North Carolina Department of Environmental Quality
Divison of Energy, Mineral and Land Resources
S. Daniel Smith, Director
Kenneth B. Taylor, State Geologist

North Carolina Geological Survey
Open File Report 2019-04

CORRELATION OF MAP UNITS

AGE UNKNOWN

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

NEOPROTEROZOIC

Metasedimentary Rocks

- Zss — Metasandstone
- Zun — Undivided
  - Zgs — Graphitic schist
  - Za — Amphibolite

(stratigraphic relations uncertain)

INTRODUCTION

The Old Fort 7.5-minute quadrangle lies in western North Carolina in portions of McDowell and Yancey counties. The town of Old Fort is the largest community on the quadrangle. Much of the quadrangle north of the town of Old Fort lies within Pisgah National Forest owned by the U.S. Forest Service. Major transportation corridors include Interstate 40, the Blue Ridge Parkway, and Highway 70. Major streams include the Catawba River and its tributaries Curtis Creek, Cane Creek, and Mackey Creek. Total elevation relief is 3,770 ft with a low of 1,330 ft along Cane Creek and a high of 5,100 ft on Black Ridge.

GEOLOGIC OVERVIEW

Bedrock of the Old Fort quadrangle comprises the following units (from northwest to southeast): An undivided Neoproterozoic metasedimentary unit with interlayers of amphibolite and graphitic schist; a 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 Old Fort 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). In the Old Fort quadrangle, ductile shearing attributed to Brevard Zone deformation is observed in a zone up to 9 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 center of the Old Fort 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. 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 metasedimentary units possibly correlative with the Ashe and Alligator Back Metamorphic Suites. These rocks are thick sequences of complexly deformed and metamorphosed clastic sediments deposited in marine rift basins. Interspersed with these sediments are lesser amounts of mafic volcanic rocks and ultramafic rocks thought to have originated as oceanic crust at a spreading center (Misra and Conte, 1991; Raymond and Abbott, 1997). These metasedimentary lithologies were complexly deformed and metamorphosed to amphibolite facies conditions during Taconic orogenesis. The effects of Brevard Zone shearing increase from northwest to southeast within these units. The metasandstone unit does not contain schist, amphibolite, or garnet while the undivided unit contains schist, amphibolite, and garnet along with lithologies found in the metasandstone unit. This may represent a shift in depositional environment from shallower marine in the SE to deeper marine in the NW.

Southeast of the Brevard zone, the mixed gneiss unit contains biotite gneisses of unknown affinity and may contain the Ordovician Henderson Gneiss. 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. Portions of this biotite gneiss may be correlative to the Tallulah Falls Formation mapped to the SE by Bream (1999). 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) determined the age of the Henderson Gneiss is 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

