North Carolina Department of Environmental Quality
Divison of Energy, Mineral and Land Resources
Brian Wrenn, Director
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North Carolina Geological Survey
Open File Report 2020-05

This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program.

CORRELATION OF MAP UNITS

AGE UNKNOWN
- bzmp — Mylonite / phyllonite
- mx — Mixed gneiss

DEVONIAN
- Dpg — Porphyroclastic biotite gneiss

ORDOVICIAN / SILURIAN
- SOgg — Granitic orthogneiss

Henderson Gneiss
- Ohg — Augen orthogneiss

Poor Mountain Formation
- Opm — Undivided

NEOPROTEROZOIC

Ashe / Alligator Back Metamorphic Suite
- Zss — Metasandstone

INTRODUCTION

The Moffitt Hill 7.5-minute quadrangle lies in western North Carolina in portions of Buncombe, McDowell, and Rutherford counties. Within the quadrangle are the communities of Old Fort, Moffitt Hill, Davistown, and Lackey Town. Portions of the quadrangle in the northwest are owned by the U.S. Forest Service, including a popular hiking trail to Catawba Falls. Interstate 40 is the major transportation corridor on the quadrangle. Major streams include the Catawba River, Crooked Creek, and Cedar Creek. Total elevation relief is 2,547 feet with a low of 1,057 feet along Cedar Creek and a high of 3,604 feet at Stone Mountain along the Rutherford and Buncombe county line.

GEOLOGIC OVERVIEW

Bedrock of the Moffitt Hill quadrangle comprises the following units (from northwest to southeast): Neoproterozoic metasandstone; porphyroclastic biotite gneiss; mylonite/phyllonite of the Brevard Fault Zone; Ordovician Henderson Gneiss; Ordovician to Silurian granitic orthogneiss; a mixed gneiss unit with several rock types including Tallulah Falls biotite gneiss, Henderson Gneiss, and felsic gneiss; and Ordovician Poor Mountain Formation.

The northwest portion of the quadrangle is underlain by Neoproterozoic metasandstone. The metasandstone was complexly deformed and metamorphosed to amphibolite facies conditions during Taconic orogenesis. These older Taconic fabrics have been overprinted by ductile shearing of the Brevard Zone during the Neoacadian and Alleghanian orogenies.

The porphyroclastic biotite gneiss outcrops in the Moffitt Hill quadrangle immediately northwest of the Brevard Zone mylonite/phyllonite unit. Porphyroclasts within the unit are granule- to gravel-sized and circular, tending to be less ovoid and less elongate in the foliation plane than outcrops of the Henderson Gneiss. The unit has a preliminary U-Pb age date of ~360 Ma. (R. McAleer, March 2020, personal communication). Mylonitic fabric within this unit obscures original contact relationships between it and the adjoining Neoproterozoic metasediments and, possibly, Mesoproterozoic basement rocks.

The Brevard Zone is a prominent NE-SW-striking feature on the Moffitt Hill quadrangle. The Brevard Zone is a linear fault zone that extends from Alabama to Virginia. It has a complex history of multiple reactivations with the earliest movement during the Neoacadian orogeny. This first movement was ductile and high-temperature with an oblique to strike-slip motion. During the Alleghanian orogeny, the Brevard fault reactivated with ductile strike-slip motion reaching greenschist-facies conditions, and later, experienced brittle dip-slip motion (Hatcher et al., 2007). Ductile shearing attributed to Brevard Zone deformation is observed in a zone several miles wide. The mylonite/phyllonite unit within the Brevard zone likely contains highly sheared rocks of the adjoining porphyroclastic gneiss and mixed gneiss units.

Southeast of the Brevard zone, the mixed gneiss unit contains a mix of biotite gneisses possibly correlative to the Tallulah Falls Formation mapped to the SE by Bream (1999), Henderson Gneiss, and granitic orthogneiss. Intense deformation of the Brevard zone makes delineation and identification of the protoliths of the mixed gneiss unit difficult. Biotite gneisses within the unit are heterogeneous and contain local granule- to gravel-sized porphyroclasts, ribboned felsic layers, boudined pegmatite layers, and granitic orthogneiss.

The Ordovician Henderson Gneiss is a large granitic pluton that extends from SC to the NC piedmont. In its type locality the Henderson Gneiss is homogeneous and contains plentiful K-feldspar augens that are elongate with the foliation. Moecher et al. (2011) reported the age of the Henderson Gneiss as 447.6 Ma.

The Ordovician to Silurian granitic orthogneiss unit differs from the Henderson Gneiss by its lack of augens and more felsic mineralogy. Tentatively the unit is correlated with the 438 Ma intrusives into the Henderson Gneiss of Lemmon (1973).

The Poor Mountain Formation contains sillimanite-grade meta-sedimentary units interlayered with mafic and felsic meta-volcanic rocks. It is interpreted to be unconformably deposited on the Tallulah Falls Formation.

Mylonitic and non-mylonitic foliations within the quadrangle dominantly strike NE-SW and dip steeply to moderately to the SE. The prominent fracture set strikes NW-SE and is steeply dipping. A minor fracture set strikes NE-SW and is steeply dipping.

