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# Geologic Map of the Kings Mountain and Grover Quadrangles, Cleveland and Gaston Counties, North Carolina, and Cherokee and York Counties, South Carolina

By J. Wright Horton, Jr.

*Pamphlet to accompany*
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**On the cover:** The Foote mine, a large open-pit lithium mine in spodumene pegmatite, is located on the south side of the town of Kings Mountain, N.C. The mine straddles a regional lithotectonic boundary between the Inner Piedmont and Carolina terranes. This 1983 photograph shows the mine viewed from its western rim looking east toward the Pinnacle of Kings Mountain, a prominent monadnock of kyanite quartzite. Photograph by J. Wright Horton, Jr., U.S. Geological Survey.

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# Contents

# Conversion Factors

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| centimeter (cm) | 0.3937 | inch (in.) |
| millimeter (mm) | 0.03937 | inch (in.) |
| foot (ft) | 0.3048 | meter (m) |
| meter (m) | 3.281 | foot (ft) |
| kilometer (km) | 0.6214 | mile (mi) |

# Geologic Map of the Kings Mountain and Grover Quadrangles, Cleveland and Gaston Counties, North Carolina, and Cherokee and York Counties, South Carolina

By J. Wright Horton, Jr.

## Abstract

This geologic map of the Kings Mountain and Grover 7.5-min quadrangles, N.C.-S.C., straddles a regional geological boundary between the Inner Piedmont and Carolina terranes. The Kings Mountain sequence (informal name) on the western flank of the Carolina terrane in this area includes the Neoproterozoic Battleground and Blacksburg Formations. The Battleground Formation has a lower part consisting of metavolcanic rocks and interlayered schist and an upper part consisting of quartz-sericite phyllite and schist interlayered with quartz-pebble metaconglomerate, aluminous quartzite, micaceous quartzite, manganiferous rock, and metavolcanic rocks. The Blacksburg Formation consists of phyllitic metasiltstone interlayered with thinner units of marble, laminated micaceous quartzite, hornblende gneiss, and amphibolite. Layered metamorphic rocks of the Inner Piedmont terrane include muscovite-biotite gneiss, muscovite schist, and amphibolite. The Kings Mountain sequence has been intruded by metatonalite and metatrondhjemite (Neoproterozoic), metagabbro and metadiorite (Paleozoic?), and the High Shoals Granite (Pennsylvanian). Layered metamorphic rocks of the Inner Piedmont in this area have been intruded by the Toluca Granite (Ordovician?), the Cherryville Granite and associated pegmatite (Mississippian), and spodumene pegmatite (Mississippian). Diabase dikes (early Jurassic) are locally present throughout the area. Ductile fault zones of regional scale include the Kings Mountain and Kings Creek shear zones. In this area, the Kings Mountain shear zone forms the boundary between the Inner Piedmont and Carolina terranes, and the Kings Creek shear zone separates the Battleground Formation from the Blacksburg Formation. Structural styles change across the Kings Mountain shear zone from steeply dipping layers, foliations, and folds on the southeast to gently and moderately dipping layers, foliations, and recumbent folds on the northwest. Mineral assemblages in the Kings Mountain sequence show a westward decrease from upper amphibolite facies (sillimanite zone) near the High Shoals Granite in the eastern side of the map area to upper greenschist (epidote-amphibolite) facies in the south-central part of the area near the Kings Mountain shear zone. Amphibolite-facies mineral assemblages in the Inner Piedmont terrane increase in grade from the kyanite zone near the Kings Mountain shear zone to the sillimanite zone in the northwestern part of the map area. Surficial deposits include alluvium in the stream valleys and colluvium along ridges and steep slopes. These quadrangles are unusual in the richness and variety of the mineral deposits that they contain, which include spodumene (lithium), cassiterite (tin), mica, feldspar, silica, clay, marble, kyanite and sillimanite, barite, manganese, sand and gravel, gold, pyrite, and iron.

## Introduction

This geologic map of the Kings Mountain and Grover 7.5-min quadrangles covers an area in the Piedmont physiographic province along the North Carolina-South Carolina border (fig. 1 on map). The map area straddles a regional geological boundary between the Inner Piedmont terrane and the Kings Mountain sequence of the Carolina terrane as discussed below. The Kings Mountain and Grover quadrangles are located along the Interstate Route 85 corridor. They encompass most of Kings Mountain National Military Park, S.C. (the site of the October 7, 1780, Battle of Kings Mountain during the American Revolution), much of Kings Mountain State Park, S.C., and Crowders Mountain State Park, N.C. The area has a remarkable diversity of rock formations and mineral resources, and mining has played a significant role in its history from the 1700s to the present. Field-trip guides are available in Horton and Butler (1977, 1986), Horton and others (1981), and LaPoint (1992).

Intrusive rocks are classified according to International Union of Geological Sciences (IUGS) nomenclature using normalized values of modal quartz, alkali feldspar, and plagioclase (Streckeisen, 1976). Mineral modifiers are listed in order of increasing abundance for both igneous and metamorphic rocks. In descriptions, minerals are listed in order of decreasing abundance.

# Physiography and Exposure

The Piedmont province in this area is a moderately dissected upland of low relief. Linear hills and ridges underlain by resistant quartzite and quartz-pebble conglomerate rise abruptly 100 to 800 feet (ft) above the surface of low relief. Craggy precipitous cliffs occur at Crowders Mountain and at the Pinnacle.

Outcrop control of bedrock geology ranges from excellent to poor. Rock exposures occur in roadcuts, streambeds and streambanks, quarries, and along the crests and slopes of ridges. Saprolite exposures are common. Thick soils cover most of the bedrock in intervalley areas of low relief. This prevents detailed mapping in some places, but residual soil and float furnish significant information about the local bedrock in most areas. Almost all of the roads, trails, streams, ridges, pipelines, powerlines, and telephone lines were walked and numerous cross-country traverses were made.

Contacts between rock units are only approximately located and are judged to be accurate within 100 meters (m) or more, with a few notable exceptions. In areas of poor exposure and little float control, contacts are highly interpretive and certain folded contacts are based solely on extrapolation of the patterns of minor folds seen in outcrop. The beds of quartzite and quartz-pebble conglomerate were walked out and precisely located in most cases. Parts of the manganiferous schist were also walked out. Marble contacts in parts of the Grover quadrangle are known from exploratory drilling by Vulcan Materials Co.

# Previous Geologic Mapping

The map area lies within the Charlotte 1° × 2° quadrangle, where information on the geologic setting, stratigraphy, structure, and metamorphism is available from Goldsmith and others (1988). In the Kings Mountain area, the early geologic framework of Keith and Sterrett (1931) has served as a foundation for later work. The present geologic map incorporates data from previous geologic mapping in areas of spodumene-bearing pegmatites near the town of Kings Mountain, N.C. (Kesler, 1942, 1944), kyanite- and sillimanite-bearing quartzites (Espenshade and Potter, 1960), and iron deposits near Yellow Ridge (Nunan, 1983). It builds on, and supersedes, a less complete and less detailed earlier geologic map of the Kings Mountain and Grover quadrangles by Horton (1977, pl. 1).

