Geology of the Barnesville Hydrogeologic Research Site, Lamar County, Georgia

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GEORGIA DEPARTMENT OF NATURAL RESOURCES
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ABSTRACT

Geologic mapping around the Barnesville hydrogeologic research site was conducted in conjunction with the North Georgia Hydrology Program (NGHP). Structural and lithologic data, with an emphasis on directional weaknesses and weathering characteristics, are recorded for each rock unit in the Barnesville area. The Towaliga Fault Zone, a major lithologic and structural discontinuity, traverses east to west through the study area. Four lithologic units characterize the area north of the Towaliga Fault Zone: 1) porphyroblastic biotite-quartz-feldspar gneiss; 2) quartz-muscovite schist ± sillimanite; 3) interlayered gondite, gneiss, amphibolite, and schist; and 4) graphite-sillimanite schist. Lithologic units that occur within the Towaliga Fault Zone include: 1) sheared and silicified biotite-quartz-feldspar gneiss ± garnet ± muscovite; 2) sheared biotite-feldspar-quartz-muscovite schist ± garnet ± kyanite; and 3) intensely granulated cataclasite (flinty crush rock). Quartzite and garnet-quartz-muscovite schist ± kyanite occur within and at the southern margin of the Towaliga Fault Zone. Garnet-muscovite-biotite-quartz-feldspar gneiss with local cataclasite lenses characterizes the area south of the Towaliga Fault Zone. Metamorphic mineral assemblages observed within and south of the Towaliga Fault Zone indicate kyanite-grade metamorphism; whereas, mineral assemblages north of the Towaliga Fault Zone are characteristic of sillimanite-grade metamorphism. Early, regional deformation is expressed by isoclinal folding and thrust faulting. The Towaliga Fault Zone overprints the regional deformation and is characterized by an extensive belt of heterogeneously sheared and brecciated rocks that have endured multiple episodes of ductile and brittle movement. Four joint orientations are prominent in the study area: northwest-southeast, northeast-southwest, east-west, and north-south. The variable dominance of these features is a function of rock type and geographic location with respect to the Towaliga Fault Zone. Differential weathering occurs at contacts between units with significantly different rheologic properties (i.e., feldspathic gneiss versus quartzite). Deep weathering of less resistant units adjacent to more resistant units suggests preferential movement of ground water. Several units with differing rheologic contrast occur in the fault zone due to heterogeneous distribution of shearing and silicification; this heterogeneity increases the potential for the development of high yield wells.

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INTRODUCTION

Historically, hydrogeologic systems have predominantly been characterized for Coastal Plain aquifers; consequently, there has been a paucity of systematic research concerning the geologic and hydrologic controls on ground-water systems in the crystalline rocks of Georgia. In 1987, the North Georgia Hydrology Program (NGHP) of the Georgia Geologic Survey (GGS) initiated a large-scale study to develop a better understanding of hydrogeologic systems in the crystalline rocks of the Piedmont and Blue Ridge physiographic provinces of Georgia. During the past eight years, three hydrogeologic research sites were established in central and northern Georgia as a part of the NGHP (Fig. 1). Information gathered at each of these sites has been focused primarily on the hydrologic character of the specific site. Currently, the study is being expanded to incorporate a more comprehensive geologic characterization of each research site and explore its relationship to the hydrogeology in the area. Ultimately, the correlation of the geologic data to the hydrologic data will provide a better understanding of the combination of geologic features that enhance the flow of ground water in crystalline rocks. This knowledge will reduce the risk involved in ground-water supply development and protection.

The Barnesville hydrogeologic research site was developed during the summer of 1990 and consists of 1 production well and 8 monitoring wells, two of which are core holes (Fig. 2). This site was chosen as the first site for a complete and comprehensive geologic characterization and is the focus of this study. The Barnesville 7.5 minute U.S. Geological Survey quadrangle occupies nearly one-half of Lamar County, central Georgia. Topographic elevations vary from greater than 1040 feet on top of Hog Mountain to less than 620 feet in the swampy flood plains of Towaliga Creek. Streams and creeks within this quadrangle show a complex drainage pattern controlled by variable lithologic, structural and weathering characteristics of the underlying crystalline rocks (Fig. 3).

The project area comprises approximately 80% of the Barnesville quadrangle. Geologic mapping at 1:24,000 scale includes lithologic and structural characterization of an area within a four mile radius of the study site (Plate 1). Lithologic and structural data were gathered with an emphasis on directional weaknesses (i.e., compositional layering, foliation, joints, faults, shearing) and their weathering characteristics. A greater concentration of similar data were gathered within a one mile radius of the drill holes to enable a more systematic correlation with hydrogeologic data. A total of 50 days were spent in field mapping, sampling, and photo-documenting specific geologic and hydrogeologic features. Because the focus of this study is to describe pertinent geologic features, the relationship of the geologic features to the hydrogeologic data will be discussed in a separate report.

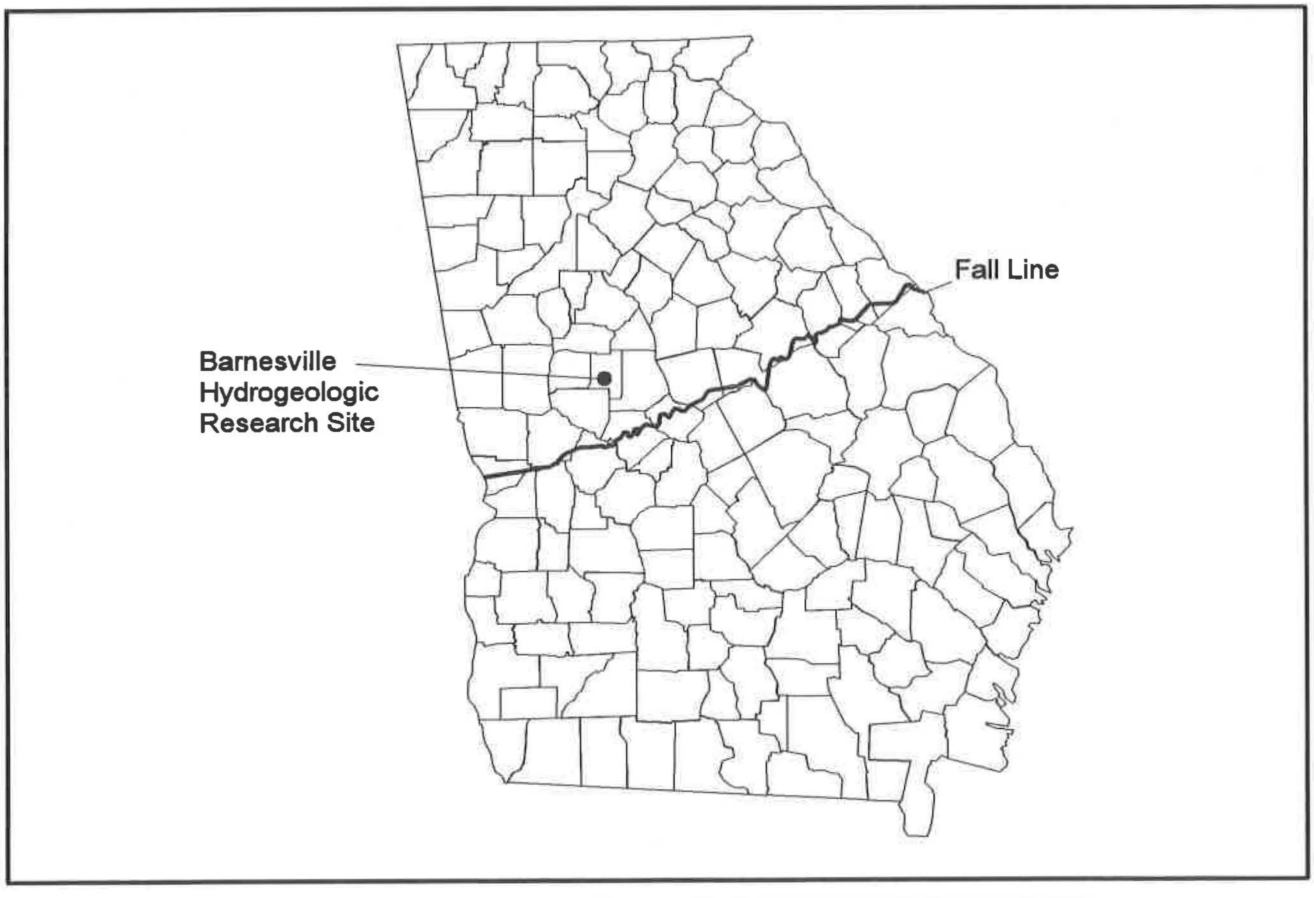

Figure 1. Location of the Barnesville Hydrogeologic Research Site.

PREVIOUS WORK

Crickmay (1952) and Pickering (1976) provide a summary and synthesis of the geology of the crystalline rocks of Georgia. Several regional geologic studies have included portions of the Barnesville quadrangle. Many of these studies have focused on the Pine Mountain Window and its northern terminus, the Towaliga Fault. Both of these features roughly trend east to west through the center of the quadrangle. Hooper and Hatcher (1989), Higgins and others (1988), Sears and others (1981), Atkins and Lineback (1992) and Higgins and Atkins (unpublished map) provide the most recent interpretations of this region. Grant (1967) provides a brief geologic description of Lamar County with an emphasis on the Towaliga Fault in the Barnesville area. A gravity survey of Lamar County was conducted by Favilla (1985), and Gorday (1989) assessed and summarized the hydrogeologic environment of Lamar County. Steele and others (in preparation) are investigating the hydrologic character of the Barnesville hydrogeologic research site.

GEOLOGIC SETTING

The Barnesville quadrangle is characterized by three northeasterly to easterly trending assemblages of rocks (Plate 1). The northwestern-most assemblage of rocks consists of an interlayered sequence of schist, gneiss, and amphibolite; whereas the southern-most assemblage consists of schist and Grenvillian-age gneiss (Higgins and others, 1988). These two assemblages of rocks are separated by the Towaliga Fault Zone. The central assemblage is characterized by an extensive belt of differentially sheared and brecciated gneisses and schists which texturally range from cataclasites to mylonites.

At least three major deformational events have been recognized within the map area (Grant, 1967). Early, tight to isoclinal, west-southwest- to west-northwest-trending folds are overprinted by broad, open north-northwest to north-northeast trending folds. A third deformational event, involving multiple episodes of ductile and brittle movement within the Towaliga Fault Zone, is recognized throughout the central portion of the project area. The Towaliga Fault Zone is interpreted as representing a major structural and lithologic discontinuity across the Barnesville quadrangle; therefore, lithologic descriptions are subdivided into three categories: rock units north of the Towaliga Fault Zone, rock units within the Towaliga Fault Zone, and rock units south of the Towaliga Fault Zone.

LITHOLOGIC DESCRIPTIONS

In this section, each major lithologic unit is characterized in relation to mineralogy, grain size, compositional layering, and various weathering features. Because of their effects on depth of weathering, efficiency of groundwater flow, and water quality, these factors are relevant to the hydrogeologic character of the rock units. The distribution of each of these units is illustrated on Plate 1.

North of the Towaliga Fault Zone

Porphyroblastic biotite gneiss

A heterogeneous mass of interlayered gneiss, amphibolite, and schist occupies most of the northern half of the Barnesville quadrangle. The gneiss is texturally and mineralogically variable, ranging from: 1) porphyroblastic gneiss (most abundant), to 2) granitic gneiss, to 3) biotite schist (least abundant), all containing variable amounts of pegmatitic material. The porphyroblastic gneiss is characterized as a granular, medium- to coarse-grained, moderately layered unit containing an equigranular biotite-quartz-feldspar "matrix" and coarser (0.5 to 4.0 cm diameter) feldspar ± quartz porphyroblasts. Garnet is rare in the northern porphyroblastic gneiss assemblage. Locally, this unit appears exfoliated in saprolite, but generally occurs as either loose, granular saprolite that maintains its fabric if undisturbed, or as deeply weathered soil. The porphyroblastic gneiss weathers reddish orange due to moderate oxidation of biotite, and is commonly characterized by black Fe-Mn oxide staining along joints. Feldspar and biotite commonly are partially weathered to completely weathered, occurring as white clay (probably kaolinite) and vermiculite, respectively. Because of the uniformity and deeply weathered nature of this gneissic sequence, the topography is characterized by nearly flat to gently rolling hills where fresh outcrop and saprolite are rare.

The granitic gneiss generally occurs as a medium-grained, equigranular quartz and feldspar gneiss with disseminated flakes of fine-grained biotite. Unlike the porphyroblastic gneiss, this unit has poorly developed segregation layering and weathers to a white to grayish orange-pink saprolite.

Locally, feldspathic quartz-biotite schist is interlayered with the porphyroblastic gneiss. The layers range in thickness from <1 to 3 meters. This unit is fine- to medium-grained, black and well foliated due to the alignment of biotite. When present in the porphyroblastic gneiss, the entire sequence appears moderately well-layered, blocky in outcrop (versus rounded) and more resistant to weathering.

Pegmatitic pods and spherical masses composed of quartz and feldspar usually occur concordant with layering in the porphyroblastic and granitic gneiss. These pods and spherical masses are highly variable in length, ranging from 1 cm to >1 m, are usually fairly narrow (1 to 10 cm), and locally appear boudined and/or rotated. They are roughly equigranular, massive, and weather white from the decomposition of feldspar and lack of ferromagnesium minerals. These units are inferred to represent metamorphic pegmatites.

Schist

Two different schists occur interlayered with the porphyroblastic gneiss: 1) quartz-muscovite schist, and 2) sillimanite-quartz-muscovite schist. The quartz-muscovite schist is medium-grained, moderately-well foliated and locally contains garnet, biotite, and chlorite. The foliation is planar and occurs as thin layers giving the schist a fissile to locally slabby appearance. The schist weathers silvery reddish-green to reddish-yellow depending on the intensity of oxidation along

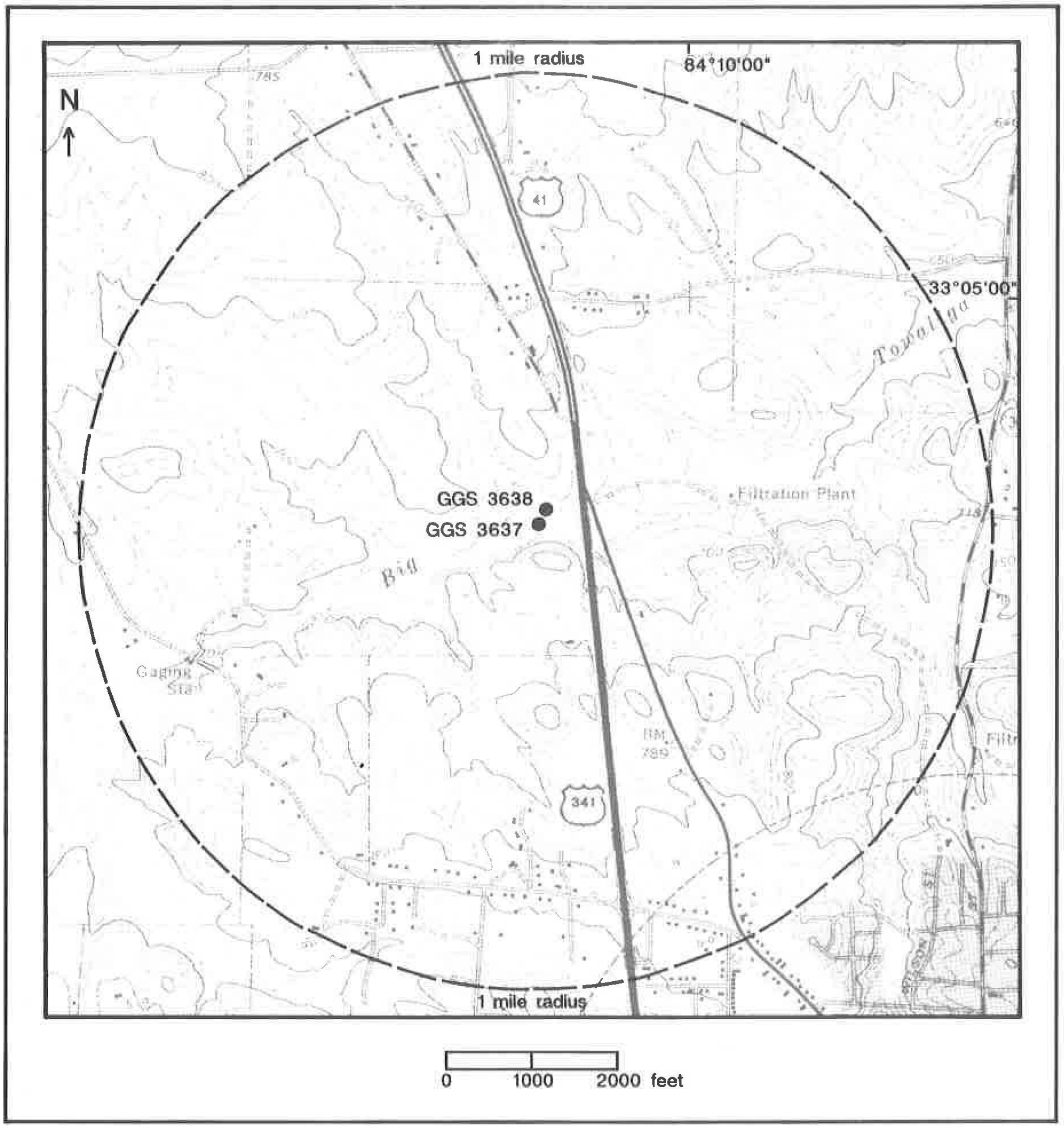

Figure 2. Drill hole location map of the Barnesville hydrogeologic research site. (Map from Barnesville U.S.G.S. 7.5 minute quadrangle, 1973.)

prominent planes of weakness (i.e. foliation). Because of the higher muscovite and quartz content, this schist is more resistant to weathering than the porphyroblastic gneiss; thus it crops out in areas where the gneiss is covered. The schistose units are scattered throughout the gneiss and range in thickness from 3 to 30 meters. Locally, pegmatitic quartz-feldspar pods occur in the schist.

