North Carolina Department of Environmental Quality
Divison of Energy, Mineral and Land Resources
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North Carolina Geological Survey
Open File Report 2019-07

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CORRELATION OF MAP UNITS

AGE UNKNOWN

- bzmp — Mylonite / Phyllonite
- bzpg — Porphyroclastic biotite gneiss
- mx — Mixed gneiss

NEOPROTEROZOIC

Metasedimentary Rocks

- 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 ft with a low of 1,057 ft along the Cedar Creek and a high of 3,604 ft 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 of unknown affinity; mylonite/phyllonite of the Brevard Fault Zone; and a mixed gneiss unit with several rock types including Tallulah Falls biotite gneiss, Ordovician Henderson Gneiss, and felsic gneiss.

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.

Stratigraphic relationships are unclear but the oldest unit on the quadrangle is interpreted to be the porphyroclastic biotite gneiss. It outcrops in the Moffitt Hill quadrangle immediately northwest of the Brevard Zone mylonite/phyllonite and mixed gneiss units. 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. This unit is of unknown age and affinity but projects along strike to the northeast into Mesoproterozoic gneisses mapped by Bryant and Reed (1970).

Northwest of the porphyroclastic gneiss, 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.

Southeast of the Brevard zone, the mixed gneiss unit contains biotite gneisses possibly correlative to the Tallulah Falls formation mapped to the SE by Bream (1999). 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. Possibly interlayered within the biotite gneiss are intrusions of the Ordovician Henderson Gneiss, 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.

Mylonitic and non-mylonitic foliations within the quadrangle dominantly strike NE-SW and dip 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.

bzpg — **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. Protoliths unknown although tentatively correlated to Mesoproterozoic gneisses mapped along strike to the northeast. Biotite gneiss is typically light-gray to grayish-black; well foliated; locally protomylonitic to ultramylonitic; medium- to coarse-grained; inequigranular; 2-10 mm sized porphyroblasts and/or porphyroclasts; lepidoblastic; consists of quartz, plagioclase, biotite, potassium feldspar, muscovite, minor epidote, garnet, and titanite.

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.

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; massive to well foliated; dominantly biotite granite that ranges to tonalite; consists of potassium feldspar, plagioclase, quartz, biotite, muscovite and sericite, epidote group minerals, opaque minerals, and trace amounts of titanite, zircon, and apatite; locally pegmatitic and migmatitic. Locally microcline augen exceed 2.5 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 — **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 does not contain schist, amphibolite, or garnet.

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

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

MN GN 6° 48´ 121 MILS 0° 41´ 12 MILS

UTM GRID AND 2016 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

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

SCALE 1:24 000

KILOMETERS: 1 0.5 0 1 2
METERS: 1000 500 0 1000 2000
MILES: 1 0.5 0 1
FEET: 1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

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

NORTH CAROLINA

QUADRANGLE LOCATION

1	2	3
4		5
6	7	8

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

ADJOINING QUADRANGLES

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

EXPLANATION OF MAP SYMBOLS

CONTACTS

Zone of Confidence: 300m

Gradational 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

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.)

- 64 Inclined metamorphic or tectonic foliation—Showing strike and dip
- 80 78 Inclined metamorphic or tectonic foliation, for multiple observations at one locality—Showing strike and dip
- Vertical metamorphic or tectonic foliation—Showing strike
- 79 Inclined mylonitic foliation—Showing strike and dip
- 38 Inclined generic foliation (origin not specified)—Showing strike and dip
- 71 Small, minor inclined joint—Showing strike and dip
- 86 66 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
- 23 46 Inclined mylonitic foliation, for multiple observations at one locality—Showing strike and dip

LINEAR FEATURES

(Symbols in red taken from Hurley, 1974.)

