrust sheet structurally overlies the Clairmont thrust sheet (fig. 2). It consists of the Wahoo Creek Formation which is a fine- to medium-grained muscovite-plagioclase-quartz gneiss that is thinly banded to laminated. The gneiss is light-gray to nearly white, weathers to slabs and generally contains porphyroblasts of potassium feldspar and layers and lenses of calc-silicate. Thin layers of epidote-hornblende-plagioclase amphibolite are common within the gneiss in places.

Atlanta Thrust Sheet

The Atlanta thrust sheet lies structurally above

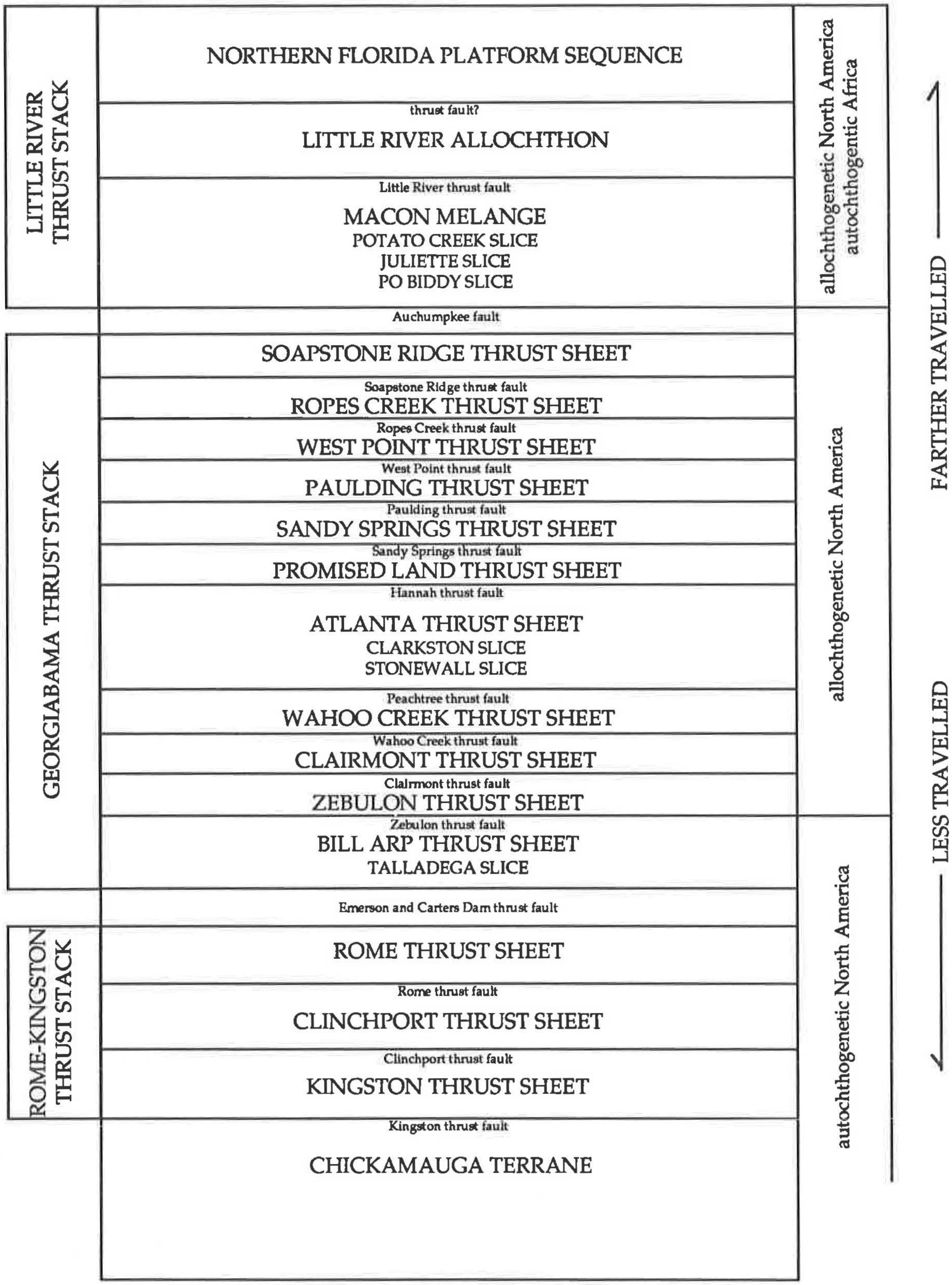


Figure 2. Stacking order of tectonostratigraphic units and thrust sheets (from Higgins and others, 1988).

the Wahoo Creek thrust sheet and contains the Atlanta Group, including the Ison Branch, Barrow Hill and Clarkston formations (fig. 2). The Ison Branch Formation consists of a very thinly laminated metamorphosed calcareous tuff that is characterized by chaotic fold patterns. The Barrow Hill Formation overlies the Ison Branch Formation and is composed of gondite (spessartine garnet quartzite) and magnetite-bearing gondite in layers less than a meter thick. The gondite is interbedded with pink to purple weathering garnet-sillimanite-muscovite-biotite schist and ocher weathering hornblende-plagioclase amphibolite in the Barrow Hill Formation. The Clarkston Formation overlies the Barrow Hill Formation and consists of pink to purple weathering sillimanite-garnet-quartz-plagioclase-biotite-muscovite schist that is locally graphitic. The schist in the Clarkston Formation is interlayered with ocher weathering, fine-grained, hornblende-plagioclase amphibolite on a scale of 1 to 20 m.

Sandy Springs Thrust Sheet

The Sandy Springs thrust sheet is structurally above the Atlanta thrust sheet (fig. 2) and is composed of the Powers Ferry Formation, the Chattahoochee Palisades Quartzite and the Factory Shoals Formation. The Factory Shoals Formation consists of light gray garnet-biotite-oligoclase-muscovite-quartz schist, muscovite-quartz schist and thinly bedded metagraywacke (Higgins and McConnell, 1978). The Chattahoochee Palisades Quartzite is a 1-3 m thick, tan-weathering, micaceous quartzite and is the only unit of the Sandy Springs thrust sheet that is present in the Cedar Rock study area. It is commonly a massive, white, yellowish, or bluish, sugary to vitreous quartzite containing accessory mica and garnets. The Powers Ferry Formation consists of interlayered purple to pink weathering sillimanite-garnet-quartz-plagioclase-biotite-muscovite schists and thin ocher weathering hornblende-plagioclase amphibolites (Higgins and McConnell, 1978).

Paulding Thrust Sheet

The Paulding thrust sheet structurally overlies the Sandy Springs (fig. 2) and is composed of the Paulding Volcanic Group, a volcanic-plutonic complex made up of hornblende- and actinolite-plagioclase amphibolites that are green or blue green, light green weathering, epidote-rich, and generally chloritic. These amphibolites are intimately interlayered with light gray to nearly white, amphibole-bearing granofels and biotite-bearing gneisses. Dikes, sills and small plutons of potassium feldspar-poor granitic rocks are common and many lenses of vermiculitic mica are present.

Ropes Creek Thrust Sheet

The Ropes Creek thrust sheet structurally overlies the Paulding thrust sheet and is composed of the Ropes Creek Metabasalt, a dark red weathering, massive to finely layered, green to greenish-black, hornblende-plagioclase amphibolite. The metabasalt contains minor amounts of fine- to medium-grained, generally amphibole-bearing granofels. The mafic rocks are at least partially chloritized and (or) epidotized. Magnetite quartzite occurs with the amphibolites.

Soapstone Ridge Thrust Sheet

The Soapstone Ridge thrust sheet is the structurally highest tectonostratigraphic unit in the Georgiabama thrust stack (fig. 2). It is composed of ultramafic-mafic complexes and small ultramafic and mafic slices. The ultramafic-mafic complexes commonly have a relatively thin basal unit of dunite or peridotite that has been sheared and altered to serpentinite and talc-chlorite schist. The basal unit is commonly overlain either by mixed units of altered ultramafic rocks and uralitized and chloritized metagabbroic rocks, or by uralitized and chloritized metapyroxenites, or by both.

Granitic Rocks

Granitic rocks of the Cedar Rock Complex and other granitic complexes present within the Georgiabama thrust stack were formed by partial or complete anatectic melting of older metamorphic rocks of the stack during the stacking process or shortly thereafter (Higgins and others, 1988). The blanketing effects of the stacking process trapped heat generated during the deformation process, resulting in melting of parts of the thrust stack. Decompression in tensional zones may have aided the melting process. Plutonic events were categorized by Higgins and others (1988) as Cambrian (and Ordovician) plutons, Silurian-Devonian plutons and Carboniferous plutons. Silurian-Devonian and Carboniferous plutons may be distinguished in the Cedar Rock Complex.

STRUCTURAL FEATURES OF THE METAMORPHIC ROCKS

The metamorphic rocks enclosing the granitic rocks of the Cedar Rock Complex contain subparallel planar structures, including schistosity and compositional layering (plate 2). These planar features strike northeast and dip southeast (appendix A, fig. A). This trend is subparallel to the regional structural trend of the crystalline rocks in the southern Appalachians. The metamorphic rocks surrounding the Complex contain a joint set striking N50°W that has a nearly vertical dip (appendix A, fig. B).

The rocks of the Georgiabama thrust stack form broad, large scale antiform or synform structures in the vicinity of the Cedar Rock Complex. The Cedar Rock Complex lies in the apical area of the northeast trending Ola anticlinorium west of Griffin (plates 2 and 3). The granites of the Complex cut across the northeast end of the Griffin synform southeast of Griffin.

Folding

The metamorphic rocks between the Towaliga and Brevard faults, including those enclosing the Cedar Rock Complex, have undergone at least five generations of folding: Buck Branch (oldest), Klondike, Elijah Mountain, Scott Creek, and Tara (Atkins and Higgins, 1980). Mineral lineations in the metamorphic rocks outside the contact aureole of the Hollonville Granite trend E-W, N-S and N45°E (appendix A, fig. C). The east-west and north-south trends, described by Atkins and Higgins (1980) and Higgins and Atkins (1981), are associated with the gently warping, open, upright Tara and Scott Creek fold generations. Lineations in the N45°E trend reflect the regional structural trend, probably related to either Buck Branch or Klondike fold generations.

Mineral lineations and fold axes in the country rock affected by the contact aureole of the Hollonville Granite also follow the regional northeasterly structural trend and predate the intrusion of the Hollonville Granite. These lineations consist of biotite and sillimanite mineral lineations and the hinge lines of folds. Lineation trends in the Hollonville contact aureole reflect the northeast trending antiformal structure that the granite intruded (appendix A, fig. D). The scatter of lineation trends shown in Appendix A, Figure D when compared to those shown by Figure C is attributed to pre-granite fold orientations and disturbance of these by the intrusion of the Hollonville Granite.

Faulting

Thrust faulting within the Georgiabama thrust stack began in the Middle Ordovician and continued through the Permian (Higgins and others, 1986, 1988). Paleozoic faults, such as the Towaliga, Modoc, Augusta, Nutbrush and Brevard faults in the southern Appalachians, exhibit a multi-tectonic history (Bobyarchick, 1981; Higgins and others, 1986, 1988). Normal fault movement, such as that along the Towaliga fault, postdates Alleghenian movement on the Appalachian detachment (Nelson and others, 1987). The High Falls and Hollonville granites of the Cedar Rock Complex are truncated by the Towaliga fault zone and are crosscut by post-metamorphic faults marked by silicified crushed rock (plates 2 and 3).

THE CEDAR ROCK COMPLEX

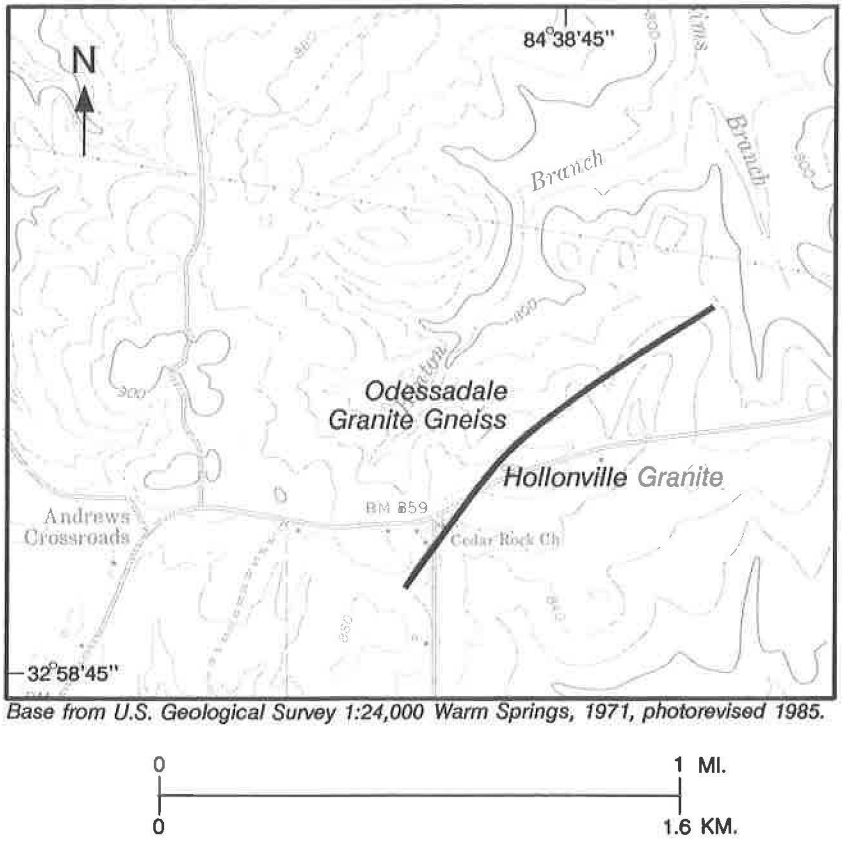
Definition

The Cedar Rock Complex is defined in this report based, in part, on exposures located near Cedar Rock Church in the Warm Springs quadrangle (fig. 3). Both the Odessadale Granite Gneiss and the Hollonville Granite crop out at this type area. Since all four of the units making up the Cedar Rock Complex are not exposed in the same outcrop, the type section of each individual unit forms a reference section for the definition of the Complex. The Cedar Rock Complex includes three granites and a granite gneiss of varying ages, structural relationships, textures, mineralogies and chemistries that crop out together in several irregular areas within the generally metamorphic terrane of the western Georgia Piedmont (plate 2). There are two lower Paleozoic units, the migmatized Odessadale Granite Gneiss and the High Falls Granite, and two upper Paleozoic granites, the Hollonville Granite and the Gay Granite. The Complex includes the contact aureoles surrounding the granite plutons, but only the Hollonville Granite has an extensive aureole (plates 2 and 3).