DESCRIPTION OF MAP UNITS[1]

bzmp **Mylonite/phyllonite —** Intensely deformed rocks with unknown protoliths. Tan to light-gray, to dark-gray, to light-olive-gray, to greenish-gray; fine- to coarse-grained; lepidoblastic to porphyroblastic; strongly foliated; mylonitic, locally ultramylonitic, locally brecciated; consists of sericite, quartz, feldspar, biotite, chlorite, and accessory graphite, garnet, sulfides, magnetite, and opaque minerals. Lenticular muscovite-aggregate porphyroblasts flattened in the mylonitic foliation planes impart a distinctive "fish scale" or "button" appearance to phyllonites. Locally interlayered with porphyroclastic biotite gneiss, granitic orthogneiss, and felsic gneiss.

mx **Mixed gneiss —** Heterogeneous unit consisting of a biotite gneiss of unknown affinity, Henderson Gneiss, granitic orthogneiss, and mylonite.

Biotite gneiss — Dark-gray to grayish-black; fine- to coarse-grained; well foliated; protomylonitic to mylonitic; inequigranular; porphyroclastic with clasts up to 10 mm in diameter and locally porphyroblastic; layering includes ribboned felsic layers and some pegmatite boudins; consists of quartz, plagioclase feldspar, biotite, potassium feldspar, muscovite, and epidote, with minor titanite and garnet. May be correlative to the Tallulah Falls Formation.

Meta-igneous Rocks

Dpg **Porphyroclastic biotite gneiss —** Heterogeneous mix of porphyroclastic and porphyroblastic, mylonitic biotite gneiss, quartzo-feldspathic gneiss, granitic orthogneiss, felsic gneiss, phyllonite, mylonite, and amphibolite, with minor biotite metawacke and metasandstone. Biotite gneiss is typically light-gray to grayish-black; well foliated; locally protomylonitic to ultramylonitic; medium- to coarse-grained; inequigranular; 2-10 mm sized porphyroclasts; locally lepidoblastic; consists of quartz, plagioclase, biotite, potassium feldspar, muscovite, minor epidote, garnet, and titanite. Radiometric age date of approximately 360 Ma (McAleer, personal communication, 2020).

SOgg **Granitic orthogneiss —** White to medium-gray to very light-gray; medium- to coarse-grained; equigranular; granoblastic; mylonitic to protomylonitic; consists of quartz, plagioclase, potassium feldspar, muscovite, biotite, and minor amounts of opaques, epidote, chlorite, and garnet. Differs from Henderson Gneiss in general lack of augen, increased muscovite content, and more felsic composition; correlative with the 438 Ma intrusives into the Henderson Gneiss of Lemmon (1973); includes local bodies of metawacke not mappable at 1:24,000-scale.

Ohg **Henderson Gneiss** — Medium-gray to medium-bluish-gray, to mottled black and white; inequigranular; medium- to coarse-grained matrix with distinctive megacrysts (augen) of microcline variable in size and abundance; typically protomylonitic to mylonitic, to granoblastic to lepidoblastic; well foliated to massive; dominantly biotite granite that ranges to tonalite; consists of potassium feldspar, plagioclase, quartz, biotite, muscovite and sericite, epidote group minerals, opaques and trace amounts of titanite, zircon and apatite; locally pegmatitic and migmatitic. Locally microcline augen exceed 3 cm in length. The augen structures are produced by a high temperature protomylonitic overprint. Radiometric age date of approximately 447 Ma (Moecher et al., 2011).