Geologic maps are available for the Shelby 15-min quadrangle (Overstreet and others, 1963) at the northwest corner of this map, for the Blacksburg South 7.5-min quadrangle (Butler, 1981b) at the southwest corner, for the Kings Creek 7.5-min quadrangle (Murphy and Butler, 1981; Folsom, 1982; Howard, 2004) to the south, and for the Filbert 7.5-min quadrangle (Nystrom, 2003) to the south. References to other geologic maps in the region are in Goldsmith and others (1988) and Horton and Dicken (2001).

# Layered and Stratified Metamorphic Rocks

Metamorphic grades in the area of this map range from greenschist to amphibolite facies, and many of the rocks now consist of metamorphic minerals.

## Kings Mountain Sequence of the Carolina Terrane

The Kings Mountain sequence, as used informally in this report, includes the Battleground and Blacksburg Formations, which are interpreted to be Neoproterozoic in age (Horton, 1984). These rocks, on the western flank of the Carolina terrane (Horton and others, 1989), include layered metasedimentary and metavolcanic rocks in the Kings Mountain belt of King (1955). A tectonostratigraphic terrane is a regional, fault-bounded assemblage of rocks characterized by a geologic history different from that of neighboring terranes (Horton and others, 1989, and references therein), and earlier belt terminology is not used in this report for reasons discussed by Horton and Zullo (1991). A separate Gaffney terrane (Horton and others, 1989) is unnecessary, if evidence that the Blacksburg Formation stratigraphically overlies the Battleground Formation is correct. The evidence consists of primary structures in drill cores from the Kings Mountain gold mine (Supplee, 1986; LaPoint, 1992), although relations are complicated by mylonitic fabrics of the Kings Creek shear zone (Horton, 1984; Goldsmith and others, 1988).

The lower part of the Battleground Formation consists of metavolcanic rocks and interlayered schist (Horton, 1984). Metavolcanic facies include metavolcanic hornblende gneiss (Zbht), felsic schist and gneiss (Zbfs), plagioclase-crystal metatuff (Zbct), siliceous metatuff (Zbmps), volcanic metaconglomerate (Zbvc), and mottled phyllitic metatuff (Zbmp). These rocks grade laterally and vertically into biotite-muscovite schist (Zbms) and some occur at multiple stratigraphic levels. This schist has a higher quartz content than normal igneous rocks, lacks volcanic textures, and probably formed from epiclastic or sedimentary material and hydrothermally altered volcanic material. The upper part of the Battleground Formation consists of interlayered metasedimentary rocks and lesser amounts of metavolcanic rock. Lithofacies include quartz-sericite phyllite and schist (Zbs) which commonly contains chloritoid, quartz-pebble metaconglomerates (Zbc, Zbd, Zbmc), aluminous quartzite (Zbaq), micaceous quartzite (Zbmq), manganiferous rock (Zbj), and local metavolcanic rocks (Zbmp and part of Zbdt). Stratigraphic interpretations are based on sporadic observations of graded bedding in the metaconglomerates; crossbedding is considered less reliable than graded bedding, because it can be mimicked by cleavage-bedding intersections. Similarities and differences among the metaconglomerate units originally lumped as Draytonville by Keith and Sterrett (1931) are discussed by France and Brown (1981) and France (1983).

Two discontinuous units of quartz-pebble metaconglomerate, the Dixon Gap Metaconglomerate Member (Zbc) and the Draytonville Metaconglomerate Member (Zbd), are separated by the intervening Jumping Branch Manganiferous Member (Zbj) as well as by quartz-sericite phyllite and schist (Zbs). The Dixon Gap Metaconglomerate Member grades laterally into aluminous quartzite (Zbaq). Aluminous quartzites occur at two stratigraphic levels on the western limb of the South Fork antiform, but their relations to similar rocks on the eastern limb are undetermined. The micaceous quartzite (Zbmq) at Yellow Ridge is interpreted to be stratigraphically higher than the Jumping Branch Manganiferous Member, and the Crowders Creek Metaconglomerate Member (Zbmc) is interpreted to be even higher. Metadacite of the undivided metadacite and metatrondhjemite unit (Zbdt) is interpreted to be the uppermost stratigraphic unit of the Battleground Formation in this area. The Battleground Formation is intruded by metatonalite (Zto) and metatrondhjemite (part of Zbdt; Zts) of Neoproterozoic age (Horton, 1984; LeHuray, 1986; Faggart and Basu, 1987).

The Blacksburg Formation consists mainly of phyllitic metasiltstone (Zbls) and interlayered marble (Zblg, Zblm), laminated micaceous quartzite (Zblq), and hornblende gneiss and amphibolite (Zbla). Minor calc-silicate interlayers are also present. The phyllitic metasiltstone is commonly graphitic and typically more micaceous than schists of the Battleground Formation. The Blacksburg Formation is predominantly metasedimentary, although amphibolites having basaltic composition may be metamorphosed sills or flows (Horton, 1984). Because the Blacksburg Formation is bounded by ductile fault zones, its upper and lower contacts are undetermined. Nevertheless, primary sedimentary structures in drill core suggest that metadacite of the undivided metadacite and metatrondhjemite unit (Zbdt) at the top of the Battleground Formation is stratigraphically overlain by the Blacksburg Formation in the vicinity of the Kings Mountain gold mine (LaPoint, 1992) although the contact has been overprinted by mylonitic fabrics of the Kings Creek shear zone. Stratigraphy within the Blacksburg is poorly constrained, and this map follows the interpretation of Horton (1984). In this interpretation, lenses of hornblende gneiss and amphibolite (Zbla) occur in the lower part, and marble (Zblg, Zblm) occurs at two stratigraphic levels. Discontinuous beds and lenses of laminated micaceous quartzite (Zblq) occur in the lower part of the formation, and at three stratigraphic levels in the upper part, as follows: (1) below the Gaffney Marble Member (Zblg), (2) equivalent to "$Q_1$" of Kesler (1944) above the Gaffney Marble Member and below the informally named marble member at Dixon Branch (Zblm), and (3) equivalent to "$Q_2$" of Kesler (1944) above the marble member at Dixon Branch. Chlorite phyllonite (Zblc) is present in the Kings Creek shear zone.

## Layered Metamorphic Rocks of the Inner Piedmont Terrane

Layered metamorphic rocks of the Inner Piedmont terrane in this area include muscovite-biotite gneiss (ЄZbg), muscovite schist (ЄZs), and amphibolite (ЄZa). No primary structures are preserved in these rocks, and their stratigraphic relations are undetermined. Metamorphic mineral assemblages are typical of the amphibolite-facies kyanite and sillimanite zones, and the layered metamorphic rocks have been intruded by Paleozoic granites and pegmatites described below.

