North Carolina Department of Environmental Quality
Division of Energy, Mineral and Land Resources
William E. Toby Vinson, Jr., Interim Director
Kenneth B. Taylor, State Geologist

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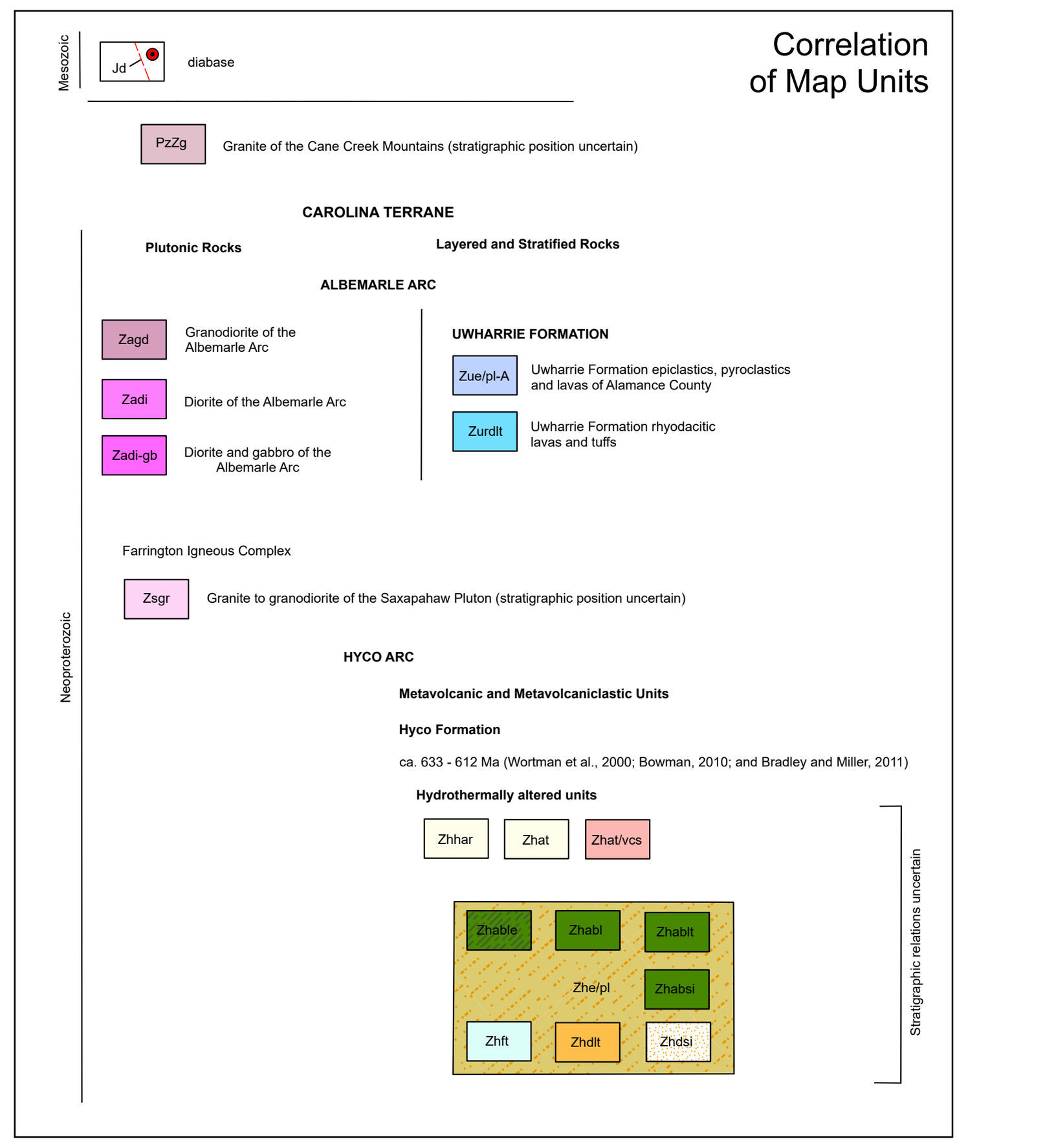
Correlation of Map Units



INTRODUCTION

This compiled geologic map, partially supported by the U.S. Geological Survey (USGS), National Cooperative Geologic Mapping Program under STATEMAP marks the first year of a multi-year project to provide Alamance County with detailed geologic data. Additionally, the mapping is part of a larger project to compile the entire bedrock portion of the Chapel Hill 30' x 60' Quadrangle (Chapel Hill 100K) in support of the USGS US Geoframework Initiative's (USGI) vision for a nation-wide, seamless geologic map.

The Snow Camp and northern portion of the Crutchfield Crossroads Quadrangles are wholly located in Alamance County. The Kimesville and Liberty Quadrangles cover portions of Randolph, Alamance, and Guilford County. The entire study area is located within the Chapel Hill 100K Quadrangle.

This compilation effort
As part of the compilation effort, the line work from the NCGS Region G Geologic map (Carpenter, 1982) was utilized and adjusted or modified according to new field observations and edge-matched with the Saxapahaw Quadrangle and Chatham County geologic maps (Bradley et al., 2022 and Bradley, 2022, respectively). From July 2022 to June 2023, NCGS staff conducted targeted foot and vehicle traverses to validate contacts from the Region G Map (Carpenter, 1982) and to collect field data to draw evidence-supported contacts. Additionally, station data was compiled from past workers when available (Clark, 2019; Hughes, 1987 and Schmidt et al., 2006).

