DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF ENERGY, MINERAL, AND LAND RESOURCES
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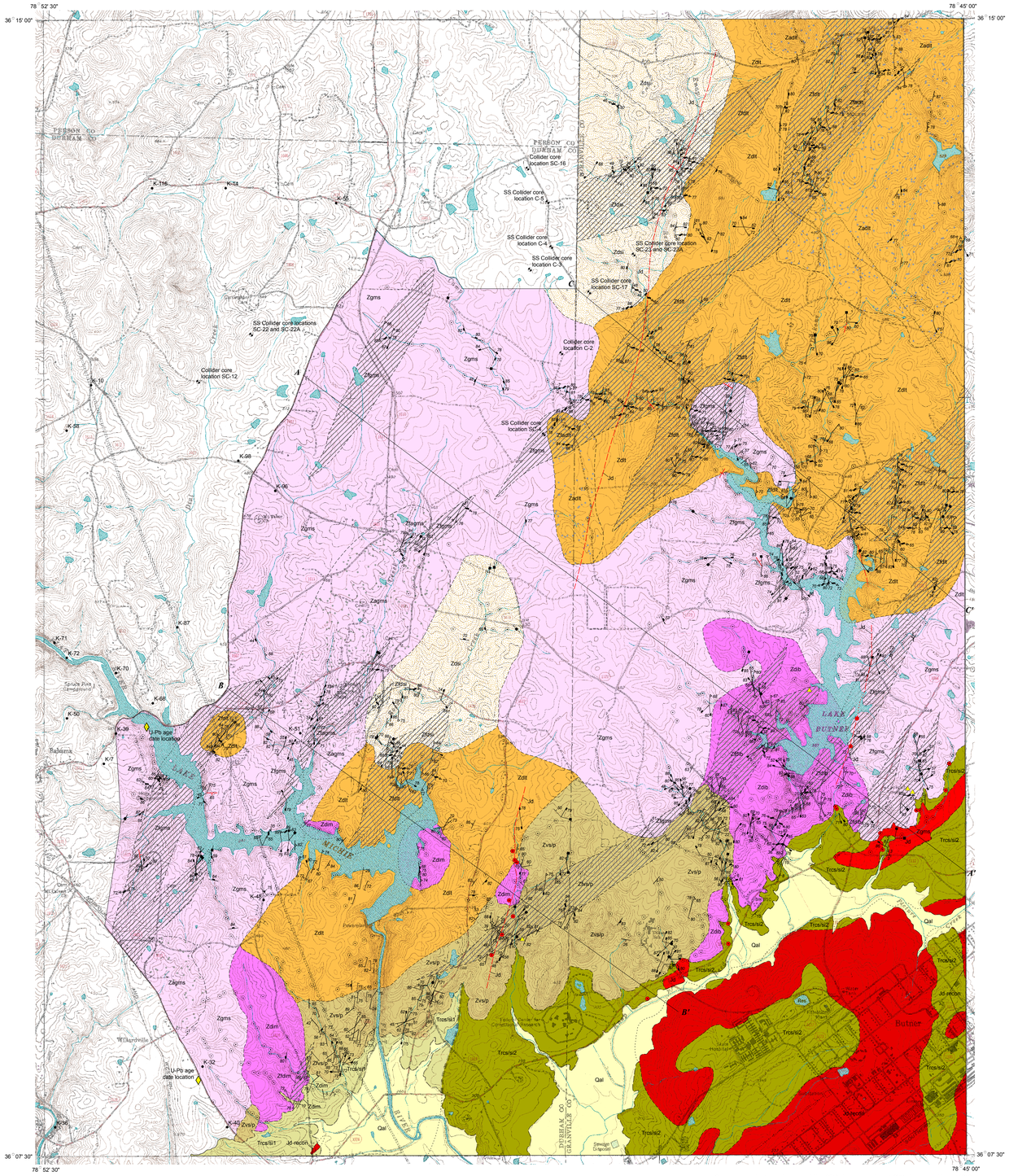
This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program

NORTH CAROLINA GEOLOGICAL SURVEY
OPEN FILE REPORT 2012-01



Geology mapped between January and May, 2010, January and August, 2011, January and August 2012.
This map supersedes NCGS Open File Report 2011-09.