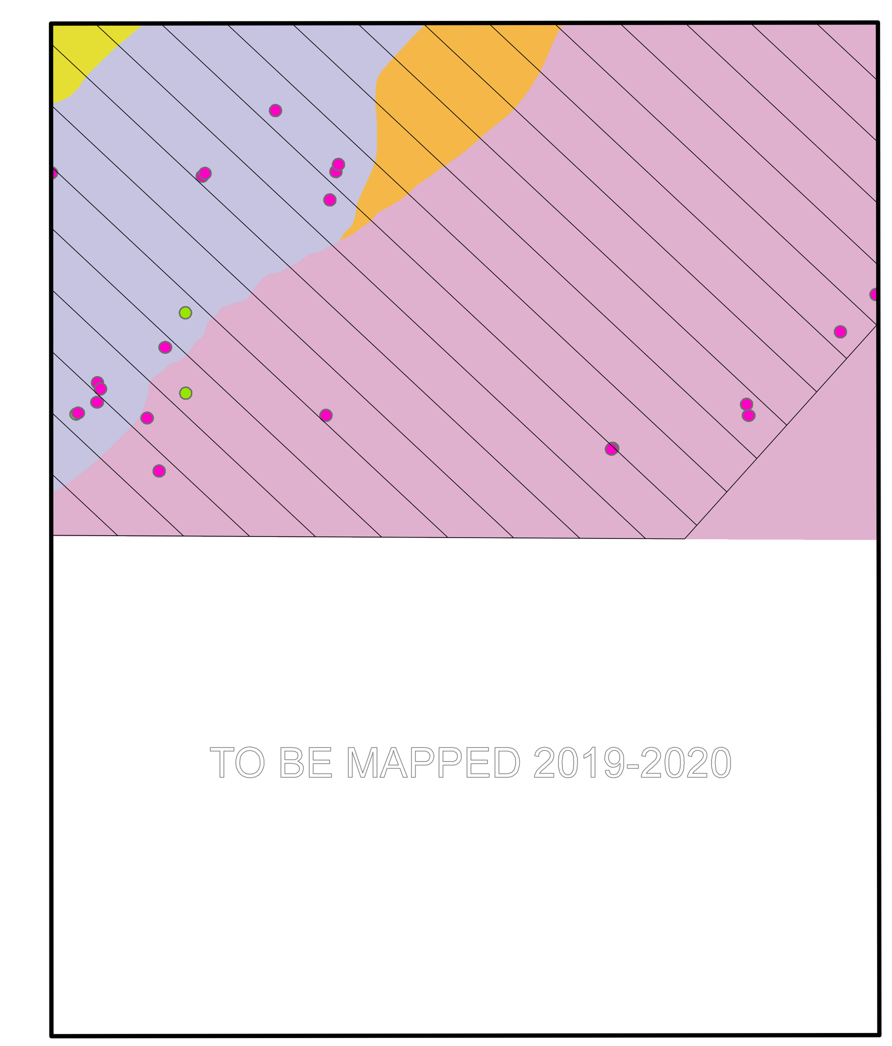
- 6 Inclined aligned-mineral lineation—Showing bearing and plunge
- 18 Inclined slickenline, groove, or striation on fault surface—Showing bearing and plunge
- 56 Inclined fold hinge of generic (type or orientation unspecified) small, minor fold—Showing bearing and plunge
- 12 Inclined generic (origin 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

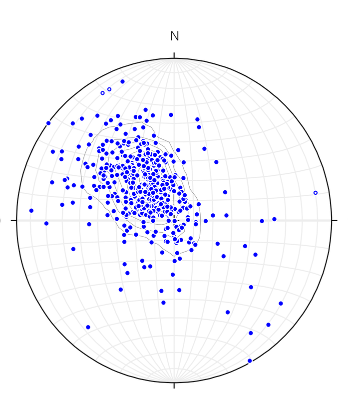
WHOLE ROCK ICP ANALYSIS[1] OF SELECTED SAMPLES