Geologic Background and Past Work
Pre-Mesozoic crystalline rocks in the Snow Camp, Kimesville, Crutchfield Crossroads and Liberty quadrangles are part of the redefined Hyco arc and Albemarle arc (Hibbard et al., 2013) within the Neoproterozoic to Cambrian Carolina terrane (Hibbard et al., 2002; and Hibbard et al., 2006). In the region of the map area, the Carolina terrane can be separated into three lithotectonic units: 1) the Hyco arc, 2) the Aaron Formation of the redefined Virgilina sequence (Hibbard et al., 2013), and 3) the Albemarle arc (Hibbard et al., 2013). The Hyco arc consists of the Hyco Formation which includes ca. 612 to 633 Ma (Wortman et al., 2000; Bowman, 2010; Bradley and Miller, 2011) metamorphosed layered volcaniclastic rocks and plutonic rocks. Available age dates (Wortman et al., 2000; Bradley and Miller, 2011) indicate the Hyco Formation may be divided into lower (ca. 630 Ma) and upper (ca. 615 Ma) portions with an apparent intervening hiatus of magmatism. In northeastern Chatham County, Hyco Formation units are intruded by the East Farrington pluton and associated West Farrington pluton. Two age dates are available for the East Farrington Pluton: a recent date of 569.0 ± 1.1 Ma from Goliber (2020) and a previous date of ca. 579 Ma from Tadlock and Loewy (2006). The Aaron Formation consists of metamorphosed layered volcaniclastic rocks with youngest detrital zircons of ca. 578 and 588 Ma (Samson et al., 2001 and Pollock, 2010, respectively). Recent work in western Chatham County (Bradley, 2022) has revealed that rocks previously interpreted to be part of the Aaron Formation contain detrital zircons as young as ca. 534 Ma. As such, a revision of the characteristics of the Aaron Formation are being evaluated.

The Hyco arc lithologies were folded and subjected to low-grade metamorphism during the ca. 578 to 554 Ma (Pollock, 2007; Pollock et al., 2010) Virgilina deformation (Glover and Sinha, 1973; Harris and Glover, 1985; Harris and Glover, 1988; and Hibbard and Samson, 1995). In the region, original layering of Hyco Formation lithologies is interpreted to range from moderately to steeply dipping due to close folds that are locally overturned to the southeast.

The Albemarle arc, best exposed in the western portions of the Carolina terrane, is a sequence of felsic to mafic volcanic rocks and a thick volcaniclastic sequence. Felsic to mafic plutonic rocks are also associated with the Albemarle arc. The Hyco arc and Albemarle arc lithologies were folded and subjected to greenschist facies metamorphism during the Cherokee orogeny (Hibbard et al., 2013).

Map units of metavolcanic and metavolcaniclastic rocks include various lithologies that when grouped together are interpreted to indicate general environments of deposition. The dacitic lavas and tuffs unit is interpreted to represent dacitic domes and proximal pyroclastics. The andesitic to basaltic lavas (with tuffs or conglomerates) units are interpreted to represent eruption of intermediate to mafic lava flows and associated pyroclastic and/or epiclastic deposits. The epiclastic/pyroclastic units are interpreted to represent deposition from the erosion of dormant and active volcanic highlands. Some of the metavolcaniclastic units within the map area display lithologic relationships similar to dated units present in northern Orange and Durham Counties.

Abundant evidence of brittle faulting at the outcrop scale and large-scale lineaments (as interpreted from hillshade LiDAR data) are present in the map area. The brittle faulting and lineaments are interpreted to be associated with Mesozoic extension. Complex brittle faulting is likely present in the quadrangle. Dikes of Jurassic-aged diabase intrude the crystalline rocks of the map area. Quaternary-aged alluvium is present in most major drainages.

Mineral Resources
There is one active crushed stone quarry in the map area (Snow Camp Quarry), two abandoned sand and gravel pits, an abandoned copper mine (Faust Mine), a gold prospect (Robeson Gold Prospect), an abandoned sericite mine (Woods Mine and also known as the Jones Pyrophyllite-Sericite Mine), the abandoned Snow Camp Mine for pyrophyllite, two pyrophyllite prospects (Snow Camp South and Major Hill) and one unnamed copper prospect. The locations of the active quarry and abandoned mines and prospects are indicated on the map.

Parts of the southern portion of the quadrangle were mapped at reconnaissance-scale and satellite remote sensing as part of the Schmidt et al. (2006) study. The area was identified as containing large zones of high-sulfidation alteration with the potential for pyrophyllite and gold resources, including the abandoned Snow Camp Pyrophyllite mine (located in the Crutchfield Crossroads Quadrangle).

Description of Map Units
All pre-Mesozoic rocks in the map area have been metamorphosed to at least the chlorite zone of the greenschist metamorphic facies. Many of the rocks display a weak or strong metamorphic foliation. Although subjected to metamorphism, the rocks retain relict igneous, pyroclastic, and sedimentary textures and structures that allow for the identification of protolith rocks. As such, the prefix "meta" is not included in the nomenclature of the pre-Mesozoic rocks described in the quadrangle. Jurassic diabase dikes are unmetamorphosed.