Metasedimentary Rocks

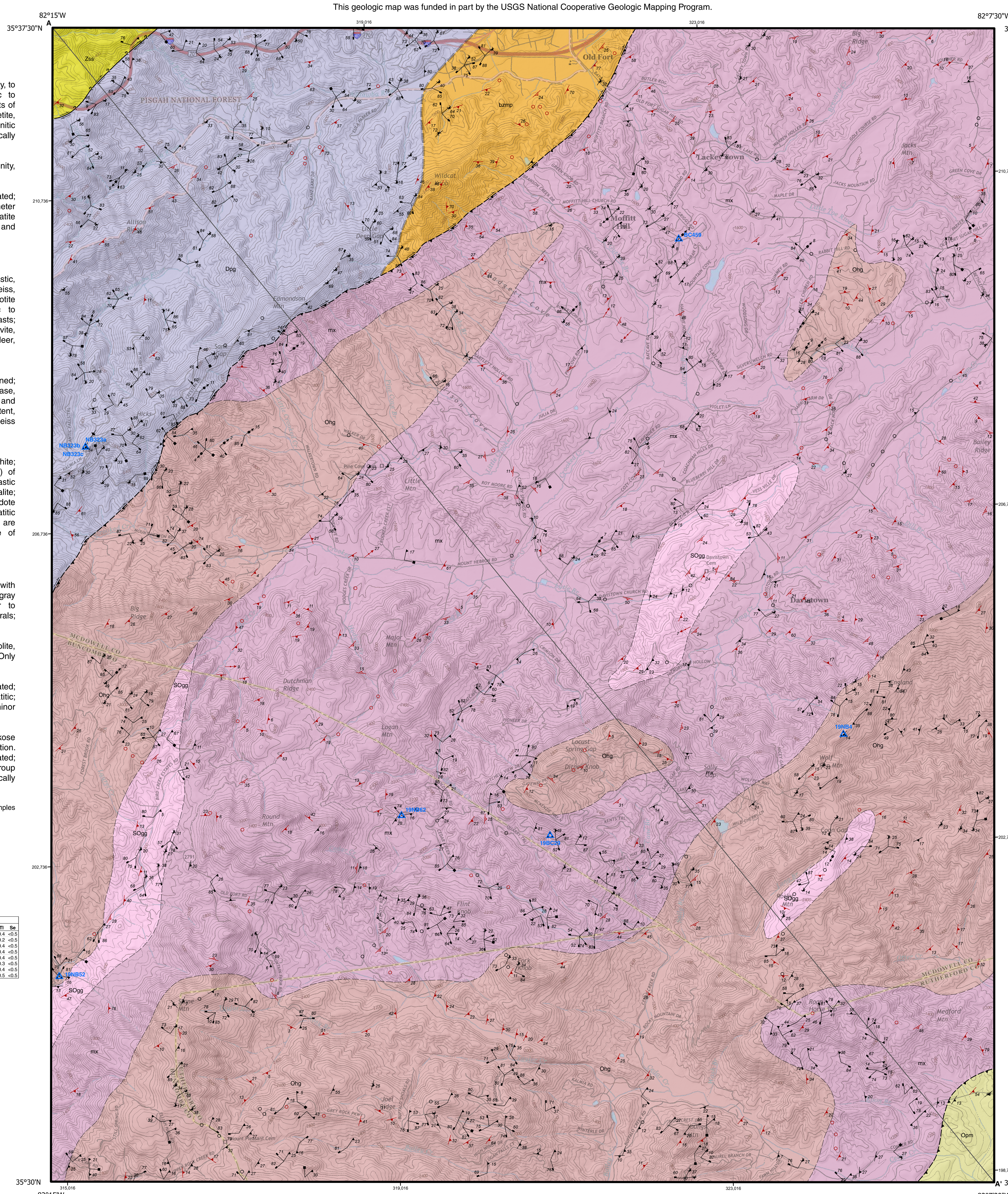
Zss **Ashe Metamorphic Suite Metasandstone —** Interlayered metamorphosed sandstones with compositions including arkosic arenite, biotite metawacke, and quartzite. Tan to medium-gray to light-green; fine- to medium-grained; foliated to locally mylonitic; equigranular to inequigranular; consists of quartz, feldspar, muscovite, biotite, and minor accessory minerals; notably contains little schist, amphibolite, or garnet.

Opm **Poor Mountain Undivided —** Heterogeneous unit of metawacke, schist, amphibolite, quartzite, metasandstone, meta-arkose, quartzo-feldspathic gneiss, and calc-silicate. Only metawacke and amphibolite are present on the Moffitt Hill quadrangle.

Metawacke — medium-light-gray to medium-dark-gray; medium- to coarse-grained; foliated; locally mylonitic; equigranular to inequigranular; granoblastic to lepidoblastic; locally migmatitic; consists of quartz, plagioclase feldspar, biotite, muscovite, potassium feldspar, garnet, minor sericite and accessory minerals, and trace opaque minerals.

Amphibolite — locally present structurally beneath metasandstone, quartzite, and meta-arkose layers and as a minor rock type throughout other map units of the Poor Mountain Formation. Amphibolite is typically mottled white to dark-green to black; fine- to coarse-grained; foliated; equigranular to nematoblastic; consists of hornblende, plagioclase, biotite, epidote group minerals, quartz, and minor garnet, chlorite, pyroxene, titanite, and opaque minerals. Locally interlayered with calc-silicate.

[1]Mineral abundances are listed in decreasing order of abundance based upon visual estimates of hand samples and thin-sections.



EXPLANATION OF MAP SYMBOLS

CONTACTS

Zone of Confidence: 300m

Gradational contact—Identity and existence certain, location approximate

Contact—Identity and existence certain, location approximate

Strike-slip fault, right-lateral offset—Identity questionable, existence certain, and location accurate. Arrows show relative motion

Thrust fault (1st option)/Strike-slip fault, right-lateral offset—Identity and existence certian, location approximate. Sawteeth on upper (tectonically higher plate). Arrows show relative motion

Thrust fault (1st option—Identity and existence certian, location approximate. Sawteeth on upper (tectonically higher plate). Arrows show relative motion

PLANAR FEATURES

(For multiple observations at one locality, symbols are joined at the "tail" ends of the strike lines)
(Symbols in red taken from Hurley, 1974.)

- Inclined metamorphic or tectonic foliation—Showing strike and dip
- Inclined metamorphic or tectonic foliation, for multiple observations at one locality—Showing strike and dip
- Vertical metamorphic or tectonic foliation—Showing strike
- Inclined mylonitic foliation—Showing strike and dip
- Inclined generic foliation (origin not specified)—Showing strike and dip
- Small, minor inclined joint—Showing strike and dip
- Small, minor inclined joint, for multiple observations at one locality—Showing strike and dip
- Small, minor vertical or near-vertical joint, for multiple observations at one locality—Showing strike
- Inclined mylonitic foliation, for multiple observations at one locality—Showing strike and dip

LINEAR FEATURES

(Symbols in red taken from Hurley, 1974.)