Odessadale Granite Gneiss

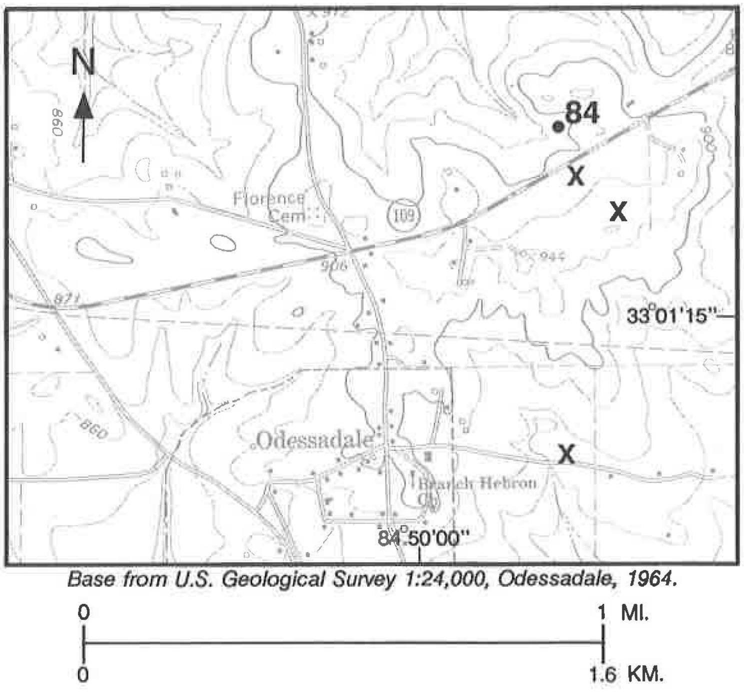
The Odessadale Granite Gneiss is here named for exposures in the Odessadale quadrangle. The type exposure occurs as pavement outcrops east of the community of Odessadale (fig. 4). Odessadale Granite Gneiss outcrops are most common in the western and central portion of the Cedar Rock Complex (plates 2 and 3). Approximately 15 percent of the area mapped as Cedar Rock Complex is the Odessadale Granite Gneiss.

The Odessadale Granite Gneiss is the oldest lithology in the Cedar Rock Complex. Both the Gay Granite and Hollonville Granite intrude the Odessadale. Odessadale xenoliths are present in the



Base from U.S. Geological Survey 1:24,000 Warm Springs, 1971, photorevised 1985.

Figure 3. Part of the Warm Springs Quadrangle showing the type area of the Cedar Rock Complex.



Base from U.S. Geological Survey 1:24,000, Odessadale, 1964.

Figure 4. Part of the Odessadale Quadrangle showing the type area of the Odessadale Granite Gneiss and the location of sample 84. Significant exposures denoted by X.

Hollonville Granite in the eastern part of the Cedar Rock Complex. The occurrence of probable Odessadale xenoliths in the High Falls Granite suggests that the Odessadale also is older than the High Falls.

The Odessadale Granite Gneiss tectonostratigraphically overlies the Zebulon Formation of the Zebulon thrust sheet in the study area. The Odessadale is structurally overlain by the Chattahoochee Palisades Quartzite of the Sandy Springs thrust sheet. The Odessadale Granite Gneiss is lithologically similar to the Lithonia Gneiss and both units are interpreted to lie in a similar tectonostratigraphic position below the Sandy Springs thrust sheet. The Lithonia Gneiss crops out east of Atlanta and structurally overlies the Promised Land thrust sheet in that area. Rocks representing the Promised Land thrust sheet are not in contact with the Odessadale Granite Gneiss. The tectonostratigraphic relationship of the Odessadale to the Atlanta thrust sheet is unclear. The Clarkston Formation of the Atlanta thrust sheet occurs east of the Flint River south of Gay and may be in contact with the Odessadale. This possible contact is obscured, however, by overlying terrace sand deposits and the numerous outcrops of Hollonville Granite in the area. Nevertheless, because of its similarity to the Lithonia Gneiss, the Odessadale Granite Gneiss is thought to represent a disrupted thrust sheet emplaced between the Promised Land and Sandy Springs thrust sheets during the stacking process.

The Odessadale Granite Gneiss is most commonly a grayish-white, fine- to medium-grained, biotite granite gneiss that contains scattered grains of garnet and magnetite. Odessadale gneissic banding ranges from planar to contorted (fig. 5). The Odessadale contains feldspar porphyroblasts and thin blebs and ribbons of granite. A less common lithology in the Odessadale is a grayish-white, medium- to coarse-grained to porphyroblastic, biotite granite gneiss with porphyroblasts of quartz, feldspar, biotite, and muscovite (fig. 6). Quartz porphyroblasts in this lithology are up to 7 mm long. A third lithology found in the Odessadale in places is a grayish-white, fine- to medium-grained biotite granite that contains garnet and magnetite without blebs and ribbons of granite.

Rounded zircons of probable sedimentary origin are present in the Odessadale Granite Gneiss as an accessory mineral. Zircons have a high thermal stability and represent the only identifiable original sedimentary grains preserved in many metasedimentary rocks.

Approximately 95 percent of the Odessadale Granite Gneiss is migmatite, which is a composite rock containing both igneous and metamorphic minerals. Migmatites form by partial melting (partial anatexis) of older rocks or by injection of granitic melt into the older rocks. The Odessadale migmatite typically contains layers and pods of granitic material parallel to or cutting across the compositional layering of a contorted biotite granite gneiss matrix.

Migmatites, such as the Odessadale, have been classified either as stromatic (layered) migmatites in which the granitic material occurs along foliation planes or non-stromatic migmatites in which gneissic rock has been extensively dissected by veins of a lighter colored rock that is generally rich in quartz and feldspar (Johannes, 1988; McLellan, 1988). The Odessadale migmatite generally contains granitic material parallel to the gneissic banding and contains granitic material that crosscuts gneissic banding in places. Figure 5 illustrates a stromatic migmatite in the Odessadale in which the granite and the feldspar phenocrysts are the younger component and the dark minerals making up the gneissic banding are the older protolith of the migmatite. The feldspar phenocrysts are oriented parallel to the gneissic banding. Biotite schlieren (tabular bodies) also are oriented parallel to the banding and are seldom longer than a few centimeters.

Petrography

The Odessadale Granite Gneiss has a medium to coarse grained texture characterized by gneissic banding on a scale of 1 to 5 mm that consists of alternating quartz-plagioclase-rich and biotite-rich layers. The modal percentages of quartz, microcline, and plagioclase (fig. 1) indicate that all but one sample of the Odessadale lie in the granite field.

Subhedral equant- to lath-like plagioclase grains of oligoclase composition (An_{14} to An_{30}) range from 1.0 to 6.0 mm long but average about 1.0 mm. Compositional zoning is present in the plagioclase and albite and percline twinning are common. The plagioclase laths show a preferred orientation in thin section. Some grains are sericitized. Myrmekite is present in places as an alteration of microcline to plagioclase and vermicular quartz.

Anhedral equant interstitial microcline grains range between 0.2 and 2.1 mm in diameter. Microcline is characterized by gridiron twinning. Quartz is present as anhedral grains in the groundmass and as phenocrysts. Some quartz grains exhibit undulatory extinction.

Subhedral tabular grains of light greenish-brown to dark brown biotite in the Odessadale range between 0.3 and 2 mm long. Some biotite is slightly bent. Subhedral muscovite plates are up to 3 mm long and muscovite also occurs as sericite alteration pro-

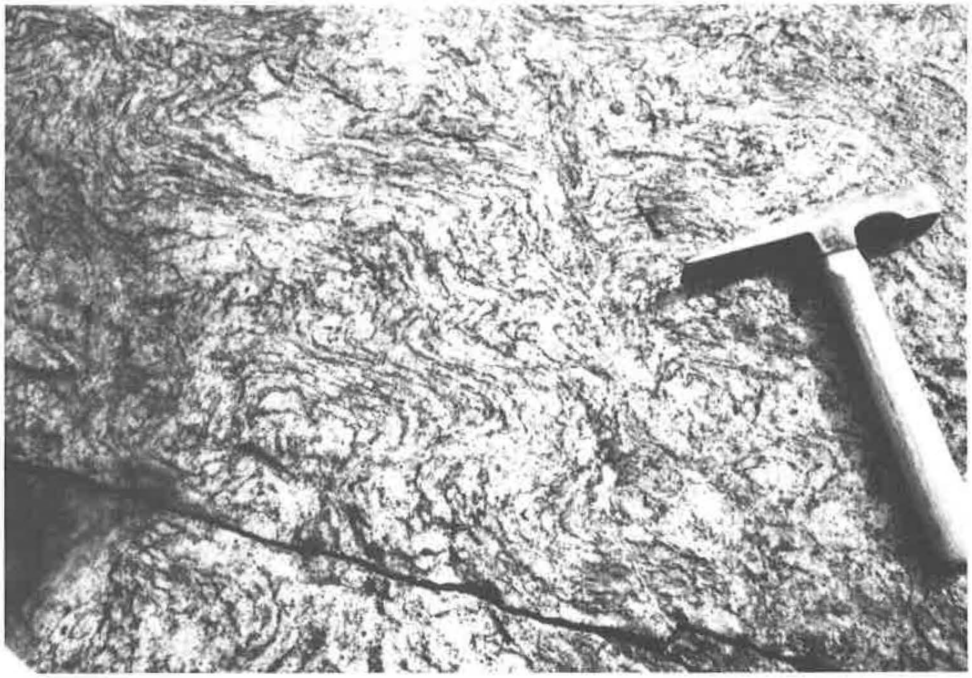


Figure 5. Contorted gneissic banding in the Odessadale Granite Gneiss.

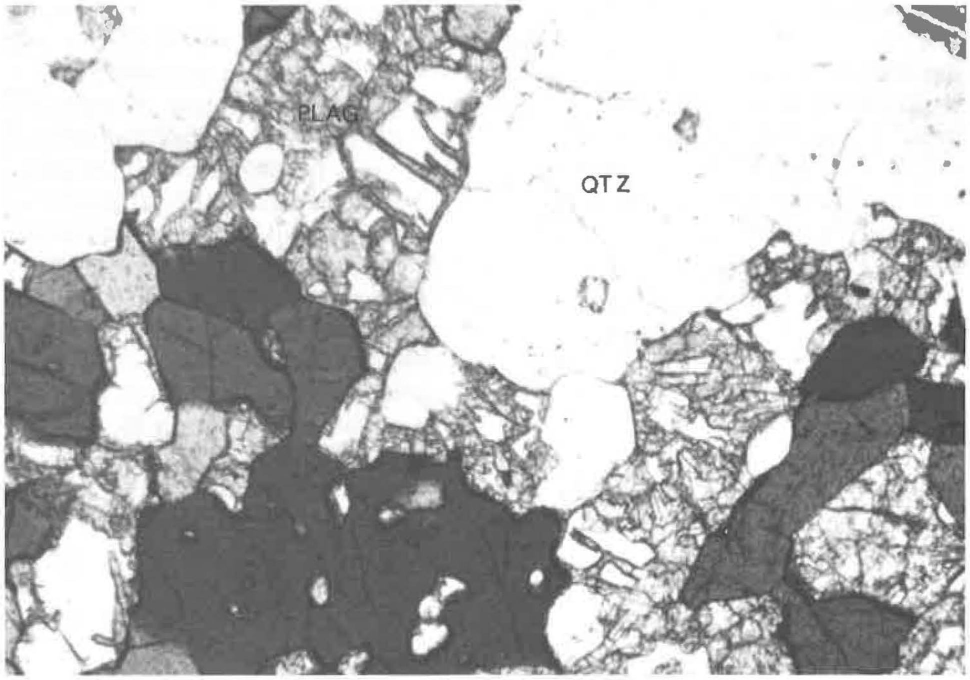


Figure 6. Photomicrograph of quartz porphyroblasts (QTZ) and untwinned anhedral plagioclase (PLA) in the Odessadale Granite Gneiss.

ducts in plagioclase.

Accessory minerals in the Odessadale include magnetite, garnet, sphene, and zircon. Some zircons exhibit zoning and are rounded. Rounded zircons may indicate a sedimentary origin for the Odessadale. Epidote, and chlorite are present as alteration products of plagioclase and biotite respectively. Chloritization, epidotization and the presence of undulatory quartz suggests that the Odessadale may have been metamorphosed.

Structure

Gneissic banding is the most common structure observed in the Odessadale Granite Gneiss. The banding is defined by variations in the relative proportions of dark and light minerals and by grain shape elongation. Gneissic banding in the Odessadale is generally horizontal or dips at a low angle. The trend of the banding (plates 2 and 3) is not parallel to flow structures in the Hollonville Granite. Pi axes for the Odessadale gneissic banding reflect the same regional northeast and north-south trends found in the surrounding metamorphic rocks of the Georgiabama thrust stack (appendix B, fig. A). The consistency in orientation of the foliation in the Odessadale Granite Gneiss with that of the surrounding rocks suggests that the Odessadale rock fabric is controlled by regional stress. The Odessadale also thickens into apical regions of folds suggesting metamorphic induced plasticity.

Folds in the Odessadale vary from open upright warps to reclined and isoclinal folds. Fold orientation also is variable. Some folds are disconnected and separated by 0.1-2 m. Ductile shearing caused dislocation of planar structures in the Odessadale without visible cataclasis (crushing) and may be associated with folding. Shears in the Odessadale occur in groups in which individual shears are 6 to 15 cm apart, 1 to 4 cm in width and traceable for several meters. Ductile shear zones in the Odessadale Granite Gneiss are usually vertical; however, at the Mountville Quarry in the Mountville quadrangle, some ductile shear planes have low dips. The shear zones provided paths for granitic magma to intrude or were zones for anatectic melting.