# Igneous Intrusive Rocks

Igneous intrusive rocks in the Battleground and Blacksburg Formations include metatonalite (Zto) and metatrondhjemite (Ztr, Zts). The metatonalite is most abundant in the lower part of the Battleground, and it may include shallow sills or plugs that intruded their own volcanic ejecta (Horton, 1977; Murphy and Butler, 1981). The metatonalite (Zto) has a nearly concordant U-Pb zircon age of about 570 Ma (LeHuray, 1986), and the metatrondhjemite has a whole-rock Sm-Nd age of 628 Ma (Faggart and Basu, 1987). Metagabbro and metadiorite (Pzgd) occurs as small bodies in the Battleground and locally as dikes cutting the metatonalite, and may be related to similar rocks in Mecklenburg County, N.C. (Goldsmith and others, 1988).

The Toluca Granite (Dtg) is found only in the Inner Piedmont terrane, and it occurs as lenticular bodies mostly concordant to the regional foliation in the northwestern part of the Grover quadrangle. Horton and McConnell (1991) and Horton and Dicken (2001) inferred a provisional Ordovician(?) age for the Toluca from discordant conventional U-Pb zircon dates ranging from about 540 to 445 Ma (Davis and others, 1962; Odom and Fullagar, 1973; Harper and Fullagar, 1981). However, recent ion-microprobe U-Pb geochronology of zircons indicates a Devonian age of ~378 Ma for the Toluca (Mapes, 2002). The Cherryville Granite (Mc, Mcp) occupies a large area of the Inner Piedmont terrane within the map area. Contacts are mostly concordant but locally discordant with the country-rock foliation. The Cherryville and associated pegmatites (Mp, Ms) have Mississippian whole-rock Rb-Sr ages (Kish, 1977, 1983; Kish and Fullagar, 1996). Dikes and concordant sheets of spodumene pegmatite (Ms) are concentrated in a narrow belt along the southeastern flank of the Inner Piedmont terrane near the Kings Mountain shear zone.

The High Shoals Granite (ℙhs) along the eastern edge of the map area is a coarse-grained, porphyritic, gneissic biotite granite, which has a Pennsylvanian U-Pb zircon age of 317 Ma (Horton and others, 1987). Maps of regional metamorphic zones (Horton and others, 1987) show a decrease in grade with distance from the High Shoals Granite as discussed below.

Early Jurassic diabase dikes (Jd) in the area are nearly vertical and typically strike N. 40°– 50° W. Most range from a few centimeters to a few meters in thickness. The largest, near Henry Knob in the southeast corner of the Kings Mountain quadrangle, is about 15 m thick and 13 kilometers (km) long (Butler, 1966). The dikes are concentrated in swarms from Henry Knob to Dixon Gap and beyond, and from the south side of Crowders Mountain through the northeast side of the town of Kings Mountain.

## Structural Geology

As many as five episodes of folding and related deformation have been recognized in the Battleground and Blacksburg Formations (Horton, 1981b; Schaeffer, 1981). The distribution of map units is controlled largely by folds of the two earliest episodes, $F_1$ and $F_2$. These folds are locally disrupted by ductile faults, which are roughly parallel to the regional schistosity (Butler, 1981b; Horton, 1981b). The largest map-scale fold is the South Fork antiform, which is interpreted as an $F_2$ structure based on structural relations in the Bessemer City quadrangle to the north (Horton, 1981b). The isoclinal to tight Sherrars Gap synform (Espenshade and Potter, 1960) and Crowders Mountain antiform are map-scale folds of the earliest episode, $F_1$. Both lie on the west limb of the north-plunging South Fork antiform and are refolded by parasitic $F_2$ folds, which produce the same Z-shaped asymmetry on opposite limbs. Structures younger than $F_2$ are conspicuous in the shear zones but sporadically distributed elsewhere, and have little influence on the map pattern southeast of the Kings Mountain shear zone. The dominant metamorphic foliation or schistosity in the area, $S_2$, is essentially parallel to axial surfaces of second-generation, $F_2$, folds. A much weaker older schistosity, $S_1$, is parallel to bedding and layering except in the hinges of mesoscopic $F_1$ isoclinal folds. The dominant $S_2$ schistosity transects bedding or compositional layering in many areas of the Battleground Formation. It crosses the older Sherrars Gap synform, for example, and has the same angular relation to bedding on both limbs.

The map shows several ductile shear zones, where mylonitic fabrics overprint earlier structures. The Kings Mountain shear zone forms a major tectonic boundary between the Inner Piedmont and Carolina terranes in this area. Rock units on both sides of the shear zone are clearly truncated by it southwest of this map area (Horton, 1981a; Goldsmith and others, 1988). Spodumene pegmatite of Mississippian age was emplaced during the waning stage of deformation in the Kings Mountain shear zone (Horton, 1981a), and the other zones are inferred to be about the same age. The Kings Creek shear zone separates the Battleground and Blacksburg Formations in the Kings Mountain and Grover quadrangles. Similar en echelon shear zones lie along the southeast side of the metadacite and metatrondhjemite (Zbdt) unit in the northern part of the map area and along the northwest side of the metatrondhjemite and amphibole gneiss (Ztr) in the southern part of the map area.

Structural styles change across the Kings Mountain shear zone, from steeply dipping layers, foliations, and folds in the Battleground and Blacksburg Formations to gently and moderately dipping layers, foliations, and recumbent folds in the Inner Piedmont terrane. In the Inner Piedmont an early foliation, which is parallel to gneissic layering except in rare vestigial fold hinges, has been folded by mesoscopic gently plunging, recumbent, isoclinal folds (Goldsmith and others, 1988). These early folds have been re-folded by minor crenulations and by upright folds into broad synforms and antiforms. The polydeformed rocks of the Inner Piedmont terrane are interpreted to be part of an allochthonous stack of crystalline thrust sheets (Goldsmith and others, 1988, and references therein).

Some northeast-striking faults may be related to folding, and others are younger. An early Jurassic diabase dike close to the western edge of the Kings Mountain quadrangle, northeast of the intersection of Interstate Route 85 and Dixon School Road (State Route 2283), is offset 1.2 m in a horizontal direction by a subvertical northeast-striking fault (Horton and Butler, 1977, p. 125). Some northwest-striking faults and joints may be related to the fracture system intruded by early Jurassic diabase dikes. Quartz veins generally dip steeply, strike northeast at varied angles, and locally appear along fault surfaces.

## Metamorphism

Maps showing the distribution of metamorphic mineral assemblages and isograds in these quadrangles and surrounding areas are presented in Horton and others (1987) and Goldsmith and others (1988). Metamorphic grades within the area of this map range from greenschist to amphibolite facies. In the Battleground and Blacksburg Formations, mineral assemblages show a westward decrease from upper amphibolite facies (sillimanite zone) near the High Shoals Granite to upper greenschist (epidote-amphibolite) facies in the south-central part of the map area near the Kings Mountain shear zone. In the Inner Piedmont terrane, amphibolite-facies mineral assemblages increase in grade from the kyanite zone near the Kings Mountain shear zone to the sillimanite zone in the northwestern part of the map area. Map relations south of these quadrangles indicate that the Kings Mountain shear zone truncates metamorphic zones on both sides (Horton and others, 1987; Goldsmith and others, 1988). The age of peak metamorphism was late Paleozoic (Alleghanian) in the Battleground and Blacksburg Formations of the Carolina terrane, and middle Paleozoic in nearby parts of the Inner Piedmont terrane in this area (Horton and others, 1987).