The sillimanite-quartz-muscovite schist occurs as a medium-grained, moderately-well foliated, fissile schist with local concentrations of graphite, garnet and feldspar. Locally, quartz veins or pods containing sillimanite and feldspar occur concordant with foliation. This unit weathers purplish to pinkish red and has black Fe-Mn oxide staining and pods developed coplanar with foliation and joint faces. Similar to the quartz-muscovite schist, the sillimanite-quartz-muscovite schist is also more resistant to weathering than is the gneiss.

Amphibolite

Plagioclase-hornblende amphibolite is characterized as a fine-grained, equigranular unit that is massive and resistant to weathering. In more deeply weathered outcrops, this unit forms a yellowish to reddish-brown saprolite that contains a distinctive boxwork texture (appears honeycombed at hand-lens scale), giving the rock a characteristic porous appearance. The amphibolite usually crops out as rectangular blocky masses due to extensive joint development. Interlayers of amphibolite in the porphyroblastic gneiss are very sparse, occurring as relatively thin (<1m), discontinuous lenses.

Migmatitic gneiss and schist

The porphyroblastic gneiss and associated schist have been migmatized to varying degrees in the northeastern corner of the Barnesville quadrangle by intrusive effects of the Hollonville Granite. The Hollonville Granite occurs north of the Barnesville quadrangle on the Orchard Hill quadrangle (Atkins and Lineback, 1992, and Higgins and Atkins, unpublished mapping). The migmatized units occur as medium-grained, equigranular, moderately well-layered porphyrobastic and granitic gneiss interlayered with biotite schist. The schist layers, locally garnetiferous, contain high concentrations of biotite and the gneiss/schist contacts are abrupt. Biotite segregations are moderately-well foliated and define ptygmatic folding. Locally, areas less migmitized appear similar to the porphyroblastic gneiss. Migmitization is best developed in heterogeneous zones where more schistose units are interlayered with the gneiss. This association may be indicative of preferential movement of hydrothermal fluids along planes of weakness. The migmitized gneiss weathers reddish-orange and has local black Fe-Mn oxide staining and "pod-like" concentrations along foliation planes. This unit is generally more resistant than its unmigmatized parent and is more commonly exposed.

Analogous to the porphyroblastic gneiss, the migmitized gneiss is intercalated with biotite-sillimanite-quartz-muscovite schist, and quartzo-feldspathic pegmatitic pods aligned like augens or boudins along foliation. Unlike the porphyroblastic gneiss, the migmitized gneiss and associated sillimanite schist are locally garnetiferous, possibly indicating effects of hydrothermal alteration and/or contact metamorphism related to the Hollonville Granite.

Gondite-Amphibolite-Schist-Gneiss

A band of interlayered gondite, amphibolite, schist, and gneiss (referred to inclusively as gondite) trends northeast-southwest across the northwestern corner of the Barnesville quadrangle. This intercalated sequence of rocks is generally 100 to 200 meters thick (in outcrop width) and extends for several kilometers northeast and southwest of the Barnesville quadrangle, serving as an excellent regional marker bed in this part of the Piedmont (Higgins and Atkins, unpublished mapping). Gondite occurs as a texturally massive, thin (up to 1 m) layer that is fine- to medium-grained and equigranular consisting of spessartine-rich garnet and quartz ± muscovite. In weathered outcrops, the gondite characteristically occurs as a fairly resistant, blocky unit. The typical black color of this unit is due to a high manganese content. The associated schist comprises the bulk of this sequence of rocks and is characterized as a medium-grained, moderately-well foliated, fissile to slabby, garnetiferous sillimanite-quartz-muscovite schist that weathers purplish-red. Numerous amphibolite and porphyroblastic gneiss interlayers represent a minor portion of this rock unit and are similar to those previously described.

Graphite-Sillimanite Schist

The graphite-sillimanite schist occurs northwest of the gondite-bearing unit in the extreme northwestern corner of the Barnesville quadrangle. The graphite-sillimanite schist is medium-grained, moderately-well foliated and is locally garnetiferous. This unit weathers pinkish to purplish red-white, has local concentrations of Fe-Mn oxide, and is usually fairly resistant to weathering. Sillimanite occurs as white, fibrous needles roughly 5 to 10 mm long and 0.5 to 1 mm wide, with a less prominent cleavage oriented perpendicular to the long axis. Submetallic, black graphite plates, up to 0.5 to 1 mm in diameter, are near-ubiquitous within the sillimanite fibers. Foliation is generally planar, although locally it is highly deformed as indicated by complex interference patterns at outcrop scale. Quartz veins containing sillimanite ± feldspar occur concordant to foliation. Additionally, a single interlayer of porphyroblastic gneiss was observed in the extreme northwestern corner of the quadrangle.

.A wide zone of resistant, intensely folded and faulted graphite-sillimanite schist occurs in three outcrops along topographically high areas that trend parallel to the gondite-bearing unit. The graphite-sillimanite schist is interlayered with biotite-muscovite-quartz schist ± chlorite ± feldspar and massive blocks of porphyroblastic gneiss which appear to be infolded in the schist. Several elongate lenses and pods of massive, very competent, equigranular quartz ± garnet granofels (gondite) occur in the schist. The adjacent foliation is highly deformed, probably accommodating strain around the more resistant granofels pods. A single muscovite-quartz-feldspar pegmatite was observed. An abundance of quartz veining occurs in all graphite-sillimanite schist outcrops and two temporally distinct

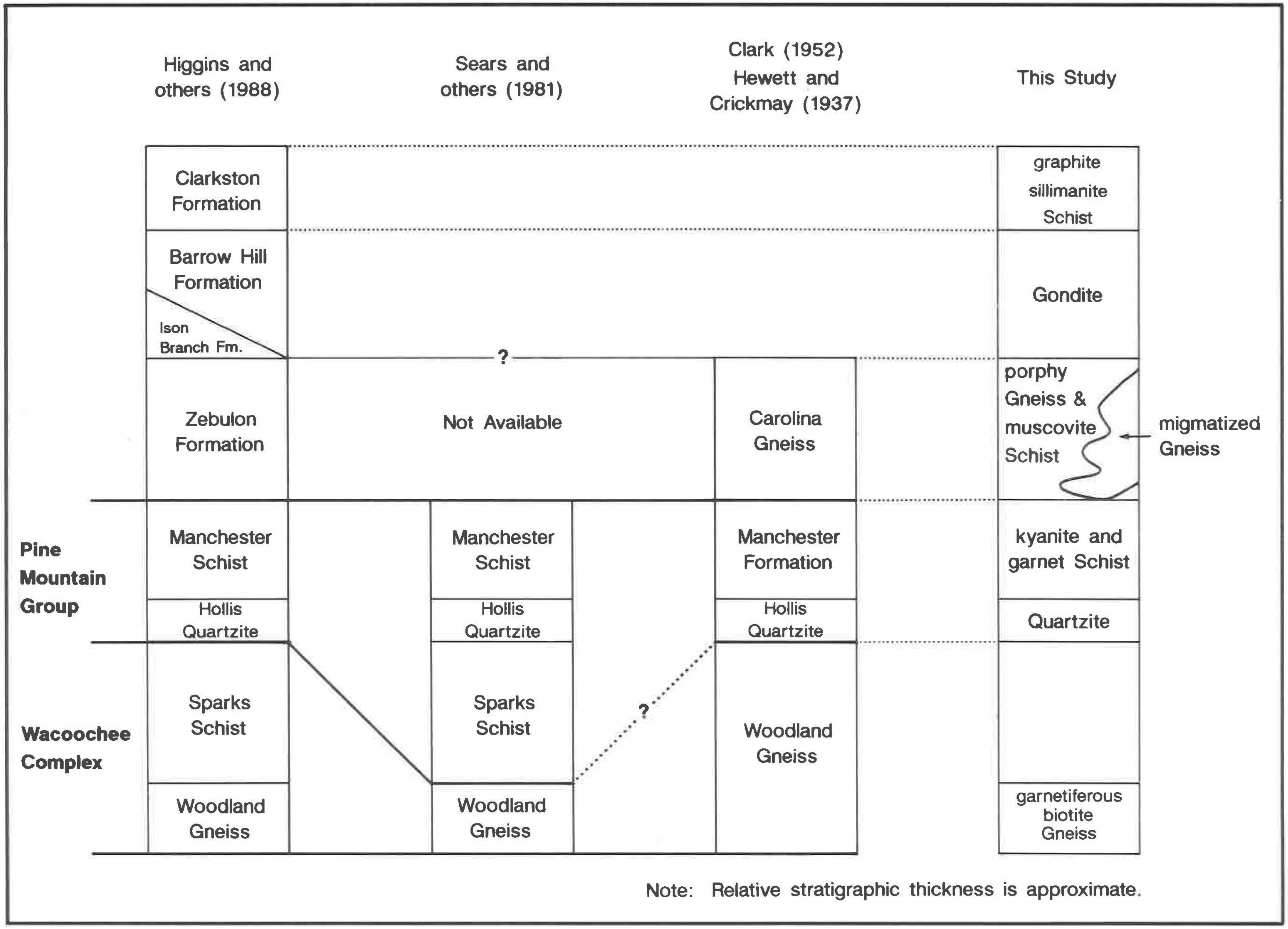

Figure 3. Regional stratigraphic correlation of lithologies mapped on the Barnesville Quadrangle.

generations were noted. The first occurs as small lenses concordant to foliation and probably formed as "sweat-out" veins during prograde metamorphism. These veins have subsequently been deformed creating "S", "Z", and "M" type folds, and local boudins. The second type of quartz vein is temporally later and occurs as large, cross-cutting irregular masses.

Towaliga Fault Zone

Augen gneiss

The heterogeneous effects of shearing are best displayed in the gneiss and gneissic schist in the Towaliga Fault Zone. Sheared biotite-quartz-feldspar gneiss ± garnet ± muscovite is primarily characterized by the presence of augened feldspar ranging from 0.05- to 3-cm long and ribboned lenses of interstitial quartz. These features are highlighted by numerous thin biotite laminae which anastomose and deflect around the feldspar and quartz producing a well layered, anisotropic/mylonitic fabric. Garnet, when present, is typically concentrated in the more biotite-rich laminae. Muscovite is locally present in variable amounts. Feldspar porphyroblasts are commonly observed aligned along foliation and probably represent a stretching lineation associated with shearing.

The augen gneiss grades laterally (east and west) into zones of moderate to pervasive silicification that usually occur as very resistant blocky, porphyroblastic (feldspar clasts >5 to 10 mm) gneiss with abundant associated quartz veins. The resistant nature of this unit is expressed topographically by relatively steep ridges and isolated knolls. Unlike the augen gneiss, the silicified gneiss is not well layered and contains a lower volumetric abundance of mica (both biotite and muscovite). Lensoidal shaped zones of cataclasites (possibly microbreccia, although no petrographic analysis has been performed), with abrupt contacts, occur within the silicified gneiss and augen gneiss. These zones have been previously referred to, in a general sense, as flinty crush rock (FCR) by various workers in the southeast. These lenses trend northeast to southwest, roughly paralleling the orientation of the Towaliga Fault Zone, and range in size from discreet laminae within the gneiss to extensive, mappable units. The cataclasites are characterized as very fine-grained to microcrystalline, massive, white quartz ± feldspar ± muscovite with an associated well-developed shear foliation.

The occurrence of a unit characterized by medium- to coarse-grained, rounded feldspar porphyroclasts set in a black, aphanitic matrix of rock flour (probably quartz , feldspar, and mica) was also observed interlayered with the augen gneiss. This unit texturally represents a blastomylonite and/or ultramylonite (Sibson, 1977) and indicates that this portion of the Towaliga Fault Zone has undergone more intense cataclasis than the surrounding units.

Schistose gneiss

A sequence of intercalated schist, schistose gneiss, and augen gneiss occurs along the east-central margin of the Barnesville quadrangle within the Towaliga Fault Zone. The schist is characterized as a medium-grained, well foliated feldspar-quartz-muscovite schist ± garnet ± biotite ± chlorite ± kyanite. This unit weathers silvery pinkish-red to greenish-gray, is fissile to slabby, and is locally porous due to degradation of feldspar. Granulated kyanite-bearing quartz veins occur locally in the schist. These veins are variable in thickness, contain scarce submetallic sheet-like hematite and have a boxwork texture formed from the decomposition of feldspar. Local pegmatitic quartz-feldspar lenses were observed, and are concordant to the dominant foliation. Effects of ductile deformation are indicated by the development of shear fabrics such as "mica fish", quartz ribbons, and button schist (Lister and Snoke, 1984). Laterally, this schist grades into biotite-feldspar-quartz-muscovite schist ± kyanite, into feldspar-quartz-muscovite-biotite schist with pegmatitic lenses, and into sheared quartz-feldspar-biotite gneiss ± muscovite. The schists and gneisses are similar mineralogically but vary texturally in that the schist is moderate to well foliated and displays numerous shear fabrics. An attempt was made to map the sheared gneissic schist separately from the sheared augen gneiss on Plate 1. However, these contacts are very imprecise due to their extremely transitional nature.

South of the Towaliga Fault Zone

Interlayered Quartzite and Schist

A narrow zone of quartzite traverses, east to west, across the entire quadrangle near the southern margin of the Towaliga Fault Zone. This unit is characterized as a medium-grained, granular, micaceous-feldspathic quartzite. Medium- to coarse-grained muscovite generally defines a moderately-well developed foliation, with the schistose layers averaging >0.25 mm thick and the granular quartz layers averaging 0.5 to 1 mm thick. The quartz layers are commonly ribboned and coarse-grained mica fish are locally developed. Magnetite occurs in variable abundances as an accessory mineral. Garnet was observed in mica-rich layers in a few places The quartzite weathers tannish to orangish-white, is usually well jointed, flaggy to blocky (depending on muscovite content), and becomes porous and friable as the feldspar weathers and leaches away. This unit is usually very resistant to erosion and typically is expressed as a topographic ridge. Several 6 mm to 10 cm thick lenses of porous, highly concentrated zones of iron oxide are located concordant and discordant to foliation and along some joint surfaces. These lenses commonly contain muscovite and quartz.

The quartzite ranges in outcrop width, from 30 to 275 meters. Thinner portions are generally characterized by a mylonitic texture. The pinch and swell appearance in map pattern is most likely due to tectonic attenuation, although it could, in part, also represent original difference in depositional thickness. On the eastern edge of the quadrangle, the quartzite unit becomes more heterogeneous, alternating with a garnetiferous quartz-muscovite schist ± feldspar. These schistose interlayers vary from 1 cm to 5 meters thick on outcrop scale, and up to 200 meters thick on a regional scale. The smaller scale micaceous interlayers weather darker and are slightly less resistant than the quartzite, giving the unit a stripped look.

Additionally, these layers act as marker "beds" within the quartzite and prove useful in delineating structures. The larger scale schistose interlayers (50 to 200 meters) are characterized as medium- to coarse-grained, well foliated, garnet-quartz-muscovite schist ± feldspar with local platy graphite. This unit weathers purplish-red to yellowish-orange, is preferentially oxidized along foliation, and has a black Fe-Mn oxide staining coplanar to foliation and along joint surfaces.

Two continuous units of variably sheared quartzite crop out north of the main quartzite sequence within the Towaliga Fault Zone. Locally, these limbs are mineralogically and texturally indistinguishable from the larger quartzite unit. The southern-most of these two thinner units grades laterally from sheared quartzite to mylonitic quartzite and, locally cataclasite, showing a wide variation in development of tectonic flow structure. These units are very resistant to weathering, probably due to localized secondary silicification associated with shearing. They are commonly expressed as ridges but are often well exposed in creek beds. The units have been relatively unaffected by weathering and generally crop out as fresh, unoxidized rock.

These two thin quartzite units enclose a body of aluminous schist. The schist is characterized as a medium- to very coarse-grained, moderately layered kyanite-garnet-quartz-muscovite schist ± feldspar. Kyanite generally occurs in heterogeneously concentrated layers within the schist and probably represents zones originally rich in alumina. The kyanite is characterized as elongate, bluish-green blades and the garnet and kyanite are variable in grain size, ranging from 1 mm to 2 cm, and 5 mm to 1.5 cm, respectively. Shear fabrics noted in this unit include quartz ribbons, mica fish, and a stretching mineral lineation defined by kyanite. The kyanite-garnet schist weathers purplish-red to yellowish-red and is moderately-well exposed along Big Towaliga Creek between the two enclosing units of thin quartzite. This schist unit differs from the garnetiferous schist that is interlayered in the main quartzite sequence only by the presence of kyanite. Because kyanite is so heterogeneously developed in the kyanite-garnet schist, the garnetiferous schist may be the same unit but without the alumina-rich zones developed to the same extent as in the kyanite-garnet schist.