The nomenclature of the International Union of Geological Sciences subcommission on igneous and volcanic rocks (IUGS) after Le Maitre (2002) is used in the classification and naming of the units. The classification and naming of the rocks are based on relict igneous textures, modal mineral assemblages, or normalized mineral assemblages when whole-rock geochemical data is available. Pyroclastic rock terminology follows that of Fisher and Schmincke (1984).

Intrusive and Metaintrusive Units

Jd

Jd – Diabase: Black to greenish-black, fine- to medium-grained, dense, consists primarily of plagioclase, augite and may contain olivine. Occurs as dikes up to 100 ft wide. Diabase typically occurs as spheroidally weathered boulders with a grayish-brown weathering rind. Red station location indicates outcrop or boulders of diabase.

PzZg

PzZg – Granite of the Cane Creek Mountains: Distinctively pink to orange-pink, leucocratic, medium-grained hypidomorphic granular granite. Locally silicified. Silicification causes parts of rock to break conchoidally, similar to felsic volcanic rocks. Potassium feldspar minerals are obvious; mafic minerals are composed of aggregates of chlorite. This unit intrudes rocks interpreted to be related to Albemarle Arc. Locally leucocratic, medium-grained granodiorite. Similar in appearance to Zagd. Equivalent to Granite intrusions in the Cane Creek Mountains (Zcg) of Schmidt et al. (2006). Schmidt et al. (2006) interpreted this to be the youngest rock in the study area, a Carboniferous-age pluton, but lacks an age date.

Albemarle Arc Plutons

Hibbard et al. (2006) indicate that the plutonic rocks in the northern part of the map area are part of the Greensboro Igneous Suite. Hibbard et al. (2007) reported a Nd-Sm isotopic age of ca. 545 Ma for a diorite from the Hicone quarry (~14 miles from the map area) within the Greensboro Igneous Suite. In the map area, foliated map-scale units, interpreted to be xenoliths of Hyco Formation rocks, are present in the diorite-gabbro (Zadi-gb) and granodiorite (Zagd) units. Hyco Formation map units are truncated by these plutons and outcrop-scale xenoliths of foliated Hyco Formation rock types have been observed in the granodiorite body. Based on these observations, the plutons are likely Albemarle arc related.

Zagd

Zagd – Granodiorite of the Albemarle arc: Unfoliated to locally very weakly foliated, leucocratic (CI less than 10), very light gray to yellowish gray, medium- to coarse-grained, hypidiomorphic granular, metamorphosed granodiorite to tonalitic granodiorite. Mafic minerals present in rock are biotite intergrown with chlorite. Weathering of rock produces distinctive coarse quartz sand grains in soil. Resistant, andesitic to basaltic, spheroidal boulders are common throughout the pluton and are interpreted as xenoliths. Cross cutting dikes of similar mineralogy are present in Hyco Formation rock types. Appears to crosscut the Zadi-gb unit. Pluton map pattern truncates Hyco Formation volcanics and pluton contains foliated xenoliths of volcanic rocks; as such, the pluton is interpreted to be related to the ca. 546 Ma Roxboro pluton (Wortman et al., 2000).

Zadi

Zadi – Diorite of the Albemarle arc: Mesocratic (CI~50), greenish-gray to grayish-green, fine- to medium-grained, metamorphosed, hypidiomorphic granular diorite. Major minerals include plagioclase and amphibole. Plagioclase crystals are typically sericitized and saussuritized. Amphiboles are typically altered to chlorite and actinolite masses. Gabbro intermingled locally. Locally, microdiorite to andesitic-textured rock present.

Zadi-gb

Zadi-gb – Diorite and gabbro of the Albemarle arc: Mesocratic (CI~50) to melanocratic, medium-grained, equigranular, hornblende diorite intermingled with dark-gray to greenish-gray to black, medium-grained gabbro with pyroxene. Plagioclase crystals are typically saussuritized and exhibit a greenish color. Cm- to m-scale enclaves of greenstone, either very fine-grained diorite or andesite, are locally abundant throughout the pluton. Local occurrences of dikes of Zagd.

Farrington Related Plutons (?)

Zsgr

Zsgr - Granite to granodiorite of the Saxapahaw pluton: Mainly, leucocratic, medium-grained hypidomorphic granular, granite to granodiorite. Quartz grains are conspicuous and weather in positive relief. Mafic minerals are composed of aggregates of chlorite and epidote (likely from the alteration of biotite). Schmidt et al. (2006) interpreted the pluton as being noticeably silicified. Schmidt et al. (2006) reported several whole rock and point count analyses with interpreted rock types included granite, porphyritic granite, granite porphyry, porphyritic granodiorite and quartz monzonite. Based on map pattern and intrusive relationships (high angle truncation of Hyco Formation units), the Saxapahaw pluton may be related to the Farrington pluton family or Albemarle arc plutonism. Ingle (2003) reported a discordant age from the pluton with an upper intercept of 605 +-7.4 Ma.