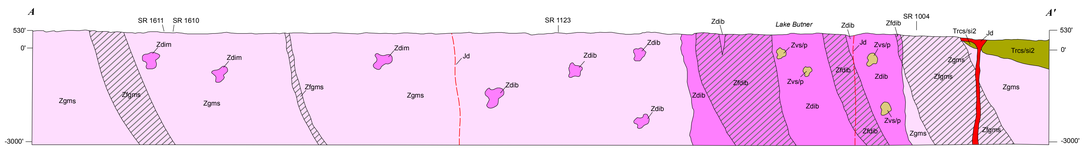
SCALE 1:24 000

1 0.5 0 1 Miles
1,000 500 0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 Feet
1 0.5 0 1 Kilometers

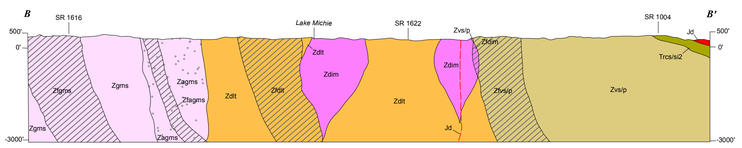
CONTOUR INTERVAL 10 FEET

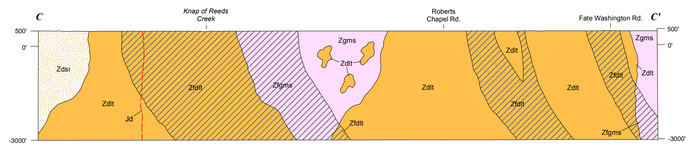
UTM GRID AND 1974 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

NORTH CAROLINA
MAP LOCATION



cross section scale: 1:24 000 elevation in feet no vertical exaggeration





GEOLOGIC MAP OF THE EASTERN AND CENTRAL PORTIONS OF THE LAKE MICHIE 7.5-MINUTE QUADRANGLE, DURHAM, GRANVILLE, AND PERSON COUNTIES, NORTH CAROLINA

By Daniel L. Rhodes, David E. Blake, Robert H. Morrow, Joshua D. April, Amy L. Gross, and Jacob M. Kendall.

Digital representation by Michael A. Medina and Philip J. Bradley

2012

INTRODUCTION

The pre-Mesozoic crystalline rocks of the Lake Michie 7.5-minute Quadrangle are part of the Virgilina sequence of the Carolina terrane, specifically the upper portion (ca. 615 Ma) of the Hyco Formation (Wortman and others, 2001; Hibbard and others 2002; Bradley and Miller, 2011). These rocks are metamorphosed to the chlorite zone of the lower greenschist facies during Late Precambrian and Paleozoic tectonothermal activity. Only Late Triassic sedimentary rocks and Jurassic diabase are not regionally metamorphosed, although contact metamorphic effects occur locally where diabase intrudes sedimentary rocks. While subjected to this low-grade metamorphism and locally displaying fracture, foliation, and lineation, most crystalline rocks preserve relict plutonic, volcanic, or volcanogenic sedimentary textures, which when combined with bulk rock compositions, allow for protolith identification. Therefore, the prefix "meta" is not included in the nomenclature of the pre-Mesozoic rocks described in the quadrangle. In some exposures, especially adjacent to the western boundary of the Deep River Mesozoic rift basin, highly partitioned strain produces either variably fractured, phyllonitic, or protomylonitic and mylonitic rocks of meta-igneous origin. Local outcrops of highly silicified, epidotized, and/or sericitized, or silicified-epidotized cataclasite rock have unclear protolith affinity. All sedimentary rocks of Mesozoic and Cenozoic age have a detrital origin involving mud- to gravel-sized clasts.