SAMPLE[2]	COORDINATES[3]	ROCK TYPE	MAP UNIT	MAJOR OXIDES IN PERCENT SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3	LOI[4]	Sum[5]
NB323a	207,763N 315,509E	porphyroclastic biotite gneiss	bzpg	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	bzpg	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	bzpg	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

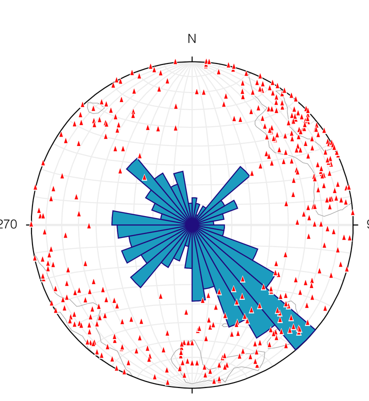
SAMPLE[2]	ELEMENTS IN PPM[6] Ba	Ni	Sc	Be	Co	Cs	Ga	Hf	Nb	Rb	Sn	Sr	Ta	Th	U	V	W	Zr	Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Mo	Cu	Pb	Zn	Ni	As	Cd	Sb	Bi	Ag	Au	Hg	Tl	Se
NB323a	971	<20	11	2	11.1	0.4	19.5	12	20.6	86.5	3	417.9	1.2	8.3	1.3	85	<0.5	452.9	34.9	67	143	16.3	59.6	10.7	2.14	8.82	1.28	7.08	1.33	3.69	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

[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.

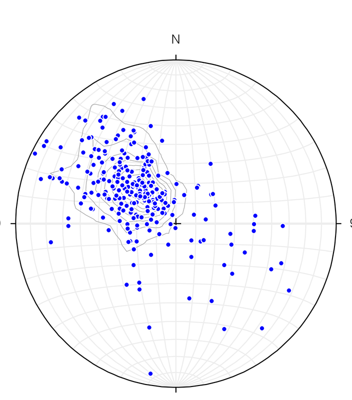
SCHMIDT EQUAL AREA STEREONET DATA



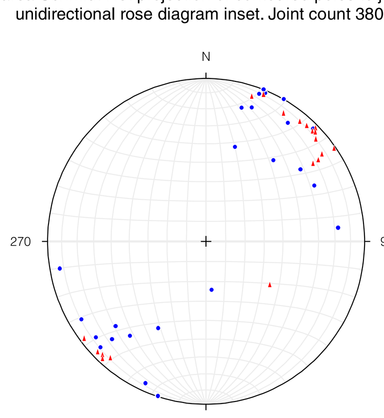
Equal area Schmidt Net projection of contoured poles to foliation. Foliation count 454.



Equal area Schmidt Net projection of contoured poles to joints and unidirectional rose diagram inset. Joint count 380.



Equal area Schmidt Net projection of contoured poles to mylonitic foliation. Mylonitic foliation count 268.



Equal area Schmidt Net projection of bearing and plunge of fold hinges in blue and mineral lineations in red. Fold hinge count 24. Mineral lineation count 20.

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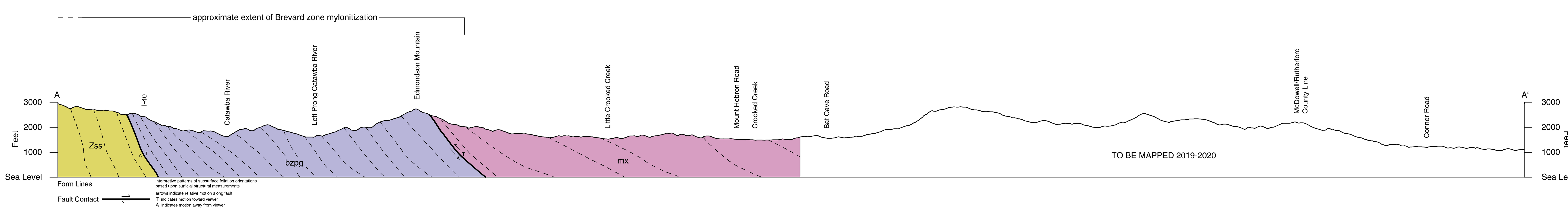