Uwharrie Formation

Zue/pl-A

Zue/pl-A – Uwharrie Formation epiclastics, pyroclastics and lavas of Alamance County: Grayish-green to greenish-gray, metamorphosed tuffaceous sandstones, conglomeratic sandstones, siltstones and minor phyllite. The siltstones typically are weakly phyllitic. Contains lesser amounts of tuff and intermediate to mafic lavas. Quartz and feldspar crystal fragments are common in the sedimentary components, tuffs and lavas. Similar looking rocks in Chatham County yielded an U-Pb zircon age of 548.7 ± 1.1 Ma (Goliber, 2020). The unit is interpreted to be in unconformable contact with adjacent Hyco Formation units.

Zurdlt

Zurdlt – Uwharrie Formation rhyodacitic lavas and tuffs: Gray to dark gray, siliceous, aphanitic dacites and tuffs, quartz-bearing tuffs and quartz-dacite porphyry. Dacites and tuffs are vitric and moderately foliated.

Hyco Formation

Zhhar

Zhhar – Hydrothermally altered rocks: Mixed unit of hydrothermally altered rocks consisting of: dense siliceous cryptocrystalline rock; quartz-pyrophyllite rocks, +- kaolinite, andalusite, chloritoid, sericite, paragonite and iron oxides; quartz-sericite rocks, +- paragonite, k-feldspar and iron oxides; and quartz-chloritoid-chlorite rocks, +- sericite and hematite. Described in detail by Hughes (1987) and Schmidt et al. (2006).

Zhat

Zhat – Altered tuffs: Very light gray to light greenish-gray (whitish in areas) with red and yellow mottling. Alteration consists of silicified, sericitized and pyrophyllitized rock. Sericite phyllite, pods of pyrophyllite, and quartz + pyrophyllite rock all with less than 1 mm to 2 mm diameter weathered sulfides are common. Fine-grained chloritoid porphyroblasts (less than 1 mm) are present in some pyrophyllite bearing rocks. Relict lithic clasts and kaolinitized feldspar crystal shards are visible in some exposures. Relict structures are obliterated in heavily altered rocks. Map area contains boulders (up to several feet in diameter) and outcrop of massive milky quartz and quartz + sericite rock.

Zhat/vcs

Zhat/vcs - Altered tuffs and volcaniclastic sedimentary rocks: Mixed unit of altered volcaniclastic rocks and volcaniclastic sedimentary rocks. Alteration consists of silicified, sericitized and pyrophyllitized rock. Chloritoid locally present. Volcaniclastic sedimentary rocks include conglomeratic siltstone to conglomerate that may be variably altered. Includes area of quartz-sericite-paragonite rock (Zvqs) of Schmidt et al. (2006). Andesitic to basaltic lavas and massive quartz locally present.

Zue/pl

Zhe/pl - Mixed epiclastic-pyroclastic rocks with interlayered dacitic lavas: Grayish-green to greenish-gray, locally with distinctive reddish-gray or maroon to lavender coloration; metamorphosed: conglomerate, conglomeratic sandstone, sandstone, siltstone and mudstone. Lithologies are locally bedded; locally tuffaceous with a cryptocrystalline-like groundmass. Siltstones are locally phyllitic. Locally contain interbedded dacitic lavas identical to Zhdlt unit. Contains lesser amounts of fine- to coarse tuff and lapilli tuff with a cryptocrystalline-like groundmass. Pyroclastics, lavas, and epiclastics are mainly felsic in composition. Minor andesitic to basaltic lavas and tuffs present. Silicified and/or sericitized altered rock are locally present. Conglomerates and conglomeratic sandstones typically contain subrounded to angular clasts of dacite in a clastic matrix. Fine- to medium-grained diorite is locally present. Portions of the Zhe/pl unit are interpreted to have been deposited proximal to active volcanic centers represented by the Zhdlt unit but are also interpreted to record the erosion of proximal volcanic centers after cessation of active volcanism.

Zhabsi

Zhabsi - Andesitic to basaltic shallow intrusives: Grayish-green to light green, metamorphosed: plagioclase porphyritic andesite to basalt with a granular-textured groundmass to very fine-grained diorite and gabbro (with intrusive texture visible with 7x hand lens – microdiorite/microgabbro). Contains lesser amounts of fine- to medium-grained diorite and gabbro. Plagioclase phenocrysts typically range from 1 mm to 4 mm. Dark green to black colored amphibole, when present, occur as phenocrysts (less than 1 mm to 1 mm) and as intergrowths with plagioclase.

Zhablt

Zhablt - Andesitic to basaltic lavas and tuffs: Green, gray-green, gray, dark gray and black; typically unfoliated, amygdaloidal, plagioclase porphyritic, amphibole/pyroxene porphyritic and aphanitic; andesitic to basaltic lavas and shallow intrusions. Hyaloclastic texture is common and imparts a fragmental texture similar to a lithic tuff on some outcrops. Locally interlayered with pyroclastic rocks and meta-sediments identical to the Zhe/pl unit.

Zhable

Zhable – Andesitic to basaltic lavas with interlayered epiclastic rocks: Light green, gray-green, gray, and dark gray; typically unfoliated, amygdaloidal, plagioclase porphyritic, amphibole/pyroxene porphyritic and aphanitic; metamorphosed: andesitic to basaltic lavas and shallow intrusions. Hyaloclastic texture is common and imparts a fragmental texture on some outcrops and float boulders. Contains lesser amounts of grayish-green, light green, and light gray to white; metamorphosed conglomerate, conglomeratic sandstone, sandstone, siltstone and mudstone.