The classification and naming of metaigneous rocks in the Lake Michie 7.5-minute Quadrangle uses the nomenclature of the International Union of Geological Sciences (IUGS) subcommission on the systematics of igneous rocks after Le Maitre (2002). Relict igneous textures, modal mineral assemblages, or normalized mineral assemblages when whole-rock geochemical data are available, provide the basis for naming meta-igneous lithodemes. A preliminary lithodemic designation is developed here following Articles 31-42 of the North American Stratigraphic Code. These rock units, which lack in geochronologic data and stratigraphic facing directions, warrant such a designation. Past maps and lithologic descriptions of McConnell and Glover (1982), Blake and others (2009), and Bradley and others (2011) assisted the development of the current U.S. Geological Survey STATEMAP mapping results.

SEDIMENTARY UNITS

Qal – alluvium: Tannish-yellow to gray to reddish-brown, unconsolidated, and poorly sorted and stratified deposits of angular to subrounded clay, silt, sand and gravel- to cobble-sized clasts. Deposits generally occur in major stream drainages and around the shorelines of Lake Michie and Lake Butner.

Trcs/si – sandstone with interbedded siltstone and conglomerate of the Chatham Group Lithofacies Association I: Pinkish-gray, light gray, and light tan; fine- to coarse-grained, micaceous, slightly clayey, moderately poor to moderately well sorted, subangular to subrounded arkose and lithic arkose; maroon, very silty, micaceous, moderately well sorted, fine-grained sandstone; maroon, massive, and thickly laminated, micaceous to very micaceous siltstone and mudstone; and poorly sorted, angular to subrounded metavolcanic- and metaplutonic -clasts conglomerate derived from surrounding meta-igneous crystalline rocks that may be clast or matrix supported with reddish-brown to tannish-brown to pinkish-brown, medium- to coarse-grained, poorly to well sorted sandstone, micaceous siltstone or mudstone. Beds are massive or locally thinly bedded, wavy, or cross bedded. Rocks are assigned to the Lithofacies Association I of Hoffman and Gallagher (1989) and have been extended into the Lake Michie Quadrangle to edge-match with the Northeast Durham Geologic map (Phillips et al., 2004 (revised 2010)).

Trcs/si2 – sandstone with interbedded siltstone of the Chatham Group Lithofacies Association II: Cyclical depositional sequences of whitish-yellow to grayish-pink to pale red, coarse- to very coarse-grained, trough cross-bedded lithic arkose that fines upward through yellow to reddish-brown, medium- to fine-grained sandstone, to reddish-brown, burrowed and rooted siltstone. Bioturbation is usually surrounded by greenish-blue to gray reduction halos. Coarse-grained portions contain abundant muscovite, and basal gravel lags consist of clasts of quartz, bluish-gray quartz crystal tuff, and mudstone rip-ups. These rocks are assigned to the Lithofacies Association II of Hoffman and Gallagher (1989) and have been extended into the Lake Michie Quadrangle to edge-match with the Northeast Durham Geologic map (Phillips et al., 2004 (revised 2010)).

FAULT ZONE UNITS

PCsc – silicified and epidotized cataclasite: White, tan, tan-green and pale-green, silicified, epidotized, and highly fractured zones containing mm- to cm-scale, angular silicified and locally original protolith clasts. Silicified and epidotized clasts of metamorphosed diorite, tonalite, granodiorite, and dacite have been observed. Extensional veins filled with syntaxial rhombohedral quartz prisms and epidote common. In many samples, silicification and epidotization is so extensive protolith relationships are completely obscured; in some samples, epidote invades and overprints the crystalline rocks as diffuse, fine-grained mineral domains reminiscent of fluid fronts. Considered to be Mesozoic or Cenozoic in age, but may also be attributed to middle or late Paleozoic deformation.

INTRUSIVE AND META-INTRUSIVE UNITS

Jd – diabase: Black to greenish black, fine to medium phaneritic or aphanitic, dense, consists primarily of plagioclase, augite and may contain olivine. Occurs as dikes and sills and is typically seen as spheriodally weathered stream boulders and cobbles. Weathered surfaces are generally brownish to grayish in color. Red station location indicates outcrop or boulders of diabase.

Jd-recon - diabase reconnaissance: Jurassic diabase from reconnaissance and geophysical data as depicted in Gottfried, et al., (1991).