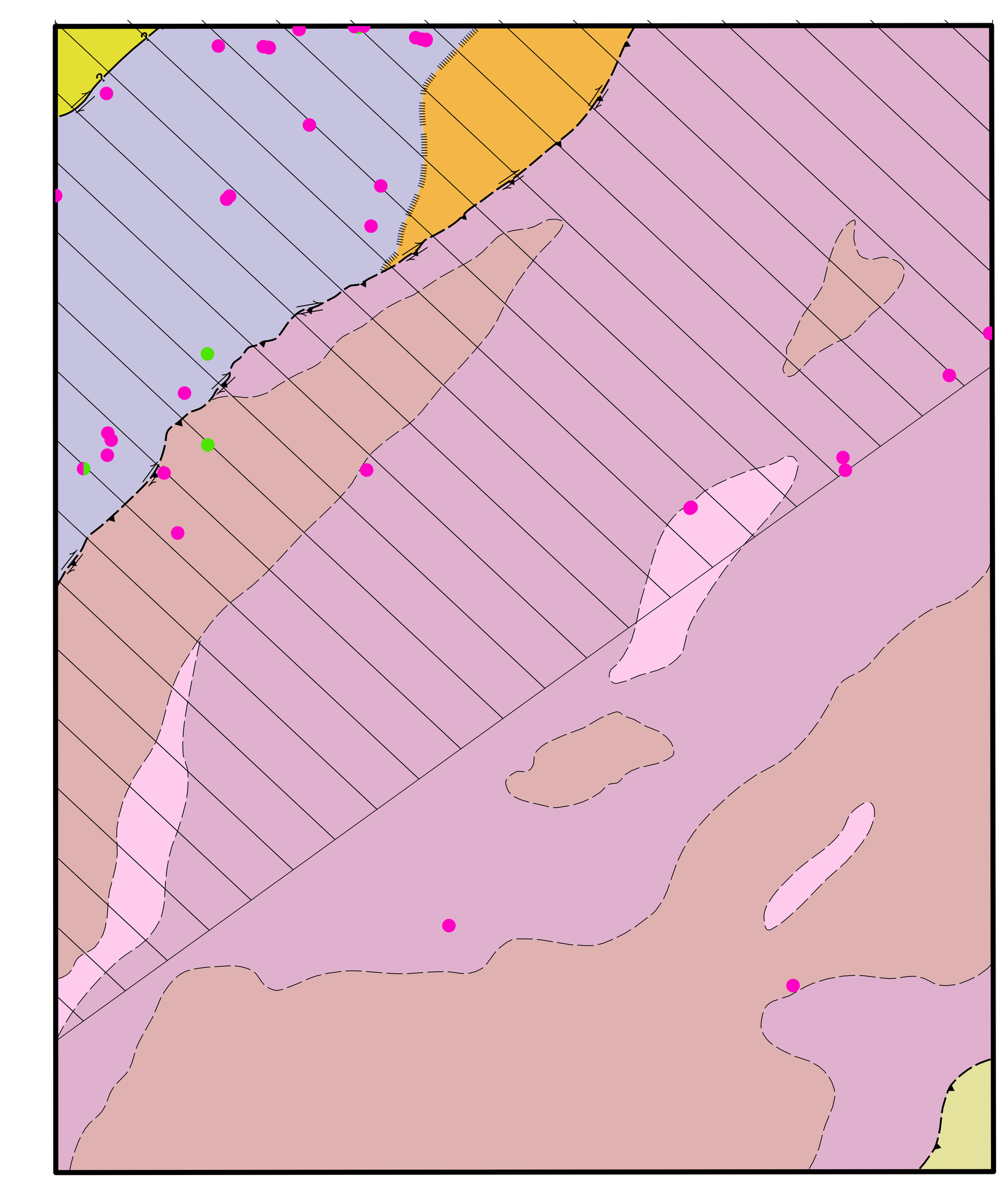
- Inclined aligned-mineral lineation—Showing bearing and plunge
- Inclined slickenline, groove, or striation on fault surface—Showing bearing and plunge
- Inclined fold hinge of generic (type or orientation unspecified) small, minor fold—Showing bearing and plunge
- Inclined generic (origin or type not known or not specified) lineation or linear structure—Showing bearing and plunge

OTHER FEATURES

(Symbols in red taken from Hurley, 1974.)

- Float station
- NB206 — Thin section and whole rock analysis sample location

METAMORPHIC AND TECTONIC CONDITIONS



- Location where chlorite was observed
- Location where garnet was observed
- Brevard Zone deformation