Horton and others (1987) show that a north-trending isograd marking the breakdown of chloritoid to produce staurolite lies between the Pinnacle and Crowders Mountain. Significantly, kyanite is present in quartzites (but not in pelitic rocks) on the low-temperature side of this isograd up to 4 km away to the west, suggesting that the distribution of kyanite is influenced by rock composition in addition to temperature and pressure. The presence of andalusite, in schists both east and west of kyanite quartzite on Crowders Mountain, also suggests that rock composition has an influence on the distribution of these metamorphic index minerals. Where more than one $Al_2SiO_5$ polymorph occurs in the same rock, petrographic relations show kyanite replacing andalusite (consistent with increasing pressure), and sillimanite replacing both kyanite and andalusite (consistent with increasing temperature); Horton and others (1987) proposed a clockwise pressure-temperature-time path of increasing pressure followed by increasing temperature of prograde metamorphism to explain these relations.

A lower greenschist-facies metamorphic overprint is present in the shear zones. Contact metamorphism related to spodumene pegmatites was described by Kesler (1961) and Horton (1977).

# Mineral Resources

The Kings Mountain and Grover quadrangles are unusual in the richness and variety of the mineral deposits that they contain. These include spodumene, cassiterite, mica, feldspar, silica, clay, marble, kyanite and sillimanite, barite, manganese, sand and gravel, gold, pyrite, and iron.

The belt of spodumene pegmatites, described by Kesler (1942) as the "Carolina tin-spodumene belt," is one of the largest developed reserves of lithium in the world (Kesler, 1976; Evans, 1978). Overviews of the lithium deposits and their resource potential are provided by Horton (1987) and Horton and Gair (1989). Cassiterite is a minor constituent of the spodumene pegmatites and associated greisen, and the pegmatites were first worked for tin. Geology of the Foote Mineral Company's lithium mine on the south side of the town of Kings Mountain is described by Kesler (1961), Horton and Butler (1977, 1986), Horton and Simpson (1978), and Horton and others (1981). This mine is widely known for its remarkable variety of primary and secondary minerals (Marble and Hanahan, 1978; White, 1981).

Production of mica, feldspar, quartz, and kaolin from weathered Cherryville Granite and associated pegmatites is described by Connor (1990). Griffitts and Olson (1953) described the Herndon mine, the Rice mine, and several mica prospects, and the Moss mine has been described as a field-trip stop (Horton and others, 1981, Stop 3).

Marble from the Blacksburg Formation has been quarried for crushed stone and agricultural limestone by Vulcan Materials Co., in quarries south and southeast of the town of Grover (Horton and Butler, 1977, Stop 4; Horton and Butler, 1986, Stop 3). Martin Marietta Corp. has produced crushed stone from a quarry in marble on the southeast side of the town of Kings Mountain. The quarries owned by Martin Marietta and Vulcan Materials are in the marble member at Dixon Branch (Zblm). Earlier marble quarries were described by Ruffin (1843, p. 59–69), Sloan (1908), Keith and Sterrett (1931), and Conrad (1960).

Aluminous quartzite (Zbaq) in the Battleground Formation contains large reserves of kyanite and smaller reserves of sillimanite. Espenshade and Potter (1960) estimated that the principal deposits in the region, most of which are in the Kings Mountain quadrangle, contain 40 million tons of rock with 10 to 30 percent kyanite. The most significant mining in the area was at Henry Knob near the southeast corner of the map, where kyanite was produced with pyrite as a byproduct before 1966 (Smith and Newcome, 1951; Espenshade and Potter, 1960; Butler, 1966; Horton and Butler, 1986). Large deposits of kyanite exist at the Pinnacle, at Crowders Mountain, and at the Shelton properties. Smaller deposits of sillimanite occur at the Will Knox property (Espenshade and Potter, 1960). Those at the Pinnacle and Crowders Mountain lie in and near Crowders Mountain State Park. An overview of the kyanite and sillimanite deposits and their resource potential is available from Horton (1987) and Horton (1989a).

A belt of barite deposits that crosses the map area (Van Horn and others, 1949; Wilson, 1958; McCauley, 1962) lies in the Battleground Formation southeast of the main quartzite and quartz-pebble conglomerate beds. Hand-cobbing operations at the Lawton (Lawson) and Wyatt mines had significant production in the past, and the Lawton and Craig properties may have significant reserves (Van Horn and others, 1949; Horton and Butler, 1977). Barite is not currently mined in the region. Most of the production has been from en echelon, northeast-striking veins of massive barite, but disseminated barite in the surrounding schist reaches concentrations as high as 20 percent (Van Horn and others, 1949). An overview of the barite deposits and their resource potential in the region is available in Horton (1987) and Horton (1989b).

Manganese deposits occur in the Jumping Branch Manganiferous Member (Zbj) of the Battleground Formation on both limbs of the South Fork antiform (Horton, 1987, 1989c). Manganese oxides are derived from weathering of stratabound spessartine-almandine garnet in the schist, and the schist has been prospected for manganese (White, 1944; O'Neill and Bauder, 1962). In recent decades, saprolite and weathered (oxidized) manganiferous rock have been quarried intermittently from elongate pits just west of Kings Mountain National Military Park for use as a dark brown additive in the manufacture of bricks.

Gold mines and prospects in the Battleground Formation of the Kings Mountain and Grover quadrangles were described by Sloan (1908), Keith and Sterrett (1931), Pardee and Park (1948), Butler (1966), and McCauley and Butler (1966). The most significant gold deposit in the Blacksburg Formation is at the Kings Mountain gold mine, which produced $750,000 to $1,000,000 in gold prior to 1895 (Graton, 1906; Keith and Sterrett, 1931; Pardee and Park, 1948). Descriptions by Supplee (1986) and LaPoint (1992) are based on renewed exploration by Texasgulf Minerals and Metals, Inc., from 1983 to 1988. Other abandoned mines and prospects on gold- and pyrite-bearing quartz veins are part of the Smyrna district (Butler, 1981a).

Stratabound iron deposits are interesting from geologic and historical perspectives (Moss, 1981; Gair, 1989). Those at Yellow Ridge, about 4 km southeast of the town of Kings Mountain, are described by Nunan (1983).

More information on mineral resources is available from Horton and Butler (1981), Posey (1981), and papers in Gair (1989).

## Acknowledgments

This geologic map incorporates initial data accumulated by Horton (1977, pl. 1), with field assistance from Stephen B. Harper, and substantial unpublished data generated by Horton as a byproduct of U.S. Geological Survey (USGS) geologic mapping in the Charlotte 1° × 2° quadrangle (Goldsmith and others, 1988). Yolanda Fong Sam provided assistance with data tabulation and computer graphics. USGS digital compilation by Boris J. Barrios, E. Allen Crider, Danielle Denenny, and James Triplett was partly supported by the National Park Service (NPS) as part of a nationwide Geologic Resources Inventory. The USGS provided additional support through the National Cooperative Geologic Mapping Program.