Zdsi – dacitic shallow intrusions: Gray-green, light green to green, greenish-gray to light gray; plagioclase porphyritic aphanitic dacite, aphanitic dacite and micro-granodiorite. Plagioclase phenocrysts range from less than 1 mm to 5 mm and are commonly saussuritized. Blocky, less than 1 mm to 3mm quartz also occur as phenocrysts. Contains lesser amounts of dark gray, phenocryst poor aphanitic dacite. Leucocratic (CI=5-30) granodiorite ranges from fine to medium crystalline. Major minerals include plagioclase, alkali feldspar, quartz and lesser amounts of biotite. This unit is interpreted as shallowly emplaced dacite/granodiorite and is distinguished from Zdlt by the abundance of dacitic lava/shallow intrusive and the disappearance of tuff. Silicification, sulfide mineralization, and aggregates of white mica and quartz highlight steeply dipping and plunging foliation and lineation domains inferred to be highly fractured and/or phyllonitic and protomylonitic high strain zones (**Zfdsi**).

Zgms – granodiorite tonalite of the Stem and Moriah plutons: Leucocratic (CI=5-15), light tan-gray white, bluish-gray white, or pinkish-white, medium to coarse phaneritic, hypidiomorphic to xenomorphic granular granodiorite and tonalite. This unit combines the previously mapped Zstg unit in the Stem (Blake and others, 2009) and eastern Lake Michie Quadrangles and the Moriah pluton of McConnell (1974) in the western portion of the Lake Michie Quadrangle. Major minerals include plagioclase, alkali feldspar, and quartz with lesser amounts of biotite and amphibole, interpreted to be hornblende. Plagioclase is highly sericitized and in lesser amount saussuritized, especially in calcic-rich phenocryst cores. Alkali feldspar typically displays granophytic texture in thin section. If present, biotite is commonly recrystallized to chlorite while hornblende may be recrystallized to chlorite, epidote, and actinolite-opaque mineral. Metamorphosed trondhjemitic and monzonite pods are present and may represent dikes or differentiated portions of the pluton. Locally becomes granitic in the western portion surrounding Lake Michie. Outcrops locally contain enclaves of microdiorite of the Zdim and Zdib units. Locally, mm- to cm-scale granite dikes crosscut granodiorite. Wortman et al. (2000) report a 613.4 +2.8/-2 Ma U-Pb zircon date from granite and a 613.9 +1.6/-1.5 Ma U-Pb zircon date from diorite sampled from the Moriah pluton in the western portion of the Lake Michie Quadrangle. Aggregates of white mica, quartz, plagioclase, and orthoclase highlight steeply dipping foliation and dip-parallel lineation domains inferred to be highly fractured and/or phyllonitic and protomylonitic high strain zones (**Zfgms**). This unit is correlative to the Zmpf unit of Bradley and others (2011) in the adjacent Rougemont 7.5-minute Quadrangle.

Zagms – altered granodiorite and granite of the Moriah pluton: Leucocratic (CI=10-30), light pinkish gray to gray, fine- to medium-phaneritic, equigranular to porphyritic granodiorite and granite that is highly recrystallized and hydrothermally and chemically altered. Major minerals forming a relict xenomorphic granular phaneritic texture likely included plagioclase, alkali feldspar, and quartz that are now combinations of fine to medium crystalline, foliated and non-foliated domains of white mica and recrystallized feldspar and quartz. Outcrops, and more commonly float cobbles and boulders display apparent silicification, while other samples display chemical weathering that develops predominantly clay mineralization mixed with silica. Some rocks additionally display Fe-oxide-hydroxide staining. Unit interpreted to be a hydrothermally recrystallized and altered portion of Zgms. Domains of highly foliated rocks of this unit are separated as **Zfagms**.