Zhabl

Zhabl - Andesitic to basaltic lavas: Green, gray-green, gray, dark gray and black; typically unfoliated, amygdaloidal, plagioclase porphyritic, amphibole/pyroxene porphyritic and aphanitic; andesitic to basaltic lavas and shallow intrusions. Hyaloclastic texture is common and imparts a fragmental texture on some outcrops and float boulders. Conglomeratic rocks consisting of angular clasts of andesite and/or basalt occur locally and are interpreted as resedimented hyaloclastite.

Zhdsi

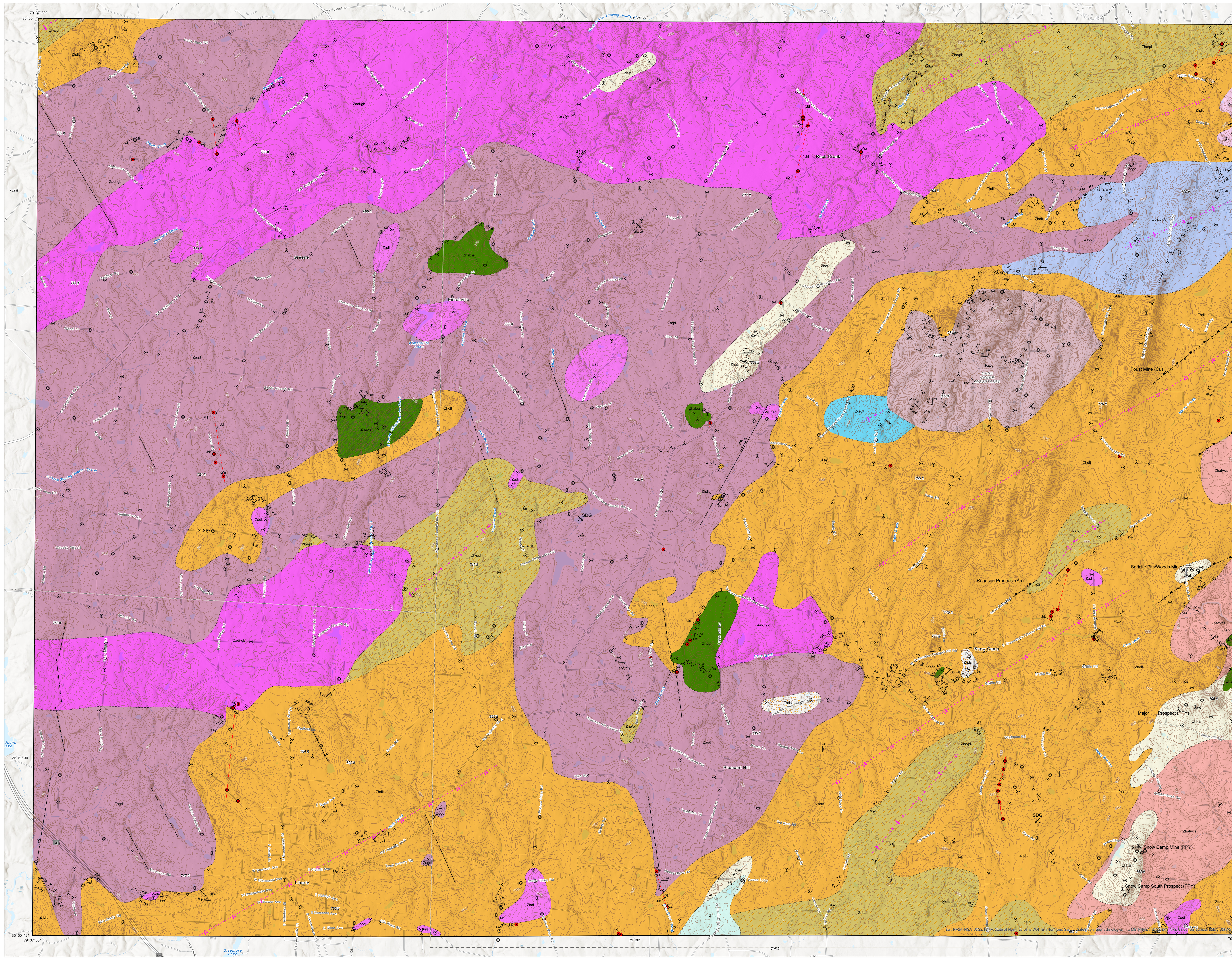
Zhdsi - Dacitic shallow intrusives: Gray-green, light green to green, greenish-gray to light gray; dacite, plagioclase porphyritic dacite with a granular-textured groundmass to micro-granodiorite (intrusive texture visible with 7x hand lens). Locally fine- to medium- grained granodiorite present. Plagioclase phenocrysts, when present, range from less than 1 mm to 4 mm. Black colored amphibole, when visible, occurs as phenocrysts (less than 1 mm to 1 mm) and as intergrowths with plagioclase. Amphibole intergrowths distinguish rock from fine-grained tuffs. Interpreted as shallowly emplaced dacite probably co-magmatic with Zhdlt unit.