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# Description of Map Units

[Intrusive rocks are classified according to IUGS nomenclature using normalized values of modal quartz, alkali feldspar, and plagioclase (Streckeisen, 1976). Mineral modifiers are listed in order of increasing abundance for both igneous and metamorphic rocks. In descriptions, minerals are listed in order of decreasing abundance.]

## Unconsolidated Surficial Materials

af **Artificial fill (Holocene)—**Unconsolidated material in areas filled for construction of roads, dams, and buildings

d **Mine dump (Holocene)**

Qal **Alluvium (Holocene)—**Unconsolidated stream deposits of gravel, sand, silt, and clay

Qc **Colluvium (Holocene and Pleistocene)—**Coarse cobbles, boulders, and blocks of quartzite that were transported by gravity and modified by freeze-thaw cycles on the slopes of Kings Mountain and Crowders Mountain

## Intrusive Rocks

Jd **Olivine diabase (Early Jurassic)—**Unmetamorphosed, dark-gray, fine- to medium-grained diabase having uniform composition and texture. Composed of labradorite, augite, olivine, and accessory disseminated magnetite. Ophitic texture is common. Dikes strike northwest and generally range up to 5 m in thickness. Mapped largely on the basis of float; dike thickness increased on map to enhance legibility

Phs **High Shoals Granite (Pennsylvanian)—**Very-light-gray, coarse-grained, porphyritic, gneissic biotite granite or granitic augen gneiss. Consists of oligoclase and albite (35 percent), microcline (25 percent), quartz (22 percent), brown biotite (13 percent), myrmekite (3 percent), sphene (1 percent), magnetite-ilmenite and pyrite (1 percent), and trace amounts of epidote, allanite, zircon and apatite (Horton and Butler, 1977, p. 137). White, euhedral to subhedral microperthitic (5 percent albite) microcline phenocrysts average about 1.5 centimeters (cm) in length. Carlsbad twinning is common. Phenocrysts are subparallel to foliation as defined by biotite. Oligoclase occurs as zoned, euhedral to subhedral crystals which are 1 to 5 millimeters (mm) long. Sodic oligoclase or albite occurs as small grains, some of which are myrmekitic, and as rims around larger oligoclase crystals. Myrmekite also occurs as embayments in microcline where oligoclase is in contact. Lenticular inclusions (screens) of country rock characterize the High Shoals Granite in the Kings Mountain quadrangle

Ms **Spodumene pegmatite (Mississippian)—**White, medium- to coarse-grained, and generally unzoned pegmatite. Composed of spodumene, microcline, quartz, albite, and muscovite. Trace amounts of beryl, manganapatite, ferrocolumbite, cassiterite, and zircon are present. Secondary minerals such as vivianite, fluorapatite, and siderite occur in fractures and vugs. Only spodumene and microcline commonly exceed 2 cm in size, which defines a pegmatite; these crystals are rarely longer than 30 cm. Spodumene and microcline are commonly fractured and the fractures are filled with a sugary matrix of albite and quartz. Yellowish-white muscovite crystals, commonly twisted, are typically less than 2 cm long. Whole-rock Rb-Sr age is 340±10 Ma (2σ) (Kish and Fullagar, 1996). Pegmatites occur as dikes and sills in a narrow belt in and just west of the Kings Mountain shear zone, and are most abundant in and near bodies of amphibolite. Pegmatites range from nonfoliated to strongly foliated, and locally crosscut foliation in the Kings Mountain shear zone. Locally, particularly near wall-rock contacts, blastomylonitic or augen-gneiss texture is developed

Mp **Granite pegmatite (Mississippian)—**White, coarse-grained pegmatite composed mainly of microcline, oligoclase, quartz, muscovite, and biotite. Euhedral garnet as much as 1 cm in diameter is a common accessory. Other accessories include magnetite-ilmenite, zircon, apatite, beryl, and chlorite. Composition is similar to that of the Cherryville Granite, but muscovite is more abundant and biotite is less abundant. Large books of mica are undeformed. Textures visible in hand samples include graphic intergrowths of feldspar and quartz, overgrowths of muscovite on biotite, and plumose cones of muscovite intergrown with quartz. Whole-rock Rb-Sr age is 341±40 Ma (2σ) (Kish and Fullagar, 1996). Occurs as swarms of irregular dikes, sills, and pods up to a few meters thick near southeastern contact of Cherryville Granite. Pegmatite swarms shown by overprint pattern

**Cherryville Granite (Mississippian)**

Mcp Coarse-grained granite and pegmatite—Very-light-gray, coarse-grained biotite-muscovite granite grading into pegmatite and crosscut by pegmatite dikes; granite composed mainly of microcline, oligoclase, quartz, muscovite, and biotite; includes graphic granite; weakly foliated

Mc Muscovite-biotite granite—Very-light-gray, medium- to coarse-grained, and weakly foliated granite. Consists of microcline, oligoclase, quartz, biotite, and muscovite. Accessories include magnetite-ilmenite, apatite, zircon, chlorite, epidote, and rarely beryl. Contacts are mostly concordant but locally discordant to country-rock foliation. Whole-rock Rb-Sr age is 351±20 Ma (2$\sigma$) (Kish and Fullagar, 1996)

Dtg **Toluca Granite (Devonian)—**Very-light-gray, medium- to coarse-grained, strongly foliated biotite granite and subordinate granodiorite composed of oligoclase, microcline, quartz, biotite, and minor muscovite. Accessories include garnet, monazite, ilmenite, rutile, sillimanite, apatite, and zircon. Bodies are generally conformable to regional foliation in surrounding muscovite-biotite gneiss; foliation within the granite is not always parallel to contacts, perhaps due to rheological differences. Recent ion-microprobe U-Pb geochronology of zircons indicates a Devonian age of ~378 Ma for the Toluca Granite (Mapes, 2002).

Pzgd **Metagabbro and metadiorite (Paleozoic?)—**Dark-gray, medium- to coarse-grained hornblende-quartz gabbro and hornblende-quartz diorite. Textures range from massive to strongly foliated and gneissic. Composed mainly of labradorite or andesine, green hornblende, and quartz, with variable amounts of epidote, accessory biotite, and magnetite. Small bodies crop out in the southern part of the Kings Mountain quadrangle. Dikes of similar rock (too small to show on the map) crosscut the metatonalite (Zto)

Zts **Silicified metatrondhjemite (Neoproterozoic)—**White to tan to pale-green, massive metatrondhjemite; composed mainly of plagioclase and quartz; accessory minerals include magnetite (0–3 percent), disseminated pyrite (1–2 percent), sericitic white mica, and chlorite. Contains abundant crosscutting quartz veins and gold-bearing mineralized zones. Occurs as a single body previously described as silicified porphyry (LaPoint, 1992). Interpreted as hypabyssal(?) intrusion into metadacite of undivided metadacite and metatrondhjemite unit (Zbdt)