Garnetiferous Biotite Gneiss

A fairly heterogeneous sequence of granitic gneiss with pegmatitic lenses and schistose interlayers exists in the southern half of the Barnesville quadrangle. Mineralogically, this unit is very similar to the porphyroblastic gneiss north of the Towaliga Fault Zone; however, it is texturally distinct. The gneiss south of the Towaliga Fault Zone is characterized as a medium- to coarse-grained, well-layered garnet-biotite-quartz-feldspar gneiss ± muscovite ± pyrite. The well layered appearance of this gneiss is attributed to the thorough development of segregation banding between the leucosomes and melanosomes. Garnet and biotite occur both as disseminated grains in the quartz-feldspar leucosomes and in concentrated aggregates or clots that form a lineation in the plane of foliation. The garnetiferous biotite gneiss is generally more micaceous (both biotite and muscovite) than the porphyroblastic gneiss north of the Towaliga Fault Zone. Because of the mica enrichment and segregation, the saprolite is well preserved compared to the saprolite observed in the porphyroblastic gneiss. Lens-shaped quartz-feldspar pegmatites within the garnetiferous biotite gneiss have 0.5 to 2 cm biotitic haloes, probably reflecting effects of metamorphic segregation. The gneiss weathers orangish-red to dark red with scattered Fe-Mn oxide-enriched biotite clots that probably represent remnant garnet-biotite aggregates. This unit crops out as planar slabs and blocks, but is most commonly observed as saprolitic soil.

Near the garnetiferous biotite gneiss-quartzite contact, a transitional zone occurs, grading from thinly laminated garnetiferous biotite gneiss to augened garnetiferous biotite gneiss to sheared biotite-feldspar-quartz-muscovite schist to quartzite. This transition is observed over roughly 30 meters and occurs discontinuously but persistently along the southern and northern margins of the main quartzite body.

When the garnetiferous biotite gneiss does not grade transitionally into a sheared schist directly south of the quartzite contact, it occurs as an intensely sheared unit that is deeply weathered. This weathering characteristic is probably a function of the greater susceptibility of gneiss to weathering than the quartzite due to a greater abundance of feldspar in the gneiss. The gneiss and schist in this transition zone are very similar to that described within the Towaliga Fault Zone and may represent the same stratigraphic unit, or may have endured similar physical processes as the sheared gneissic schist and the augen gneiss.

Cataclasite

Several interlayers of cataclasite (sometimes referred to as flinty crush rock) occur within the garnetiferous biotite gneiss. These units are white, very fine-grained to microcrystalline, have a well-developed shear foliation and are locally brecciated as evidenced by open-space veins filled with coarse (<5 cm long), inward -projecting quartz crystals. Locally, these veins are not completely infilled with quartz crystals and partial permeability in the vein is preserved. These brittle features were also observed in local portions of cataclasites in the Towaliga Fault Zone. The interlayers of cataclasite occur up to 3.5 km south of the Towaliga Fault Zone but were not observed north of the Towaliga Fault Zone.

STRATIGRAPHIC CORRELATION

An attempt to correlate lithologic units of the Barnesville quadrangle with the Piedmont stratigraphy is important because of the potential to indicate the amount of relative movement experienced along the Towaliga Fault Zone in the Barnesville area and to correlate age and tectonic relations determined elsewhere in the region. Terminology of previous workers together with that of the present study is summarized in Figure 3 The garnetiferous biotite gneiss south of the Towaliga Fault Zone is generally believed to represent the Grenvillian basement and is referred to as the Woodland gneiss of the Wacoochee Complex by Bentley and Neathery (1970). Hewett and Crickmay's (1937) description of the Sparks schist correlates with that of the sheared gneissic schist and the transitionally adjacent augen gneiss. Bentley and Neathery (1970) and Higgins and others (1988) included this unit in the Wacoochee Complex; however, Sears and others (1981) have included the Sparks Schist in the Pine Mountain Group. The thick quartzite and the two thinner units correlate with the Hollis quartzite, which is considered to stratigraphically overlie the Sparks Schist (Hewett and Crickmay, 1937). The kyanite-garnet schist and garnetiferous schist are probably equivalent to the lowermost member of the Manchester Schist as described by Clarke (1952). The Hollis quartzite and the Manchester Schist are interpreted as belonging to the Pine Mountain Group (Bentley and Neathery, 1970). The porphyroblastic gneiss north of the Towaliga Fault Zone represents the Zebulon Formation and the gondite and graphite-sillimanite schist belong to the Barrow Hill and Clarkston Formations, respectively (Higgins and others, 1988).

STRUCTURE

Orientation of compositional and structural anisotropies (i.e., foliation, lineations, fold axes, faults,) are of great importance in controlling fracture behavior. These features will be discussed in this section. Joint openings frequently provide one of the most efficient interconnected pathways for ground water flow. The joint sets measured and described during this investigation and their relationship to structural features will be discussed in a separate section.

Early Folds and Faults

The schist, gneiss, and amphibolite north and south of the Towaliga Fault Zone have endured a polydeformational history. These rocks have a penetrative schistosity (S1), expressed primarily as the alignment and concentration of biotite and/or muscovite in the gneiss and muscovite ± sillimanite in the quartzite and schist. S1 is generally observed parallel with layering that is believed to represent the original compositional layering (So). The intensity of S1 foliation is variable, being more intense in the schist and quartzite than in the gneissic units. A summary plot of measured regional foliation orientations is given in Figure 4. The calculated mean foliation (S1) is N81°E, 51° NW. A lineation (L1) observed in units north and south of the Towaliga Fault Zone is a nonpenetrative mineral lineation defined by the preferential alignment of feldspar and biotite along S1 planes. This lineation trends N52°E, 20-40°SW and is consistent with that recognized by Grant (1967).

Tight to isoclinal style folding (F1) associated with axial planar S1 and L1, is locally observed in all rock types north and south of the Towaliga Fault Zone. These fold sets trend WNW to ENE (averaging N84°E), have a shallow plunge (5°-20°) to the southwest and axial planes dip to the north 10-35 degrees. The best exposures of the tight sequence of isoclinal folding is in the Hollis quartzite where the schistose interlayers provide excellent marker beds. Additionally, variability of foliation in the garnetiferous biotite gneiss indicates a series of tight folds throughout the southern half of the quadrangle.

Effects of probable thrust faulting associated with isoclinal folding were also observed. A thrust contact has been interpreted between the porphyroblastic gneiss and gondite/graphite-sillimanite schist sequence by Higgins and Atkins (unpublished mapping). A narrow (2 to 3 cm) layer of oxidized clay occurs at the contact between an abrupt change in lithology (gneiss and gondite/schist) and a change in the average foliation (S1) orientation to N65°E. This zone may represent the plane of movement. Given the juxtaposition of two different lithologic units that are not in their normal stratigraphic sequence, the possible clay-filled fault zone, and the abrupt change in structural attitude, the interpretation of a thrust contact seems reasonable.

The two thin units of quartzite and interlayered kyanite-garnet schist are tentatively interpreted as an imbricate thrust slice off the main Hollis quartzite. The average foliation orientation in the northern-most thin quartzite unit changes from N80°E to N60°E in the last 3.5 km before its northeastern termination. This change is consistent with a change observed in the trend of the Towaliga fault. As indicated on Plate 1, the sequence of the thin quartzite units and interlayered kyanite-garnet schist and the main section of Hollis are all enclosed within the same unit (augen gneiss). These thin quartzite units have previously been interpreted as discontinuous cataclastic and mylonitic zones created during movement along the Towaliga Fault Zone and were not believed to be related to the Hollis quartzite (Hewett and Crickmay, 1937; Grant, 1967; Higgins and Atkins, unpublished mapping). This is a viable interpretation; however, by considering that: 1) locally, the units are indistinguishable mineralogically and texturally from the main Hollis quartzite and associated Manchester Formation, 2) the units grade laterally into cataclasites which are commonly associated with thrust faults; and 3) repetition of the lithologic sequence is indicated; the interpretation that the quartzite-schist sequence represents an imbricate thrust off of the Hollis is well supported. Alternative interpretations including effects of repetition by folding have also been considered. The repetition of the lithologic sequence could have been produced during the F1 isoclinal event. Unlike the main body of quartzite, mesoscopic folding is not indicated in the thin quartzite units in outcrop. However, effects of thrust faulting are indicated at outcrop scale in the surrounding gneiss and schist; therefore, repetition of units by imbricate thrusts is currently the favored interpretation.

A second generation of broad, open-style folding (F2) gently warps the isoclinal folds, locally. This event was not penetrative, however, as the S0/S1 layers appear to be unaffected (i.e., no associated S2 is recognized).

Towaliga Fault Zone

The Towaliga Fault Zone, which is interpreted to be younger than the regional foliation (S0/S1), is oriented N60° to 70°E, 50°-70° NW. The fault zone is characterized by a variably exposed width of ductile deformation ranging from 1 to 3 km on the Barnesville quadrangle. The fault zone is also characterized by a prominent stretching mineral lineation (L2) trending N25°W, and plunging 49° to the northwest and is consistent with that documented by Grant (1967). This stretching lineation was probably developed in response to dip-slip movement along the Towaliga Fault Zone. Figures 5 and 6 are summary plots of all foliation measurements within the Towaliga Fault Zone and the one-mile radius around the research site, respectively. The distribution of poles on figure's 4, 5, and 6 are very similar, indicating that the orientation of shear-induced foliation (S2) is so similar to regional foliation that it is indistinguishable from S1 on a composite plot.

A later, brittle stage of movement along the Towaliga Fault is locally depicted in a zone of offset where the sheared northern thin quartzite unit is juxtaposed against the garnetiferous quartz-muscovite schist with a narrow zone of fault gouge dividing the two units. The attitude of this fault is N70°E, 80°NW and parallels that of the Towaliga Fault.

The northern margin of the Towaliga Fault Zone, characterized by augen gneiss, mylonitic schist, and local cataclasite, has a relatively abrupt contact with adjacent rock units. Augen gneiss, mylonitic schist and quartzite, and cataclasite also characterize the southern margin of the Towaliga Fault Zone, but narrow zones of high strain subparallel to the main zone occur sporadically up to 3.5 km south of the margin. This is indicated by the occurrence of discontinuous cataclastic lenses and interlayers of mylonitic schist in the garnetiferous biotite gneiss. These lenses and interlayers maintain a similar shear foliation orientation (N65°E) as that observed in the Towaliga Fault Zone. These shear features indicate that ductile and brittle movement occurred within and south of the Towaliga Fault Zone; subsequently, these units were juxtaposed against the relatively unsheared units north of the Towaliga Fault Zone. The central portion of the Towaliga Fault Zone consists of extensive cataclasites, brecciated cataclastics, augen gneiss, mylonitic gneissic schist and quartzite, and ultramylonitic gneiss.

Shear zones are typically very heterogeneous internally. Structural discontinuities tend to intersect at acute angles producing an anastamosing array of shears that envelope zones of lower strain (Bursnell, 1989). Effects of shearing are heterogeneously distributed throughout the Towaliga Fault Zone. This is indicated most clearly around the sheared gneissic schist units and in the drill core from the hydrogeologic research site. The sheared gneissic schist has been observed to occur within the augen gneiss and locally along the quartzite-augen gneiss and quartzite-garnetiferous biotite gneiss contacts. A fainter foliation plane occurs in the sheared gneissic schist and its combination with S1 probably promoted development of the button schist fabric within the sheared gneissic schist. This foliation (S2?) was not developed well enough, however, to obtain a reliable measurement. As mentioned in the lithologic descriptions, the sheared gneissic schist and augen gneiss are very transitional units, possibly originating from the same protolith. It is conceivable that during shearing and accompanying fluid infiltration of a gneissic unit, feldspar content would decrease and muscovite content would increase due to crystallization from breakdown of feldspar. Addition-

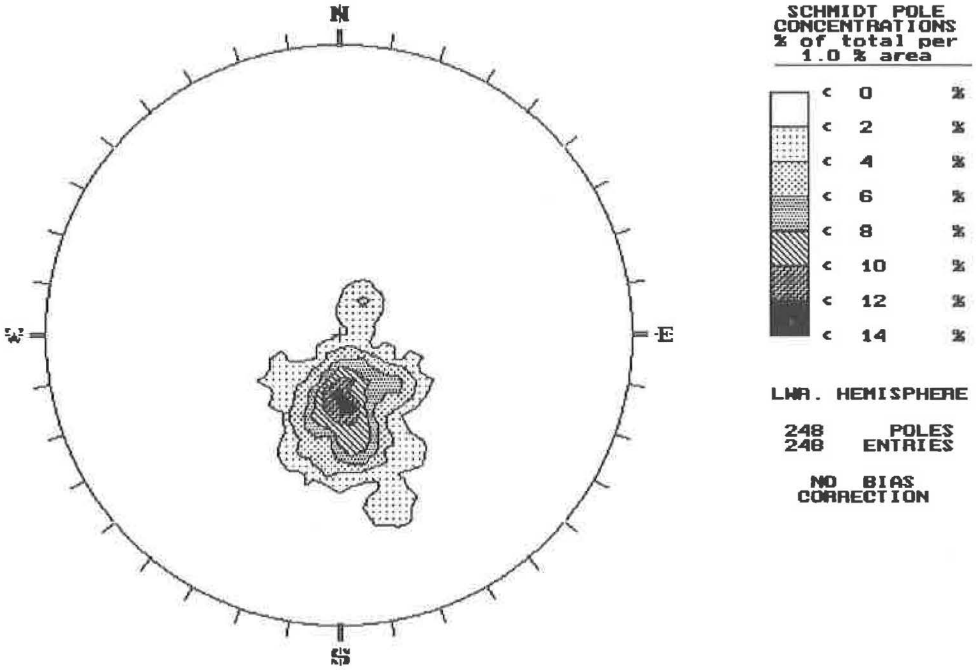

FIGURE 4. Contoured, lower hemisphere, equal-area stereoplot of 248 poles to foliation outside the Towaliga Fault Zone. The solid black area represents the maxima and indicates that 12% to 14 % of the data occur in an area equal to one percent of the total area of the diagram. The calculated mean regional foliation is N81E, 51°NW.

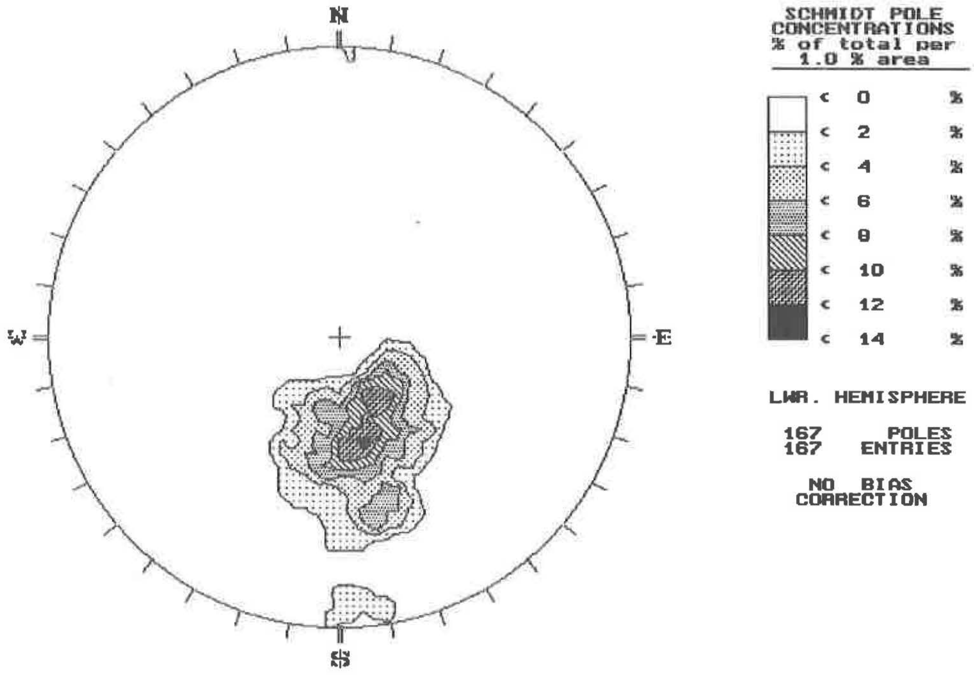

FIGURE 5. Contoured, lower hemisphere, equal-area stereoplot of 167 poles to foliation within the Towaliga Fault Zone. The calculated mean foliation within the Towaliga Fault Zone is N77E, 50°NW.

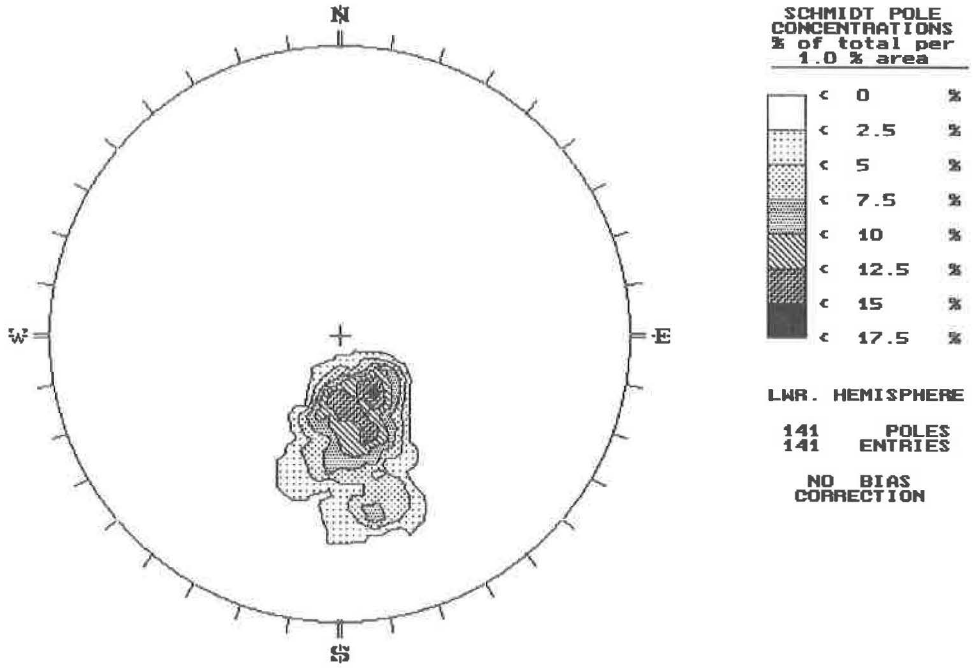

FIGURE 6. Contoured, lower hemisphere, equal-area stereoplot of 141 poles to foliation in a one-mile radius around the Barnesville hydrogeologic research site. These data primarily lie within the Towaliga Fault Zone. The calculated mean foliation within this radius is N78E, 50°NW.

ally, biotite would initially become more highly concentrated, imparting a more schistose fabric to the gneiss, and ultimately the biotite would be depleted due to interaction with shear-induced fluids. The resultant "sheared schist-gneiss" would be mineralogically similar to the original gneiss (with the exception of relative mineral abundance), and texturally similar to a sheared schist. The sheared gneissic schist may represent portions of the augen gneiss that have been sheared to a greater degree, perhaps as a result of anastomosing splays within the Towaliga Fault Zone. Alternatively, the sheared gneissic schist may simply represent compositionally discrete interlayers of schist within the gneiss, both of which have undergone intense shearing.