Schlieren (tabular biotite clots) lie parallel to the gneissic banding in the Odessadale. Schlieren range from 1 to 10 mm in length. The long axes of euhedral microcline crystals and schlieren plunge at a very low angle and are oriented N5°E, N85°E and N20°W (appendix B, fig. B). The N5°E and the N20°W mineral lineations are close to the north-south maxima found in the metamorphic rocks surrounding the Cedar Rock Complex, and the N85°E Odessadale maxima is close to the east-west maxima in the surrounding rocks. Mineral lineations, therefore, suggest a close relationship between the structure and metamorphic history of the Odessadale and the surrounding metamorphic rocks.

Joints in Odessadale outcrops are spaced from a few centimeters to a meter apart. Joint strike trends in the Odessadale Granite Gneiss are E-W, N50°E, N10°E, and N40°W with a near vertical dip (appendix B, fig. C). These trends are the same as joint orientations found in the metamorphic rocks surrounding the Odessadale.

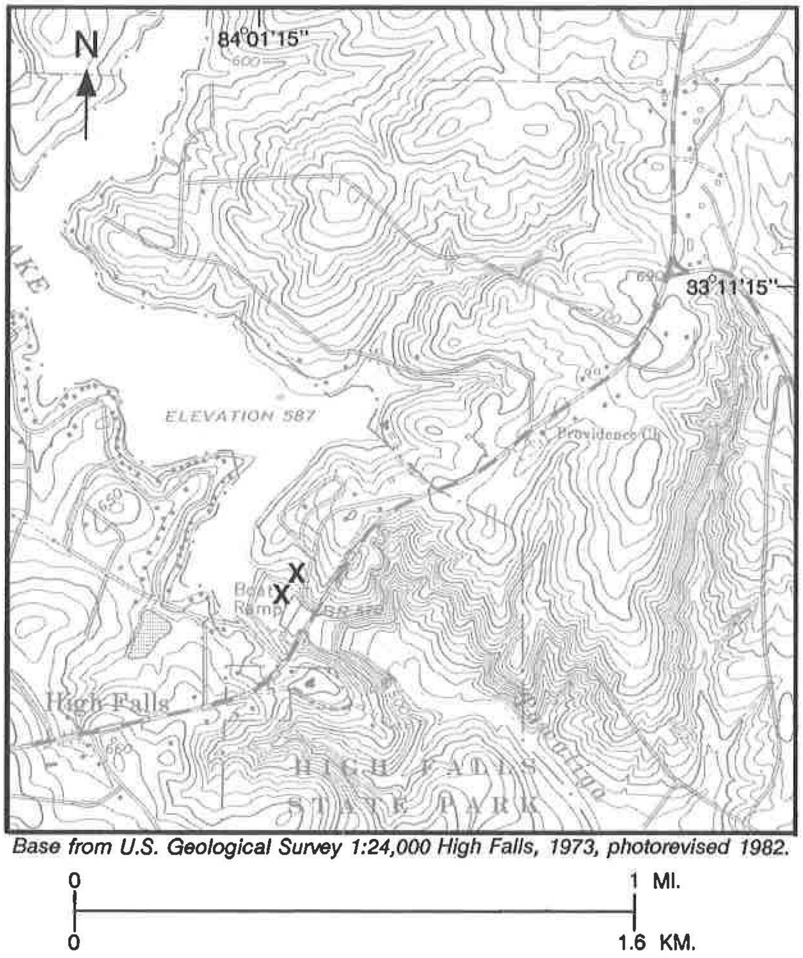
High Falls Granite

The High Falls Granite is here named for High Falls located in the High Falls quadrangle. The type exposures occur along the Towaliga River at High Falls (fig. 7). Approximately 5 percent of the area mapped as Cedar Rock Complex is High Falls Granite. The High Falls Granite occurs only in the eastern part of the Complex. Only the exposures of the High Falls along the Towaliga River at High Falls State Park have sufficient extent in which to measure structural data. The High Falls Granite intruded the Zebulon Formation, a part of the Zebulon thrust sheet of the Georgiabama thrust stack (fig. 2).

The High Falls Granite is a very coarse-grained, porphyritic, biotite granite. Poikiloblastic, white, microcline phenocrysts (3-12 cm) are common in the High Falls Granite and contain inclusions of biotite, quartz and plagioclase. Some of the microcline phenocrysts exhibit mechanical deformation that we interpret to be associated with emplacement of the High Falls Granite and not due to later movement along the Towaliga fault. Some of the mechanically deformed microcline phenocrysts were subsequently folded by northwest trending flow folds. The number of feldspar phenocrysts varies widely within an outcrop. Well developed flow banding in the High Falls Granite is defined by biotite schlieren and feldspar phenocrysts in parallel alignment (fig. 8). Northwest and northeast trending dikes of the younger Hollonville and Gay Granites intrude the High Falls Granite (fig. 9). Granite gneiss xenoliths similar to the Odessadale are present in the High Falls Granite, suggesting that the High Falls is younger.

Petrography

The High Falls Granite has a medium- to coarse-grained, porphyritic, subhedral to anhedral texture. The modal percentages of quartz, microcline,



Base from U.S. Geological Survey 1:24,000 High Falls, 1973, photorevised 1982.

Figure 7. Part of the High Falls Quadrangle with the type area of the High Falls Granite shown by XX.

Figure 8. Large euhedral to subhedral microcline phenocrysts in the High Falls Granite at High Falls.

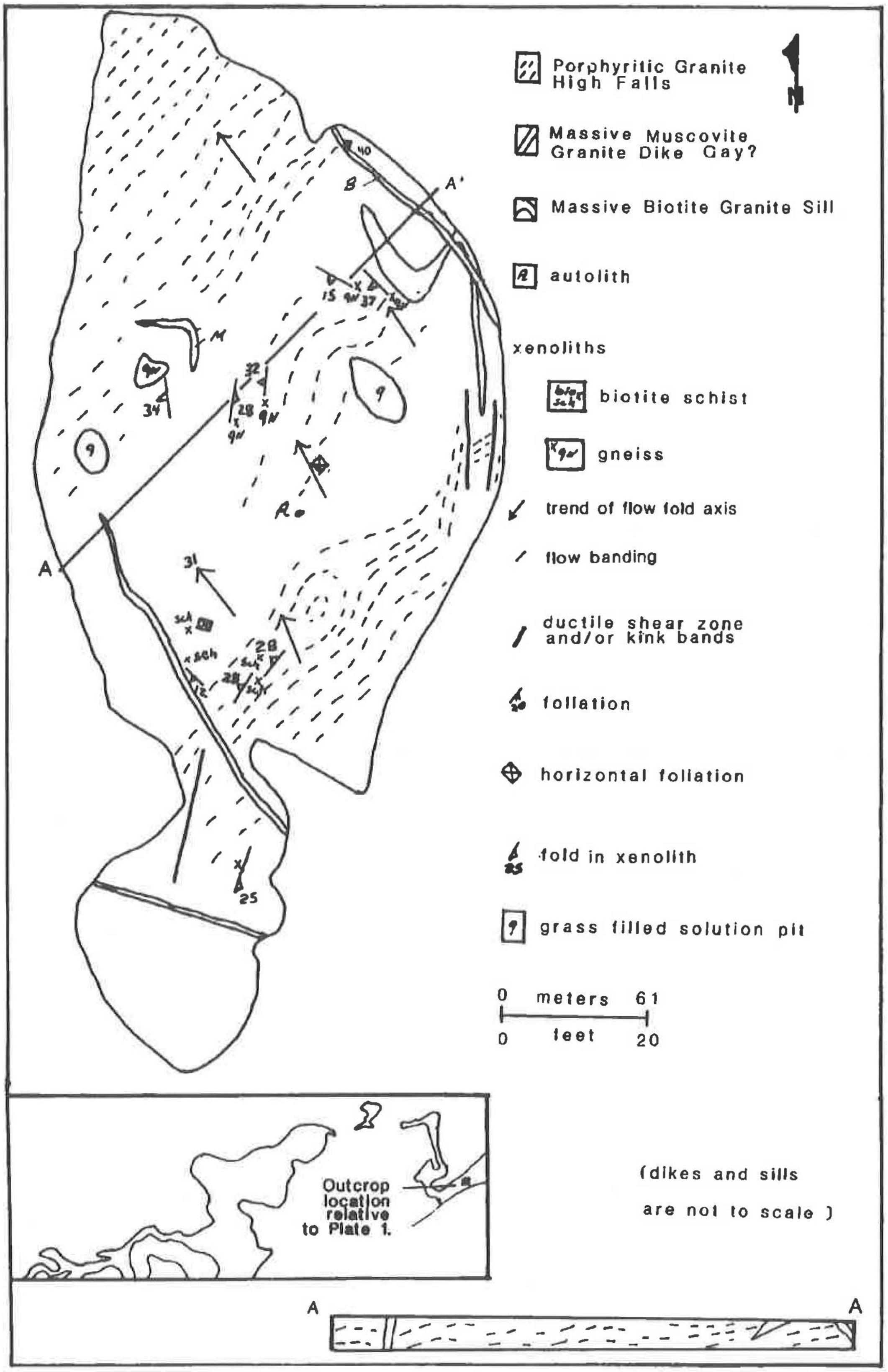


Figure 9. Geologic sketch map of a granite outcrop at High Falls.

and plagioclase in the High Falls indicate that it has a granite composition (fig. 1).

Plagioclase in the High Falls Granite is present as euhedral to subhedral tabular phenocrysts that range up to 4 mm long in thin section. Anhedral plagioclase occurs in the groundmass and as inclusions in microcline phenocrysts. The plagioclase laths are strongly oriented parallel to the flow foliation. Composition ranges from An_9 to An_{12} (oligoclase). Compositional zoning is present in the plagioclase and albite and percline twinning are common. Myrmekite is present as the alteration of microcline to plagioclase and quartz. Sericitization varies from slight to total replacement of the plagioclase crystals. The seritization and the presence of myrmekite suggest that the High Falls Granite has undergone metamorphism or deuteric alteration after its emplacement.

Euhedral to subhedral poikilitic phenocrysts of microcline are up to 6 mm in length and are characterized by gridiron twinning. Inclusions in the microcline include quartz, biotite, plagioclase, opaques, and smaller microcline crystals.

Subhedral plates of olive green or brownish-red biotite in the High Falls Granite range between 0.2 and 3.0 mm in length. Muscovite is present as subhedral plates and minute grains that typically range between 0.5 and 2.5 mm. The muscovite is associated with biotite and sericite.

Anhedral quartz grains in the High Falls range between 0.5 and 3 mm in diameter. Accessory minerals include magnetite, garnet, and zircon. Garnet is associated with biotite-rich layers that may represent xenocrystic material not absorbed by the granite magma.

Structure

The majority of 43 flow planes measured in the High Falls Granite cluster around a northeast trend with a northwest dip that is parallel to the strike and dip of compositional layering in the Zebulon Formation (plates 2 and 3; appendix C, fig. A). Flow-fold axial traces are oriented to the northwest. A geologic sketch map of a pavement outcrop at High Falls State Park illustrates the relationship between northeast trending flow banding, northwest trending flow folding, and emplacement of later northwest trending granite dikes in the High Falls Granite (fig. 9). Interference fold patterns form dome structures. On the east-northeast side of the sketch map, flow banding has been kink-folded or sheared along north-south trending kink bands. A granite dike has intruded along the trend of the axial plane of one of the kink bands (fig. 9).

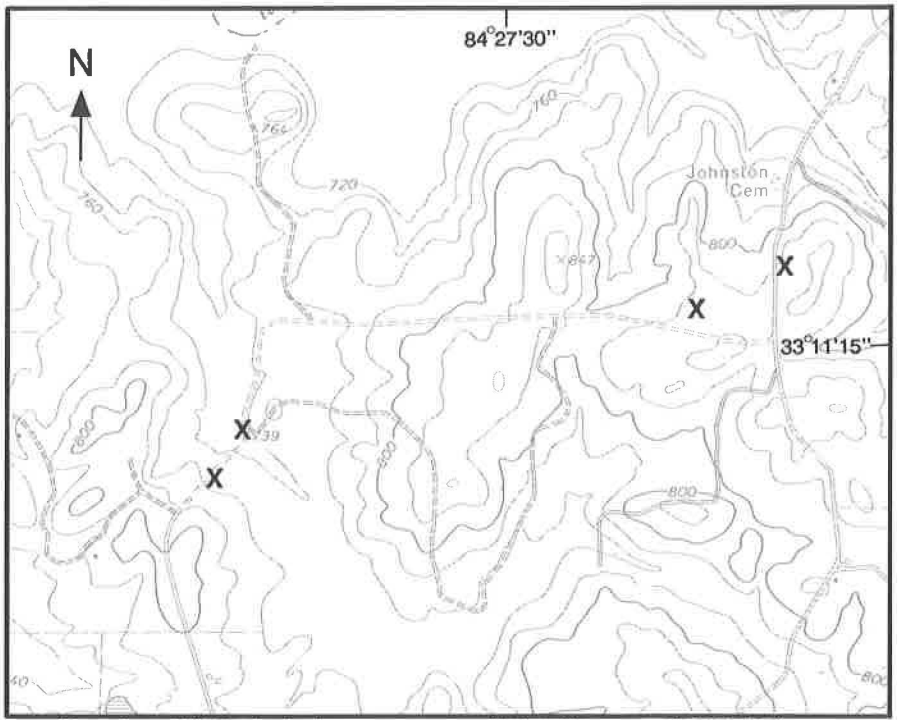
The long axes of mineral lineations in the High Falls Granite plunge dominantly to the southwest at a low angle. The majority of feldspar phenocrysts at High Falls State Park have a northeast orientation (fig. 9). Figure 9 also shows local feldspar trends that have been folded by the northwest trending flow folds and northeast trending folds.

Hollonville Granite

The Hollonville Granite is a grayish-white, medium- to coarse-grained porphyritic biotite granite which contains garnet in places. White microcline phenocrysts up to 3 cm long contain inclusions of biotite, quartz and plagioclase. The Hollonville Granite is here named for exposures in the Hollonville quadrangle north of the town of Hollonville (fig. 10). The Hollonville Granite is present throughout the Cedar Rock Complex and approximately 75 percent of the area mapped as Cedar Rock Complex is Hollonville Granite (plate 2). Cross cutting relations indicate that the Hollonville Granite is older than the Gay Granite but younger than the Odessadale Granite Gneiss. Field relations of the Hollonville Granite with the High Falls Granite are uncertain. Dikes of granite lithologically similar to the Hollonville intrude the High Falls. Unpublished radiometric dating indicates that the High Falls is early Paleozoic whereas the Hollonville is late Paleozoic. The Hollonville Granite intrudes the Zebulon Formation, Clairmont melange, Ison Branch Formation, Barrow Hill Formation, Clarkston Formation, Chattahoochee Palisades Quartzite and Ropes Creek Metabasalt.