Zhdlt

Zhdlt - Dacitic lavas and tuffs: Greenish-gray to dark gray, siliceous, aphanitic dacite, porphyritic dacite with plagioclase phenocrysts, and flow banded dacite. Dacite with hyaloclastic textures are common. Welded and non-welded tuffs associated with the lavas include: greenish-gray to grayish-green, fine tuff, coarse plagioclase crystal tuff and lapilli tuff. Locally, interlayers of immature conglomerate and conglomeratic sandstone with abundant dacite clasts are present. The dacites are interpreted to have been coherent extrusives or very shallow intrusions associated with dome formation. The tuffs are interpreted as episodic pyroclastic flow deposits, air fall tuffs or reworked tuffs generated during formation of dacite domes. The unit occurs as map scale pods often surrounded by clastic rocks of Zhe/pl unit. Wortman et al. (2000) report the following ages from the unit: an age of 615.7+3.7/-1.9 Ma U-Pb zircon date for a dacitic tuff in the Rougemont Quadrangle and an age of 632.9 +2.6/-1.9 Ma zircon date from a sample of dacite within the Chapel Hill Quadrangle.

Zhft

Zhft - Felsic tuffs: Grayish-green to greenish-gray and silvery-gray; massive to foliated volcaniclastic pyroclastic rocks consisting of fine- to coarse tuffs, lapilli tuffs and minor welded tuffs. Tuffs are differentiated from other volcaniclastic rocks by the presence of zones of cryptocrystalline texture that exhibit conchoidal-like fractures in between foliation domains. Layering ranges from massive to thinly bedded. Contains lesser amounts of volcaniclastic sedimentary rocks consisting of volcanic sandstones, and greywackes with minor siltstones and phyllite.



EXPLANATION OF MAP SYMBOLS

CONTACTS, FAULTS AND OTHER FEATURES

inferred contact
inferred brittle fault
inferred diabase
inferred fault, high angle reverse, existence questionable
linear geomorphic feature interpreted from hillshade LiDAR - origin uncertain
interpreted fold hinge of overturned anticline; dotted where concealed, queried where questionable
interpreted fold hinge of syncline; dotted where concealed

PLANAR AND LINEAR FEATURES

strike and dip of bedding or layering (multiple observations at one location)
strike and dip of inclined joint
strike and dip of foliation
strike and dip of inclined joint (multiple observations at one location)
strike and dip of foliation (multiple observations at one location)
strike of vertical joint
strike and dip of cleavage
strike of vertical joint (multiple observations at one location)
strike and dip of welding/compaction
strike and dip of cleavage (multiple observations at one location)
strike and dip of slickenside
slickenline

QUARRIES AND OTHER FEATURES

STN_C Snow Camp Quarry (crushed stone) - active
PPY Snow Camp Mine (pyrophyllite) - abandoned
mine - abandoned
SDG sand and gravel pit - abandoned
Prospects [copper (Cu), gold (Au) and pyrophyllite (PPY)]
observation station location
diabase station location

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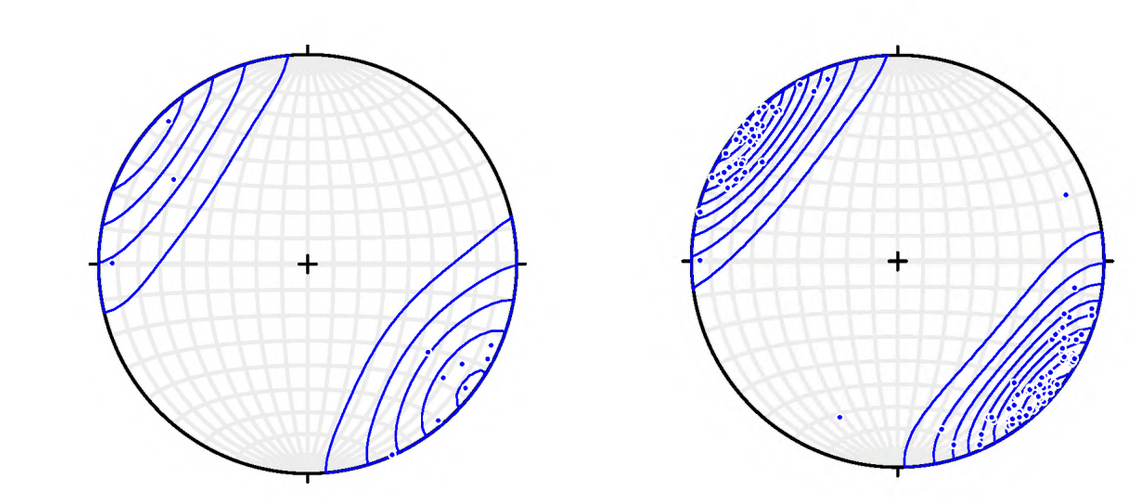
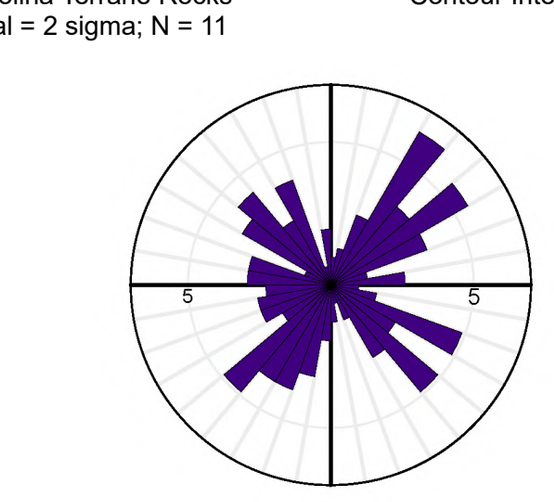
Equal Area Schmidt Net Projections and Rose Diagram