Heterogeneous effects of shearing in the Towaliga Fault Zone are also observed in diamond drill holes GGS#3637 and GGS#3638. Drill core from GGS#3637 represents a 328.5 foot penetration of the augen gneiss. The upper half of this hole consists of augened and ribboned gneiss. Below 170 feet, this unit grades into a zone of greater penetrative deformation as evidenced by the gradual development of a mylonitic flow fabric along with comminution of augens to microaugens. Very locally, blastomylonite is observed and probably represents the advent of movement along the Towaliga Fault Zone (Grant, 1967). The bottom portion of this hole encountered alternating intervals of ultramylonite and cataclasites. Drill hole GGS#3638 is collared in micaceous, mylonitic quartzite and represents the northern-most of the thin quartzite units. This unit is followed by an interval of intense brecciation and veining. The breccia consists of numerous randomly oriented clasts of schist, quartzite, vein quartz and sillimanite needles. This breccia may represent the area where the southern and northern quartzite limbs merge, as observed in surface exposures. Sixty feet of cataclasite with transitional zones of mylonitic quartzite were encountered below the brecciation, and another zone of brecciation follows the cataclasite. The bottom portion of the hole is characterized by an interval of gradational cataclasite, mylonitic quartzite and mylonitic schist, all containing vein quartz.

METAMORPHISM

The metamorphic mineral assemblages observed north of the Towaliga Fault Zone appear to vary with bulk composition. The graphite-sillimanite schist is characterized by graphite + sillimanite + garnet + muscovite + feldspar + quartz ± biotite; whereas, the gneiss contains biotite + feldspar + quartz. During this field investigation, garnet has not been observed as part of the metamorphic assemblage in the gneiss; however, Grant (1967) reported the rare occurrence of garnet in this unit. Although no geothermometry has been obtained, based on mineral assemblages, the metamorphic signature in this area is characterized as sillimanite zone of the almandine-amphibolite facies (Mason, 1978).

The metamorphic mineral assemblages observed within and south of the Towaliga Fault Zone differ from those north of the Towaliga Fault Zone by the occurrence of kyanite in the schist and abundant garnet in the gneiss. The kyanite-garnet schist, garnetiferous schist, and sheared gneissic schist are characterized by muscovite + feldspar + quartz + kyanite + garnet ± biotite and the augen gneiss and garnetiferous biotite gneiss are characterized by garnet + muscovite + biotite + quartz + feldspar. Quantitative data are not available for geothermometry based on garnet-biotite equilibrium pairs; therefore, qualitatively, this area is presumed to have achieved staurolite to kyanite-grade metamorphism(Mason, 1978).

HYDROGEOLOGY

426 foliation and 519 joint measurements were taken during the geologic mapping segment of this investigation (Plates 1 and 2). Before gathering joint data, each outcrop was visually assessed to identify the most prominent joint sets. This qualitative method of filtering data could have been performed quantitatively and statistically by measuring all joints present and plotting them on appropriate structural diagrams for each outcrop. This approach has previously been taken by various consulting firms in the region; however, the results are essentially the same as those acquired from the qualitative method and the quantitative method takes significantly longer.

Structural data collected at each outcrop includes orientation of foliation and/or compositional layering, joint sets, lithologic contacts, veins, folds, and faults. Additional characteristics of potential hydrogeologic significance, such as degree and depth of weathering, and spacing, persistence, and dilation of joint sets were recorded for the structural discontinuities where applicable. Lithologic features such as mineralogy also have a hydrogeologic impact and are discussed in the Lithologic Descriptions portion of this report. These structural and lithologic data are presented in Appendix I.

A variety of methods are used to compare structural data; the most effective are stereonets and rose diagrams. These types of graphical representation enable quick assimilation of data and allow direct comparison of structural trends. Although there is significant scatter in the data, a few generalizations can be made for prominent joint orientations related to different lithologies and different geographic locations, relative to the Towaliga Fault Zone.

Joint set data are categorized by two criteria: 1) lithology, and 2) relation to the Towaliga Fault Zone (i.e., south, within, and north of the Towaliga Fault Zone). Dominant joint orientations are indicated in seven of the ten lithologies described. Eighty-five percent of the lithologies display a broad northwest joint set with a strong north-northwest subset. This orientation is generally perpendicular to the regional foliation (S1). Another weaker joint set oriented roughly northeast occurs in 70% of the lithologies. This orientation is generally parallel to S1. Two minor, north-south and east-west sets are also observed in 70% of the lithologic units. Many of these joints are vertical; however, some depart up to 30° from this attitude. These four dominant joint sets are commonly observed in crystalline rocks throughout the Georgia Piedmont (Crawford, T., per. comm., 1991).

Joint orientations were also arranged by geographic position relative to the Towaliga Fault Zone (Plate 2). North of the

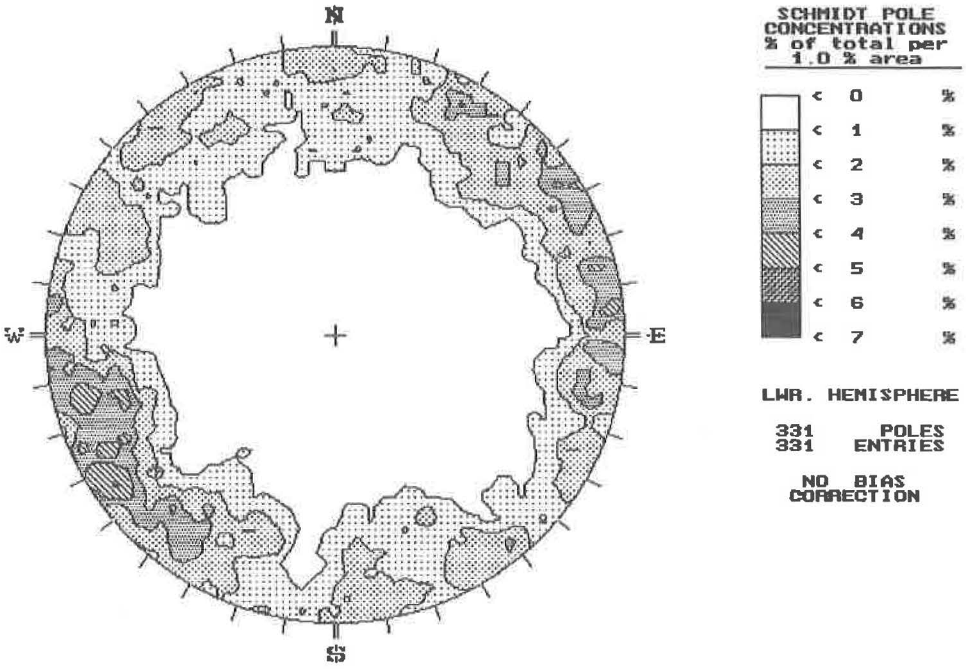

FIGURE 7. Contoured, lower hemisphere, equal-area stereoplot of 330 poles to joint surfaces outside the Towaliga Fault Zone. The most prominent joint set has a broad, northwest orientation with a strong north-northwest subset. Minor areas of 3-4% mark subsidiary sets of joints orientated northeast and east-west. The symmetrical placing of the maxima near the perimeter indicate that the joints are commonly near vertical.

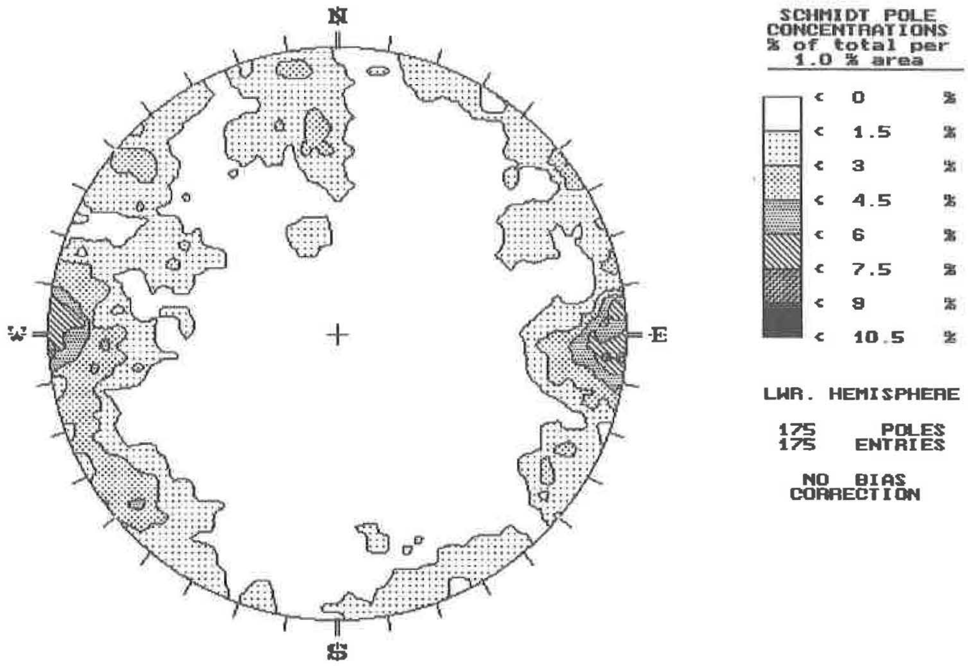

FIGURE 8. Contoured, lower hemisphere, equal-area stereoplot of 175 poles to joint surfaces within the Towaliga Fault Zone. The dominant joint sets within the Towaliga Fault Zone are oriented north-south. Minor northeast and east-west oriented sets are indicated by the 3-4.5 % area.

Towaliga Fault Zone, joint sets have a prominent broad northwesterly orientation with a north-northwest subset and a weaker northeasterly orientation (Fig. 7). Near the margin and within the Towaliga Fault Zone, the dominant joint set is roughly north-south to north northeast (Fig. 8). This set may represent fracturing in response to latent stresses associated with dip-slip movement along the Towaliga as it is oriented parallel to the stretching lineation (L2) observed during this investigation and noted by Grant (1967). Other joint sets in the Towaliga Fault Zone include the east-west orientation and a weaker northeasterly and northwesterly alignment (Fig. 8). Joint orientations sorted for an area within a one mile radius of the hydrogeologic research site within the Towaliga Fault Zone display strongly shear-controlled fabrics. The two dominant joint sets include a north-south and a northeast set (Fig. 9). The northeast orientation is only observed as a dominant joint set within the one-mile radius. These two sets probably represent fracturing in response to latent stresses associated with dip-slip (L2) and strike-slip (S2) movement along the Towaliga Fault Zone, respectively.

South of the Towaliga Fault Zone, the dominant joint sets are analogous to those observed north of the Towaliga Fault Zone, and are characterized by a prominent broad northwesterly and weaker northeasterly, and east-west orientations (Fig. 7). The symmetrical placing of the maxima on the perimeter on Figure's 7, 8, and 9, indicates that the joints, though somewhat variable, are statistically near vertical.

Gorday (1989) performed a rectilinear stream analysis of Lamar County in conjunction with a hydrogeologic study of the area. Gorday observed three dominant directions of stream-segment alignment. These regional stream-segment orientations parallel three of the four joint sets commonly observed on the Barnesville quadrangle, indicating a structurally controlled drainage pattern. On a quadrangle and smaller scale, the relationship of stream-segment alignment and planar weakness varies in different rock types. Commonly, streams occur bisecting intersections of planar features (i.e., two joint sets, or one joint set and foliation) in quartzite and biotite gneiss; whereas, in schistose units, streams tend to occur parallel to planar weaknesses. Although this observation is empirical, the relationship may bear potential hydrologic significance.

Generalizations concerning frequency and abundance of fracturing for a given lithologic unit or geographic position are more difficult to make. These types of generalizations may be biased by the amount of exposure and degree of weathering as well as a response to a particular rock type or the stress field of a specific area. The greatest frequency of outcrops occurs in the sheared gneissic schist, augen gneiss, cataclasite and quartzite. All of these units occur within or adjacent to the Towaliga Fault Zone and have the greatest concentration of penetrative joint sets. These observations could indicate the following: 1) the abundance of well-developed joint sets in this band of rocks within the Towaliga Fault Zone does not necessarily indicate that these rock types were more amenable to fracturing than other lithologic units south and north of the Towaliga Fault Zone. The units appear more resistant to weathering, possibly

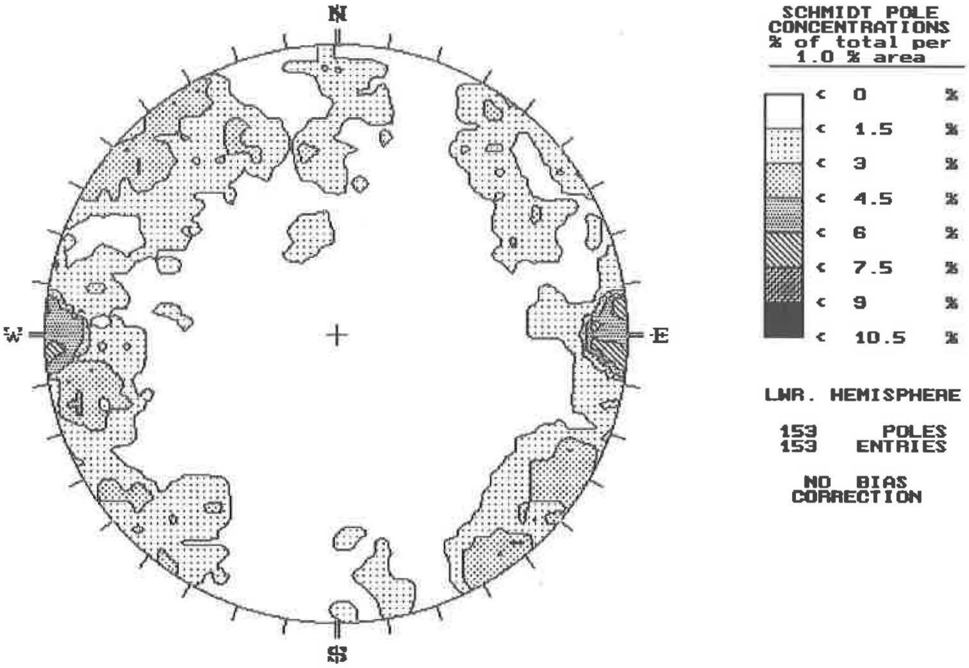

FIGURE 9. Contoured, lower hemisphere, equal-area stereoplot of 153 poles to joint surfaces within a one-mile radius around the Barnesville hydrogeologic research site. The dominant joint set is oriented north-south and is similar to that observed within the Towaliga Fault Zone. A strong northeast orientation is also indicated and is unique to the area.

due to partial silicification, thus jointing is more evident than in deeply weathered outcrops. For example, the porphyroblastic gneiss does not have a high occurrence of outcrop, but when exposed, this unit is usually fairly well fractured. 2) Because these rock types are more resistant, they react brittlely to latent stress fields; consequently, they are more susceptible to secondary fracturing. This band of rocks traverses west to east through the center of the one mile radius around the hydrogeologic research site. Even though the frequency and abundance of joint sets appears to be greater in this area, determination of whether or not this is a function of the units' proximity to the Towaliga Fault Zone is difficult to make. However, because of the inherent heterogeneous distribution of rock types and silicification in the one-mile radius, this area would intuitively seem to be favorable for a higher concentration of jointing. This high frequency of jointing is probably responsible for the high yield well at the research site.

The scatter in joint orientation data may be related to locally different inherent variations in the rock fabrics. Despite effects of polydeformational events, regional foliation (S1) is generally planar; however, the attitude of foliation does vary. Many joint sets appear to have formed in response to the foliation orientation; therefore, wide variation in joint set orientation may be a function of variations in foliation dip and dip direction. Therefore, a slight change in one foliation orientation may moderately affect three or four joint orientations. When joints measured from a larger geographic area are combined, more scatter is introduced due to the larger statistical variation in foliation; consequently, generalizations made on a large scale may not be applicable to the outcrop scale. Given this understanding, it is fairly surprising that even weak generalizations can be made at this scale. This does not, however, preclude the attempt to model effects of different geologic systems with hydrologic characteristics. To develop a predictive model to effectively locate high yield wells, comprehensive geologic characterization of an area must be systematically compared and correlated to hydrologic data from the immediate area. Additionally, stronger correlations and consequently more useful information can be obtained on a smaller, more site specific scale, where the variation of interaction between foliation and joint development is minimized.

CONCLUSIONS

1. Eleven lithologies were mapped on the Barnesville quadrangle: graphite-sillimanite schist, gondite, quartz-muscovite schist, porphyroblastic gneiss, sheared gneissic schist, augen gneiss, cataclasite, kyanite-garnet schist, garnetiferous schist, quartzite, garnetiferous biotite gneiss. Seven of these lithologies were mapped in detail within a one mile radius of the Barnesville hydrogeologic research site: porphyroblastic gneiss, augen gneiss, sheared gneissic schist, cataclasite, quartzite, kyanite-garnet schist, garnetiferous biotite gneiss. Four of these lithologies were encountered in the two core holes: sheared gneissic schist, quartzite, augen gneiss, cataclasite. All units have highly variable weathering characteristics. This differential weathering is particularly evident when two units of contrasting rheology are adjacent to one another.