Zdib – diorite of the Butner pluton: Mesocratic to melanocratic (CI=40-70), greenish-gray to grayish-green to green, fine- to medium-phaneritic diorite, microdiorite and quartz diorite. Textures range from equigranular to porphyritic with hypidiomorphic to xenomorphic granular plagioclase and hornblende phenocrysts ranging up 1-3 mm in tabular length. Major minerals include plagioclase and amphibole, interpreted to be hornblende. Plagioclase crystals are highly saussuritized and in lesser amounts sericitized. Some crystals display evidence of Ca-rich cores with Na-rich rims. Hornblende may be recrystallized to chlorite, epidote, and actinolite-opaque mineral. Locally contains 5-10% quartz classifying it as a quartz diorite. The western portion of the unit is typically finer grained, having crystal size increasing towards the east. Foliated metadacite enclaves are common within the intrusive unit. Silicification, sulfide mineralization, typically pyrite, and aggregates of white mica and quartz highlight steeply dipping and plunging foliation and lineation domains inferred to be highly fractured and/or phyllonitic and protomylonitic high strain zones (**Zfdib**). Locally, highly leached and stained outcrops of pyrite-Fe-oxide-hydroxide mark these deformation zones. Texturally and mineralogically equivalent to Zdim.

Zdim –diorite of the Moriah pluton: Mesocratic to melanocratic (CI=40-70), greenish-gray to grayish-green to green, fine- to medium-phaneritic diorite, microdiorite and quartz diorite. Textures range from equigranular to slightly porphyritic with hypidiomorphic to xenomorphic granular plagioclase and hornblende phenocrysts ranging up to 1-3 mm in tabular and prismatic length, respectively. Major minerals include plagioclase and amphibole, interpreted to be hornblende. Plagioclase crystals are highly saussuritized and in lesser amounts sericitized. Hornblende may be recrystallized to chlorite, epidote, and actinolite-opaque mineral. Locally contains 5-10% quartz highlighting differentiated outcrops of quartz diorite. Foliated equivalent mapped as **Zfdim**. Texturally and mineralogically equivalent to Zdib.

METAVOLCANIC UNITS

Zvs/p – mixed volcanogenic sedimentary and pyroclastic rocks: Grayish-green to greenish-gray, siltstone/mudstone, sedimentary, and tuffaceous sandstone. Contains lesser amounts of fine- to coarse ash tuff and lapilli-crystal lithic tuff. Siltstone is medium to thickly laminated (3mm-7mm) and alternate in color between greenish and greenish gray. Locally contains domains of massive magnetite rock and thinly laminated layered magnetite-enriched siltstone. Sandstone is generally massive with subangular to subrounded, moderately to well sorted quartz grains and lithic fragments. Tuffaceous sandstone is typically massive with moderately to poorly sorted, angular to subangular grains of plagioclase and quartz crystals. Pyroclastic tuff is generally massive and contains relict xenomorphic to subidiomorphic plagioclase and quartz phenocrysts in a fine, recrystallized ash groundmass. Minor basaltic to andesitic lavas/shallow intrusions occur locally in the southern portion of the mapped unit. The western and middle portion of the mapped unit is predominantly sedimentary; volcanic material occurs in the eastern portion of the unit in contact with metaplutonic rocks. Rocks are comparable to the Ze/p unit in the adjacent Rougemont Quadrangle immediately to the west (Bradley and others, 2011). Domains of highly foliated rocks of this unit are separated as **Zfvs/p**.

Zdlt – dacitic lavas and tuffs: Greenish-gray to dark gray to tannish gray, siliceous, aphanitic dacite tuff, porphyritic dacite, and flow banded dacite. Dacite is usually massive and ranges from fine ash to coarser plagioclase crystal tuff and lapilli tuff. Locally contains interlayers of immature pebbly to conglomeratic sandstone having lapilli-sized dacite clasts. Also contains outcrops of massive magnetite rock, usually found within close proximity to the contact with Zvs/p. Porphyritic dacite contains plagioclase and hornblende phenocrysts ranging from 3 to 10 mm in prismatic and tabular length, respectively, set in a recrystallized aphanitic groundmass. Locally, dacite may display relict ash flow layering. Unit is correlative to the Zdlt unit of Blake and others (2009) in the Stem Quadrangle and comparable to the Zdlt unit of Bradley and others (2011) in the Rougemont Quadrangle. Silicification, sulfide mineralization, and aggregates of white mica and quartz highlight steeply dipping and plunging foliation and lineation domains inferred to be highly fractured and/or phyllonitic and protomylonitic high strain zones (**Zfdlt**).