WHOLE ROCK ICP ANALYSIS[1] OF SELECTED SAMPLES

SAMPLE[2]	COORDINATES[3]	ROCK TYPE	MAP UNIT	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O	MnO	Cr_2O_3	LOI[4]	Sum[5]
				MAJOR OXIDES IN PERCENT												
NB323a	207,763N 315,509E	porphyroclastic biotite gneiss	Dpg	62.63	16.44	5.96	1.73	3.54	3.57	3.53	1	0.35	0.07	0.002	0.9	99.78
NB323b	207,763N 315,509E	biotite gneiss	Dpg	70.62	15.19	2.56	0.82	2.48	4.48	1.82	0.35	0.13	0.04	<0.002	1.4	99.9
NB323c	207,763N 315,509E	biotite gneiss and schist	Dpg	69.09	15	3.41	1.13	2.27	3.71	4.1	0.48	0.16	0.05	0.005	0.4	99.9
BC459	210,039N 322,717E	biotite gneiss	mx	71.56	14.33	2.77	0.64	2.06	3.69	3.84	0.37	0.13	0.05	<0.002	0.4	99.91
19BC29	202,923N, 320,945E	biotite gneiss	mx	70.9	14.34	3.01	0.78	2.03	3.4	3.87	0.43	0.2	0.05	<0.002	0.8	99.89
19NB62	203,218N, 319,167E	biotite gneiss	mx	72.87	14.15	2.15	0.41	1.36	3.43	4.57	0.24	0.07	0.03	<0.002	0.6	99.93
19NB4	204,027N, 324,510E	augen gneiss	Ohg	70.06	14.9	2.63	0.67	1.37	2.84	5.56	0.42	0.13	0.05	<0.002	1.2	99.9
19NB52	201,414N, 314,995E	augen gneiss	Ohg	61.28	17.06	5.89	1.41	3.47	3.81	4.6	1.03	0.3	0.12	<0.002	0.6	99.79

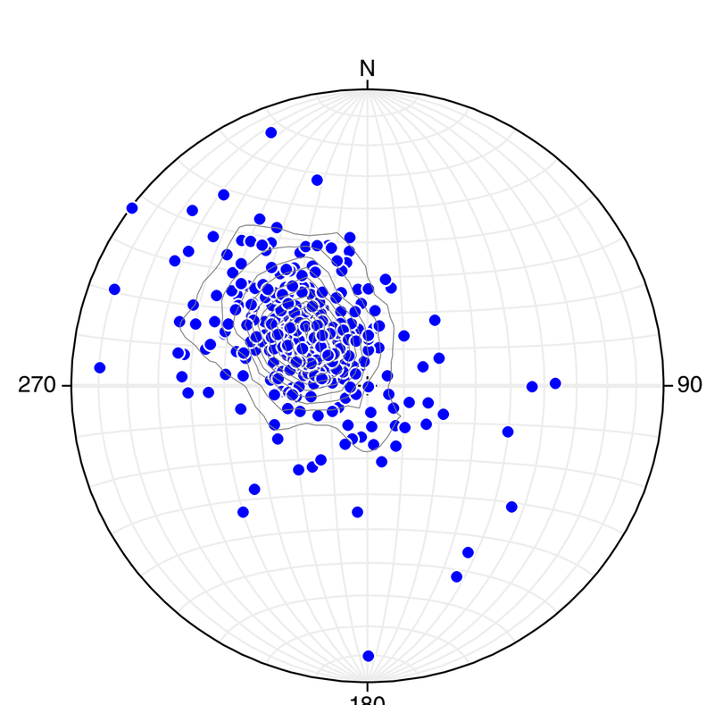
ELEMENTS IN PPM[6]

SAMPLE	Ba	Ni	Sc	Be	Co	Cs	Ga	Hf	Nb	Rb	Sn	Sr	Ta	Th	U	V	W	Zr	Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Mo	Cu	Pb	Zn	Ni	As	Cd	Sb	Bi	Ag	Au	Hg	Tl	Se
NB323a	971	<20	11	2	11.1	0.4	19.5	11.5	20.6	86.5	3	417.9	1.2	8.3	1.3	85	<0.5	452.9	34.9	67	142.7	16.3	59.6	10.66	2.14	8.82	1.28	7.08	1.33	3.69	0.51	3.18	0.43	0.7	30.3	3.2	74	8.2	<0.5	<0.1	<0.1	<0.1	<0.1	<0.5	<0.01	0.4	<0.5
NB323b	479	<20	4	4	4.7	0.2	17.5	3.6	9.4	48.4	2	294.1	0.8	9.9	1.1	42	0.5	137.7	8.7	33.2	58.6	6.07	20.4	3.42	0.86	2.93	0.39	1.97	0.32	0.84	0.12	0.72	0.09	0.4	6.9	4.7	36	5.4	<0.5	<0.1	<0.1	<0.1	<0.1	<0.5	<0.01	0.2	<0.5
NB323c	495	<20	7	5	7.3	0.6	19.4	3.9	40.6	80	2	275.2	3.1	9.5	3.3	51	<0.5	128.2	14.3	23.8	43.1	5.02	19	3.48	0.9	3.13	0.5	2.71	0.57	1.51	0.22	1.45	0.19	1.6	5.2	3.5	44	10.7	<0.5	<0.1	<0.1	<0.1	<0.1	1.8	<0.01	0.4	<0.5
BC459	624	<20	5	3	4.3	2	15.3	4.4	11.8	108.6	2	231.3	0.7	6.7	3.7	33	<0.5	153.6	9.1	14.3	33.1	2.94	11	2.12	0.51	2.09	0.33	1.87	0.36	0.96	0.14	0.92	0.14	5.3	6.6	2.7	36	4.7	<0.5	<0.1	<0.1	<0.1	<0.1	0.7	<0.01	0.4	<0.5
19BC29	1014	<20	6	3	4.4	2	15.6	5.5	14.1	105.3	1	302	0.7	15.1	2.3	32	<0.5	187.9	9.3	15.2	70.2	3.53	12.6	2.84	0.59	2.37	0.35	1.94	0.35	1.05	0.14	1.08	0.15	0.9	11.5	5.1	44	3.2	<0.5	<0.1	<0.1	<0.1	<0.1	<0.5	<0.01	0.4	<0.5
19NB62	471	<20	4	2	3.1	1.7	14.5	4	10.9	129.4	2	160.3	0.5	14.1	2.7	16	<0.5	139.7	15	7.7	54.8	1.66	6.4	1.72	0.51	1.91	0.39	2.6	0.54	1.74	0.25	1.6	0.26	1.8	4.5	4.7	30	3.7	<0.5	<0.1	<0.1	<0.1	<0.1	<0.5	<0.01	0.3	<0.5
19NB4	704	<20	6	<1	4.4	4	15.5	5.9	15.9	181.8	2	169.2	1.4	18.5	2.3	32	<0.5	202.4	17.1	18.4	70.1	4.23	15.3	3.06	0.58	2.57	0.47	3.25	0.66	2.06	0.31	2.12	0.34	0.6	2.5	3.9	42	3.8	<0.5	<0.1	<0.1	<0.1	<0.1	<0.5	<0.01	0.4	<0.5
19NB52	1995	<20	15	3	9.1	2	20.5	15.5	27.2	113.1	2	330.4	0.9	4.7	1.6	64	<0.5	658.6	32.1	53.6	92.2	11.59	46.1	8.39	2.84	7.49	1.04	6.12	1.19	3.17	0.44	2.84	0.44	1.1	9	1.7	92	6.6	<0.5	<0.1	<0.1	<0.1	<0.1	<0.5	<0.01	0.5	<0.5