2. A penetrative regional schistosity is expressed throughout the field area (S1: N81°E, 51°NW) and is generally developed parallel to compositional layering. This regional foliation is locally variable and is associated with effects of isoclinal folding and thrust faulting. Isoclinal folds trend WNW to ENE (averaging N84°E) and plunge gently ranging from 5 to 20 degrees. A regional mineral lineation (L1) observed by Grant (1967) and during this investigation, is axial planar with the isoclinal folds.

3. The Towaliga Fault Zone is an area of major distributive movement, extending from eastern Alabama through central Georgia. This zone is interpreted to be younger than the regional foliation and strikes N60-70°E across the central portion of the Barnesville quadrangle. The Towaliga Fault Zone dips 50 to 70 degrees to the north, and has a variably exposed width of 1 to 3 km. A stretching mineral lineation (L2) trending N25°E, 49°NE is consistent with that observed by Grant (1967) and is probably associated with dip slip movement along the Towaliga fault.

4. Heterogeneous effects of shearing of lithologic units are manifested by texture and mineralogy. Texturally, select portions of the quartzite, kyanite-garnet schist and augen gneiss have been mylonitized to various degrees, and cataclasized. Effects of late brecciation and subsequent partial to complete infilling by inwardly projecting quartz crystals are seen in the quartzite and augen gneiss. Locally, these breccia zones are associated with cataclasites, but are more commonly observed in mylonitic quartzite. Mineralogically, alterations due to shearing include the crystallization of muscovite from feldspar in the sheared gneissic schist and augen gneiss, and local partial to pervasive silicification of the augen gneiss, quartzite, and cataclasite.

5. Lithologic units north of the Towaliga Fault Zone appear to have achieved sillimanite-grade metamorphism. In contrast, lithologic units within and south of the Towaliga Fault Zone appear to have achieved kyanite-grade metamorphism.

6. Because of the great variability of rock types, it is difficult to characterize the depth of weathering for each lithologic unit. However, in a general sense, the unsheared gneissic units (porphyroblastic gneiss and garnetiferous biotite gneiss) are more deeply weathered than the schist (quartz-muscovite schist, garnetiferous schist, kyanite-garnet schist), and the schist is more deeply weathered than the quartzite. The massive central portion of the quartzite is much more resistant than the flanks where the quartzite becomes interlayered with schist. The sheared gneissic schist is generally more resistant to weathering than the augen gneiss (depending on amount of silicification) and less resistant than the quartzite. The only rock units that appear to be ubiquitously competent are the silicified cataclastic lenses where intense granulation has diminished grain size to a microscopic scale. This reduction in grain size has taken place under high pressure conditions; therefore, the rock remains highly competent and is not reduced to a fine powder.

7. 519 joint measurements were taken throughout the area. Four distinct orientations are dominant amidst abundant scatter

of data: northwest with a north-northwest subset, north-south, east-west, and northeast. The northwest, east-west and northeast sets appear to be slightly more pervasive north and south of the Towaliga Fault Zone, and the north-south set appears to be more pervasive within the Towaliga Fault Zone. Three of the four dominant joint orientations are paralleled by dominant drainage patterns in Lamar County. The variable dominance of joint sets is most likely a function of the most influential local rock fabric (foliation, lineation, fold axes). These generalizations, however, are probably not reliable on a site specific scale and should not be used as a tool for depicting hydrogeologic characteristics of a specific area.

8. Generalization concerning frequency and abundance of fracturing for a given rock type or geographic location are difficult to make. The lithologic units within the Towaliga Fault Zone (and the one-mile radius around the research site) apparently have more joint sets developed than in rock types north and south of the Towaliga Fault Zone. This relationship may be a function of abundance of outcrop: rocks within the Towaliga Fault Zone are much better exposed than rocks north and south of the Towaliga Fault Zone. Where lithologic units north and south of the fault zone crop out (specifically the porphyroblastic gneiss and garnetiferous biotite gneiss), they generally contain numerous joint sets; therefore, it is difficult to determine whether occurrence and abundance of jointing is enhanced in shear zones.

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APPENDIX I
Foliation and Joint Data

Appendix I represents the compilation of select structural and lithologic data gathered during the field portion of this investigation. The easting and southing coordinates for each map station where data were recorded are measured from an arbitrary 0,0 reference point (scale: 1" = 100') located at the northwestern corner of the quadrangle (Plates 1 and 2). The lithologic and structural abbreviations used on this table are listed below.

Rx Type = rock type
Fol = foliation
Space = spacing measured between joints
Persist = persistence of joints
Dilat = relative degree of dilation along joints
Weath = weathering characteristics of joints
D = dilated joint
SD = semi-dilated joint
Fe, Mn = Fe and Mn oxide staining
Bleach = bleached halo around joint
KAOL = kaolinite infilling of joint
SiO_2 = quartz infilling of joint
Lithologies
GSS = graphite-sillimanite schist
QMS = quartz-muscovite schist
BQFG = biotite-quartz-feldspar gneiss
GQMS = garnetiferous quartz-muscovite schist
AMPH = amphibolite
QGG = quartz-garnet granofels (gondite)
QTE = quartzite
GBQFG = garnetiferous biotite-quartz-feldspar gneiss
SBQFG = sheared and/or silicified biotite-quartz-feldspar gneiss
SSG = sheared gneissic schist
FCR = flinty crush rock (cataclasite)
GKQMS = garnetiferous kyanite-quartz-muscovite schist
IP = igneous pegmatite

							Joints						
Map Sta	**Easting**	**Southing**	**Rx Typ**	**Fol Trend**	**Fol Dip**		**Trend**	**Dip**	**Plunge**	**Space**	**Persist**	**Dilat.**	**Weath.**
1	**500**	**60**	**GSS**										
2	485	82	GSS				N0W	90E					
2	485	82	GSS	N69E	39NW		N42W	85NE		4"	24-36"	D	OPEN
3	435	345	QMS	N64E	14NW		N37W	89SW					
4	418	285	QMS	N84E	45SE	FOLD	N80W		80NW				
5	405	230	BQFG	N25W	14SW		N45W	84NE				CLOSED	
5	405	230	BQFG				N72W	71NE				CLOSED	
5	405	230	BQFG				N45E	72NW				SD	Fe
6	355	140	GQMS	N21W	30SW		N13W	69NE					
7	355	110	GSS	N38E	15NW								
8	360	55	GSS	N50E	30NW		N40W	80SW		2"	6"	D	FE,MN
8	360	55	GSS				N22W	76NE		2-8"	36-48"	D	OPEN
8	360	55	GSS			FOLD	N65W		26SE				
9	355	20	GSS										
10	395	0	GSS	N6W	49SW		N52W	66NE			30"	D	
10	395	0	GSS				N37E	88NW					
10	395	0	GSS				N26W	83NE		1.5"	36"	D	MN
10	395	0	GSS			FOLD	N30E		29SW				BLEACH
11	470	0	GSS	N27E	56NW		N75W	85SW		2-6"	24"	D	FE
11	470	0	GSS	N4E	18NW		N10W	56SW					
11	470	0	GSS			FOLD	N8W		50NW				
11	470	0	GSS				N33W	80NE		4-8"	6"	CLOSED	
12	530	0	AMPH			FOLD	N52E		15NE				
12	530	0	BQFG	N85E	64SE		N75W	89NE				D	KAOL
12	530	0	BQFG				N45E	89NW				D	KAOL
12	530	0	BQFS				N15W	89NE				D	KAOL
12	530	0	QMS	N34E	40NW		N31W	88NE					
13	570	35	BQFG	N19E	17NW		N60E	76SE				D	OPEN
13	570	35	BQFG				N45E	13SE			96"		
13	570	35	BQFG				N10W	84SW			12"		
13	570	35	BQFG				N80E	66NW		6"	48"	D	OPEN
13	570	35	BQFG				N70W	72NE		1"	12"	D	
13	570	35	BQFG				N52W	80NE		1"	12"	SD	FE
14	650	270	BQFG										
15	265	485	BQFG	N54E	48NW		N33W	85SW		6"	6"	D	FE
15	265	485	BQFG				N43W	73SW		6"	6"	D	FE
15	265	485	BQFG				N12E	66NW				CLOSED	
15	265	485	BQFG				N40W	70NE				CLOSED	
16	220	510	BQFG	N70E	23NW		N30W	82NE		12"	36"	CLOSED	
16	220	510	BQFG				N52W	81NE					
16	220	510	BQFG				N47W	73SW					
16	220	510	BQFG				N29W	82NE		12"	36"	CLOSED	
16	220	510	BQFG				N12W	80NE		12"	36"	SD	FE
17	125	505	QMS	N44W	15SW		N80W	89NE				CLOSED	
17	125	505	QMS	N60W	20SW		N60W	18SW					
17	125	505	QMS	N50W	22SW		N72W	66NE				D	FE
18	145	500	QMS	N38W	18SW		N7E	77NW		3"	12"	D	FE
18	145	500	QMS				N10W	80SW		3"	12"	SD	FE
19	275	270	BQFG	N75E	32NW		N75E	32NW					
19	275	270	BQFG				N25W	80SW				D	FE
19	275	270	BQFG				N55W	80SW					
19	275	270	BQFG				N75E	80NW					
19	275	270	QMS	N58E	10NW		N61W	81NE					FE,SI02
19	275	270	QMS	N72E	24NW		N51W	86NE					
19	275	270	QMS				N72E	24NW		1"	120"	D	SI02
19	275	270	QMS				N10E	80NW		1"			
19	275	270	QMS				N85W	32NE			60"	D	FE,SI02
20	265	255	BQFG	N60W	10NE		N20E	82SE					
20	265	255	BQFG				N20E	75SE		3"		D	
20	265	255	BQFG				N5E	75NW		3"	36"	D	
20	265	255	QGG	N30E	18NW		N10W	78NE					
21	195	190	GSS										
22	175	160	GSS	N28E	39NW	FOLD	N73W		28SE				
22	175	160	GSS				N85E	73NW				D	FE
22	175	160	GSS				N75E	87SE		9"	60"	D	FE
22	175	160	GSS				N45W	62SW			72"	CLOSED	
22	175	160	GSS				N19W	89NE					
22	175	160	GSS	N35E	28NW	FOLD	N20E		24SW				
22	175	160	GSS				N82W	86NE				D	FE
23	145	125	GSS	N20W	44SW		N70E	90W				D	FE

							Joints						
Map Sta	Easting	Southing	Rx Typ	Fol Trend	Fol Dip		Trend	Dip	Plunge	Space	Persist	Dilat.	Weath.
23	145	125	GSS				N25E	80NW			36"	D	FE
24	110	80	GSS	N13E	84NW								
25	95	50	GSS	N25W	34SW								
25	95	50	GSS	N15E	30NW		N55W	73NE		4"	12"	D	MN,SI02
25	95	50	GSS				N20W	68NE					
25	95	50	GSS				N15E	70SE					
26	85	35	QMS	N54E	38SE								
27	75	15	BQFG	N28E	23NW		N43E	78SE					
27	75	15	BQFG				N28E	90W			12"	D	FE
27	75	15	BQFG				N78E	70SW				SD	FE
28	50	200	GSS	N74E	45NW		N11W	89NE			3"	SD	MN
29	115	200	GSS	N48E	46NW		N85E	89NW					MN
30	150	20	GSS	N30E	55NW		N10W	51NE			12"		
30	150	20	GSS				N55W	62SW		1"			
30	150	20	GSS				N70E	86NW		2"	12"	D	FE
31	235	0	GSS	N42E	59NW	FOLD	N30W		50NW				
31	235	0	GSS			FOLD	N30E		49SW				
32	265	0	GSS	N79E	20NW		N52W	75NE		2"	60"	D	FE,MN
32	265	0	GSS	N5E	32NW		N70W	75NE		4"	72"	D	FE,MN
32	265	0	GSS				N10W	84SW			6"		
32	265	0	GSS				N89E	78SE		6"	120"	D	FE,MN
32	265	0	GSS				N30W	82SW		6"	36"	SD	OPEN
32	265	0	GSS			FOLD	N35E		14SW				
32	265	0	GSS			FOLD	N50E		7SW				
32	265	0	GSS			FOLD	N5E		7SW				
33	320	0	GSS	N26E	35NW								
34	140	555	BQFG				N47E	87SE					
34	140	555	BQFG				N71W	85SW		12"	4"		
34	140	555	BQFG				N25W	70NE			12"	SD	FE
34	140	555	BQFG				N68W	69NE			24"	D	SI02
34	140	555	QMS	N54W	13SW		N70W	80NE		4"	24"	D	FE
34	140	555	QMS	N63W	15SW		N36W	80NE		4"	6"	CLOSED	
35	125	610	BQFG	N20W	8SW		N20W	78NE		.5"	24"	CLOSED	MN
35	125	610	BQFG				N76W	76NE		4"	18"	D	FE
35	125	610	BQFG				N40W	80SW		5"	12"		
36	110	615	QMS	N44E	26NW								
37	25	605	BQFG	N8E	38NW		N10W	89NE			18"	D	SI02
38	65	660	QMS	N40E	33NW								
39	80	705	BQFG	N39E	17SE		N40W	85SW			4"	SD	FE
40	25	870	QMS	N3E	31NW		N55E	89NW		2"	12"	CLOSED	FE
40	25	870	QMS				N35W	89NE		2"			
40	25	870	QTE	N45E	29NW		N0W	88NE			12"		
41	530	360	BQFG										
42	650	380	QMS										
43	620	660	BQFG	N58W	10SW		N59W	84NE		2"	12"	CLOSED	
43	620	660	BQFG				N15W	80NE		3"	12"	D	
43	620	660	QMS	N70W	11SW		N26W	86SW		2"	5"	CLOSED	
43	620	660	QMS				N74E	74SE		2"	5"	CLOSED	
43	620	660	QMS				N80E	81NW		1"	24"	CLOSED	
44	650	730	BQFG	N72W	33SW								
44	650	730	QMS	N64E	40SE								
44	650	730	QMS	N80E	35SE								
45	755	705	QMS	N76E	73SE		N36W	40NE		.5"	24"	D	FE
45	755	705	QMS				N55W	51SW			2"	CLOSED	
46	500	645	QMS	N26E	33NW								
47	445	810	BQFG				N39W	80NE		.75"	24"	CLOSED	
47	445	810	BQFG				N41E	80NW		1"	12"	CLOSED	
48	645	1145	QMS	N70W	38NE								
48	645	1145	QTE	N87E	45NW		N20W	80NE		3"	36"	CLOSED	
48	645	1145	QTE				N0W	90E			24"	CLOSED	
48	645	1145	QTE				N28E	89SE			24"	CLOSED	
49	870	1995	BQFG										
50	805	2005	AMPH										
51	645	2085	QMS	N69W	50NE								
52	540	1995	GBQFG	N65W	19NE		N83E	73SE		2"	24"	D	OPEN
52	540	1995	GBQFG				N16W	68SW		12"	24"	CLOSED	
52	540	1995	GBQFG			FOLD	N85E		12SW				
53	650	1710	FCR										
54	850	1775	BQFG	N60W	81NE								
55	745	1635	BQFG	N21E	12NW								