WHOLE ROCK ICP ANALYSIS[1] OF SELECTED SAMPLES

SAMPLE[2]	BC79	NB73	NB43	NB130	NB105	NB278	NB148	BC255	BC247	NB21
COORDINATES[3]	224,781N 323,691E	224,199N 322,499E	223,952N 320,927E	220,115N 318,886E	218,419N 318,989E	219,164N 323,890E	216,016N 321,787E	215,772N 322,588E	214,214N 320,311E	213,927N 318,819E
ROCK TYPE	feldspathic metawacke	feldspathic metawacke	muscovite schist/phyllonite	feldspathic metawacke	feldspathic metawacke	mylonitic granitoid	biotite gneiss	biotite gneiss	metawacke	biotite gneiss
MAP UNIT	Zun	Zun	Zun	Zun	Zss	bzpg	bzpg	bzpg	bzpg	bzpg
MAJOR OXIDES IN PERCENT										
SiO_2	74.81	76.69	55.1	74.71	71.83	73.37	60.17	68.43	55.84	72.05
Al_2O_3	10.53	10.37	20.69	11.11	11.59	14.59	18.01	14.51	15.69	14.68
Fe_2O_3	4.95	4.65	8.79	4.41	4.73	1.59	5.83	5.28	11.63	2.87
MgO	1.43	0.98	1.89	1.12	1.37	0.22	1.82	1.97	3.34	0.8
CaO	1	1.52	0.17	0.63	2.3	0.98	2.74	1.19	3.7	2.75
Na_2O	2.77	2.59	0.15	2.48	2.29	3.05	4.48	2.53	2.79	4.13
K_2O	2.69	1.4	8.08	3.19	3.2	5.07	3.31	2.68	3.32	1.37
TiO_2	0.62	0.74	0.87	0.71	0.65	0.13	0.97	0.69	1.9	0.3
P_2O_5	0.07	0.08	0.13	0.15	0.18	0.06	0.46	0.17	0.3	0.09
MnO	0.05	0.09	0.05	0.06	0.07	0.02	0.12	0.09	0.15	0.03
Cr_2O_3	0.005	0.006	0.009	0.005	0.004	<0.002	<0.002	0.008	0.011	<0.002
LOI[4]	0.9	0.7	3.8	1.2	1.6	0.8	1.9	2.2	1	0.8
SUM[5]	99.89	99.88	99.86	99.87	99.85	99.94	99.83	99.86	99.78	99.87
ELEMENTS IN PPM[6]										
Ba	851	323	1205	673	573	1025	427	551	797	340
Ni	<20	22	37	<20	<20	<20	<20	27	54	<20
Sc	7	7	16	6	8	3	19	12	25	6
Be	2	<1	3	<1	<1	<1	4	4	2	4
Co	7.8	11.7	11.4	6.3	5.2	1.2	9.7	12.9	31.4	4.6
Cs	0.3	0.6	0.9	<0.1	0.4	<0.1	2.6	1.6	6.2	2.2
Ga	11.8	11.3	29.2	13.6	15.8	16.9	20.3	17.6	19	13.5
Hf	8.6	9.3	6	10.2	10.3	1.3	6.5	5.3	6.4	3.7
Nb	8.8	10.6	22.7	11.9	13	5.3	30.4	14.3	16	6.2
Rb	57	45.9	230.5	69.2	106.3	74.5	153	84.3	110.5	51.6
Sn	2	4	5	2	2	2	13	2	2	<1
Sr	163.5	186.2	36.2	218.3	131.1	263.7	260.1	159.7	246.8	297.5
Ta	0.6	0.6	1.5	0.7	0.9	0.2	2.1	0.9	1	0.4
Th	4.7	6	16.3	10.8	11.9	8.4	7.8	9.4	7.3	15.6
U	1.3	1.8	2.9	2.1	3	0.6	2.3	2.2	1.8	1.7
V	65	59	96	44	59	<8	67	66	225	38
W	<0.5	<0.5	2.1	1	0.6	<0.5	<0.5	1.7	1.6	0.7
Zr	341.8	359.6	228.4	401.7	403.2	35.6	306	194.5	239.2	136.8
Y	21.1	30.6	16.1	20.3	33.9	4.3	39.8	27.1	35	9.2
La	20.4	34.7	22.5	20.2	47.9	22.7	17.8	35.1	35.3	34.1
Ce	41.8	58.6	81	67.3	98.6	20	42.7	71.8	74.3	65.7
Pr	4.97	7.83	5.06	5.09	11.41	4.13	4.27	7.91	8.55	6.75
Nd	19.9	30.7	18.2	19.4	43.7	14.8	16.9	31.9	35.6	22.4
Sm	4.09	6.09	3.76	4.09	8.14	2.59	4.78	5.95	7.35	3.5
Eu	0.96	1.4	0.76	0.82	1.37	0.55	0.75	1.13	1.87	1.08
Gd	3.65	6.22	3.5	3.67	7.05	1.83	6.04	5.33	7.25	2.47
Tb	0.61	0.92	0.59	0.58	1.08	0.22	1.14	0.78	1.13	0.33
Dy	3.56	5.66	3.67	3.5	6.32	0.97	7.45	4.8	6.81	1.72
Ho	0.78	1.09	0.74	0.8	1.3	0.17	1.42	0.99	1.36	0.31
Er	2.46	3	2.22	2.27	3.73	0.41	4.07	2.83	3.87	0.93
Tm	0.36	0.43	0.37	0.34	0.55	0.06	0.54	0.41	0.52	0.15
Yb	2.36	2.78	2.43	2.17	3.57	0.29	3.29	2.54	3.53	0.95
Lu	0.37	0.43	0.43	0.32	0.55	0.05	0.5	0.41	0.52	0.13
Mo	4.7	2.1	1.9	4.2	1	0.8	0.7	1	1.6	1
Cu	11.1	14.3	14.2	12	2.7	1.6	28.6	15	58.7	6.2
Pb	5.4	3.7	3.1	3.6	3.2	4.2	3.8	2.2	2	4.7
Zn	48	65	49	43	60	16	80	80	114	42
Ni	12.2	20.8	19.1	10	9.6	1.5	6.3	24	47	6.3
As	0.6	0.6	<0.5	0.7	0.8	<0.5	<0.5	<0.5	2.2	<0.5
Cd	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sb	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bi	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ag	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Au	<0.5	<0.5	0.8	<0.5	1.7	<0.5	<0.5	<0.5	<0.5	0.9
Hg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tl	0.3	0.3	0.5	0.4	0.5	<0.1	0.7	<0.1	0.6	0.2
Se	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<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.