Plots and calculations created using Stereonet v. 10.2.0 based on Allemendinger et al. (2013) and Cardozo and Allmendinger (2013)



Equal Area Schmidt Net Projection of Contoured Poles to Primary Bedding, Layering and Welding/Compaction Foliation in Carolina Terrane Rocks
Contour Interval = 2 sigma; N = 11

Equal Area Schmidt Net Projection of Contoured Poles to Foliation and Cleavage in Carolina Terrane Rocks
Contour Interval = 3 sigma; N = 113

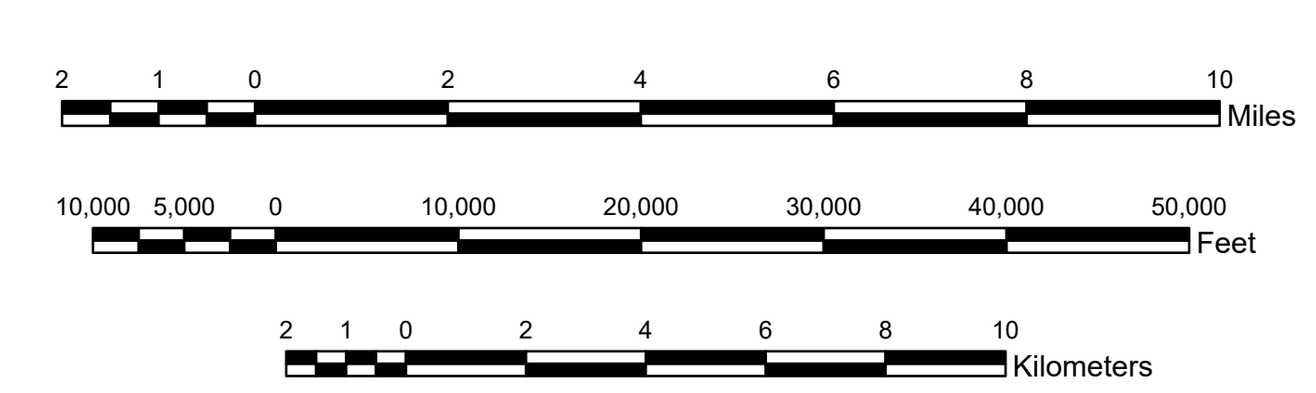


Unidirectional Rose Diagram of Joints
N = 307, Outer Circle = 6%
Mean vector = 61°

Base map from ESRI ArcGIS online base maps. Also, see sources listed in the lower right portion of the map.

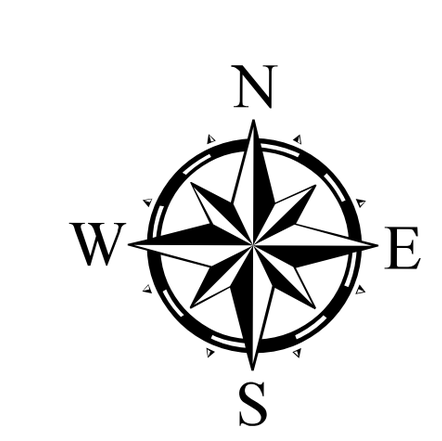
Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program under STATEMAP (Awards - 2022, G22AC00395).

This is an Open File Map. It has been reviewed internally for conformity with North Carolina Geological Survey mapping standards and with the North American Stratigraphic Code. Further revisions or corrections to this Open File map may occur.