							Joints						
Map Sta	**Easting**	**Southing**	**Rx Typ**	**Fol Trend**	**Fol Dip**		**Trend**	**Dip**	**Plunge**	**Space**	**Persist**	**Dilat.**	**Weath.**
56	740	1550	GBQFG	N68W	20NE								
57	735	1500	BQFG	N70E	16NW		N0E	90W		1.5"	6"	D	OPEN
58	730	1450	BQFG	N85E	10NW		N2W	65SW					
59	1035	615	IP										
60	1010	620	GSS	N48E	70SE		N55W	78NE		36"	6"	D	SI02
60	1010	620	GSS				N20W	80SW		2"	3"	D	SIO2,FE
61	810	820	AMPH				N53E	89SE		3"	6"	SD	FE
61	810	820	AMPH				N55W	60NE		2"	12"	D	MN,FE
61	810	820	AMPH				N28E	87NW		1"	12"	SD	MN
61	810	820	GSS	N75E	66SE		N8W	83NE		1"	6"	D	OPEN
62	1005	1020	QTE	N47E	26NW		N76E	82NW		.5"	1"	CLOSED	
62	1005	1020	QTE	N42E	20NW		N29E	70NW		1.5"	12"	CLOSED	
62	1005	1020	QTE	N50E	24NW		N12W	73NE		6"	>120"	CLOSED	
62	1005	1020	QTE				N44W	76SW		1.5"	6-8"	CLOSED	
62	1005	1020	QTE	N42E	14NW								
62	1005	1020	SBQFG	N48W	18NE								
62	1005	1020	SSG	N45E	25NW								
62	1005	1020	SSG	N52E	27NW								
62	1005	1020	SSG	N82E	25NW								
63	1010	1000	GQMS	N48E	32NW		N38W	87NE		1"	6"	D	OPEN
63	1010	1000	GQMS				N68E	72SE			6"	D	FE
64	1115	685	BQFG	N72W	21SW		N90W	50N			12"	SD	FE
64	1115	685	BQFG				N20W	82NE		2"	8"	SD	OPEN
64	1115	685	BQFG				N50W	74NE					
64	1115	685	BQFG				N15E	85SE		9"	3-4"	CLOSED	
65	1200	915	FCR	N75E	88NW		N84E	60SE					
65	1200	915	FCR				N59W	57SW		12"	24"	D	OPEN
65	1200	915	FCR				N5E	48SE		.25"	3"	CLOSED	
66	1210	915	QTE	N72E	68NW		N85E	66SE		6"	5"	CLOSED	
66	1210	915	QTE	N74E	65NW		N19W	88NE		6"	24"	CLOSED	
66	1210	915	QTE	N69E	52NW		N50E	67SE				D	MN,SIO2
66	1210	915	QTE	N75E	60NW		N56E	32SE		5"	60"	CLOSED	
66	1210	915	QTE				N16W	90E		2-3"	60"	CLOSED	
66	1210	915	QTE				N35W	86NE		1"	>24"	D	OPEN
66	1210	915	QTE				N30E	65SE		7"	24"	SD	MN,SIO2
66	1210	915	SSG	N85W	70NE								
67	1210	920	SBQFG	N70E	42NW								
68	1210	960	QTE	N86E	21NW		N50W	87SW		2-3"	6"	CLOSED	
68	1210	960	QTE	N83W	22NE		N72E	64SE		6"	18"	CLOSED	
68	1210	960	QTE	N90E	20N		N12E	78SE		.5"	60"	CLOSED	
68	1210	960	QTE				N45E	81SE		29"	12"	CLOSED	
68	1210	960	QTE				N58E	85NW		.5-1"	96"	SD	FE
69	1250	995	BQFG	N72E	62NW								
69	1250	995	BQFG	N86W	32NE								
69	1250	995	QMS	N84E	40NW								
69	1250	995	QTE	N63E	37NW		N53E	33SE			48	CLOSED	
69	1250	995	QTE	N62E	48NW		N69E	74SE		.5-1"	24"	D	SIO2
69	1250	995	QTE				N76W	62SW		.5"	36"	D	OPEN
69	1250	995	QTE	N58E	19NW		N45E	64SE		4"	48"	D	OPEN
69	1250	995	SSG	N65E	48NW								
70	1330	915	QTE	N72W	52NE		N22E	84NW		2"	12"	SD	OPEN
70	1330	915	QTE				N80E	37SE		2.5"	12"	SD	OPEN
71	1385	960	QTE	N70W	30NE		N49E	87SE		2-4"	36-48"	CLOSED	
71	1385	960	QTE				N14W	80NE		2"	>180"	CLOSED	
72	1340	925	GKQMS										
73	1310	900	SBQFG				N75E	39SE		6"	5"	CLOSED	
73	1310	900	SBQFG				N30W	66SW		.5-1"	8"	CLOSED	
74	1310	890	SBQFG	N88E	66NW								
75	970	330	GSS	N57W	45SW		N65W	46NE		1"	6"	SD	FE
75	970	330	GSS	N55W	35SW		N85E	85SE		12"	36"	SD	OPEN
76	1080	185	BQFG	N86E	36SE		N59W	56NE			4"	SD	FE
77	1240	290	BQFG	N68W	20SW		N58E	85NW		.5-1"	1"	CLOSED	
77	1240	290	BQFG	N87W	14SW		N70W	85NE			36"	D	OPEN
77	1240	290	GSS	N40W	22SW		N25W	72NE		1"	12"	SD	FE
78	1175	580	BQFG				N68E	83NW		.5-1"	6"	D	OPEN
79	1355	110	GSS										
80	1415	140	BQFG	N87W	72NE	FOLD	N86E		4SW				
80	1415	140	BQFG				N15W	80NE		36"	48"		
80	1415	140	BQFG				N50W	80NE		2"	2"	CLOSED	
81	1475	180	BQFG	N3W	32SW		N65E	80SE		8"	9"	D	OPEN

							Joints						
Map Sta	**Easting**	**Southing**	**Rx Typ**	**Fol Trend**	**Fol Dip**		**Trend**	**Dip**	**Plunge**	**Space**	**Persist**	**Dilat.**	**Weath.**
81	1475	180	BQFG				N45E	90NW					
81	1475	180	BQFG				N60W	90NE					
82	1490	185	BQFG	N15W	50NE		N15W	89NE		18"	12"	D	OPEN
82	1490	185	BQFG				N85E	89NW					
82	1490	185	BQFG				N60W	89NE					
83	1545	215	BQFG	N4W	25NE		N65W	88NE		9"	6"	CLOSED	
83	1545	215	BQFG				N25W	85NE		4"	8"	CLOSED	
83	1545	215	BQFG				N75E	88NW		4"	18"	CLOSED	
84	1570	235	BQFG	N22E	27SE		N70E	77SE		1"	6"	SD	OPEN
84	1570	235	BQFG				N30W	89NE		12"	24"	D	FE
84	1570	235	BQFG				N10E	88NW		1"	4"	CLOSED	
85	1625	255	BQFG	N20E	34NW		N30E	73SE		1"	48"	D	MN, OPEN
85	1625	255	BQFG				N10E	82NW		48"	36-48"	D	OPEN
85	1625	255	GSS	N28W	82SW								
85	1625	255	GSS			FOLD	N24E		51SW				
85	1625	255	GSS				N50E	80SE		8"	12"	CLOSED	
86	1690	290	GSS	N20E	62NW	FOLD	N49E		18SW				
87	1705	295	BQFG	N22E	12NW		N34E	84SE			9"	CLOSED	
88	1750	305	GSS	N34E	61NW		N40W	80NE		8"	36"	SD	FE
88	1750	305	GSS	N40E	52NW		N60W	51NE		4-5"	12"	SD	FE
89	1805	320	GSS	N39E	75NW		N82E	79NW			6"	CLOSED	
90	1815	320	BQFG				N85E	68NW		6-9"	36"	CLOSED	
91	1790	355	QMS	N55E	10SE		N20W	50NE		2"	6"	SD	MN
91	1790	355	QMS				N69E	71NW		2"	12"	SD	MN
91	1790	355	QMS				N38E	48NW					
91	1790	355	QMS				N55E	10SE					
91	1790	355	QMS			FOLD	N70E		25SW				
92	1540	205	BQFG				N30W	87SW		2"	15"	CLOSED	
92	1540	205	BQFG				N4W	68NE		5-8"	30"	SD	OPEN
92	1540	205	BQFG				N70W	70SW		6"	10"	CLOSED	
93	1625	115	BQFG				N85E	80NW		1"	24"		
93	1625	115	BQFG				N12W	70NE		6"	120"	SD	OPEN
94	1700	25	BQFG				N10W	82SW		1"	4"	SDS	OPEN
95	1470	65	GSS	N76E	60SE		N10W	80NE			24-36"	CLOSED	
96	1470	30	GSS	N62E	70SE		N45W	60NE		6"	12"		
97	1470	15	GSS	N65E	65SE		N5E	75SE		4"	2"	D	OPEN
97	1470	15	GSS				N90E	77N		1.5"	36"	CLOSED	
97	1470	15	GSS				N60E	77NW		.25"	18"	CLOSED	
97	1470	15	GSS				N30W	86NE		2"	42"	D	OPEN
98	1465	205	BQFG				N32W	66NE		24"	72"	CLOSED	
98	1465	205	BQFG				N30E	52SE		12"	24"	D	OPEN
99	1460	410	GSS	N72E	63NW		N20E	80NW					
99	1460	410	GSS				N80E	80SE					
100	1460	455	BQFG				N85E	60SE			48"	CLOSED	
100	1460	455	BQFG				N70W	70NE		1"	6"	CLOSED	
100	1460	455	BQFG				N62E	72SE		1"	6"	CLOSED	
101	1485	545	SBQFG				N35W	85NE					
101	1485	545	SBQFG				N75W	60NE					
101	1485	545	SBQFG				N60E	47SE		1"	6"	SD	MN,OPEN
102	1460	715	BQFG	N20W	60SW		N32W	77NE		3"	15"	CLOSED	
102	1460	715	BQFG	N11W	28NE		N10E	85SE		.5"	48"	CLOSED	
102	1460	715	BQFG	N10E	20NW		N45W	80NE		1"	12"	CLOSED	
102	1460	715	BQFG ?				N13W	76NE		2"	6"		
102	1460	715	SBQFG	N0W	35E		N85E	72SE		2.5"	3"	CLOSED	
103	1410	740	SSG	N50E	20NW		N55W	83NE		.5-2"	6"	CLOSED	
103	1410	740	SSG	N49E	27NW		N55E	88NW			24"	D	OPEN
103	1410	740	SSG	N65E	24NW		N10E	53NW		1.5"	6"	D	OPEN
103	1410	740	SSG				N85E	74NW		.5"	36"	CLOSED	
104	1460	725	FCR	N28E	22NW		N75W	68SW		4"	12"	D	OPEN
104	1460	725	SBQFG	N10E	15NW		N55E	84NW		1"	12"	CLOSED	
104	1460	725	SBQFG				N10W	83SW		4"	4"	CLOSED	
104	1460	725	SBQFG				N85E	90NW			36-48"	CLOSED	
104	1460	725	SBQFG				N45W	90NE		6-12"	8"	D	OPEN
104	1460	725	SSG	N22E	26NW		N58E	72SE					
105	1460	800	QMS	N70W	30NE		N45E	85SE		.5"	6"	D	OPEN
105	1460	800	QMS				N2W	70NE		2.5"	2"	D	OPEN
106	1450	840	QTE	N47E	25NW		N5E	78SE		1"	18-24"	CLOSED	
106	1450	840	QTE				N5W	70SW					
106	1450	840	QTE				N75E	45SE		2"	12"	CLOSED	
106	1450	840	SBQFG	N54E	26NW		N25E	65SE		.5"	18"	SD	MN

							Joints						
Map Sta	**Easting**	**Southing**	**Rx Typ**	**Fol Trend**	**Fol Dip**		**Trend**	**Dip**	**Plunge**	**Space**	**Persist**	**Dilat.**	**Weath.**
106	1450	840	SBQFG	N77W	23NE		N65W	72SW		1"	4"		
106	1450	840	SBQFG	N80W	35NE		N85W	80SW		.5-1"	12"	D	FE,MN
106	1450	840	SBQFG				N5W	78SW		6"	24"	D	MN,OPEN
106	1450	840	SBQFG	N17W	29SW		N35E	69SE		18"	48"	D	MN
106	1450	840	SBQFG				N65E	70SE		2"	36"	SD	MN
106	1450	840	SBQFG			FOLD	N80W		20NW				
107	1440	915	QMS										
108	1435	960	QTE	N80E	25NW		N55W	85SW		3"	12"	CLOSED	
108	1435	960	QTE	N85E	34NW		N50E	82NW		3"	12"	SD	FE
109	1445	970	QTE	N86W	29NE		N85E	76NW		1"	24"	D	SIO2,MN
109	1445	970	QTE	N45E	20NW		N40E	78NW		1"	36"	SD	FE
109	1445	970	QTE	N80W	16NE		N45W	85NE		1"	1-2"	SD	
110	1435	985	QTE	N83W	29NE		N35W	73SW		1"	4"	CLOSED	
110	1435	985	QTE	N75W	20NE		N0W	88SE		.5-2"	72-84"	D	VQ,OPEN
110	1435	985	QTE	N70W	38NE		N75W	76SW		4"	8"	CLOSED	
110	1435	985	QTE				N10E	55SE		2"	24"	CLOSED	
110	1435	985	QTE			FOLD	N68W		8NW				
110	1435	985	QTE	N80E	6NW		N50E	76SE		1-2"	48"	D	FE,VQ
111	1435	1065	SBQFG	N85E	21NW		N44E	82SE		30"	30"	SD	OPEN
111	1435	1065	SBQFG	N54E	37NW		N30E	73SE		1"	36"	D	OPEN
111	1435	1065	SBQFG	N75E	37NW		N65E	61SE		24"	36-48"	D	open
112	1465	885	SSG	N88W	32NE		N40W	61NE		1"	6"		
112	1465	885	SSG	N60E	22NW								
113	1510	860	SSG	N60E	35NW		N22E	70SE		12"	24"	D	OPEN
113	1510	860	SSG	N85E	35NW		N0E	86W		2"	5"	SD	FE
113	1510	860	SSG				N35W	71NE		12"	18-36"	SD	OPEN
113	1510	860	SSG				N80E	68NW			48"	SD	OPEN
114	1555	835	SSG	N84E	21NW		N0E	88W		36"	12"	CLOSED	
114	1555	835	SSG				N65W	44NE					
115	1610	820	SBQFG	N65W	44NE		N15E	88SE		4"	8"	CLOSED	
115	1610	820	SBQFG				N5E	86NW		1"	6"	CLOSED	
115	1610	820	SBQFG				N75E	88SE		.5"	2"	SD	FE
115	1610	820	SSG	N75W	55NE								
116	1720	1110	BQFG	N80W	80NE								
117	1830	1085	BQFG	N85W	25NE								
118	1885	1075	QTE	N80E	43NW		N30W	88NE		2.5"	4"	SD	FE
118	1885	1075	QTE				N45E	66SE		2"	6"		
119	1640	820	SBQFG	N78E	36NW		N0E	89NE		2"	6"	CLOSED	
119	1640	820	SBQFG	N80W	47NE		N70E	80SE		.5"	12"	CLOSED	
119	1640	820	SBQFG	N53W	53NE		N37E	85SE		18"		D	OPEN
119	1640	820	SBQFG				N35W	77SW		36"		D	OPEN
120	1745	810	SSG	N72W	43NE								
121	1740	780	SBQFG	N20E	33NW		N70E	83NW		2-6"	3"		
121	1740	780	SBQFG	N30E	31NW		N5E	74NW		6"	60"	D	OPEN
121	1740	780	SBQFG				N60W	32SW		3"	6"	CLOSED	
121	1740	780	SBQFG				N30W	86NE		2-18"	6-24"	CLOSED	
122	1750	710	QTE	N72W	43NE		N88E	53NW		2"	2"	SD	OPEN
122	1750	710	QTE				N5W	35NE		3"	18"		
122	1750	710	QTE				N80E	86SE					
122	1750	710	SSG	N10E	26SE								
123	1770	665	SBQFG	N12W	10NE		N10E	70NW		8"	18"	D	OPEN
123	1770	665	SBQFG	N34E	28NW		N35W	80NE			12"	SD	OPEN
123	1770	665	SBQFG				N60W	78NE		10"	8"	D	OPEN
124	1825	660	SSG	N40E	34NW		N80E	79SE		2"	48"	CLOSED	
124	1825	660	SSG	N65E	53NW		N5E	79SE		2-4"	3"	SD	OPEN
124	1825	660	SSG	N84E	35NW								
125	1875	625	SSG	N53E	43NW		N45W	90NE			6"	CLOSED	
126	1890	550	SBQFG	N42E	44NW		N62E	87NW		12"	36"	D	OPEN
126	1890	550	SBQFG				N8E	76NW		1"	24"	SD	OPEN
126	1890	550	SBQFG				N15W	64NE		1"	6"	SD	FE
126	1890	550	SBQFG				N18E	56NW		5-1"	5"	SD	OPEN
127	1860	665	SSG	N42E	34NW		N5W	70NE					
127	1860	665	SSG	N55E	49NW								
128	1850	700	SSG	N50E	25NW		N12W	42NE		24"	18"	SD	
128	1850	700	SSG				N50W	80SW			60"	SD	FE
129	1810	775	SSG	N55E	29SE		N65W	80SW		1"	12"	SD	OPEN
129	1810	775	SSG				N23E	80SE			48"	SD	OPEN
130	1850	730	SBQFG	N40E	24NW		N74E	62SE		.5"	6"	SD	MN,FE
130	1850	730	SBQFG				N2W	85NE		1"	10"		
131	1755	815	SSG	N70W	43NE								