Ztr **Metatrondhjemite and amphibole gneiss (Neoproterozoic)—**Metatrondhjemite (felsic gneiss of trondhjemite composition) and less abundant amphibole gneiss interlayers. Metatrondhjemite is very light gray to yellowish gray, fine to medium grained, weakly foliated to schistose to gneissic, and composed mainly of plagioclase (oligoclase and albite) and quartz with accessory biotite, muscovite, and chlorite. Amphibole gneiss is dark greenish gray, mostly medium grained, and composed mainly of plagioclase, actinolite, hornblende, and chlorite. Interlayering at centimeter-to-meter scales is mostly concordant, but metatrondhjemite locally crosscuts amphibole gneiss (Murphy and Butler, 1981). Previously mapped as "metatrondhjemite" (Goldsmith and others, 1988); coextensive with rocks to the southwest mapped as "interlayered mafic and felsic gneiss" (Howard, 2004), "metatrondhjemite-amphibolite complex" (Murphy and Butler, 1981), and "metatrondhjemite with numerous mafic dikes" (Butler, 1981b)

Zto **Metatonalite (Neoproterozoic)—**Largely very-light-gray to medium-gray, medium- to coarse-grained metatonalite composed of oligoclase and quartz with minor albite, biotite, muscovite, and locally hornblende. Common accessories include epidote, sphene, chlorite, magnetite, pyrite, zircon, and apatite. Microcline and orthoclase are present in some places. Unit is predominantly biotite tonalite but contains minor amounts of hornblende tonalite, trondhjemite, and granodiorite. Textures range from weakly foliated to schistose. Angular xenoliths and granitic textures indicate an intrusive origin. May have originated as shallow intrusions associated with volcanogenic deposits of the Battleground Formation. Unit equivalent, in part, to "metatonalite and volcaniclastic rocks" of Howard (2004)

## Inner Piedmont Layered Metamorphic Rocks

ꞒZa **Amphibolite (Cambrian or Neoproterozoic)—**Dark-gray, fine-grained, equigranular, layered amphibolite composed of a metamorphic mineral assemblage of plagioclase and hornblende with smaller amounts of diopside, calcite, epidote, and quartz. Accessories include sphene, apatite, and pyrrhotite. Biotite and chlorite are present adjacent to schist layers. Calcite-rich layers occur locally

ꞒZs **Muscovite schist (Cambrian or Neoproterozoic)—**Yellowish-gray, medium-grained schist composed mainly of muscovite, quartz, minor biotite, and locally oligoclase. Garnet, staurolite, and kyanite are locally present; secondary chlorite is a common accessory. Muscovite flakes average 2 mm in length and quartz grains average 1 mm in diameter. Weathered schist is grayish pink to pale red. Composition indicates metamorphosed pelitic sediment. Unit is coarse grained and quartz-rich near Cherryville Granite and associated pegmatites. Radial clusters of tourmaline are common in schist near spodumene pegmatite

€Zbg **Muscovite-biotite gneiss (Cambrian or Neoproterozoic)—**Light-gray to dark-gray, fine- to medium-grained, muscovite-biotite gneiss composed of quartz, oligoclase, biotite, muscovite, and lesser amounts of sillimanite and garnet; accessory magnetite is common. The gneiss is inequigranular, well foliated and layered, and locally mylonitic, and it contains minor schist interlayers. Equivalent to “unit 6” of Overstreet and others (1963)

## Kings Mountain Sequence of the Carolina Terrane

**Blacksburg Formation (Neoproterozoic)—**The Blacksburg Formation is composed mostly of phyllitic metasiltstone (Zbls) with discontinuous lenses of hornblende gneiss and amphibolite (Zbla), marble at two stratigraphic levels (Zblg, Zblm), and discontinuous beds and lenses of laminated micaceous quartzite (Zblq) at different stratigraphic levels. Chlorite phyllonite (Zblc) occurs along the Kings Creek shear zone

Zblc Chlorite phyllonite—Light-greenish-gray, fine- to medium-grained chlorite phyllonite. Composed primarily of chlorite (20–40 percent), quartz, and plagioclase. Common accessory minerals are epidote, hornblende, opaque minerals, white mica, and graphite. Texture is phyllonitic or blastomylonitic. Plagioclase porphyroclasts up to 4 mm in diameter are subrounded to rounded and strongly saussuritized. The abundance of chlorite and plagioclase with smaller amounts of hornblende and epidote suggests a retrogressively altered hornblende gneiss. Lenses of light-bluish-gray, banded dolomitic marble lie within the chlorite phyllonite at the Kings Mountain gold mine (Keith and Sterrett, 1931, fig. 4; LaPoint, 1992)

Zbls Phyllitic metasiltstone—Light-gray to dark-gray, fine-grained, variably phyllitic metasiltstone, composed mainly of quartz and white mica, and smaller amounts of biotite; local accessory minerals include garnet, chloritoid, chlorite, calcite, graphite, and opaque minerals. Quartz grains average about 0.1 mm in diameter. Generally well foliated but locally blocky and quartz-rich. Contacts with other members of the Blacksburg Formation are gradational and interfingering. Generally, quartz-rich metasiltstone is near quartzite and micaceous phyllite is near marble and amphibolite. Locally shows composite planar fabrics and “mica fish” texture

Zblm Marble member at Dixon Branch (informal name)—Very-light-gray to medium-bluish-gray, fine- to coarse-grained calcite marble and dolomitic marble. Composed of calcite or dolomite (80–90 percent), phlogopite, and locally tremolite. Graphite is a common accessory. Compositional banding is well defined by layers of pale-olive calc-silicate rock composed of tremolite, quartz, and phlogopite with smaller amounts of calcite or dolomite, epidote, and pyrite. Layers of schistose marble contain white mica and chlorite as major constituents. Layers of dark-gray, fine-grained amphibolite composed of hornblende and quartz with minor epidote, calcite, and biotite are also present. Contacts between amphibolite layers and marble are sharp. Maximum thickness 200 m. Unit is well exposed in open-pit quarries

Zblg Gaffney Marble Member—Very-light-gray to medium-bluish-gray, fine- to coarse-grained calcite marble and dolomitic marble; commonly banded and locally schistose. Similar to marble member at Dixon Branch (Zblm) but generally thinner and not as well exposed as that unit in these quadrangles

Zblq Laminated micaceous quartzite—White to yellowish-gray, fine- to medium-grained, equigranular, laminated micaceous quartzite with phyllite (schist) layers. Composed of anhedral quartz and disseminated white mica with variable amounts of accessory biotite and magnetite. Laminated appearance is caused partly by foliation banding and partly by rhythmic layering with phyllite (schist). Individual quartzite and phyllite layers typically have a thickness of a few meters or less. Crops out as discontinuous beds that are not thicker than 140 m

Zbla Hornblende gneiss and amphibolite—Dark-gray, fine- to coarse-grained, essentially equigranular hornblende gneiss and amphibolite. Composed of hornblende, plagioclase, quartz, epidote, opaque minerals, and in some places augite. Occurs sporadically as discontinuous, foliation-parallel lenticular sheets

**Battleground Formation (Neoproterozoic)**—The lower part of the formation consists of metamorphosed pyroclastic and epiclastic rocks (Zbht, Zbfs, Zbct, Zbmps, Zbvc, and Zbmp) interlayered with the biotite-muscovite schist (Zbms). The upper part of the formation consists of interlayered metasedimentary rocks, including quartz-sericite phyllite and schist (Zbs), quartz-pebble metaconglomerate (Zbc, Zbd, Zbmc), aluminous quartzite (Zbaq), micaceous quartzite (Zbmq), manganiferous rock (Zbj), and smaller amounts of felsic metavolcanic rock (Zbmp and part of Zbdt)