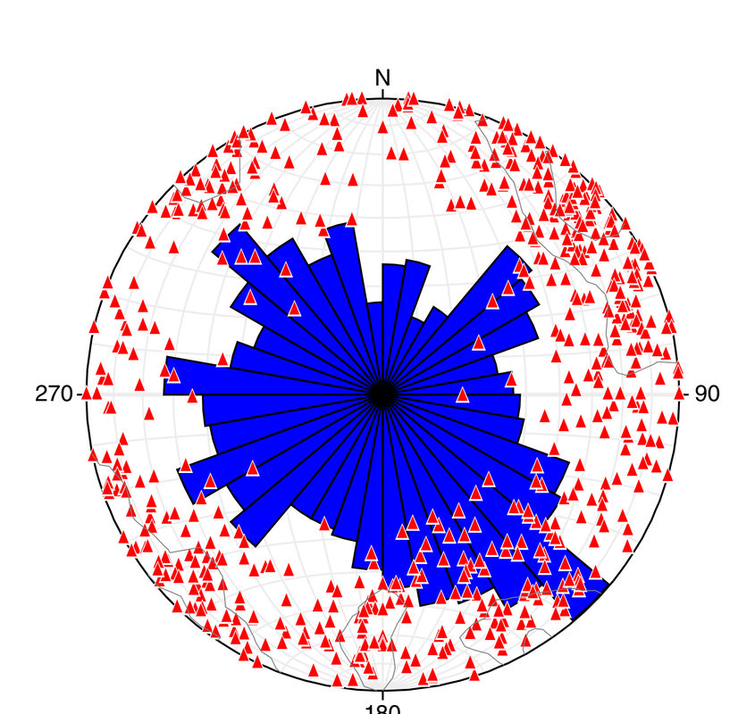
[1]Whole Rock Inductively Coupled Plasma - Atomic Emission/Mass Spectrometer analysis conducted by Bureau Veritas, 9050 Shaughnessy St, Vancouver, BC Canada V6P 6E5.
[2]Sample numbers correspond to thin section and whole rock sample localities shown on geologic map
[3]State Plane Coordinate System
[4]LOI = loss on ignition in percent
[5]SUM = Sum total in percent
[6]PPM = parts per million. Ni analyzed by Bureau Veritas LF200 and AQ200 procedures.

SCHMIDT EQUAL AREA STEREONET DATA

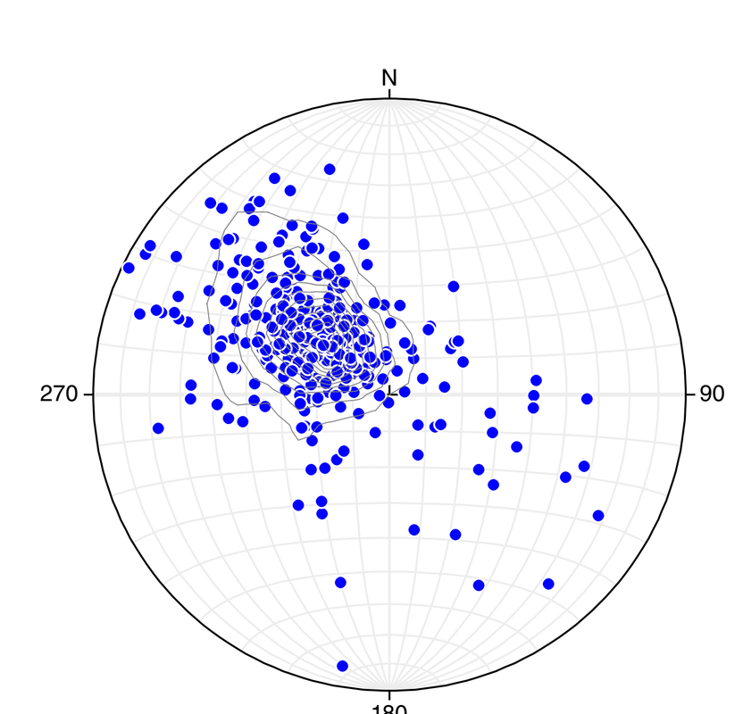
Stereonets created using Stereonet 10 (Allmendinger, et al., 2012; Cardozo and Allmendinger, 2013.)