							Joints						
Map Sta	Easting	Southing	Rx Typ	Fol Trend	Fol Dip		Trend	Dip	Plunge	Space	Persist	Dilat.	Weath.
132	1710	875	BQFG										
133	1670	930	QTE	N72W	32NE		N65W	51SW		2-4"	12-36"	D	OPEN
133	1670	930	QTE	N84W	35NE		N25E	64SE		2"	48"	SD	
133	1670	930	QTE	N50W	27NE		N90E	71S		1-2"	4-6"	SD	FE
133	1670	930	QTE				N20W	85NE		1"	3"	CLOSED	
133	1675	940	QTE	N67W	43NE								
133	1675	940	QTE	N58W	33NE		N8E	88SE		12"	192"	D	OPEN
134	1675	965	GQMS	N40W	29NE		N14W	67NE					
134	1675	965	GQMS	N52W	29NE		N88E	40NW		12-120"	96"	D	FE
134	1675	965	GQMS				N35W	45NE		12"	60"	D	FE
134	1675	965	GQMS				N90E	70S		12-36"	96"	D	Q,FE,OPE
134	1675	965	QTE				N50E	64SE		1"	8"	CLOSED	
134	1675	965	QTE				N45W	70SW		8"	16"	CLOSED	
134	1675	965	QTE				N15E	88SE		3"	24"	CLOSED	
134	1675	965	QTE			FAULT	N70E	80NW					
134	1675	965	VQ			FOLD	N45W		11NW				
135	1670	980	QTE	N64E	56NW								
136	1675	1010	QTE	N85W	18NE		N63W	78SW		12-36"	36"	SD	FE
136	1675	1010	QTE	N80W	14NE		N55W	37SW		12"	36"	D	MN
136	1675	1010	QTE	N90E	60N		N87E	60SE			60"	D	MN,VQ
136	1675	1010	QTE	N80E	24NW		N47E	45SE		2"	48"	SD	MN,FE
136	1675	1010	QTE	N88W	29NE		N10W	88NE		1"	24-36"	D	FE,MN
136	1675	1010	QTE	N80E	21NW		N30E	80SE		.25-1"	12"	SD	MN,OPEN
137	1665	1030	BQFG	N85E	13NW		N5W	79SW		12"	48"	SD	
137	1665	1030	BQFG				N60E	70NW			10"	CLOSED	
137	1665	1030	BQFG				N30W	85NE			6"	D	FE
138	1630	1140	BQFG	N81E	34NW		N18W	80SW		6"	12"	D	FE,OPEN
139	1890	1040	GQMS	N65E	16NW								
139	1890	1040	QTE	N75E	21NW		N40W	83SW		1"	4"	D	MN
139	1890	1040	QTE				N30E	80SE		.5-1"	12"	CLOSED	
139	1890	1040	QTE				N10W	85SW		1"	8"	SD	FE
139	1890	1040	QTE				N90E	75N		1-2"	2-3"	CLOSED	
139	1890	1040	QTE				N65E	89SE		4"	16"	D	FE,OPEN
140	1850	1030	SSG	N69W	12NE								
141	1840	1005	QMS	N37W	20NE								
142	1835	1005	QTE	N50E	9NW		N60W	77SW		1"	4-6"	CLOSED	
142	1835	1005	QTE	N80W	20NE		N55E	88NW		12"	12"	D	FE
142	1835	1005	QTE				N40W	75NE		3"	36-48"	D	OPEN
142	1835	1005	QTE				N25E	74NW		2"	6"	CLOSED	
143	1830	970	QTE	N67W	23NE		N65W	75SW		6"	12"	D	OPEN
143	1830	970	QTE				N40W	90E		.5"	12"	D	OPEN
144	1845	940	SBQFG	N69W	28NE		N65W	83SW		1"	12"	D	FE
144	1845	940	SBQFG				N67E	77SE		1.5"	6"	SD	FE
145	1885	890	AMPH	N43E	77NW								
145	1885	890	SSG	N68E	23SE		N70W	89NE		12"	36"	D	FE
145	1885	890	SSG	N82E	25SE		N10E	80NW		1"	24"	D	FE
146	1895	850	SBQFG	N67W	23NE								
147	1210	855	SSG	N70W	65NE								
148	1095	1410	BQFG	N12E	44NW								
148	1095	1410	BQFG	N15W	40SW								
149	1000	1335	AMPH										
150	600	1150	QTE	N40E	34SE								
151	575	1145	QTE	N65E	55NW		N27W	80SW			48"		
151	575	1145	QTE				N20E	64SE		.5-1"	4"	CLOSED	
152	500	1115	SBQFG	N40W	27NE		N8E	82NW		3-8"	12-18"	D	MN,FE
152	500	1115	SBQFG				N30E	87NW					
152	500	1115	SBQFG				N89E	59SE					
153	220	1000	BQFG				N60W	88NE		5"	12"	CLOSED	
153	220	1000	BQFG				N30W	58SW		.5-2"	18"		
154	65	1340	BQFG	N74W	26NE								
154	65	1340	BQFG	N85E	35NW								
154	65	1340	QMS	N78W	50NE								
154	65	1340	QTE	N75E	32NW		N27W	77NE		3"	18"	SD	FE
154	65	1340	QTE	N56W	53NE		N90E	70S		3"	2-3"	SD	FE
154	65	1340	QTE	N80E	44NW		N60E	44SE		.5-1"	4"		
154	65	1340	QTE	N76E	47NW		N0W	70E		10-12"	24"	D	OPEN
154	65	1340	QTE				N15W	85NE		24"	36-48"	CLOSED	
154	65	1340	SSG	N72W	33NE		N4E	77SE		8-12"	4"	CLOSED	
155	100	1480	GBQFG	N40E	30NW								
156	210	1350	SSG	N76E	53NW								

							Joints						
Map Sta	**Easting**	**Southing**	**Rx Typ**	**Fol Trend**	**Fol Dip**		**Trend**	**Dip**	**Plunge**	**Space**	**Persist**	**Dilat.**	**Weath.**
157	285	1300	SBQFG	N76E	27NW		N10E	76NW		6"	24"	CLOSED	
157	285	1300	SBQFG	N90E	35N		N76E	39SE		.5-1"	8-12"	CLOSED	
157	285	1300	SBQFG	N67W	29NE		N25E	77SE			2"	CLOSED	
157	285	1300	SBQFG	N80W	18NE								
157	285	1300	SBQFG	N76E	46NW								
157	285	1300	SBQFG	N82W	31NE								
158	335	1615	BQFG	N70W	37NE		N84W	37NE					
159	50	1995	SSG	N10W	18NE		N65E	65NW		.5"	3"	SD	FE
159	50	1995	SSG				N15W	64SW		.5"	.5"	SD	
160	30	2230	SBQFG	N40E	32SE		N40E	36SE			4"		
160	30	2230	SBQFG				N20W	70SW			1"		
160	30	2230	SBQFG				N90E	70S		18"	12"	D	OPEN
160	30	2230	SBQFG				N60E	65NW		12"	12"	D	OPEN
160	30	2230	SBQFG				N55W	70SW					
161	330	2180	BQFG	N45E	34SE								
162	1015	2230	GBQFG	N65W	4NE		N90E	90W					
163	600	1095	SBQFG	N58E	50SE		N5W	88NE					
163	600	1095	SBQFG				N0E	75W		36"	48-72"		
163	600	1095	SBQFG				N25W	90E			8"		
163	600	1095	SBQFG				N38E	80NW					
163	600	1095	SBQFG				N75W	85SW					
164	1215	1750	SSG	N74W	63SW								
165	1240	1840	GBQFG				N23E	75SE					
165	1240	1840	GBQFG				N61W	68NE					
165	1240	1840	GBQFG				N34E	7NW					
165	1240	1840	QMS	N25W	21NE								
165	1240	1840	QMS	N62W	31NE								
165	1240	1840	QMS	N30W	6NE		N84E	90W					
166	1260	1860	QMS	N38W	29NE		N80E	90W					
167	1300	1945	GBQFG	N20W	30NE		N82W	33SW					
167	1300	1945	GBQFG	N30W	25NE		N25E	60NW					
168	1290	2225	GBQFG	N58E	33SE								
168	1290	2225	GBQFG	N42E	30SE								
168	1290	2225	GBQFG	N68E	49SE								
169	1175	2000	BQFG	N72W	19NE		N8E	85NW		2-7"	8"		
169	1175	2000	BQFG				N50W	87NE					
169	1175	2225	BQFG				N18W	17NE					
170	1440	1635	GBQFG	N25W	4NE		N84W	83SW		8-10"	6"	D	OPEN
170	1440	1635	GBQFG				N20E	75SE			24-36"		
171	1525	2045	GBQFG	N18W	33NE		N21E	88NW		5"	12"	D	OPEN
171	1525	2045	GBQFG				N42W	80SW		18"	24"	D	OPEN
171	1525	2045	GBQFG				N70E	67NW					
171	1525	2045	GBQFG				N21W	85SW					
172	1520	2070	GBQFG	N40W	23NE								
173	1325	2030	SSG	N50E	48SE		N80E	63NW		.5-1"	10"	SD	OPEN
173	1325	2030	SSG				N40W	72SW		1"	4-6"	D	OPEN
173	1325	2030	SSG			VQ	N0W	36E		2-5"	96"		
174	1555	2070	SSG	N40W	40NE								
175	1570	1685	BQFG	N30W	65NE								
176	1770	1860	SSG	N46E	43SE		N19E	83SE			36"	CLOSED	
176	1770	1860	SSG	N38E	40SE		N60W	82SW		12"	2-6"	CLOSED	
176	1770	1860	SSG				N60E	80NW					
177	1640	1470	BQFG	N78W	26NE								
178	1850	1560	GBQFG	N43W	44NE								
179	1905	1595	QMS	N71W	64NE		N12W	85SW					
179	1905	1595	QMS	N84E	38NW		N55W	90E					
180	1910	1745	BQFG	N31W	43NE								
181	1615	1285	FCR				N14E	88NW			4"	CLOSED	
181	1615	1285	FCR				N32W	59SW					
181	1615	1285	FCR				N35E	41NW					
182	1770	1285	GBQFG	N62W	58NE								
183	1920	1325	SSG	N50W	42NE		N60W	62SW					
183	1920	1325	SSG				N16W	42SW			48"	D	FE
183	1920	1325	SSG				N40E	40NW		8"	36"	CLOSED	
183	1920	1325	SSG				N0E	39W		6"	18"	D	OPEN
184	1815	1140	FCR	N10E	90W		N70W	80SW					
184	1815	1140	FCR				N55W	78NE		1-18"	60"	CLOSED	
185	1885	1085	QTE	N78E	23SE		N0E	90W		.5"	36"	D	OPEN
185	1885	1085	QTE	N47E	28SE		N68W	86SW		2"	6"	D	OPEN
185	1885	1085	QTE				N30W	71SW		3"	5"	D	OPEN

							Joints						
Map Sta	Easting	Southing	Rx Typ	Fol Trend	Fol Dip		Trend	Dip	Plunge	Space	Persist	Dilat.	Weath.
186	1885	1100	QTE	N85W	36NE								
186	1885	1100	QTE	N68W	21NE								
187	1900	1140	GQMS	N15W	35SW		N80W	87SW		.5"	2"	D	OPEN
187	1900	1140	GQMS	N65E	43NW		N5W	77NE			1"	D	OPEN
187	1900	1140	GQMS	N90E	11N								
188	1900	1110	GQMS	N85W	23NE								
189	1905	1065	QTE	N58W	69NE								
190	1835	990	GSS										
191	1910	835	GBQFG	N56E	28NW								
192	1215	855	SSG	N86W	32NE		N12E	20SE					
193	1180	815	GSS	N27E	28NW		N0W	62E		1"	1"	D	FE
193	1180	815	GSS				N10W	87NE					
194	1715	435	BQFG										
195	1600	510	QMS	N35E	30NW		N34E	56SE					
195	1600	510	QMS				N10E	60SE		.5-1"	10-12"	D	OPEN
196	1595	560	BQFG	N8E	23NW								
197	1395	1115	BQFG	N84W	29NE								
197	1395	1115	BQFG	N60E	15NW								
198	905	315	BQFG										
199	1100	1285	FCR	N10E	80NW								
200	1400	1510	GBQFG										
201	1215	1215	BQFG	N70W	54NE		N13E	79NW		12-24"	36-48"	D	OPEN
202	1150	1145	BQFG	N45E	28NW								
203	715	1060	SSG	N20E	41SE								
204	670	1025	SBQFG	N60E	46NW		N25E	60SE					
204	670	1025	SBQFG	N70E	44NW		N5E	71NW		1"	12"	D	OPEN
204	670	1025	SBQFG				N40E	81SE		1.5"	18"	D	OPEN
204	670	1025	SBQFG				N48W	75SW		.5"	6"	CLOSED	
205	850	825	GSS	N72W	79SW								
206	1250	770	SSG	N85W	23NE		N74E	89NW		.5"	4-6"	CLOSED	
206	1250	770	SSG				N10W	88NE					
207	1255	755	SSG	N78E	59NW		N35E	76NW		4"	12-18"	D	OPEN
207	1255	755	SSG				N35W	80SW		12"	18"	D	OPEN
207	1255	755	SSG				N10E	84SE		3"	40"	CLOSED	
207	1255	755	SSG				N15W	81NE		.5-1"	12"	CLOSED	
208	1240	780	SSG	N50E	23NW		N60W	90E					
208	1240	780	SSG	N60E	30NW		N55E	90W					
208	1240	780	SSG				N15E	76SE					
209	1365	740	SSG	N88E	66NW		N60E	18SE				CLOSED	
209	1365	740	SSG				N50W	76NE		1"		CLOSED	
210	1385	1015	SBQFG	N75E	26NW		N15E	62SE					
211	1375	945	GBQFG	N60W	12NE		N55W	90E		1.5"	1"	D	OPEN
211	1375	945	GBQFG				N45E	90W		1"	12"	D	OPEN
212	1410	980	QTE	N79E	32NW								
213	1000	1015	SSG	N40W	2NE		N70E	70NW		1-3"	24-36"	D	OPEN
213	1000	1015	SSG	N13E	27NW		N60E	90W					
213	1000	1015	SSG	N82E	37NW		N70W	80NE					
213	1000	1015	SSG				N0W	90E		6"	2"	D	OAL,OPE
213	1000	1015	SSG			FOLD	N85E		13SW				
214	960	1025	QTE	N75W	40NE		N30E	85NW		1-2"	>120"	CLOSED	
214	960	1025	QTE	N80E	35NW		N90E	65N		1-6"	4"	CLOSED	
214	960	1025	SBQFG	N85W	51NE								
215	930	1035	QTE	N49E	20NW		N25E	76SE		1-6"	>120"	CLOSED	
215	930	1035	QTE				N85E	80SE		1-8"	1-6"	CLOSED	
216	920	1040	SBQFG	N40E	4SE								
216	920	1040	SSG	N35E	43NW								
217	920	1040	QTE	N64E	29NW		N20E	87NW					
217	920	1040	QTE			FOLD	N20E		17NE				
218	915	1040	SBQFG	N70E	27NW								
218	915	1040	SSG	N48E	38NW								
219	1055	995	GBQFG	N45E	30NW		N20W	75NE					
219	1055	995	SSG	N58E	35NW		N65E	56NW					
220	1035	950	QTE	N85E	60NW								
221	1065	935	GKQMS	N80W	45NE		N25W	80SW			8"	CLOSED	MN
222	1070	930	QTE	N85W	35NE		N40E	75SE		1"	>48"	CLOSED	
222	1070	930	QTE				N20W	60SW		8"	12-24"	CLOSED	
222	1070	930	QTE				N0E	90W					
223	1080	930	GKQMS	N80W	30NE								
224	1080	950	FCR	N75W	60NE		N20W	71SW			36"	CLOSED	
224	1080	950	FCR				N70E	38SE					

							Joints						
Map Sta	**Easting**	**Southing**	**Rx Typ**	**Fol Trend**	**Fol Dip**		**Trend**	**Dip**	**Plunge**	**Space**	**Persist**	**Dilat.**	**Weath.**
225	1160	995	QTE	N80W	37NE		N50W	75SW		4-6"			
225	1160	995	QTE				N45E	82NW					
226	1145	990	TE/FC	N80W	19NE		N5W	75SW		12"	8"	D	OPEN
226	1145	990	TE/FCR				N45E	77NW		4"	96-108"		
227	895	1045	QTE	N84E	42NW								
227	895	1045	QTE	N70E	46NW								
228	985	1025	QTE	N85W	26NE		N0W	90E		1-4"	12"	D	OPEN
228	985	1025	QTE				N60W	75NE		4"	4"		
228	985	1025	SBQFG				N85E	60SE		1-2"	24-36"	CLOSED	
228	985	1025	SBQFG				N25W	70NE		1"	12"	CLOSED	
229	875	1055	SBQFG	N64E	42NW								
230	825	1070	GBQFG	N79E	41NW								
231	805	1065	SBQFG	N55E	50NW								
232	1175	905	FCR	N75E	62NW								
233	1160	915	SSG	N85E	48NW		N5W	85NE		12"	48"	CLOSED	
233	1160	915	SSG				N26E	49SE		8-12"	36"	CLOSED	
233	1160	915	SSG				N80W	36SW					
234	1135	915	FCR	N74E	48NW								
235	1150	910	SSG	N62E	37NW								
236	1125	920	FCR	N69E	44NW		N30W	71SW		7"		CLOSED	
236	1125	920	FCR				N34E	86NW		6"		CLOSED	
237	1160	900	QTE	N82E	36NW		N36E	85SE		8-10"	24"		
237	1160	900	QTE				N87W	50SW					
237	1160	900	QTE				N26W	75SW		14"			
238	1670	925	GQMS	N85E	82NW	FOLD	N90E		30E				
238	1670	925	SBQFG	N85E	40NW								
239	1635	945	QTE	N64W	21NE								
239	1635	945	QTE	N50E	30NW								
240	1595	970	QTE	N73E	44NW								
241	1595	1010	QTE	N90E	21N								
242	1540	1020	GQMS	N90E	32N		N10E	82SE		6"	4-6"	D	FE
243	1550	1015	QTE	N88E	37NW		N38W	88NE		4-8"	12-18"	D	OPEN
243	1550	1015	QTE				N42E	61SE		1-4"	12-18"	D	OPEN
243	1550	1015	QTE				N80W	70SW					
244	1220	1000	QTE	N40E	54NW								
244	1220	1000	SBQFG	N70E	37NW		N55W	67NE		3"	8"	D	MN
244	1220	1000	SBQFG				N0E	87W		1"	36"	D	OPEN
244	1220	1000	SBQFG	N75W	32NE		N35E	77SE					
244	1220	1000	SBQFG				N60E	75NW					
244	1220	1000	SSG	N90W	22N								
244	1220	1000	SSG	N65E	52NW								
245	1190	975	QTE	N75W	52NE		N55E	75SE		4"	24-36"	CLOSED	
245	1190	975	QTE				N85W	80SW		6-12"	18"	CLOSED	
245	1190	975	QTE				N55W	80SW		4-6"	12"	CLOSED	
245	1190	975	SSG	N74W	55NE								
246	1200	995	GBQFG	N75E	38NW								
247	1230	980	QTE	N75E	25NW		N30E	90NW		2"	18-24"	CLOSED	
247	1230	980	QTE	N70E	18NW		N60E	84SE		4-24"	24-36"	CLOSED	
247	1230	980	QTE	N77E	27NW		N45W	80NE		1-2"	8"	CLOSED	
248	1150	975	QTE	N70W	41NE		N30W	45SW		12"	24"	CLOSED	
248	1150	975	QTE				N60E	65SE		6-8"	12"	CLOSED	
249	1300	990	QTE	N88W	30NE		N60E	77SE		4"	48-60"	CLOSED	
249	1300	990	QTE				N50W	68SW		3-4"	8"	CLOSED	
249	1300	990	QTE				N10E	85NW		1"	12-24"	CLOSED	
250	1435	995	FCR			FAULT	N80E	70NW					
250	1435	995	QTE	N30W	18SW		N20E	86NW					
250	1435	995	QTE				N85W	89NE					
250	1435	995	QTE				N60E	85NW					
250	1435	995	QTE				N30W	83NE					
250	1435	995	QTE	N70W	31NE		N65E	82SE					
250	1435	995	QTE	N0E	80W								
250	1435	995	QTE				N82W	72SW					
251	1550	975	QTE	N84E	26NW								
252	1735	1050	QTE	N45W	44NE		N30E	87NW		1"	36-48"	D	KAOL
252	1735	1050	QTE	N55W	30NE		N60W	83SW		2"	36"	D	OPEN
252	1735	1050	QTE				N10E	85NW		4"	12"	D	MN
252	1735	1050	QTE				N90W	89S					
252	1735	1050	SBQFG	N60W	37NE								
253	240	1285	QTE										
254	1005	950	SSG	N63E	60NW								