The Hollonville Granite is magmatic and contains flow banding marked by an enrichment of biotite relative to quartz and feldspar, numerous biotite schlieren and many xenoliths. Flow banding in the Hollonville Granite dips gently to the southeast but is vertical in places in the Hollonville quadrangle. Xenoliths in the Hollonville Granite have been identified as being from the Odessadale Granite Gneiss, Ropes Creek Metabasalt, Zebulon Formation and Clarkston Formation.

The Hollonville Granite is surrounded by an extensive contact aureole consisting of metasedimentary rocks that have been additionally altered, injected or recrystallized by the intrusion of the Hollonville Granite (plates 1 and 2). Medium-grained, porphyritic, Hollonville biotite granite intruded both concordantly and discordantly as centimeter- to meter-scale dikes and sills into the metamorphic rocks of the contact aureole. Feldspar laths and apparently isolated pods of granite in the host rock suggest that some anatexis took place in addition to intrusion.



Base from U.S. Geological Survey 1:24,000 Hollonville, 1971, photorevised 1982.

Figure 10. Part of the Hollonville Quadrangle showing the type area of the Hollonville Granite. Significant exposures indicated by X.

Contact metamorphism of the host rocks by the Hollonville Granite is indicated by undeformed radiating sillimanite masses and less commonly by biotite porphyroblasts that cut across the compositional banding of the older rocks. These features sometimes occur in the apical region of folds in the metamorphic rocks (fig. 11). Because of the sill-like character and the low dip of the Hollonville Granite body, the contact aureole may extend as far as 7 km beyond continuous exposures of the Hollonville in places (plate 2).

Petrography

The Hollonville Granite has a medium-grained, anhedral granular texture with abundant feldspar phenocrysts. The modal percentages of quartz, microcline, and plagioclase in the Hollonville lie in the granite field (fig. 1).

Plagioclase is present in the Hollonville Granite as subhedral laths ranging in length between 1.0 and 5.0 mm with a mode between 1.0 and 2.0 mm. The plagioclase phenocrysts are smaller than the microcline phenocrysts. Plagioclase composition ranges from oligoclase to andesine (An_{20} to An_{36}). The cores of many of the plagioclase phenocrysts are sericitized and their rims are twinned (fig. 12). Myrmekite is present as an alteration of microcline to plagioclase and quartz.

Subhedral equant crystals and lath-shaped crystals of microcline typically range between 0.5 and 1.8 mm in length. Microcline phenocrysts up to 7 mm in length are present in places and are oriented parallel to the flow banding. Microcline phenocrysts are poikilitic, with inclusions of muscovite, plagioclase, epidote, quartz, biotite, and opaques.

Anhedral interstitial blebs of quartz range between 1.0 and 2.0 mm. Some of the quartz exhibits an undulatory extinction that is suggestive of post-solidification deformation. Biotite occurs as subhedral platelets that range between 0.3 and 1.5 mm in length. Biotite is generally light tan green to dark green, but in places is brown or reddish-brown. Some biotite is altered to chlorite. Subhedral muscovite grains are up to 1.5 mm in length. Accessory minerals in the Hollonville include magnetite, apatite, and zircon. Zircon commonly occurs as inclusions in biotite.

The apparent crystallization sequence of the Hollonville Granite suggests that some biotite and microcline were present prior to or during intrusion. Biotite and microcline inclusions occur within the microcline phenocrysts. Unzoned and untwinned plagioclase crystals, such as those that are found in the Hollonville, were probably inherited from the source rock and are therefore xenocrysts rather than phenocrysts (Whitney and others, 1976).

The crystallization history of the Hollonville Granite is suggested to be:

1) intrusion as a silicic magma containing xenocrystic feldspar, biotite, and quartz;
2) orientation of the micaceous minerals producing a flow foliation and of the prismatic minerals such as microcline producing a flow lineation;
3) after intrusion, crystallization of the twinned plagioclase and potassium feldspar on the available nuclei of plagioclase and microcline forming larger phenocrysts;
4) crystallization of the interstitial magma forming the groundmass; and
5) sericitization of plagioclase, replacement of potassium feldspar by quartz, and chloritization of biotite possibly occurred.

Structure

The Hollonville Granite occurs throughout the Cedar Rock Complex, but has sufficient exposure to provide structural data only in the central area of the Complex. The irregular map patterns and the low dips of planar structures illustrate the Hollonville Granite is a sheet-like intrusion (plates 2 and 3).

Mineral lineations in the Hollonville Granite consist mainly of oriented biotite clots and prismatic microcline phenocrysts. The strikes of horizontal lineations concentrate around N55°W (appendix D, fig. A). The orientation of flow banding in the Hollonville varies from place to place (plate 2). Small biotite flakes (mm scale) are oriented parallel to each other in definite bands. Equal area plots of the flow banding show a crude fit of the poles to a great circle. This great circle defines a N30°W trending and gently plunging pi axis (appendix D, fig. B).

Xenoliths, including xenoliths of the texturally different Odessadale Granite Gneiss, are common in the Hollonville Granite and vary in shape and size. Xenoliths range from 1 cm to 2 m in length. Poles to foliation within xenoliths in the Hollonville have a pi axis to the southeast which is subparallel to those of the biotite foliation (appendix D, fig. C). Joint sets in the Hollonville Granite are vertical and oriented N43°E and N62°W (appendix D, fig. D).

The dip of planar structures in the Hollonville Granite suggests that the Hollonville sheet-like intrusion is 1.5 to 3 km thick. Flow planes from the northwest section of the pluton define a southwest plunging

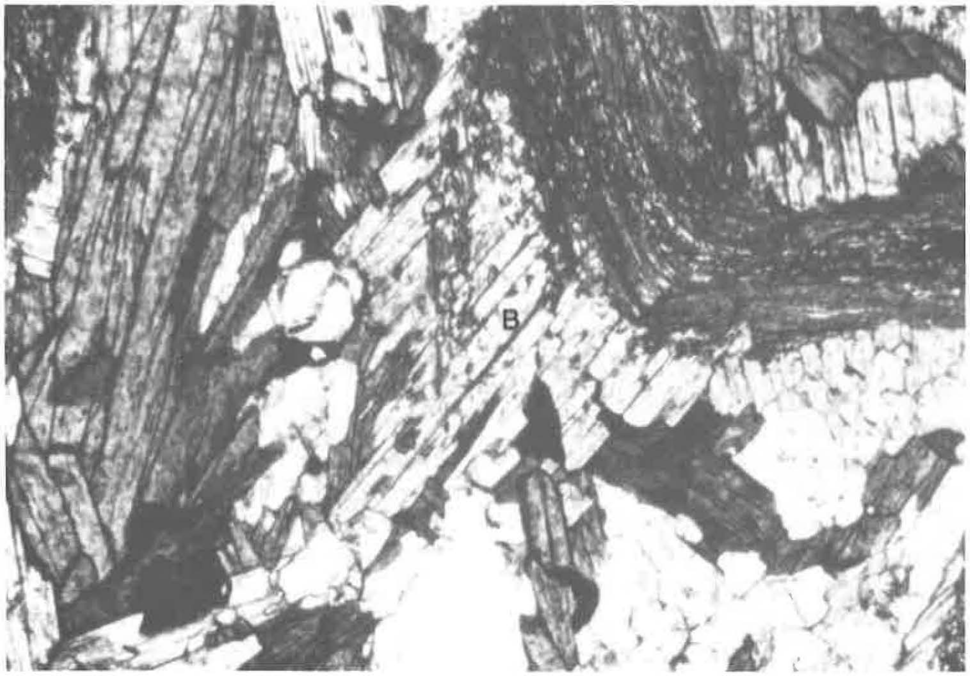


Figure 11. Photomicrograph of biotite porphyroblasts (B) crosscutting the compositional banding and fold axes in host rocks of the Hollonville contact aureole.

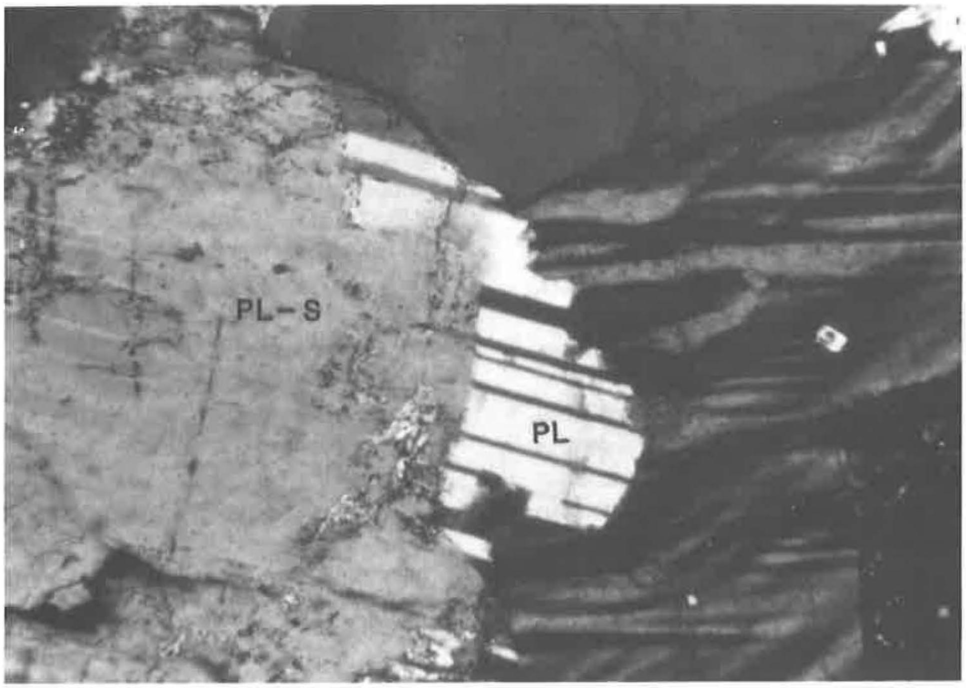


Figure 12. Photomicrograph showing sericitization (PL-S) of the core of an anhedral plagioclase crystal (PL).

pi axis, flow planes from the southeast section of the pluton define a pi axis plunging to the northwest (Appendix D, fig. B) and vertical to near vertical flow planes are present south of Hollonville near the center of the pluton (plate 2). The Hollonville Granite may have moved upward at the core of the pluton and then moved outward along S surfaces.

Gay Granite

The Gay Granite is a grayish-white, foliated to massive, medium-grained, equigranular to porphyritic biotite granite. The Gay Granite is named in this report for exposures (A and B) in the Gay quadrangle south of the town of Gay near Red Oak Creek (fig. 13). The Gay Granite intrudes the Odessadale Granite Gneiss at localities A and B and both localities form part of the type section. The Gay Granite is the youngest granite in the Cedar Rock Complex forming less than 3% of the Complex. The Gay Granite crops out primarily in the central portion of the Complex but is present in all parts. The Gay Granite intrudes the Hollonville, Odessadale and High Falls. It occurs as both dikes and sills and coarsens near its contacts to a pegmatitic texture (fig. 14).

Petrography

The Gay Granite has a medium- to coarse-grained (1-2 mm) anhedral to subhedral equigranular texture with microporphyritic phenocrysts (1-4 mm) of microcline and plagioclase. The Gay Granite plots in the granite field (fig. 1) and is similar in mineralogy to the Hollonville Granite (table 1).

Euhedral to anhedral plagioclase laths in the Gay Granite range from 1 to 4 mm in length and show no preferred orientation. Plagioclase composition ranges from An_4 to An_{13} (albite-oligoclase) and most plagioclase grains are highly altered and untwinned. Subhedral to anhedral microcline laths (1 to 4 mm in length) show gridiron twinning. Microcline also occurs as minute interstitial grains in places.

Anhedral quartz grains in the interstitial groundmass range from 0.5 to 1 mm. Anhedral quartz phenocrysts range from 2 to 3 mm in diameter and up to 8 mm in length. Subhedral plates of olive green to dark greenish-brown biotite have ragged ends and range from 0.4 to 1 mm in length. Biotite is altered to chlorite in places. Subhedral plates of muscovite (0.5 to 3 mm in length) are associated with biotite or are present as sericite in plagioclase. Accessory minerals in the Gay Granite include epidote, chlorite, zircon, opaques and apatite.

Structure

The Gay Granite intruded the other units of the Cedar Rock Complex as dikes and sills. Most dikes and sills are less than a meter thick but some exceed 100 m. Dikes of Gay Granite commonly have a 45-50 cm wide core enclosed within a 1-2 cm wide pegmatite selvage (fig. 14). The granite is generally massive, but in some places it shows distinct flow banding parallel to the wall rock. The margins of Gay dikes commonly have biotite selvages where they intrude the porphyritic Hollonville Granite (fig. 15).