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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.

Zun — **Undivided** — Heterogeneous unit consisting of interlayered layers and lenses of laterally and vertically grading sedimentary and mafic volcanic rocks metamorphosed to kyanite- and sillimanite-grade. Rock types include metawacke, arkosic meta-arenite, schist, graphitic schist, mylonite, phyllonite, biotite gneiss, and amphibolite. Thickness of layering ranges from centimeters to meters.

Biotite metawacke — Medium-light-gray to medium-dark-gray; medium- to coarse-grained; foliated; protomylonitic to mylonitic; equigranular to inequigranular; granoblastic to lepidoblastic; locally migmatitic; consists of quartz, plagioclase feldspar, biotite, muscovite, garnet, epidote, sillimanite and/or kyanite, staurolite, chlorite, opaque minerals, trace potassium feldspar and zircon; thickness of layering ranges from decimeters to meters.

Muscovite metawacke — Light-tan to light-gray; fine- to medium-grained; foliated; protomylonitic to mylonitic; granoblastic to lepidoblastic; consists of quartz, plagioclase feldspar, muscovite > biotite, sericite, chlorite, with minor amounts of garnet, potassium feldspar, titanite, apatite, and other accessory minerals; locally has millimeter scale "pin-striped" fabric.

Arkosic meta-arenite — Tan to medium-light-gray to gray; medium-grained, equigranular to inequigranular, foliated; consists of quartz, feldspar, with minor amounts of muscovite, biotite, and other accessory minerals.

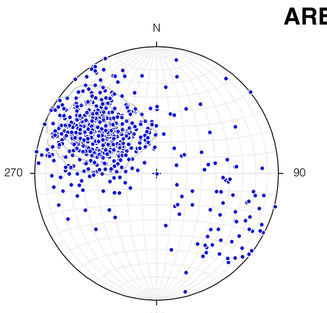
Schist — Garnet-mica schist, muscovite schist, muscovite-biotite schist; very light-gray to greenish-gray to medium-gray; medium- to coarse-grained; well foliated and locally mylonitic; inequigranular; lepidoblastic; consists of muscovite, biotite, garnet, quartz, plagioclase feldspar, potassium feldspar, and minor accessory minerals; locally contains chlorite, staurolite, tourmaline, kyanite, graphite, and trace zircon.

Zgs — **Graphitic schist** — Dark-gray to greenish-gray to medium-gray; fine- to medium-grained; well foliated to mylonitic; equigranular to inequigranular; lepidoblastic to porphyroblastic; consists of muscovite, biotite, garnet, sericite, quartz, graphite, feldspar, chlorite, pyrite, and accessory minerals; interlayered with lesser amounts of metaarkose, metawacke, garnet-mica schist, and phyllite.