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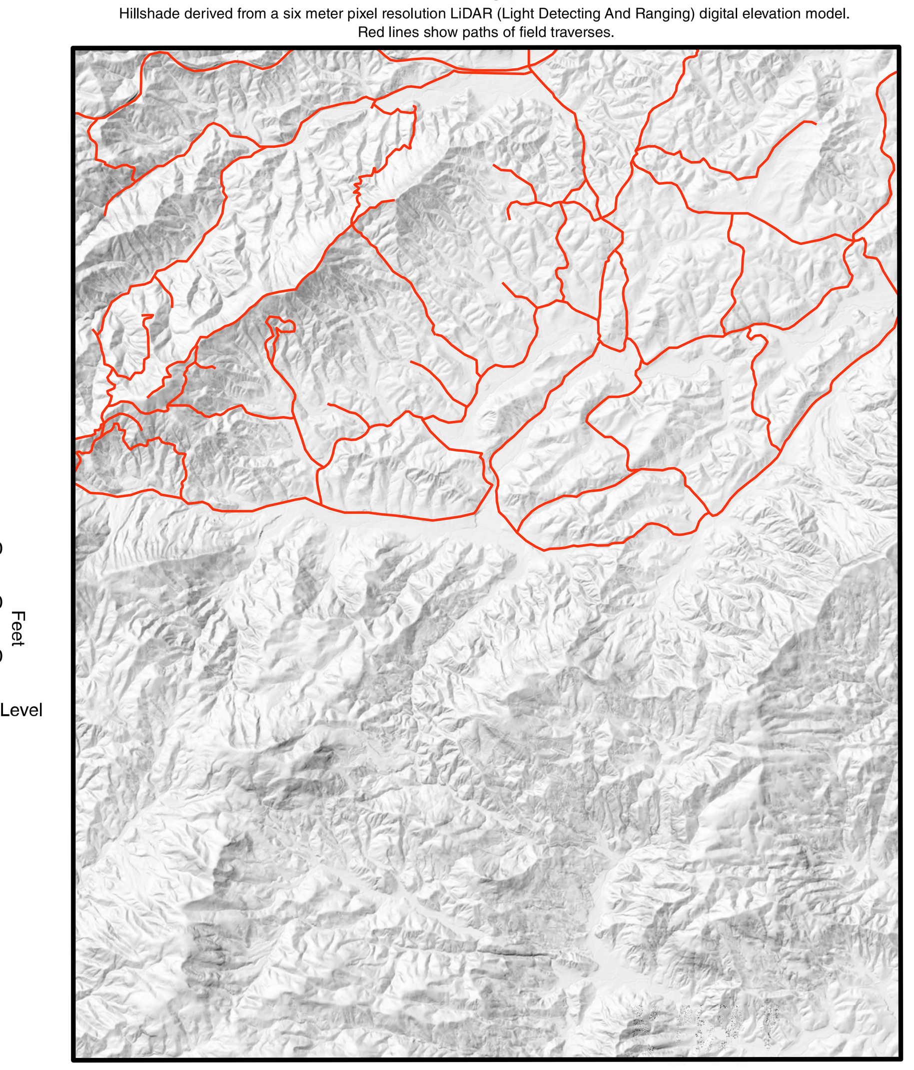
Bedrock Geologic Map of the Northern half of the Moffitt Hill 7.5-minute Quadrangle, McDowell, Rutherford and Buncombe Counties, North Carolina

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

Geology mapped from July 2018 to June 2019.
Map preparation, digital cartography and editing by G. Nicholas Bozdog, Bart L. Cattanach, and Sierra J. Isard
2019

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. Some station data omitted from map to improve readability. Please contact the North Carolina Geological Survey for complete observation and thin-section data.

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.