						Joints						
Map Sta	**Easting**	**Southing**	**Rx Typ**	**Fol Trend**	**Fol Dip**	**Trend**	**Dip**	**Plunge**	**Space**	**Persist**	**Dilat.**	**Weath.**
255	995	955	GKQMS	N75E	40NW							
256	995	960	QTE	N67E	36NW	N0E	85W		2"	12"	CLOSED	
256	995	960	QTE			N80E	72SE		.5"	8-12"	CLOSED	
257	990	955	GKQMS	N90W	45N	N2E	35SE		12"	36"	CLOSED	
257	990	955	GKQMS	N65E	71NW	N40E	51SE					
257	990	955	GKQMS			N70W	90E		1"	12"	CLOSED	
257	990	955	QTE	N90W	80N	N5W	80NE		1-3"	48"	D	OPEN
257	990	955	QTE	N65E	37NW	N45W	30SW			12"	D	MN,FE
258	980	965	QTE	N80E	66NW	N1W	90E					
258	980	965	QTE	N85E	50NW	N85W	52SW		.25"	4"	CLOSED	
258	980	965	QTE	N80E	40NW	N5W	74NE		.25-1"	4"	CLOSED	
259	950	970	GKQMS	N70E	63NW							
259	950	970	GKQMS	N90E	47N							
260	935	975	QTE	N85E	46NW	N40E	83SE		2-4"	24"	CLOSED	
261	920	985	BQFG	N55E	48NW							
261	920	985	TE/FC	N40E	46NW							
262	895	990	TE/FC	N85E	89NW							
262	895	990	TE/FC	N50E	48NW							
263	885	995	CR/QT	N75E	60NW	N15E	83SE		1"	12-18"	CLOSED	
263	885	995	CR/QTE			N5W	75NE		1-2"	24"	D	OPEN
263	885	995	CR/QTE			N70E	81NW		2"			
264	870	1000	CR/QT	N70E	56NW							
265	840	1015	QMS	N37E	35NW							
266	920	975	CR/QT	N60E	37NW							
267	940	970	SBQFG	N70E	35NW							
268	995	950	SSG	N64E	27NW							
269	1025	945	QTE	N74E	42NW							
270	1050	940	GKQMS	N54E	46NW							
271	1045	930	FCR	N80E	45NW							
272	1080	930	CR/QT	N75W	50NE							
273	1110	910	BQFG	N30E	45NW	N0W	90E		1"	12"	D	OPEN
273	1110	910	BQFG			N90W	88S		.5"		D	OPEN
274	1140	900	FCR	N82W	60NE							
275	1190	890	QTE									
276	1170	905	TE/FC	N80E	62NW							
277	1055	945	GKQMS	N65E	76NW							
278	1230	905	QTE	N80E	48NW	N50W	40SW					
279	1250	905	QTE	N86W	85NE	N15E	60SE		2-4"	12"	D	SIO2
279	1250	905	QTE			N5W	62SW		6-18"	6"	CLOSED	
279	1250	905	QTE			N75E	35NW		.5"	12-24"	CLOSED	
279	1250	905	QTE	N86E	76SE	N50W	68NE		4"	24-36"	CLOSED	
280	1265	900	TE/FC	N78E	59NW							
281	1280	910	QTE	N60E	90W							
281	1280	910	QTE	N85E	90W							
282	1300	910	GKQMS	N90E	49N							
282	1300	910	QTE	N80W	90E							
283	1310	910	QTE	N90W	49N							
284	1315	910	SBQFG	N75E	41NW							
285	1320	910	QTE	N80W	45NE	N30E	80NW		12"	48"	CLOSED	
286	1325	910	QTE	N65W	74NE							
287	1335	915	SBQFG	N60W	50NE							
288	1430	920	SSG	N65E	25NW							
289	1430	945	BQFG	N5E	49SE							
290	1405	900	QTE	N75E	27NW	N85E	65SE		.5"	12"	SD	OPEN
290	1405	900	QTE			N40W	87NE				D	OPEN
290	1405	900	QTE			N10E	86NW				D	OPEN
291	1400	910	GBQFG	N80E	44NW	N5E	84NW		2-4"	48-60"	CLOSED	
291	1400	910	GBQFG	N55W	38NE	N30W	90E		24"	36"	CLOSED	
291	1400	910	GBQFG	N90W	45N	N30E	88NW		3-12"	120"	CLOSED	
291	1400	910	QTE	N70E	32NW	N82E	88NW		1-2"	>120"	CLOSED	
292	1510	820	BQFG	N22E	25NW							
293	1520	835	QTE	N60E	18NW	N25E	80SE		4"	36-48"	CLOSED	
293	1520	835	QTE			N80W	86NE		4"	36"	CLOSED	
294	1650	760	GBQFG	N74E	35NW							
294	1650	760	QTE	N85W	25NE	N55E	87SE		2"	36"	CLOSED	
295	1645	770	BQFG	N35W	38NE							
296												
297	1580	825	SSG	N87W	44NE							
298	1650	800	GBQFG	N80E	25NW	N45W	82NE		4"	>12"	CLOSED	
298	1650	800	GBQFG			N80E	75SE		1"	48"	CLOSED	

						Joints						
Map Sta	Easting	Southing	Rx Typ	Fol Trend	Fol Dip	Trend	Dip	Plunge	Space	Persist	Dilat.	Weath.
298	1650	800	GBQFG			N10E	90W		1"	48-60"	CLOSED	
298	1650	800	SSG	N62W	28NE							
299	1650	785	BQFG	N45E	35NW							
300	1655	765	QTE	N45W	31NE							
301	1680	745	QTE	N84W	55NE							
302	1725	740	QTE	N5E	85SE							
27B	50	0	GSS	N56E	45NW							
119B	1660	815	QMS									
133B	1670	925	QTE									
154B	1320	90	BQFG									
166B	1280	1890	BQFG									
172B	1425	2070	BQFG									
208B	1315	740	GBQFG									
220B	1035	945	QTE	N65E	50NW	N20E	80NW		4-6"	12-24"	CLOSED	
220B	1035	945	QTE	N46E	51NW	N75E	70NW		.5"	4-6"	CLOSED	
220B	1035	945	QTE			N40E	30SE		4"	10-12"	CLOSED	MN

GEOLOGIC MAP OF THE BARNESVILLE HYDROGEOLOGIC RESEARCH SITE, LAMAR COUNTY, GEORGIA

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF GEORGIA
DEPARTMENT OF NATURAL RESOURCES
GEOLOGIC AND WATER RESOURCES DIVISION

BARNESVILLE QUADRANGLE
GEORGIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
SW/4 BARNESVILLE 15' QUADRANGLE

EXPLANATION

(no stratigraphic order implied)

Units north of the Towaliga Fault Zone

GSS	Graphite-quartz-muscovite-sillimanite schist with interlayers of porphyroclastic biotite-quartz-feldspar gneiss.
SGSS	Sheared graphite-quartz-muscovite-sillimanite schist and chlorite-quartz-muscovite schist with infolded biotite-quartz-feldspar gneiss and isolated pods of quartz-garnet granofels. Abundant quartz ± sillimanite veins concordant and discordant to foliation.
QGG	Intercalated gondite, biotite gneiss, amphibolite and sillimanite-quartz-muscovite schist.
BQFG	Porphyroclastic and granitic biotite-quartz-feldspar gneiss with local discontinuous interlayers of amphibolite and quartz-muscovite schist ± sillimanite.
MBQFG	Migmitized porphyroclastic and granitic biotite-quartz-feldspar gneiss with local discontinuous layers of quartz-muscovite schist ± sillimanite.

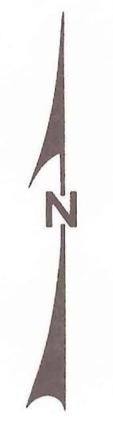
Units within and south of the Towaliga Fault Zone

GQMS GKQMS	Garnet-quartz-muscovite schist ± kyanite, locally sheared.
QTE	Feldspathic, micaceous quartzite, locally mylonitic.
SSG	Sheared biotite-feldspar-quartz-muscovite schist ± kyanite ± garnet.
SBQFG	Sheared, silicified garnet-muscovite-biotite-quartz-feldspar gneiss, ranging from augen gneiss to blasto- and ultramylonite.
FCR	Cataclasite, flinty crush rock.

Units south of the Towaliga Fault Zone

GBQFG	Garnetiferous muscovite-biotite-quartz-feldspar gneiss with local interlayers of quartz-muscovite schist, sheared schist and lenses of cataclasite.
FCR	Cataclasite, flinty crush rock.

27 ⊥	*Strike and dip of foliation*
13 ←	Trend and plunge of lineation
42 ←┬	Trend, plunge and dip of axial plane of minor folds
———	Contact
-----	Approximate contact
—▲—▲—	Inferred thrust fault
━━━	Towaliga Fault



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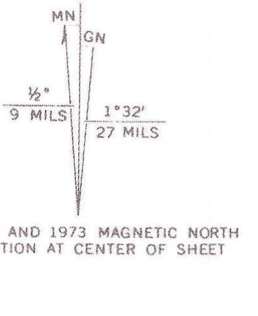
Topography by photogrammetric methods from aerial photographs taken 1973. Field checked 1973

Projection and 10,000-foot grid ticks: Georgia coordinate system, west zone (transverse Mercator)
1000-metre Universal Transverse Mercator grid ticks, zone 16, shown in blue. 1927 North American datum

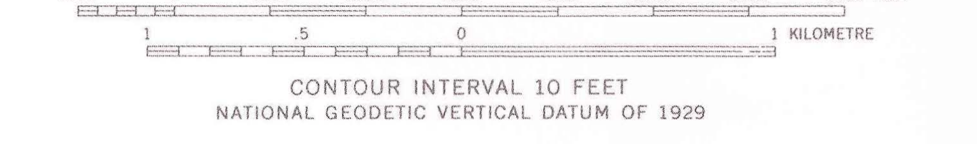
Fine red dashed lines indicate selected fence and field lines where generally visible on aerial photographs. This information is unchecked

Red tint indicates areas in which only landmark buildings are shown



UTM GRID AND 1973 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

SCALE 1:24 000



CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
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A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

ROAD CLASSIFICATION

Primary highway, hard surface	━━━	Light-duty road, hard or improved surface	═══
Secondary highway, hard surface	━━━	Unimproved road	=====

◯ Interstate Route ◯ U. S. Route ◯ State Route

BARNESVILLE, GA.
SW/4 BARNESVILLE 15' QUADRANGLE
N3300—W8407.5/7.5

1973

AMS 4150 II SW—SERIES V845

DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
GEORGIA GEOLOGIC SURVEY

INFORMATION CIRCULAR 98
PLATE 2

JOINT SET MAP
BARNESVILLE HYDROGEOLOGIC RESEARCH SITE
LAMAR COUNTY, GEORGIA

27 Strike and dip of joint

Strike and dip of vertical joint

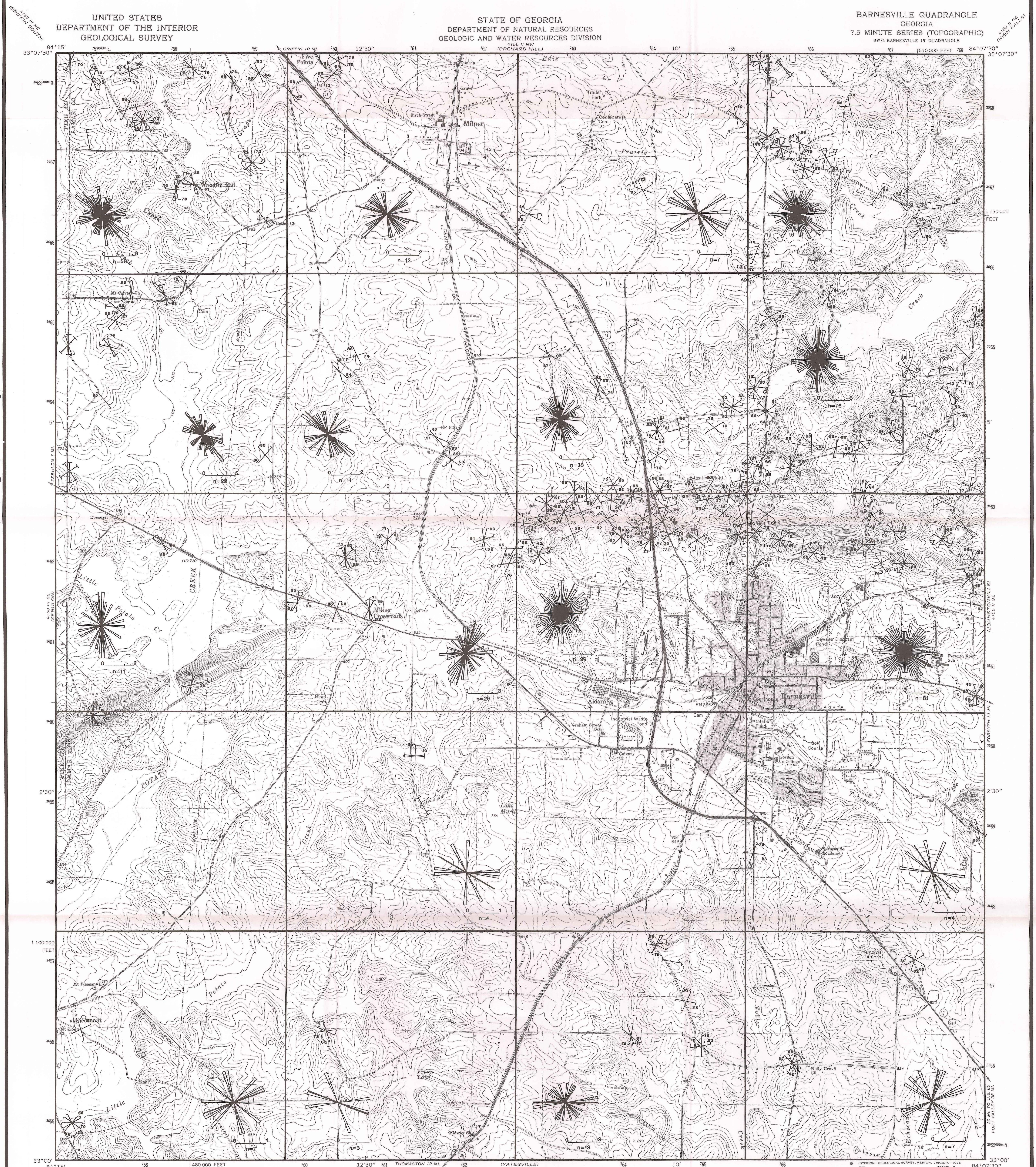
Rose diagrams summarizing strike of joint sets for a given area

0 2
n=11

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF GEORGIA
DEPARTMENT OF NATURAL RESOURCES
GEOLOGIC AND WATER RESOURCES DIVISION

BARNESVILLE QUADRANGLE
GEORGIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
SW/4 BARNESVILLE 15' QUADRANGLE



33°00'
84°15'
758
480 000 FEET
760
12'30"
761
THOMASTON 12 MI.
762
(YATESVILLE)
4149 I NW
764
10'
765
766
INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1976
767
768000m.E.
33°00'
84°07'30"

(THOMASTON)
4149 IV NE

(STROUDS)
4149 I NE

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Topography by photogrammetric methods from aerial photographs taken 1973. Field checked 1973

Projection and 10,000-foot grid ticks: Georgia coordinate system, west zone (transverse Mercator)
1000-metre Universal Transverse Mercator grid ticks, zone 16, shown in blue. 1927 North American datum

Fine red dashed lines indicate selected fence and field lines where generally visible on aerial photographs. This information is unchecked

Red tint indicates areas in which only landmark buildings are shown

MN GN
½°
9 MILS
1°32'
27 MILS
UTM GRID AND 1973 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

SCALE 1:24 000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETRE

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092
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GEORGIA
QUADRANGLE LOCATION

ROAD CLASSIFICATION

Primary highway, hard surface	Light-duty road, hard or improved surface
Secondary highway, hard surface	Unimproved road

Interstate Route U. S. Route State Route

BARNESVILLE, GA.
SW/4 BARNESVILLE 15' QUADRANGLE
N3300—W8407.5/7.5

1973

AMS 4150 II SW—SERIES V845

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Dk. Purple	Piedmont and Blue Ridge mapping and structural geology
Maroon	Coastal Plain mapping and stratigraphy
Lt. Green	Paleontology
Lt. Blue	Coastal Zone studies
Dk. Green	Geochemical and geophysical studies
Dk. Blue	Hydrology
Olive	Economic geology Mining directory
Yellow	Environmental studies Engineering studies
Dk. Orange	Bibliographies and lists of publications
Brown	Petroleum and natural gas
Black	Field trip guidebooks
Dk. Brown	Collections of papers

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Editor: Melynda Lewis

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