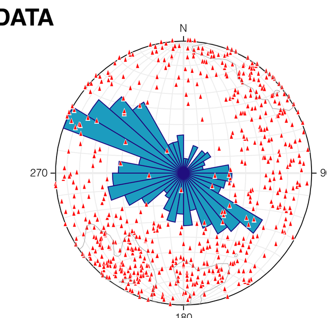
Za — **Amphibolite** — Dark-green to black; fine- to coarse-grained; weakly to strongly foliated; equigranular; granoblastic to nematoblastic; consists of hornblende, plagioclase feldspar, epidote group minerals, quartz, garnet, chlorite, relict pyroxene, titanite, magnetite, and opaque minerals. Can occur as a very minor rock type throughout the other map units, where it may represent a metamorphosed volcanic rock.

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

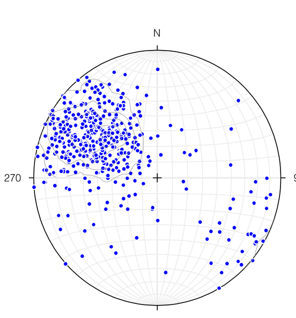
SCHMIDT EQUAL AREA STEREONET DATA



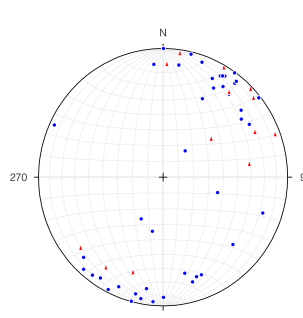
Equal area Schmidt Net projection of contoured poles to foliation. Foliation count 612.



Equal area Schmidt Net projection of contoured poles to joints and unidirectional rose diagram inset. Joint count 628.