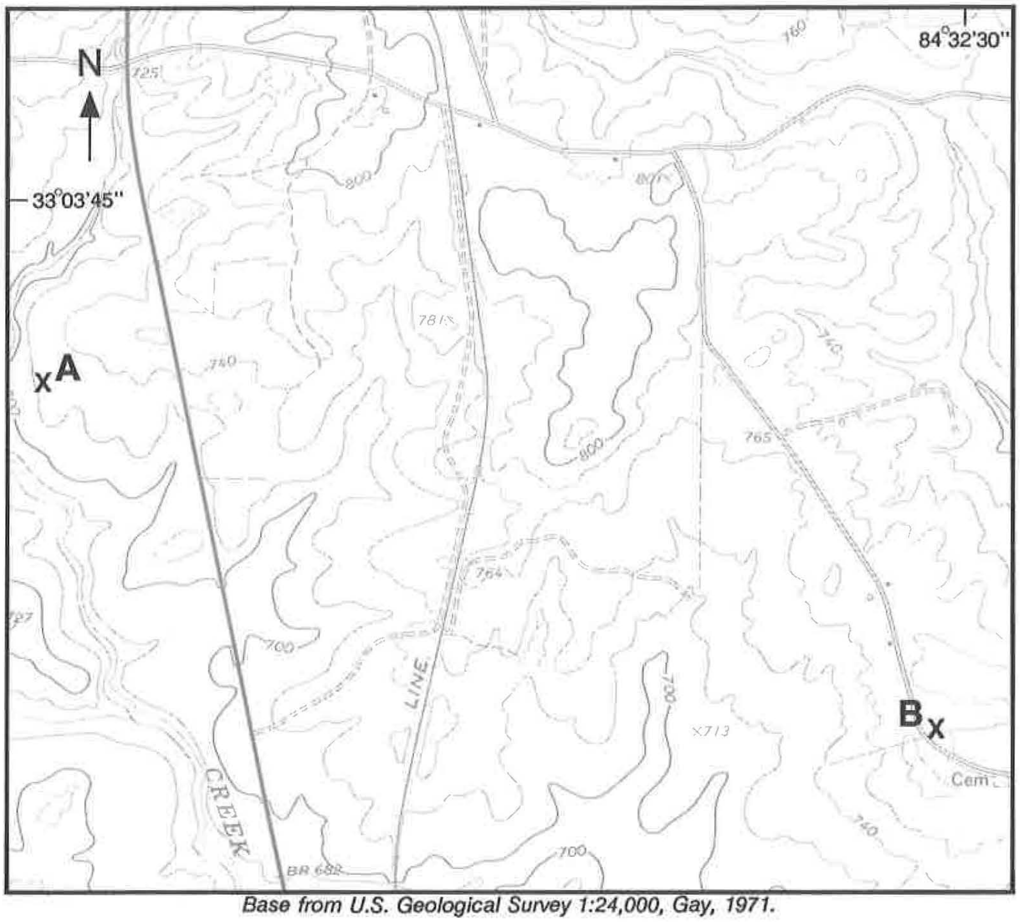
Gay Granite dikes trend N45°W, N-S and N45°E. Near Hollonville, a Gay Granite dike intruded the Hollonville Granite parallel to the Hollonville flow banding (N40-50°W). At Red Oak Creek south of Hollonville, Gay Granite intruded the Odessadale Granite Gneiss along fractures oriented N-S, N40°W, and N55°E.

Regional folds in the Georgiabama thrust stack, such as the Ola anticlinorium and Griffin synform, trend northeast. The dominant direction for Gay Granite dikes is northwest and a few dikes are oriented north or northeast. Gay Granite intrusions with northwest orientations were controlled by tensional fractures. Those with north and northeast orientations were controlled by shear fractures.

GEOCHEMISTRY

Rock samples for geochemical analysis were taken from surface exposures of the Cedar Rock Complex. Outcrops of the High Falls and Gay granites are more limited than outcrops of the Odessadale and Hollonville. No samples were taken from the High Falls Granite and only one sample was taken from the Gay Granite. The other 19 samples of the Cedar Rock Complex that were analyzed for major oxides in U.S. Geological Survey laboratories are from the Odessadale Granite Gneiss and the Hollonville Granite. This allows a meaningful comparison of granite and granite gneiss geochemistries in a Piedmont granitic complex.

Normative mineral analysis is a useful tool to compare bulk chemical analytical variations between samples or between lithologic units. A normative mineral is a mineral whose presence in a rock can be theoretically predicted from calculations based on the whole-rock chemical analysis. The mineral itself may or may not actually be present in the rock (Barth, 1952). This technique allows the chemical analyses of rocks forming the Cedar Rock Complex to be normalized to a standard mineralogy for comparative purposes.



Base from U.S. Geological Survey 1:24,000, Gay, 1971.

Figure 13. Part of the Gay Quadrangle showing type areas A and B for the Gay Granite.

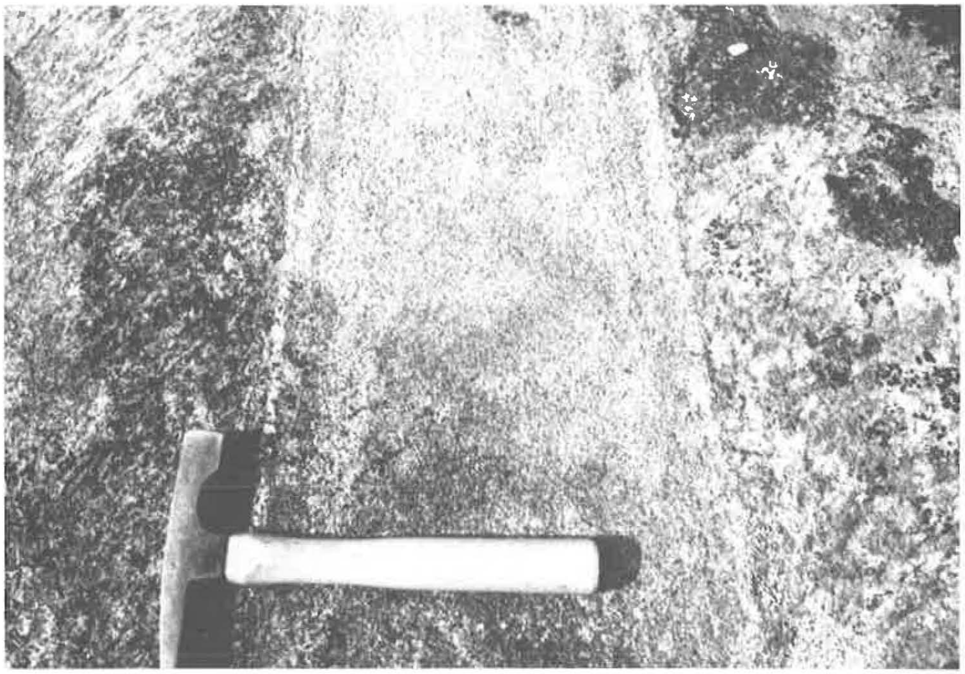


Figure 14. A Gay Granite dike showing flow banding parallel to dike borders and marginal pegmatite.

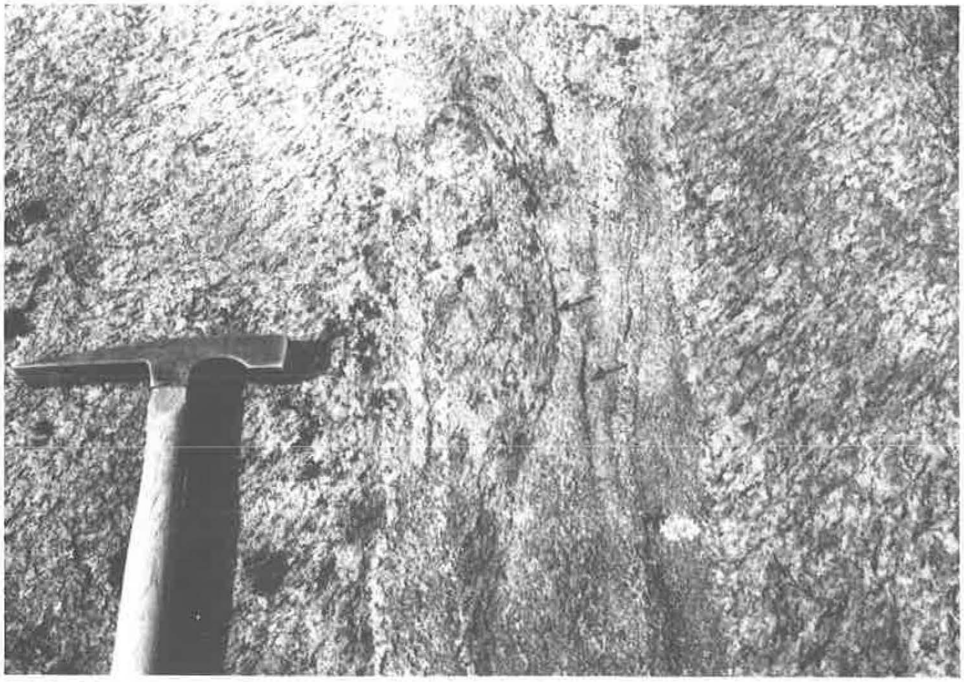


Figure 15. Flow foliation in a Gay Granite dike with biotite selvage borders and marginal pegmatite.

Odessadale Granite Gneiss

The Odessadale Granite Gneiss is peraluminous; that is, its molecular proportion of alumina exceeds the combined proportions of soda, potash, and lime. The major oxide geochemistry of the Odessadale shows that the gneiss varies somewhat in composition between localities (table 2).

The Odessadale Granite Gneiss samples are generally richer in silica and lower in alumina than the Hollonville Granite samples (tables 2 and 4). This is reflected in the higher normative quartz in the Odessadale (tables 3 and 5). Normative feldspar abundance in the Odessadale varies more than the normative feldspars in the Hollonville. The granite contains more normative femic minerals than does the granite gneiss.

The differentiation index (D.I.) is a number that represents the sum of the weight percentages of normative quartz, orthoclase, albite, nepheline, leucite, and kalsilite. The D.I. of the Odessadale Granite Gneiss ranges from 87.0 to 92.5 (table 3) and is high when compared to the D.I. average for granites of 84.2 (Le Maitre, 1976). The D.I. index indicates that the Odessadale is highly fractionated.

Hollonville Granite

The major element geochemistry of the Hollonville Granite shows relatively less variation than does the Odessadale Granite Gneiss (table 4; fig. 16). For example, the silica content of the Odessadale (74-78 percent) is higher than the silica content of the Hollonville (68-74 percent); however, the Hollonville Granite has a greater silica range than the Odessadale Granite Gneiss. The Odessadale Granite Gneiss is also more varied in weight percent of the oxides than the Hollonville Granite. The Hollonville generally has a higher content of major oxides (Na_2O, K_2O, FeO, Fe_2O_3, and CaO) than does the Odessadale. The Hollonville Granite is low in Na_2O as compared to K_2O.

Normative mineral analysis indicates that the Hollonville Granite has a slightly alumina-rich character (table 5). The mafic index of the Hollonville Granite is higher than the Odessadale. The Hollonville differentiation index is high (D.I.= 85-90) as compared to Le Maitre's (1976) average granite differentiation index of 84.2, indicating that the Hollonville is also highly fractionated. The relative normative quartz, albite and orthoclase ratios of the Gay and Hollonville Granites are similar, but different from values for the Odessadale Granite Gneiss (fig. 17). This suggests that the Hollonville and Gay Granites have similar histories that are different from the Odessadale's.

The composition of the Hollonville and Gay Granites are within the composition range of anatectic granites as determined by Winkler (1979). The Hollonville Granite magma probably was formed at a temperature of 660° to 670° C at a depth of 8 to 10 km (fig. 17).

Gay Granite

The major element geochemistry of a single sample of the Gay Granite indicates that it is similar to the Hollonville Granite but different from the Odessadale Granite Gneiss (table 6). The silica content of the Gay sample (71.4 percent) falls within the range of the Hollonville (68-74 percent) but is lower than the Odessadale range (74-78 percent). Aluminum, calcium, titanium, and phosphorus oxide contents fall within the Hollonville range but are higher than the range of these oxides in the Odessadale. Normative mineral analyses of the Gay Granite also show that the Gay has a strong similarity to the Hollonville Granite (table 4). The differentiation indices of the Gay and Hollonville Granites also are similar to each other and different from that of the Odessadale Granite Gneiss.

CONCLUSIONS

Models for the origin of the Cedar Rock Complex

Structural data, geochemistry, and regional geology were used to develop models for the origin of the granites and granite gneisses of the Cedar Rock Complex. Regional compressive stress from the southeast generated northwest trending tension fractures and northeast trending folds in the rocks of the Georgiabama thrust stack. Later, the northeast trending folds were refolded by northwest trending cross folds prior to the intrusion of the Hollonville and Gay Granites, and possibly prior to the intrusion of the High Falls Granite also. The granitic magmas probably formed through anatexis of quartz- and feldspar-rich clastic sedimentary rocks of the Georgiabama thrust stack at depths of 8 to 10 km. The granitic magmas moved up along fractures as diapirs and laterally into the low-pressure apical areas of folds. The Gay and Hollonville Granites, and possibly the High Falls Granite also, were emplaced in the apical areas of Scott Creek, Elijah Mountain and Klondike folds.

Odessadale Model

The Odessadale Granite Gneiss is a migmatized metasediment that was thrust into its current position

TABLE 2

Major oxide chemistry (percent) of the Odessadale Granite Gneiss. Sample locations shown on Plate 1.

Oxide	Average of 9 Samples percent (sd)	Sample 66	Sample 75	Sample 84	Sample 1	Sample 2	Sample 3	Sample 33	Sample 86	Sample 88
SiO_2	76.19 (1.73)	75.60	77.80	78.00	75.60	74.60	77.50	75.70	75.70	76.70
Al_2O_3	12.93 (0.98)	12.90	12.90	11.80	13.60	15.00	13.00	12.50	12.70	12.00
Fe_2O_3		0.92	0.67	0.48	0.64	0.34	0.25	0.84	0.36	0.19
FeO		0.60	0.52	0.40	0.60	0.60	0.32	0.60	0.76	0.92
MgO	0.20 (0.02)	0.22	0.12	0.10	0.29	0.26	0.16	0.30	0.19	0.19
CaO	1.09 (0.14)	0.96	1.40	0.56	1.90	1.30	0.83	1.10	0.87	0.93
Na_2O		3.00	3.90	3.20	4.60	4.30	2.70	2.70	3.50	3.00
K_2O	4.19 (1.19)	5.20	2.40	4.40	1.80	4.00	5.30	5.20	4.60	4.80
H_2O		1.70	0.95	0.57	0.45	0.42	0.60	0.63	0.35	0.65
TiO_2		0.18	0.07	0.13	0.11	0.12	0.11	0.17	0.17	0.17
P_2O_5		0.07	0.06	0.06	0.05	0.05	0.03	0.13	0.02	0.03
MnO		0.04	0.06	0.05	0.05	0.05	0.04	0.05	0.09	0.02
CO_2		0.01	0.03	0.01	0.01	0.06	0.03	0.08	0.04	0.17
TOTALS		101.40	100.88	99.77	98.70	100.59	100.87	100.00	99.35	99.77

(sd) = standard deviation

Major oxides were determined by atomic absorption methods.
Analyses were performed by R. Somers and J. Gillison, U.S. Geological Survey.

TABLE 3

Normative minerals (by percent) of the Odessadale Granite Gneiss based on major oxide chemistry. Sample locations shown on Plate 1.