Zbdt Metadacite and metatrondhjemite—Very-light-gray to yellowish-gray, fine- to medium-grained, felsic muscovite-biotite-quartz-plagioclase gneiss interpreted as metadacite and metatrondhjemite (undivided). Consists of plagioclase, blue quartz, and minor biotite; common accessories include sericitic white mica and chlorite. Locally mylonitic. Metadacite of this unit is intruded by silicified metatrondhjemite (Zts). Relicts of primary structures in drill core from the Kings Mountain gold mine area suggest that dacite of this uppermost unit within the Battleground Formation is stratigraphically overlain by the Blacksburg Formation (LaPoint, 1992), although contacts are highly sheared. Unit includes rocks previously mapped as Bessemer Granite (Keith and Sterrett, 1931), felsic gneiss (Horton, 1977), metatrondhjemite (Goldsmith and others 1988), and metadacite (LaPoint, 1992)

Zbs Quartz-sericite phyllite and schist—Very-light-gray to light-bluish-gray, light-brown, or yellowish-gray, very-fine- to medium-grained phyllite and schist, composed mainly of quartz and sericitic white mica (muscovite and (or) paragonite). Local accessory and trace minerals include plagioclase (oligoclase or albite), biotite, garnet, chloritoid or staurolite, kyanite, andalusite, chlorite, graphite, tourmaline, zircon, pyrite, and hematite, depending in part on metamorphic grade. Chloritoid porphyroblasts, 0.1 to 10 mm long, are common but not in association with biotite. Unit is locally quartzose; high-alumina minerals are most abundant near aluminous quartzite. Disseminated hematite is responsible for the bluish-gray color in parts of the unit. Contacts with interlayered metavolcanic facies are gradational and interfingering. Unit generally equivalent to “quartz schist, metasiltstone, and phyllite” of Howard (2004) and “metasedimentary rocks” (“msd”) of Murphy and Butler (1981); includes “chloritoid schists” (“csu” and “csl”) of Espenshade and Potter (1960, pl. 7) and informal “Lake Montonia sequence” of LaPoint (1992)

Zbmc Crowders Creek Metaconglomerate Member—Very-light-gray to yellowish-gray, coarse-grained, schistose quartz-pebble metaconglomerate. Quartz pebbles average about 1 cm in diameter and are moderately well sorted, generally subrounded, and flattened in the plane of schistosity. The matrix is composed of quartz, white mica, chlorite, and accessory magnetite and pyrite. Ranges from clast-supported metaconglomerate, to matrix-supported pebbly metasandstone with fewer clasts, to flaggy micaceous metasandstone. Maximum thickness about 15 m. Described by France and Brown (1981, p. 96) as “bed E” and previously mapped as the Draytonville Conglomerate Member (Keith and Sterrett, 1931) or “schistose conglomerate” (Espenshade and Potter, 1960)

Zbmq Micaceous quartzite—White to yellowish-gray, fine- to medium-grained, equigranular, micaceous quartzite (metasandstone) with phyllite or schist layers. Composed mostly of quartz and disseminated white mica with variable amounts of accessory biotite and magnetite. Schist and phyllite layers are generally a few meters thick or less. Individual beds, including schist layers, are not thicker than 50 m. Occurs as discontinuous beds and lenses at several stratigraphic levels. Micaceous quartzite (Zbmq) at Yellow Ridge is interpreted to be stratigraphically higher than the Jumping Branch Manganiferous Member (Zbj) and lower than the Crowders Creek Metaconglomerate Member (Zbmc)

Zbd Draytonville Metaconglomerate Member—Very-light-gray to medium-light-gray, coarse-grained, quartz-pebble metaconglomerate and pebbly metasandstone; matrix-supported. Quartz pebbles are moderately sorted, rarely larger than 1 cm, and flattened in the plane of foliation (commonly at an angle to bedding). The medium-light-gray matrix is composed of poorly sorted quartz grains averaging 1.5 mm in diameter, white mica, and variable smaller amounts of chloritoid and opaque minerals. Metaconglomerate grades laterally into massive to friable metasandstone northeast of State Route 161. Unit is crudely sorted, with poorly developed graded bedding observed in a few places. Thickness ranges from about 10 to 34 m. Described at Draytonville Mountain, S.C. (Hatcher and Morgan, 1981), at another locality in South Carolina (Horton and others, 1981, p. 239–240), and in North Carolina under the informal name “bed D” (France and Brown, 1981). Stratigraphically higher than the Jumping Branch Manganiferous Member (Zbj)

Zbj Jumping Branch Manganiferous Member—Light-gray to light-brown, fine-grained, equigranular garnet (50–70 percent)-quartz rock (coticule or gondite) closely interlayered with light-gray to light-brown, fine-grained, quartz-sericite phyllite and schist. Accessories include biotite, hematite, and locally hornblende and white mica.

The garnet is spessartine-almandine; grains are rounded, average 0.1 mm in diameter, and although widely disseminated, are concentrated in rhythmic bands less than 1 cm thick. Quartz grains are polygonal and average 0.15 mm in diameter. Unlike the relatively massive coticule or gondite, the quartz-sericite phyllite and schist interlayered with it is strongly foliated. It is composed of quartz, white mica, biotite, and variable amounts of spessartine-almandine. Unweathered rock (rarely exposed) resembles the adjacent quartz-sericite phyllite and schist (Zbs). Weathered rock, saprolite, and soil are readily distinguished by the characteristic dusky-brown stain of manganese oxides such as pyrolusite and psilomelane

Zbc Dixon Gap Metaconglomerate Member—Very-light-gray to medium-light-gray, coarse-grained quartz-pebble metaconglomerate. Approximately 90 percent of the clasts are white quartz pebbles. Other clasts include medium-dark-gray magnetite-bearing or ilmenite-bearing quartzite, hornblende gneiss, and quartz-rich phyllite. Pebbles average about 1 cm in diameter and are moderately sorted. They are flattened in the plane of foliation, which is commonly at an angle to bedding, and elongated, having length-to-width ratios ranging from 1:1 to 5:1. The medium-light-gray matrix is composed of poorly sorted quartz grains averaging 1.5 mm in diameter, with white mica and variable smaller amounts of chloritoid, kyanite, and opaque minerals. Unit is typically clast-supported but locally grades into matrix-supported layers having fewer clasts. Poorly developed graded beds at several places, notably in the vicinity of Dixon Gap and on both limbs of the Sherrars Gap synform, provide stratigraphic tops. Estimated thickness ranges from 10 to 40 m. Relatively thick segments commonly crop out along ridges. Described at the type locality by Horton and Butler (1977, p. 130–132) and Horton and Butler (1986, p. 241–242) and more generally under the informal name “bed C” by France and Brown (1981). Although previously lumped with the “Draytonville Conglomerate Member” by Keith and Sterrett (1931), the Dixon Gap Metaconglomerate Member (unlike the Draytonville Metaconglomerate Member, (Zbd) is stratigraphically lower than the Jumping Branch Manganiferous Member (Zbj)