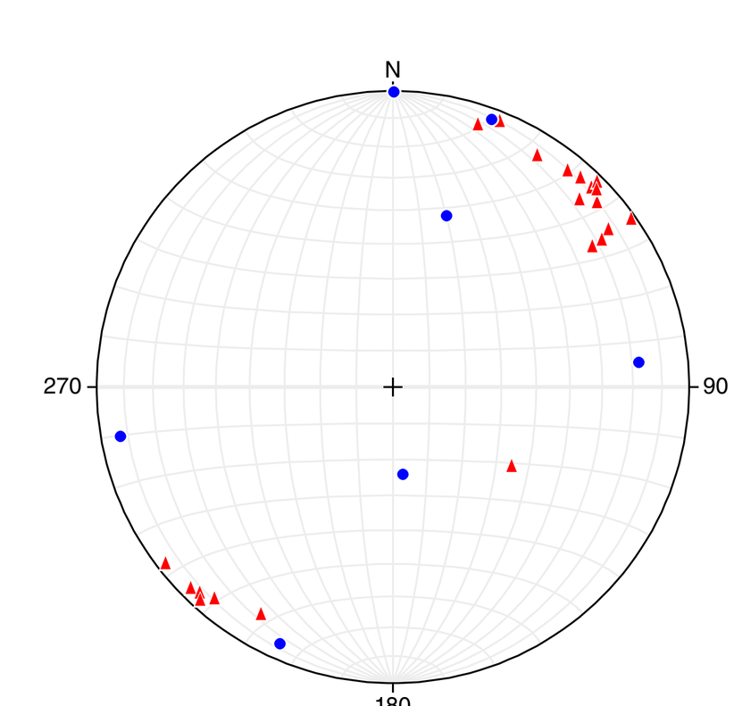
Contoured poles to foliation.
Foliation count 340.



Contoured poles to joints and unidirectional rose diagram inset.
Joint count 659.



Contoured poles to mylonitic foliation.
Mylonitic foliation count 349.



Bearing and plunge of fold hinges in blue and mineral lineations in red. Fold hinge count 6.
Mineral lineation count 22.

Topographic base produced by the United States Geological Survey.
Altered by the North Carolina Geological Survey for use with this map.
North American Datum of 1983 (NAD83).
World Geodetic System of 1984 (WGS84).
Projection: State Plane North Carolina FIPS 3200 (Meters)
4,000-meter ticks: State Plane North Carolina FIPS 3200 (Meters)

Imagery........NAIP, July 2014
Roads........U.S. Census Bureau, 2015 - 2016
Roads within US Forest Service Lands........FSTopo Data with limited Forest Service updates, 2012 - 2016
Names........GNIS, 2016
Hydrography........National Hydrography Dataset, 2014
Contours........National Elevation Dataset, 2008
Boundaries........Multiple sources; see metadata file 1972 - 2016
Wetlands........FWS National Wetlands Inventory 1977 - 2014

UTM GRID AND 2016 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

6° 48´ 121 MILS
0° 41´ 12 MILS

U.S. National Grid
100,000-m Square ID
LV
Grid Zone Designation
17S

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

This map was produced to conform with the National Geospatial Program US Topo Product Standard, 2011.
A metadata file associated with this product is draft version 0.6.19

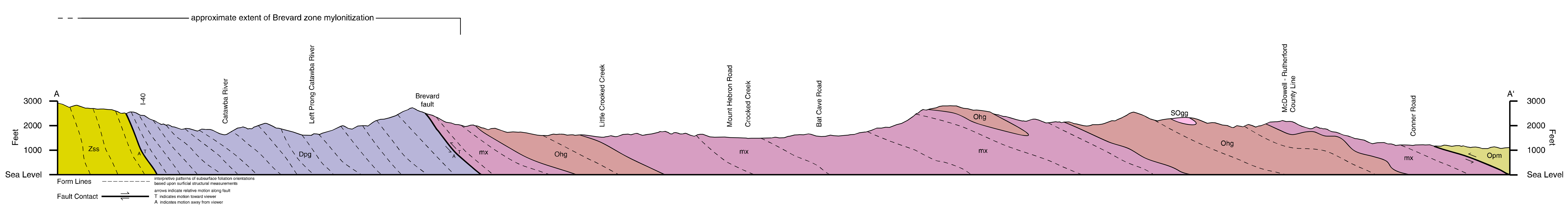
QUADRANGLE LOCATION

ADJOINING QUADRANGLES
1 Montreat
2 Old Fort
3 Marion West
4 Black Mountain
5 Sugar Hill
6 Bat Cave
7 Lake Lure
8 Shingle Hollow