Normative Minerals	Sample 66	Sample 75	Sample 84	Sample 1	Sample 2	Sample 3	Sample 33	Sample 86	Sample 88
Quartz	35.54	42.45	41.39	36.88	30.38	39.20	37.78	35.54	32.66
Corundum	0.77	1.54	0.92	0.78	1.46	1.44	0.93	0.53	0.65
Orthoclase	30.30	14.06	26.06	10.78	23.50	31.05	30.73	27.36	28.43
Albite	24.04	32.71	27.14	39.44	36.17	22.65	22.85	29.81	25.44
Anorthite	4.18	6.31	2.33	9.16	5.78	3.70	4.10	3.96	3.35
Enstatite	0.54	0.30	0.25	0.73	0.64	0.40	0.75	0.48	0.47
Ferrosilite	0.12	0.40	0.22	0.49	0.71	0.27	0.22	0.99	1.29
Magnetite	1.32	0.96	0.70	0.94	0.49	0.36	1.22	0.53	0.28
Ilmenite	0.34	0.13	0.25	0.21	0.23	0.21	0.32	0.33	0.32
Apatite	0.16	0.14	0.14	0.12	0.09	0.07	0.31	0.05	0.07
Calcite	0.02	0.07	0.02	0.02	0.14	0.07	0.31	0.05	0.07
TOTALS	98.33	99.06	99.42	99.55	99.59	99.42	99.39	99.67	99.35
Salic	95.83	97.07	97.85	97.03	97.28	98.04	96.38	97.19	96.53
Femic	2.50	1.99	1.58	2.52	2.30	1.37	3.00	2.46	2.93
Hypersthene	0.66	0.69	0.47	1.22	1.36	0.67	0.97	1.47	1.77
Hypersthene-Enstatite	0.54	0.30	0.25	0.73	0.65	0.40	0.75	0.48	0.47
Hypersthene-Ferrosilite	0.12	0.39	0.22	0.49	0.71	0.27	0.22	0.99	1.29
D.I. ratio	90.88	89.22	94.59	87.09	90.05	92.20	91.35	92.71	92.53

TABLE 4

Major oxide chemistry (percent) of the Hollonville Granite. Sample locations shown on Plate 1.

Oxide	Average of 7 Samples percent (sd)	Sample 62	Sample 74	Sample 81	Sample 7	Sample 102	Sample 5	Sample 6
SiO_2	71.40 (1.83)	72.00	74.70	70.80	69.90	71.30	68.80	73.10
Al_2O_3	14.70 (0.53)	14.80	14.10	14.60	15.20	14.50	15.60	14.00
Fe_2O_3		0.82	0.67	0.50	0.70	0.25	0.88	0.58
FeO		1.00	0.76	2.00	1.00	1.50	1.20	0.56
MgO	0.52 (0.03)	0.48	0.28	0.79	0.51	0.50	0.67	0.36
CaO	1.61 (0.40)	1.70	0.78	2.30	1.60	1.60	1.80	1.50
Na_2O		3.40	3.40	3.60	3.20	3.30	3.40	3.20
K_2O	4.81 (0.31)	4.50	4.80	3.70	5.30	5.30	5.40	4.70
H_2O		0.82	0.95	0.60	0.70	0.75	0.72	0.75
TiO_2		0.20	0.18	0.35	0.26	0.20	0.40	0.30
P_2O_5		0.19	0.10	0.10	0.14	0.13	0.15	0.06
MnO		0.05	0.05	0.10	0.06	0.07	0.04	0.04
CO_2		0.02	0.01	0.08	0.33	0.36	0.01	0.02
TOTALS		99.94	100.78	99.52	98.90	99.76	99.08	99.07

(sd) = standard deviation

Major oxides were determined by atomic absorption methods.

Analyses were performed by R. Somers and J. Gillison, U.S. Geological Survey.

TABLE 5

Normative minerals (by percent) of the Hollonville Granite. Sample locations shown on Plate 1.

Normative Minerals	Sample 62	Sample 74	Sample 81	Sample 7	Sample 102	Sample 5	Sample 6
Quartz	30.62	34.22	28.93	27.99	28.00	23.76	33.15
Corundum	1.65	2.14	0.92	2.42	1.58	1.28	1.12
Orthoclase	26.61	28.15	21.97	31.67	31.39	32.21	28.03
Albite	28.79	28.55	30.61	27.38	27.99	29.04	27.33
Anorthite	7.33	3.13	10.30	4.99	4.82	7.96	6.99
Enstatite	1.20	0.69	1.98	1.28	1.25	1.68	0.91
Ferrosilite	0.92	0.63	2.88	0.95	2.35	0.92	0.30
Magnetite	1.19	0.96	0.73	1.03	0.36	1.29	0.85
Ilmenite	0.38	0.34	0.67	0.50	0.38	0.77	0.38
Apatite	0.36	0.24	0.24	0.34	0.31	0.36	0.14
Calcite	0.05	0.02	0.18	0.76	0.82	0.02	0.05
TOTALS	99.19	99.07	99.41	99.31	99.25	99.29	99.25
Salic	95.10	96.18	92.73	94.45	93.73	94.24	96.62
Femic	4.09	2.89	6.68	4.86	5.48	5.04	2.62
Hypersthene	2.12	1.33	4.86	2.24	3.60	2.60	1.20
Hypersthene-Enstatite	1.20	0.69	1.98	1.28	1.25	1.65	0.91
Hypersthene-Ferrosilite	0.92	0.63	2.88	0.95	2.35	0.92	0.30
D.I. ratio	86.12	90.91	81.51	87.51	87.38	85.00	88.51

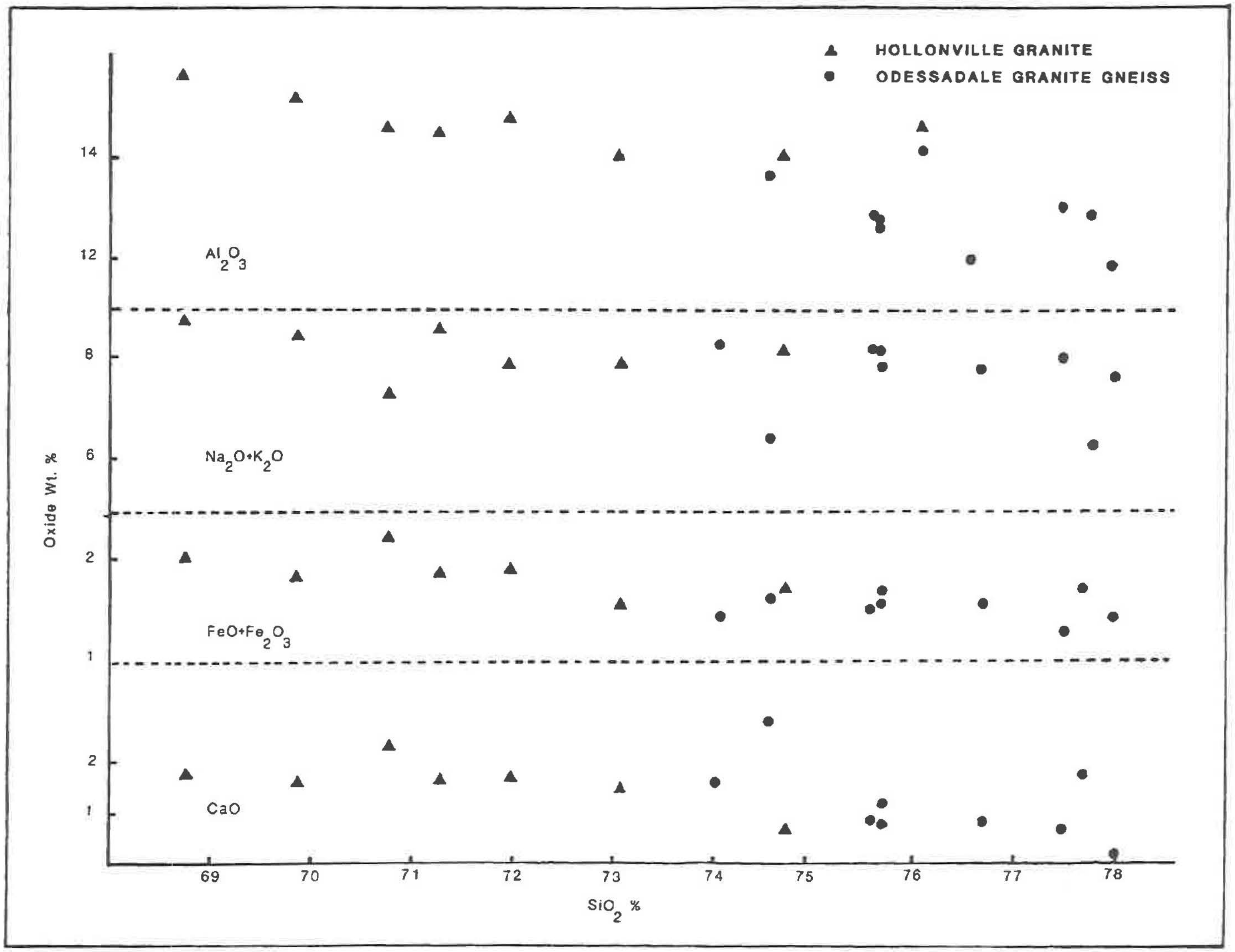


Figure 16. Variation diagrams of major oxides in the Hollonville Granite and Odessadale Granite Gneiss.

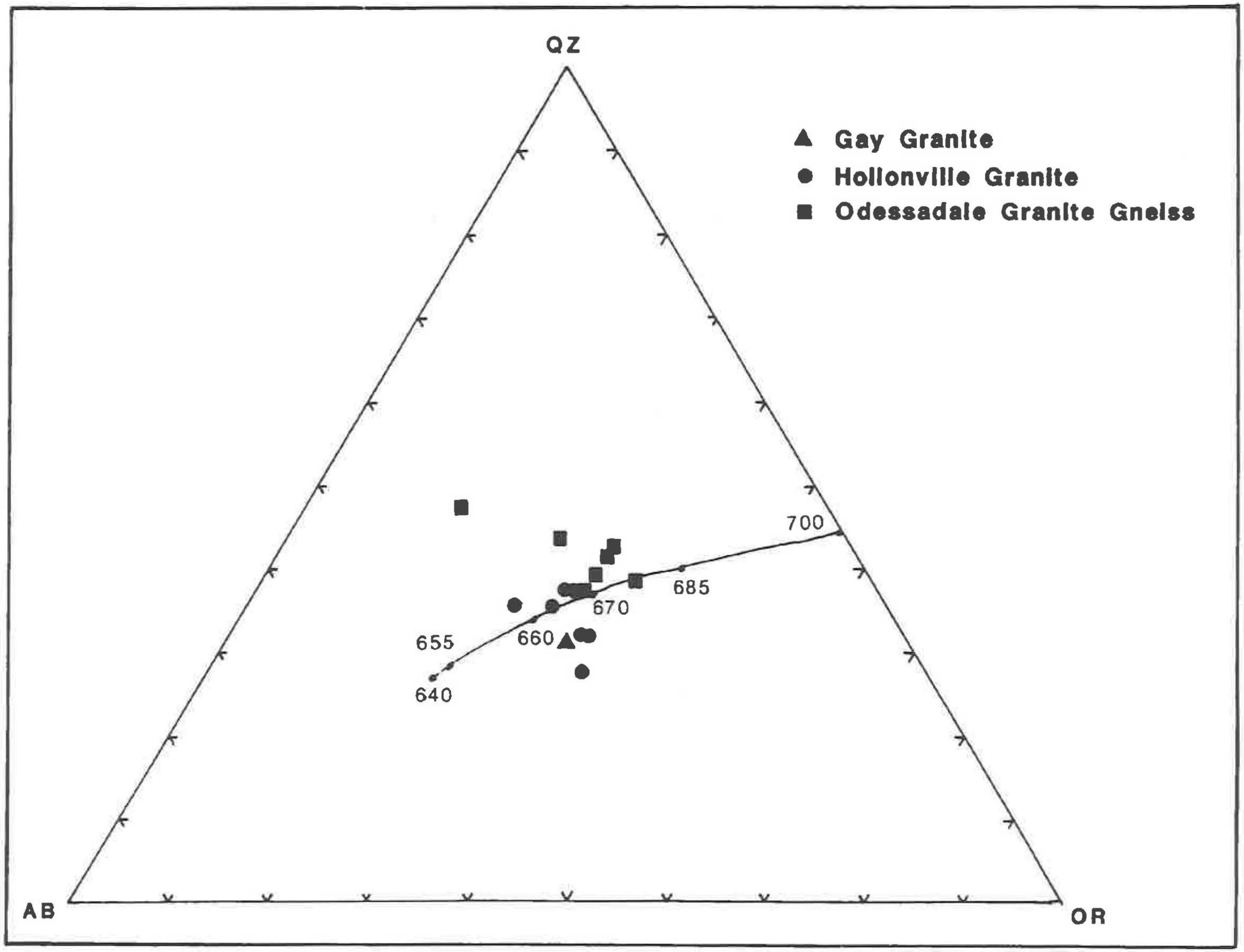


Figure 17. The relative percentages of normative quartz, albite and orthoclase for the Gay and Hollonville Granites and the Odessadale Granite Gneiss.

TABLE 6

Major oxide chemistry and normative mineral analyses of Gay Granite Sample 20.
Location shown on Plate1.

Oxides	Percent	Normative Minerals	Percent	Normative Minerals	Percent
SiO_2	71.40	Quartz	27.36	Hypersthene	2.14
Al_2O_3	15.20	Corundum	1.40	Hypersthene-enstatite	1.42
Fe_2O_3	0.99	Orthoclase	30.14	Hypersthene-ferrosilite	0.67
FeO	1.10	Albite	29.62		
MgO	0.59	Anorthite	6.90		
CaO	1.60	Enstatite	1.47		
Na_2O	3.50	Ferrosilite	0.67		
K_2O	5.10	Magnetite	1.44	D.I. ratio	87.11
H_2O	0.90	Ilmenite	0.70		
TiO_2	0.37	Apatite	0.30		
P_2O_5	0.13	Calcite	0.07		
MnO	0.04				
CO_2	0.03				
		Total	100.07		
		Salic	95.41		
Total	100.95	Femic	4.62		

Major oxides were determined by atomic absorption methods.
Analyses were performed by R. Somers and J. Gillison, U.S. Geological Survey.

between the Promised Land thrust sheet and the Sandy Springs thrust sheet in the Georgiabama thrust stack during the early Paleozoic (fig. 18). Higgins and others (1986, 1988) proposed that metamorphism and plutonism in the Georgiabama thrust stack were the result of the moving of thrust sheets, the insulating blanketing effects of the stacking process, the overpressure and the depth of burial. The Georgiabama thrust stack was assembled, beginning in the early Paleozoic, with the uppermost sheets being the farthest travelled and the lower thrust sheets being the least traveled. A sufficient thickness of rocks was assembled in the cratonward-moving thrust sheets in the early Paleozoic so that partial melting of these rocks took place. Localized partial melting of the lower thrust sheets resulted in migmatization of the rocks forming the Odessadale Granite Gneiss. The Odessadale contains folds exhibiting plastic flow, and fold generations and compositional layering oriented simularly to those in the metamorphic rocks of the Georgiabama thrust stack. The wide variation in composition, the high silica content, and the presence of rounded zircons in the Odessadale indicate a sedimentary origin for the granite gneiss. Continued faulting thrust the Sandy Springs and younger thrust sheets over the Odessadale. As a result, the Odessadale was metamorphosed and folded along with the other rocks of the Georgiabama thrust stack.