Zadlt – altered dacitic lavas and tuffs: White to red to tan, silicecious, hydrothermally altered aphanitic dacite, porphyritic dacite, and dacite lavas of Zdlt. Altered dacite is typically massive, finely crystalline and locally contains relict quartz and plagioclase phenocrysts ranging from 2 to 5 mm in size. Commonly siliceous concentrations give the rock a "chunky" appearance. Localized pyrophyllite mineralization occur as radiating crystals that range from 0.25mm to 1cm in size. Commonly Fe-oxide mineralization gives the rock a red color. Equivalent to the Zadlt unit of Blake and others (2009) in the Stem Quadrangle to the East and the to the Zbat(u) unit of Bradley and others (2011) in the Rougemont Quadrangle to the West. Silicification, sulfide mineralization, and aggregates of white mica and quartz highlight steeply dipping and plunging foliation and lineation domains inferred to be highly fractured and/or phyllonitic and protomylonitic high strain zones (**Zfadlt**).

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CONTACTS, FOLDS AND OTHER FEATURES

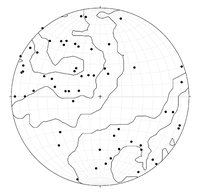
Lithologic contacts - Distribution and concentration of structural symbols indicates degree of reliability.

- contact - location inferred
- contact - location concealed
- Qal contact
- gradational contact
- diabase contact - dashed where inferred, dotted where concealed
- A — A' cross section line
- strike and dip of primary layering and/or bedding
- strike and dip of primary layering and/or bedding (multiple observations at one locality)
- strike of vertical primary layering and/or bedding
- strike of vertical primary layering and/or bedding (multiple observations at one locality)
- strike and dip of overprinting cleavage
- strike and dip of overprinting cleavage (multiple observations at one locality)
- strike of vertical overprinting cleavage (multiple observations at one locality)
- strike and dip of inclined fracture surface
- strike and dip of inclined fracture surface (multiple observations at one locality)
- strike of vertical fracture surface
- strike of vertical fracture surface (multiple observations at one locality)
- strike and dip of shear fracture
- strike and dip of foliation of enclave
- strike of vertical foliation of enclave
- strike and dip of inclined undifferentiated shear strain foliation
- strike and dip of inclined undifferentiated shear strain foliation (multiple observations at one locality)
- strike of vertical undifferentiated shear strain foliation
- strike of vertical undifferentiated shear strain foliation (multiple observations at one locality)
- Fault plane - normal
- Fault plane - reverse
- Fault plane - reverse (multiple observations at one locality)
- strike and dip of quartz vein
- strike of quartz vein
- bearing and plunge of mineral rod or aggregate lineation
- bearing of mineral rod or aggregate lineation
- bearing and plunge of slickenline
- station location
- diabase station location
- U/Pb age date location (Wortman and others, 2000)
- Superconducting Super (SS) Collider core location (Wilson and Carpenter, 1997)
- K-7 McConnell (1974) point count analysis sample location

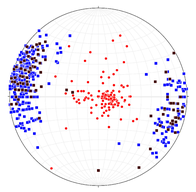
Base topographic map is a digital raster graphic image of the Lake Michie 7.5-minute quadrangle (1977), Lambert Conformal Conic projection.

This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program, award numbers G10AC00425 and G11AC20296. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

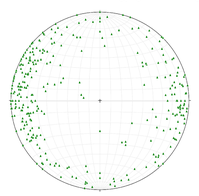
Disclaimer:
This Open-File report is preliminary and has been reviewed internally for conformity with the North Carolina Geological Survey editorial standards and in accordance with the North American Stratigraphic Code. There may be further revisions or corrections to this preliminary map.



Equal area Schmidt net projection of poles to bedding in crystalline rocks, (n=58); Kamb contour of poles to bedding at 2σ contour interval, counting area = 6% of net area.



Equal area Schmidt net projection of poles to shear foliation (Blue squares, n=435) and cleavage (black squares, n=101) and points to lines of mineral aggregate and rodding lineation (red circles, n=126).



Equal area Schmidt net of poles fractures, (n=341).

Scan with smartphone for link to GeoPDF of map. Third party App required.