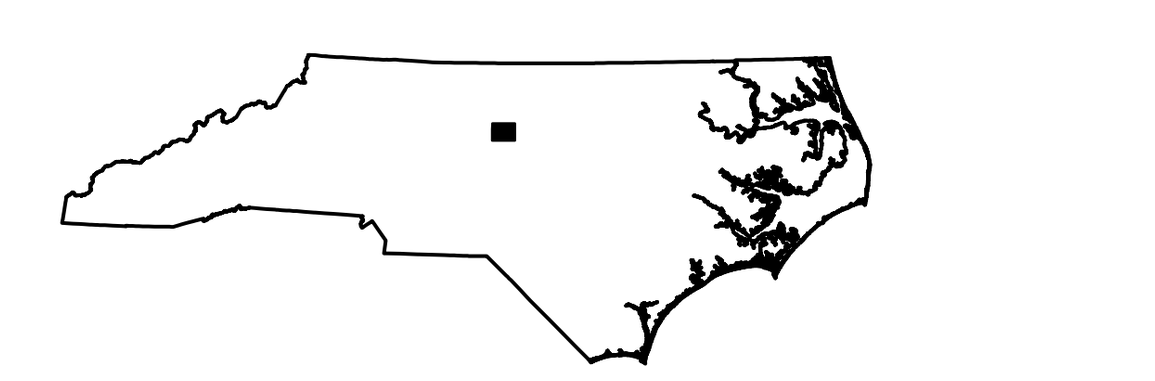


scale - 1:24,000

Geologic mapping conducted at approximately 1:50,000 scale



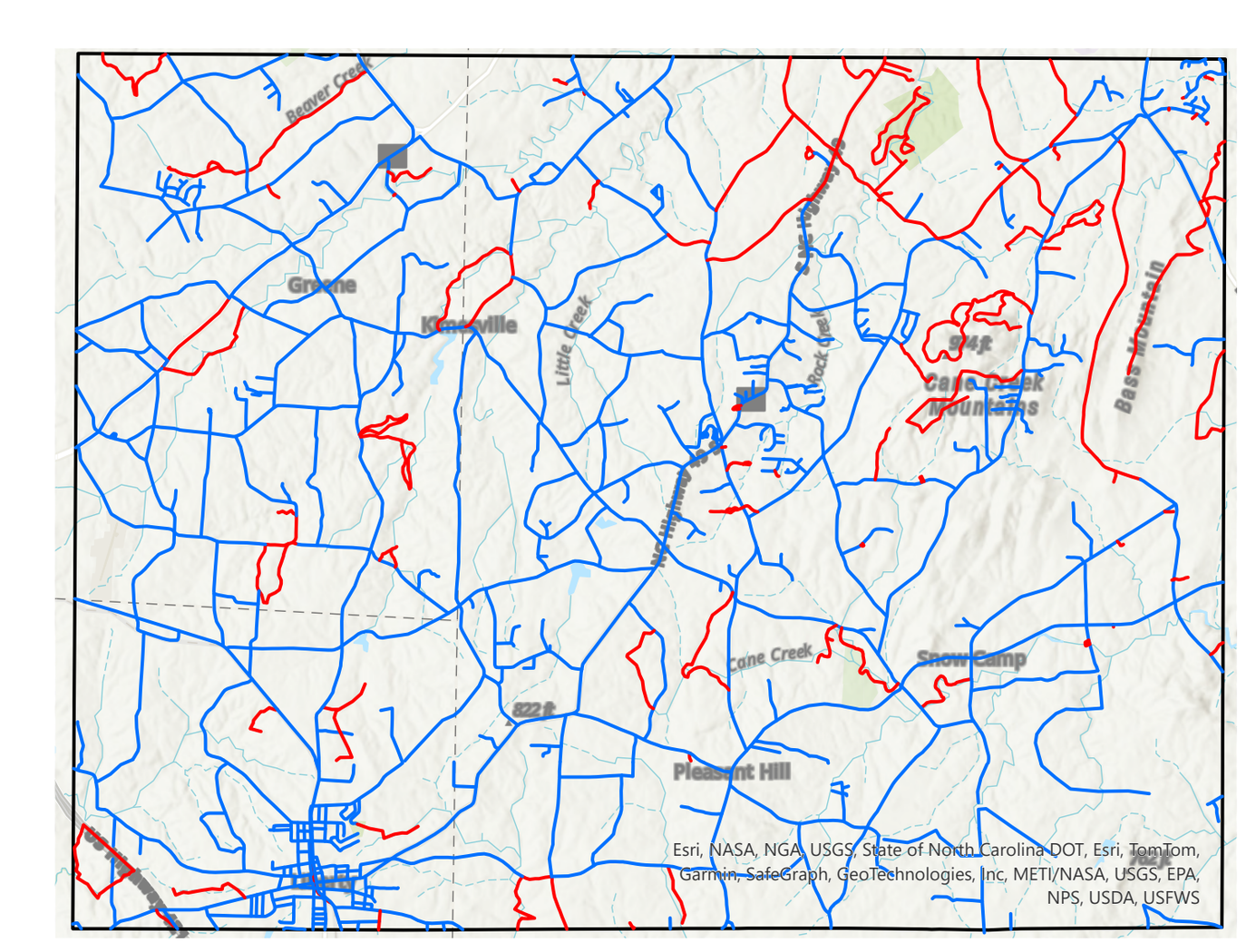
2019 Magnetic North declination at the center of the Snow Camp portion of the map.



MAP LOCATION

Mcleansville	Gibsonville	Burlington	Mebane
Climax	Kimesville	Snow Camp	Saxapahaw
Grays Chapel	Liberty	Crutchfield Crossroads	Silk Hope

QUADRANGLE INDEX



TRAVERSE MAP
by foot
by car

Bedrock Geologic Map of the Snow Camp, Kimesville and Northern Portions of the Crutchfield Crossroads and Liberty 7.5-Minute Quadrangles, Alamance, Randolph, and Guilford Counties, North Carolina Part of the Chapel Hill 100K Bedrock Compilation Project

By

Emily K. Michael and Philip J. Bradley

Map preparation and editing by Emily K. Michael, Michael A. Medina and Philip J. Bradley

Digital representation by Michael A. Medina, Emily K. Michael and Philip J. Bradley

Geologic Map of the Snow Camp, Kimesville and Northern Portions of the Crutchfield Crossroads and Liberty 7.5-Minute Quadrangles, Alamance, Randolph, and Guilford Counties, North Carolina - Part of the Chapel Hill 100K Bedrock Compilation Project