The Promised Land Formation is thought to tectonostratigraphically underlie the Odessadale as it does the Odessadale equivalent Lithonia Gneiss and is interpreted to be an island arc consisting mainly of volcanics (Higgins and others, 1988). The rocks of the Sandy Springs thrust sheet above the Odessadale are a microcontinent. If the Odessadale Granite Gneiss and Lithonia Gneiss represent a sequence of sedimentary rocks, they may have been deposited between the Sandy Springs microcontinent and the Promised Land island arc. Assembly of the Georgiabama thrust stack thrust Sandy Springs and higher thrust sheets over the Odessadale and Lithonia sediments. Burial of the sediments beneath the thick stack of thrust sheets resulted in metamorphism and partial melting producing the migmatized Odessadale Granite Gneiss and Lithonia Gneiss.

An alternative interpretation is that the Odessadale Granite Gneiss represents local migmatization of the Zebulon and Atlanta thrust sheets prior to the emplacement of the Sandy Springs thrust sheet. Burial of the sediments in the thrust sheets resulted in the partial melting of the Zebulon Formation producing the migmatized Odessadale Granite Gneiss. The continued assembly of the Georgiabama thrust stack resulted in the thrusting of Sandy Springs and younger thrust sheets over the Odessadale in this scenario.

High Falls Model

Available structural data suggest that the High Falls Granite was emplaced as a sheet-like pluton in the Zebulon thrust sheet. The strike of the flow banding in the High Falls is to the northeast and the dip is to the northwest (plate 2). The strike of the metamorphic lithologies on the northwest side of the High Falls pluton also is northeast and they dip northwest. A preliminary whole rock Rb/Sr age date suggests the High Falls Granite intruded the Zebulon Formation during the early Paleozoic (J. Arth, personal communication, 1986).

Hollonville Model

The evidence for a sheet-like magmatic intrusion of the Hollonville Granite includes the presence of oriented xenoliths of the surrounding rocks and a flow foliation parallel to the edges of the Hollonville pluton. Flow banding dips gently inward along the margins of the pluton and is nearly vertical in the center of the pluton near Hollonville (plate 2). Emplacement after metamorphism is indicated by undeformed radiating sillimanite, biotite and muscovite in the Hollonville contact aureole. Intrusion after folding is indicated by the Hollonville Granite cross cutting folds and by undeformed biotite cross cutting folds in the Hollonville contact aureole.

The Hollonville Granite pluton is concordant to the regional structural trends (plate 2). It intruded the Zebulon, Atlanta, Clairmont, Ropes Creek, and Sandy Springs thrust sheets during the late Paleozoic (Preliminary unpublished whole rock Rb/Sr age dates, J. Arth, personal communication, 1986). The emplacement mechanism of the Hollonville Granite involves the upward migration of the magma along northwest trending tension fractures into the low pressure areas in the apical regions of folds (fig. 18). The magma moved laterally to the northeast and southwest along S-planes and thinned towards the edge of the pluton.

Gay Model

Magmatic intrusion of the Gay Granite is indicated by a pronounced flow foliation parallel to the edges of Gay dikes, massive interiors in the dikes and cross cutting relationships. Gay Granite dikes have pegmatite borders that are interpreted as originating from residual magma derived from cooling Hollonville magma. This indicates that the Gay is post-Hollonville.

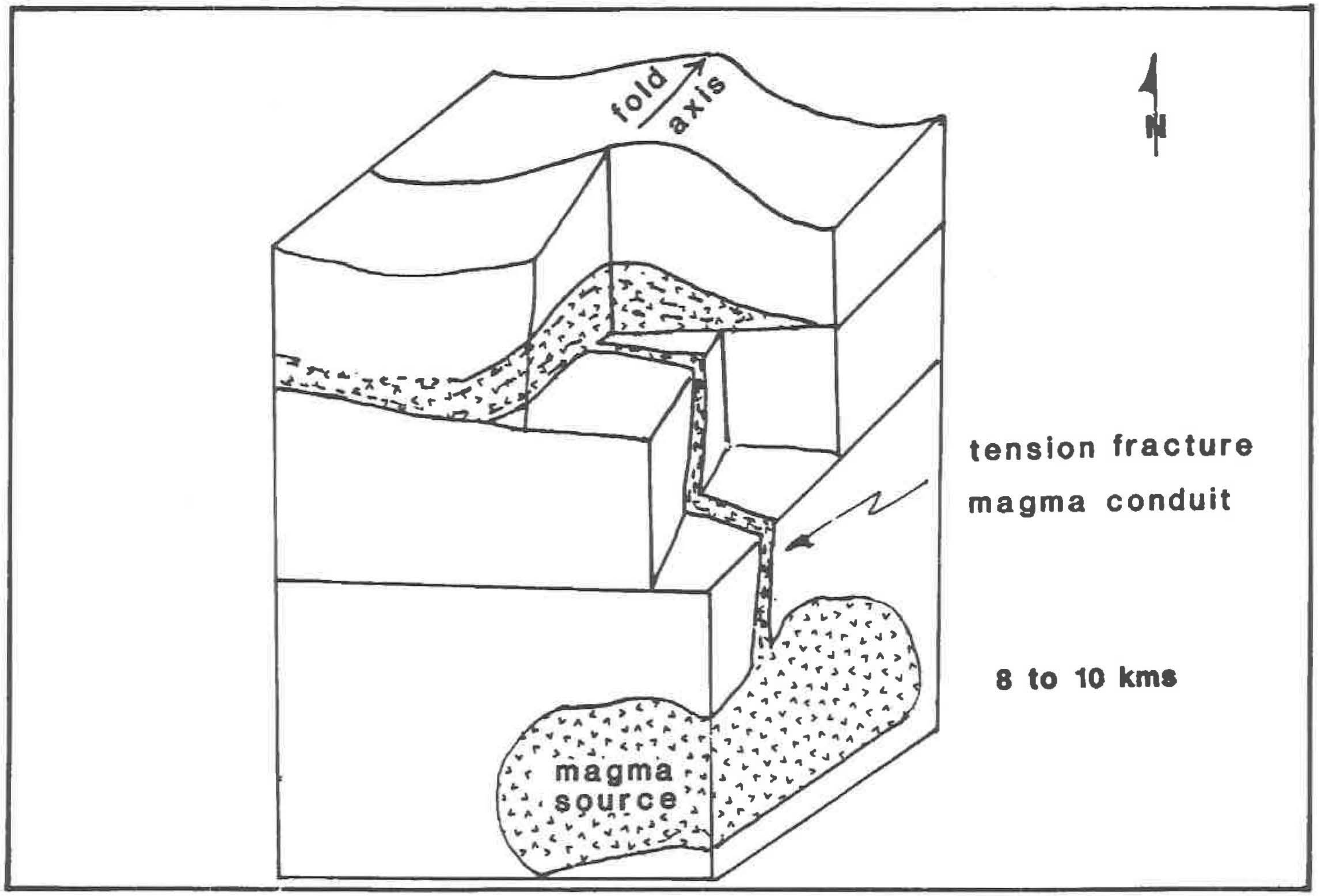


Figure 18. Schematic diagram depicting the emplacement of the Hollonville Granite in the apical areas of folds.

Geochemical evidence, modal analyses, and petrography all suggest a similarity in origin and emplacement of the Gay and Hollonville Granites. The Gay Granite represents the final pulse of the Hollonville magma. Earlier pulses of the Hollonville had already solidified. Stress, generated by continued movement of the remaining magma, caused tensional fractures along which the Gay magma intruded.

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APPENDICES

APPENDIX A

Structural data from the meta morphic rocks surrounding the Cedar Rock Complex

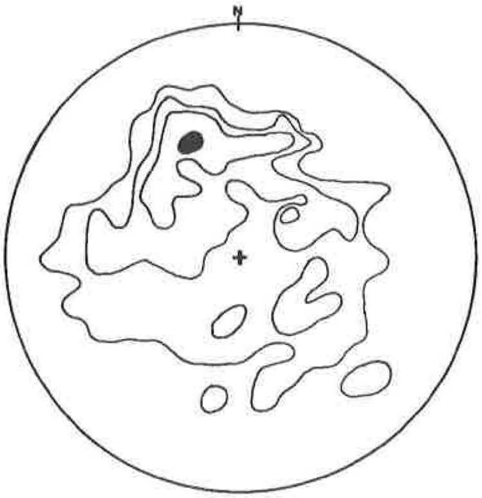

Figure A. Poles to compositional layering, foliation and schistosity. Contours: 1-2-3-4% per 1% area, 343 poles.

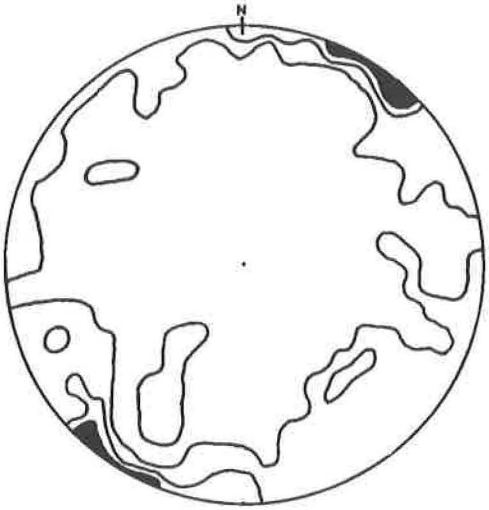

Figure B. Poles to joints. Contours 1-3-5% per 1% area, 137 poles.

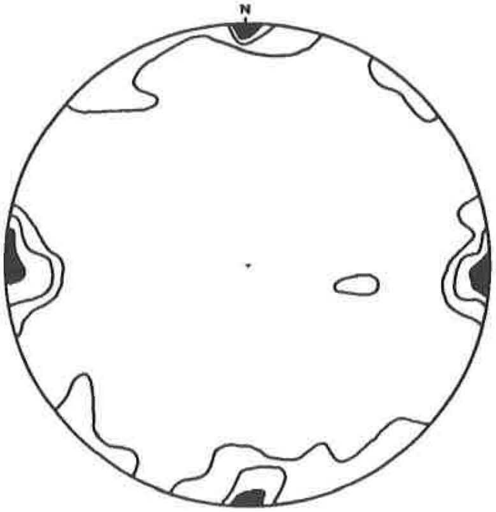

Figure C. Lineations outside the Hollonville contact aureole. Contours 2-5-10-15% per 1% area, 74 lineations.

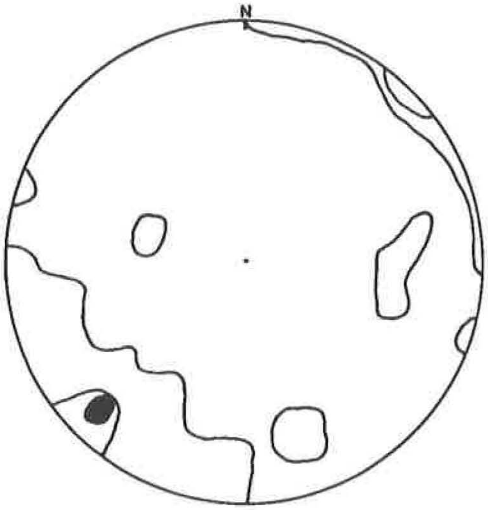

Figure D. Lineations in the Hollonville contact aureole. Contours: 3-5-7% per 1% area, 69 mineral and fold axes.

APPENDIX B

Structural data from the Odessadale Granite Gneiss.

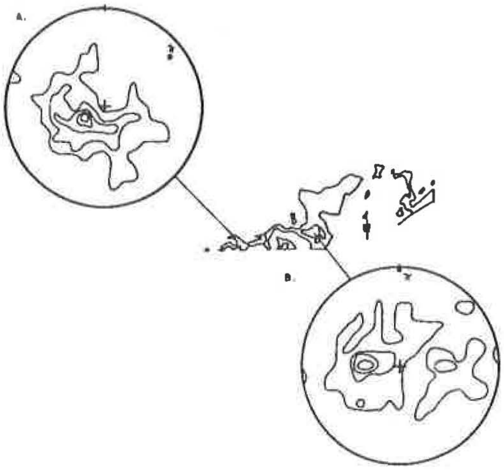

Figure A. Poles to gneissic banding. A-Contours: 1-3-6-9-12% per 1% area, 146 poles. B-Contours: 1-4-7-10% per 1% area, 73 poles

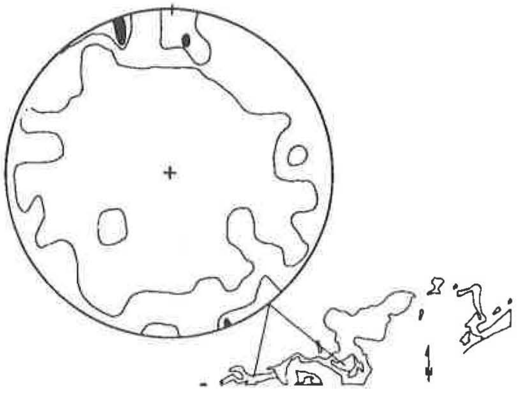

Figure B. Mineral lineations. Contours: 2-6-8% per 1% area, 51 lineations.