ROAD CLASSIFICATION
Expressway — Local Connector
Secondary Hwy — Local Road
Ramp — 4WD
Interstate Route — US Route — State Route
FS Primary Route — FS Passenger Route — FS High Clearance Route

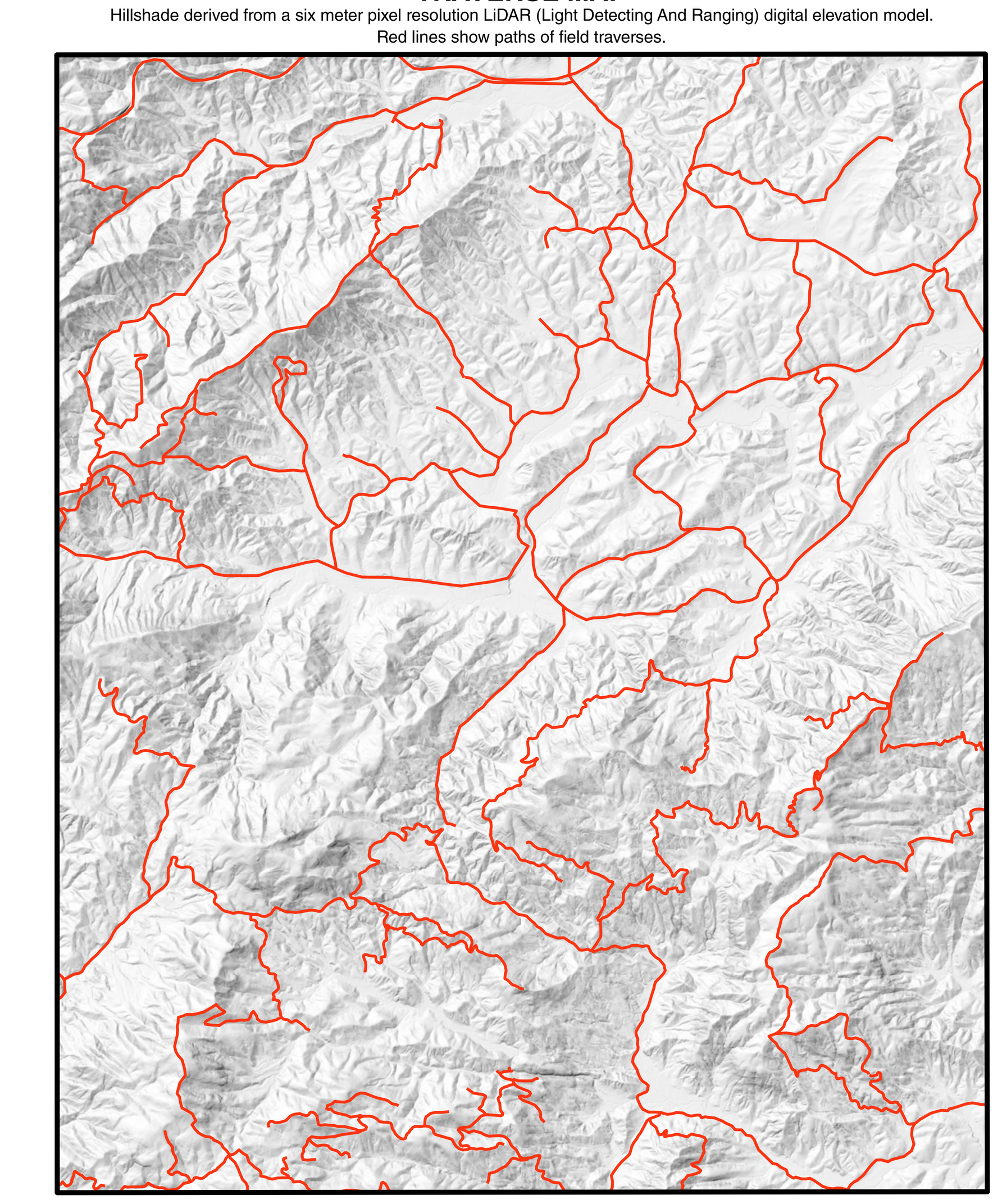
Check with local Forest Service unit for current travel conditions and restrictions.

MOFFITT HILL, NC
2016



TRAVERSE MAP

Hillshade derived from a six meter pixel resolution LiDAR (Light Detecting And Ranging) digital elevation model.
Red lines show paths of field traverses.



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Bedrock Geologic Map of the Moffitt Hill 7.5-minute Quadrangle, McDowell, Rutherford and Buncombe Counties, North Carolina

By
Bart L. Cattanach, G. Nicholas Bozdog, and Sierra J. Isard

Geology mapped from July 2019 to June 2020. Some field data and linework from Hurley, 1974.
Map preparation, digital cartography and editing by G. Nicholas Bozdog, Bart L. Cattanach, and Sierra J. Isard
2020

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