Zbaq Aluminous quartzite—Includes kyanite quartzite and sillimanite quartzite depending on metamorphic rank. The kyanite quartzite is light gray to medium gray and composed of aggregates or blades of kyanite up to 1 cm long in a matrix of fine-grained quartz. Common accessory minerals include andalusite, biotite, white mica, magnetite, and pyrite. Kyanite is typically poikiloblastic with quartz inclusions; it occurs as mats of crystals parallel to foliation or as radial clusters crossing foliation. Where present, andalusite has alteration rims of clay minerals and is cut by unaltered kyanite. Kyanite quartzite crops out as long discontinuous beds and lenses, most of which are stratigraphically equivalent to the Dixon Gap Metaconglomerate Member (Zbc). Two thin beds of sillimanite quartzite crop out near McGill Branch within 500 m of the High Shoals Granite. The medium-gray rock is composed of sillimanite (up to 40 percent) and fine-grained equigranular quartz. Minor constituents include kyanite, andalusite, biotite, white mica, magnetite, and pyrite. Sillimanite occurs as tabular blades up to 4 mm long as well as radial and matted aggregates of fibrolite. Kyanite and andalusite, where present, are rimmed by fibrolitic sillimanite

Zbmp Mottled phyllitic metatuff—Light-bluish-gray to medium-dark-gray, stratified, well-foliated, mottled sericite schist and phyllite. Unit is a metamorphosed pyroclastic rock (lapilli metatuff) composed of lithic and crystal (plagioclase) clasts in a fine-grained matrix of quartz, plagioclase, sericitic white mica, and finely disseminated iron-titanium oxides with variable smaller amounts of chloritoid, chlorite, epidote, and unidentified opaque minerals. The mica is interlayered paragonite and muscovite or a mica of intermediate composition; margarite has also been reported. Angular, matrix-supported clasts, which are lapilli-size or smaller, are poorly sorted, heterolithologic, and flattened in the plane of foliation. The distinctive mottled appearance is caused by finely disseminated iron-titanium oxides which are generally more abundant in the matrix than in the clasts. Most clasts are nearly white, but dark-gray clasts also occur. Some clasts resemble rocks in the underlying massive metatuff (Zbct) unit; others have flattened tuning-fork shapes and bubble-wall texture that suggest relict pumice fragments. Individual layers are well-sorted with some possible graded bedding. Locally interbedded with quartz-sericite phyllite and schist (Zbs). Unit equivalent to “mottled phyllite (lapilli metatuff)” of Howard (2004)

Zbvc Volcanic metaconglomerate—Yellowish-gray to medium-gray, metamorphosed polymict volcanic conglomerate. Contains clasts, mostly pebbles, of (1) gray ferruginous quartz rock with abundant disseminated iron-titanium oxides,

(2) white polycrystalline quartz, (3) biotite-muscovite schist (Zbms), (4) mottled schistose pyroclastic rock (Zbmp), and (5) massive metatuff (Zbct). The clasts are angular to subrounded and poorly sorted with a continuous gradation in size from 0.1 mm to 8 cm. Quartz grains, which range in size from fine sand to small pebbles, are typically more rounded than the schistose and metavolcanic clasts. Relict (flow?) layering is preserved in some metavolcanic fragments. Clasts are flattened in the plane of schistosity, which is generally not parallel to bedding. The matrix is composed of quartz, white mica, and commonly biotite. Crude graded bedding was observed in a few places

Zbmps Siliceous metatuff—Very-light-gray to medium-gray, fined-grained, quartzose equivalent of mottled phyllitic metatuff (Zbmp). Disseminated pyrite suggests volcanogenic hydrothermal silicification, and epiclastic mixing with quartzose sediment is also possible. Resistant unit underlies linear ridges, including the site of the 1780 Battle of Kings Mountain in Kings Mountain National Military Park

Zbct Plagioclase-crystal metatuff—Medium-gray to dark-gray, massive to schistose, andesitic to dacitic metamorphosed volcaniclastic rock. Composed of plagioclase phenocrysts up to 6 mm long in a very fine grained matrix. The matrix consists of quartz and plagioclase with smaller amounts of white mica, epidote, chlorite, calcite, biotite, pyrite, and other opaque minerals. Trace minerals include green amphibole, zircon, and apatite. Locally contains as much as 10 percent calcite. Plagioclase phenocrysts are euhedral to subhedral and they commonly have cavities and embayments. Angular lapilli-size lithic clasts similar in composition to the matrix are locally recognizable. Grain sizes averaging less than 0.01 mm commonly give the matrix a cherty appearance. Equivalent to “crystal metatuff” of Howard (2004)

Zbms Biotite-muscovite schist— Very-light-gray to light-bluish-gray, light-brown, or yellowish-gray, very fine to medium-grained schist and phyllite, composed mainly of quartz, sericitic white mica (muscovite and (or) paragonite), and minor biotite. Local accessory minerals, depending in part on metamorphic grade, include oligoclase and albite, garnet, chloritoid or staurolite, kyanite or sillimanite locally overgrowing andalusite, chlorite, tourmaline, pyrite, and hematite. Kyanite, sillimanite, and andalusite are most abundant near aluminous quartzite. Contacts with metamorphosed pyroclastic and epiclastic rocks are gradational and interfingering. Near Henry Knob the schist contains round granules and small pebbles of quartz. Unit equivalent to “biotite-chlorite-muscovite schist” of Howard (2004); includes “biotite schist and gneiss” (“bs”) of Espenshade and Potter (1960, pl. 7) and “feldspathic biotite-muscovite schist” (“fbms”) of Horton (1977, pl. 1)

Zbfs Felsic schist and gneiss (metafelsite)—White to light-gray, fine- to medium-grained feldspathic biotite schist and gneiss. Composed of calcic oligoclase and albite, quartz, biotite, white mica, and rarely microcline or orthoclase. Sillimanite, garnet, and staurolite occur locally. Foliation is weakly to strongly developed. Euhedral to subrounded plagioclase phenocrysts up to 2 mm long are common. Brown biotite is evenly disseminated or in clusters along foliation planes. Unit probably is metamorphosed dacitic tuff and mudstone. Crops out as lenticular and interfingering bodies in the eastern part of the map area

Zbht Metavolcanic hornblende gneiss—Medium-dark-gray to dark-greenish-gray metavolcanic gneiss, composed primarily of hornblende (10–45 percent), plagioclase (andesine to oligoclase), and quartz. Common accessories include biotite, epidote, microcline, sphene, opaque minerals, garnet, and apatite. Hornblende laths range from 0.1 to 3 mm in length. Quartz and much of the plagioclase is equigranular and fine grained, averaging about 0.1 mm. Euhedral to subhedral plagioclase phenocrysts up to 5 mm long are common. Angular lithic clasts up to 4 mm long are less abundant than phenocrysts. Crystal and lithic clasts make up as much as 40 percent of some layers, and most rocks appear to have been andesitic and dacitic crystal tuff or lithic crystal tuff. Largest bodies are on the eastern side of the map area