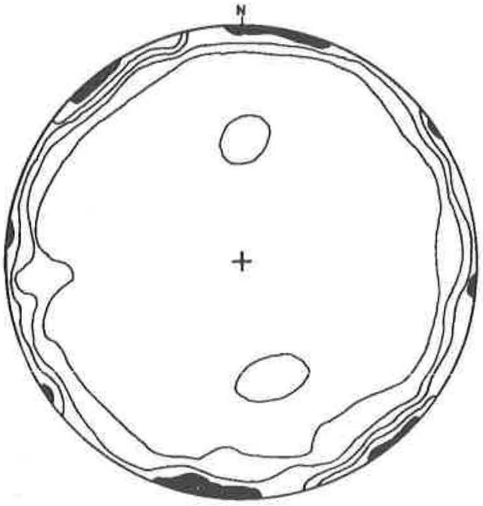

Figure C. Poles to joints. Contours: 1-3-4-5-6% per 1% area, 308 poles.

APPENDIX C

Structural data from the High Falls Granite.

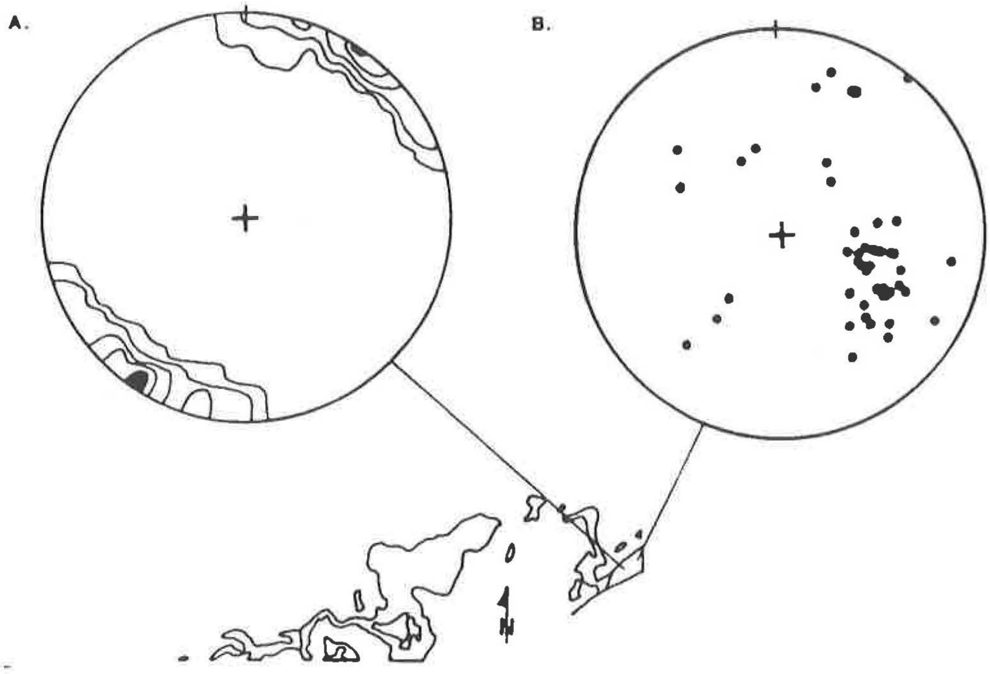

Figure A. Euhedral feldspar and biotite clot lineations (A) and poles to xenoliths and flow banding (B). A-contours: 3-5-8-11-14% per 1% area, 65 lineations. B. 43 poles to flow banding.

APPENDIX D

Structural data from the Hollonville Granite.

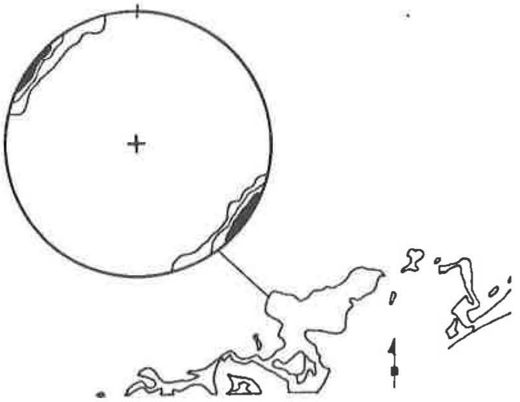

Figure A. Lineations. Contours: 5-10-15% per 1% area, 60 lineations.

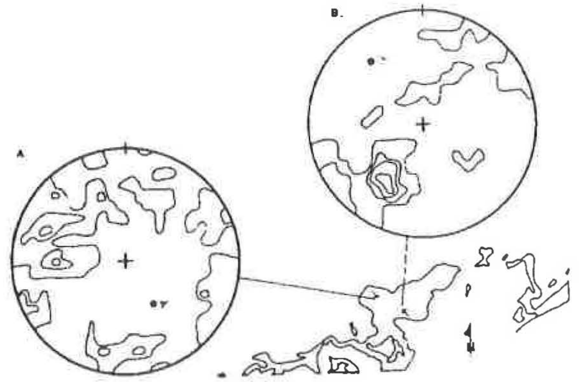

Figure B. Poles to flowing banding. A-contours: 2-4-6% per 1% area, 50 poles. B-contours: 1-5-7-10% per 1% area, 88 poles.

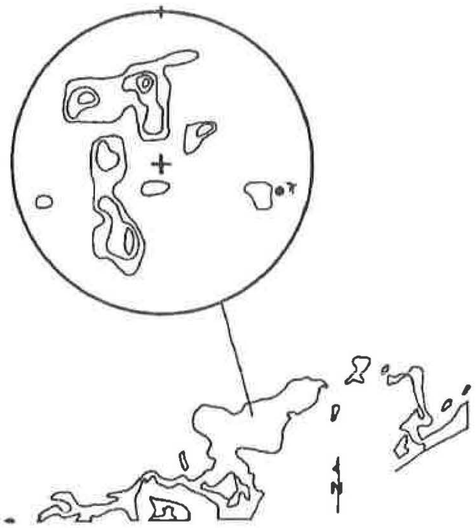

Figure C. Poles to compositional layering in xenoliths. Contours: 2-3-5-7% per 1% area, 65 poles.

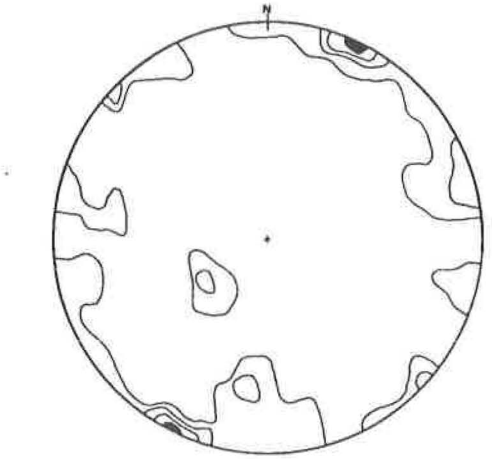

Figure D. Poles to joints. Contours: 2-4-6-8% per 1% area, 98 poles.

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PLATE 1

LOCATION MAP OF THE CEDAR ROCK COMPLEX; ITS TYPE AREAS, SUBUNITS AND GEOCHEMICAL SAMPLE LOCATIONS

Location of the Cedar Rock Complex in relation to other large granite and gneiss bodies in the Piedmont region of Georgia.

Base map from U.S. Geological Survey 1:100,000 maps: Griffin, 1979 and Thomaston, 1981.

GEOLOGIC MAP OF THE CEDAR ROCK COMPLEX

EXPLANATION

Qal ALLUVIUM
Stream deposits of tan-colored gravel, sand, silt and clay.

czs TERRACE SAND DEPOSITS
Stream and/or wind-blown deposits of tan-colored fine-grained sand, silt and clay.

trd DIABASE DIKES
Massive dark-green to black, fine-grained plagioclase-pyroxene rock with minor amounts of olivine, hornblende, magnetite and pyrite.

md MAFIC ROCKS
Fine- to medium-grained foliated to non-foliated, dark-green to black plagioclase-hornblende rock.

CEDAR ROCK COMPLEX

v v v CONTACT AUREOLE
Grayish-white, foliated to massive, medium-grained, equigranular to porphyritic granite sills and dikes on meter scale with mica schist, biotite gneiss and amphibolite. The schist and gneiss contain feldspar megacrysts as well as radiating sillimanite and/or muscovite porphyroblasts.

crh HOLLONVILLE GRANITE
Grayish-white, medium-grained to porphyritic, biotite granite. White feldspar phenocrysts contain inclusions of biotite, quartz and plagioclase.

hf HIGH FALLS GRANITE
Grayish-white, porphyritic, biotite granite. Poikiloblastic white microline phenocrysts contain inclusions of biotite, quartz and plagioclase.

cro ODESSADALE MIGMATITE
Variable lithology composed of a grayish-white, fine- to medium-grained, biotite granite gneiss that locally contains scattered garnet and magnetite. Layering ranges from planar to contorted. Contains feldspar porphyroblasts and thin blebs and ribbons of granite.

The following are tectonostratigraphic units. Stacking of the thrust sheets and lithologies are those of Higgins and others (1984, 1986, 1988).

ROPES CREEK THRUST SHEET

rc ROPES CREEK METABASALT
Predominantly composed of finely layered (centimeter scale), dark-green, hornblende-plagioclase and plagioclase-hornblende amphibolites, commonly slightly chloritic and epidotic. Locally, has thin banded magnetite quartzites on centimeter to meter scale.

PAULDING VOLCANIC THRUST SHEET

pv PAULDING VOLCANIC-PLUTONIC COMPLEX
Light-green, epidote-rich, generally chloritic hornblende and/or actinolite-plagioclase amphibolites interlayered with light-gray or nearly white, amphibole-bearing fine- to medium-grained felsic gneisses.

SANDY SPRINGS THRUST SHEET
SANDY SPRINGS GROUP

cp CHATTAHOOCHEE PALISADES QUARTZITE
Tan weathering, medium-grained quartzite varying from a micaceous to an orthoquartzite. Commonly 1 to 3 meters thick.

ATLANTA THRUST SHEET

cl CLARKSTON FORMATION
Pink- to purple-weathering, sillimanite-muscovite-biotite schist locally containing garnet interlayered with ocher-weathering plagioclase amphibolite.

bh BARROW HILL FORMATION
Pink- to purple-weathering sillimanite-muscovite-biotite schist generally spessartine garnet-bearing interlayered with hornblende-bearing amphibolite with thin layers (centimeter to meter scale) of gondite. Gondite layers commonly form a distinctive black-colored saprolite with dark red-brown brick-shaped (centimeter scale) float of garnet quartzite.

ib ISON BRANCH FORMATION
Light-gray to white weathering, finely laminated (millimeter scale), pyritic-, slightly graphitic-calcareous felsic gneiss.

WAHOO CREEK THRUST SHEET

wc WAHOO CREEK FORMATION
Light-colored, generally thin (centimeter scale) laminated, medium-grained, muscovite-plagioclase-quartz gneiss interlayered locally with fine-grained epidote amphibolite. Forms distinctive "slabby" boulder outcrops.

CLAIRMONT THRUST SHEET

cla CLAIRMONT MELANGE
Grayish-white, well-foliated, medium-grained, biotite-plagioclase gneiss containing native blocks and exotic blocks of a wide variety of rocks.

ZEBULON THRUST SHEET

sen SENOIA MEMBER
Pink- to purple-weathering, medium-grained, garnet-biotite-muscovite schist interlayered (1 to 3 centimeter scale) with fine-grained amphibolite. Locally schist and amphibolite interlayered with gondite. Gondite commonly is 0.5 meters thick.

sq SPESSARTINE GARNET QUARTZITE
Weathered fine-grained spessartine-garnet-quartz rock. Commonly forms black-colored dark saprolite with red-brown brick-shaped float.

zeb ZEBULON FORMATION
Interlayered pink- to purple-weathering, generally garnet and sillimanite-bearing schists and non-chloritic hornblende-plagioclase amphibolites. Red-brown to black weathering gondite and dark-gray biotite gneiss are locally present.

BILL ARP THRUST SHEET
GREAT SMOKY GROUP

ola OLA FORMATION
Tan, medium-grained, quartz-biotite-muscovite-sillimanite schist locally garnet-bearing interlayered (meter scale) with sillimanite-graphite schist and biotite-plagioclase gneiss.

kc KALVES CREEK FORMATION
Yellow-weathering, sillimanite-graphite schist, locally containing thin (less than 1 meter) layers of biotite-garnet schist and/or biotite-plagioclase gneiss.

OTHER MAP UNITS

my MYLONITIC ROCK OF THE TOWALIGA FAULT ZONE
Generally grayish-white, mylonite, mylonite gneisses and tan button schists.

mb MICROBRECCIA
White to gray, massive "flinty" chert-like rock consisting of fine angular fragments. Angular fragments are less than 0.5 millimeters with a very fine-grained matrix.

um METAMORPHOSED MAFIC TO ULTRAMAFIC ROCKS
Greenish-gray, medium-grained to coarse-grained metapyroxenite altered in various degrees to serpentinite and talc-chlorite schist.

a AMPHIBOLITE
Black to greenish-black, medium- to coarse-grained hornblende-plagioclase or plagioclase amphibolite.

sch SCHIST
Tan, medium-grained, garnet-muscovite-biotite schist or garnet-muscovite-sillimanite schist.

MAP SYMBOLS

——	Contact.
·······	Covered or concealed contact.
------	Inferred contact.
▲▲▲	Thrust fault with teeth on upper plate.
45	Strike and dip of metamorphic foliation.
20	Strike and dip of flow banding.
⊕	Strike and dip of vertical foliation.
↠15	Trend and plunge and strike of axial plane of upright warping fold in metamorphic rocks.
15 →20	Trend and plunge and strike and dip of axial plane of inclined to recumbent isoclinal fold in metamorphic rocks.
→15	Trend and plunge of fold axis and strike of axial plane of upright folds in the Cedar Rock Complex.
F	High angle fault in metamorphic rocks.
45	Strike and dip of inclined shear zone in the Odessadale granite gneiss.
+	Strike and dip of vertical shear zone in the Odessadale granite gneiss.
↔	Trend of horizontal mineral lineation or fold axis.
→20	Trend of inclined mineral lineation or fold axis.

All contacts south of 33°00' latitude from Clarke and Peck, 1991.

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PLATE 3

BLOCK DIAGRAM OF THE CEDAR ROCK COMPLEX

For detail of specific areas, refer to Plate 2 of this publication.

For convenience in selecting our reports from your bookshelves, they are color-keyed across the spine by subject as follows:

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Dk. Green	Geochemical and geophysical studies
Dk. Blue	Hydrology
Olive	Economic geology Mining directory
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