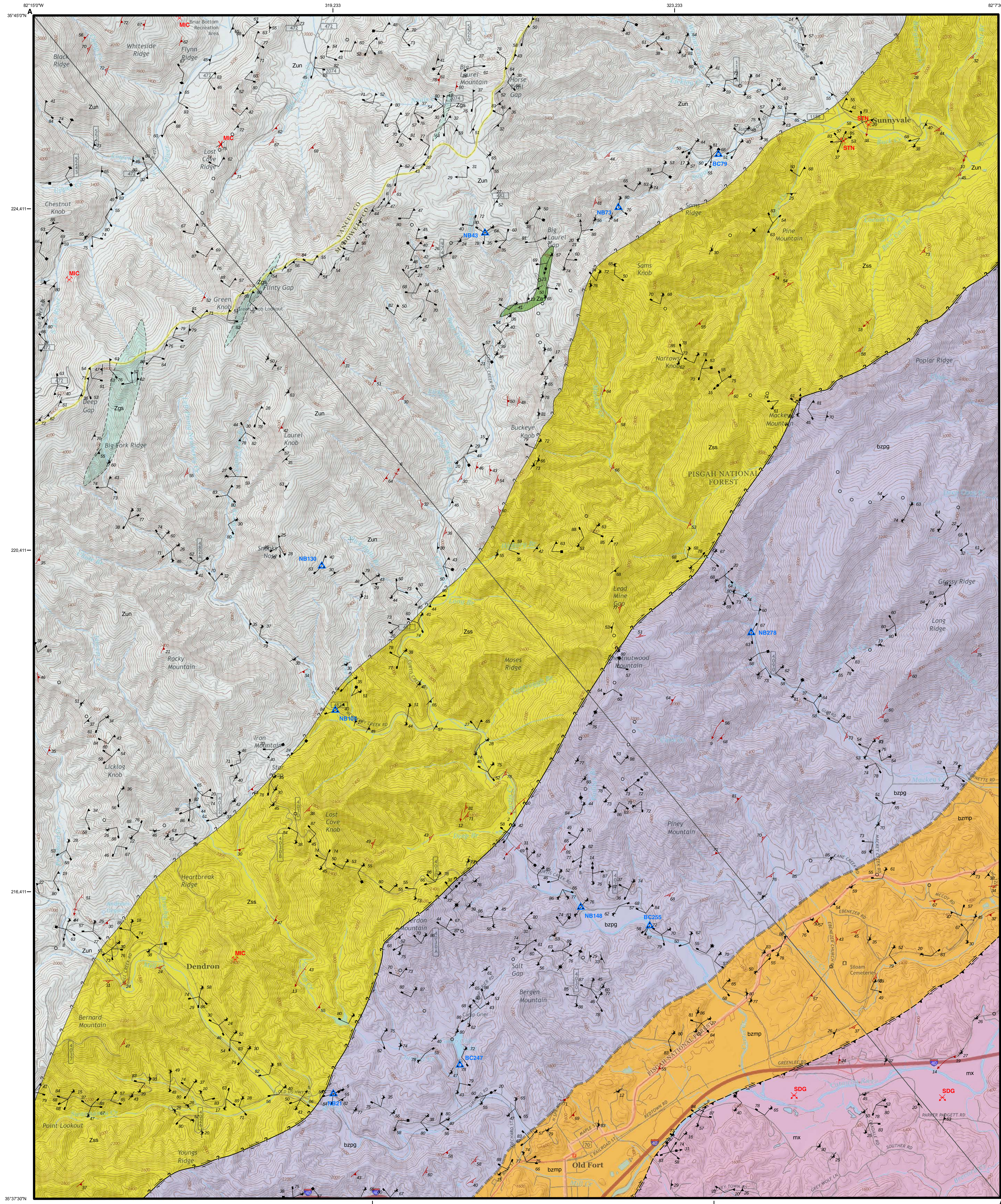


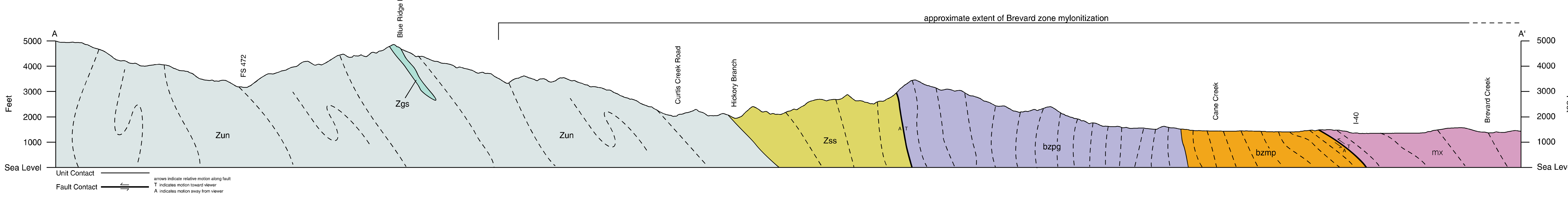
Equal area Schmidt Net projection of contoured poles to mylonitic foliation. Mylonitic foliation count 468.



Equal area Schmidt Net projection of bearing and plunge of fold hinges in blue and mineral lineations in red. Fold hinge count 43. Mineral lineation count 13.

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





EXPLANATION OF MAP SYMBOLS

CONTACTS

Zone of Confidence: 300m

- Contact—Identity and existence certain, location accurate
- Contact—Identity and existence certain, location inferred
- Contact—Identity questionable, existence certain, location accurate
- 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 Butler, 1970.)

- 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
- Vertical metamorphic or tectonic foliation, for multiple observations at one locality—Showing strike
- Inclined mylonitic foliation—Showing strike and dip
- Vertical metamorphic or tectonic mylonitic foliation, for multiple observations at one locality—Showing strike
- 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
- Vertical mylonitic foliation—Showing strike

LINEAR FEATURES

(Symbols in red taken from Butler, 1970.)

- 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
- Inclined crenulation lineation—Showing bearing and plunge

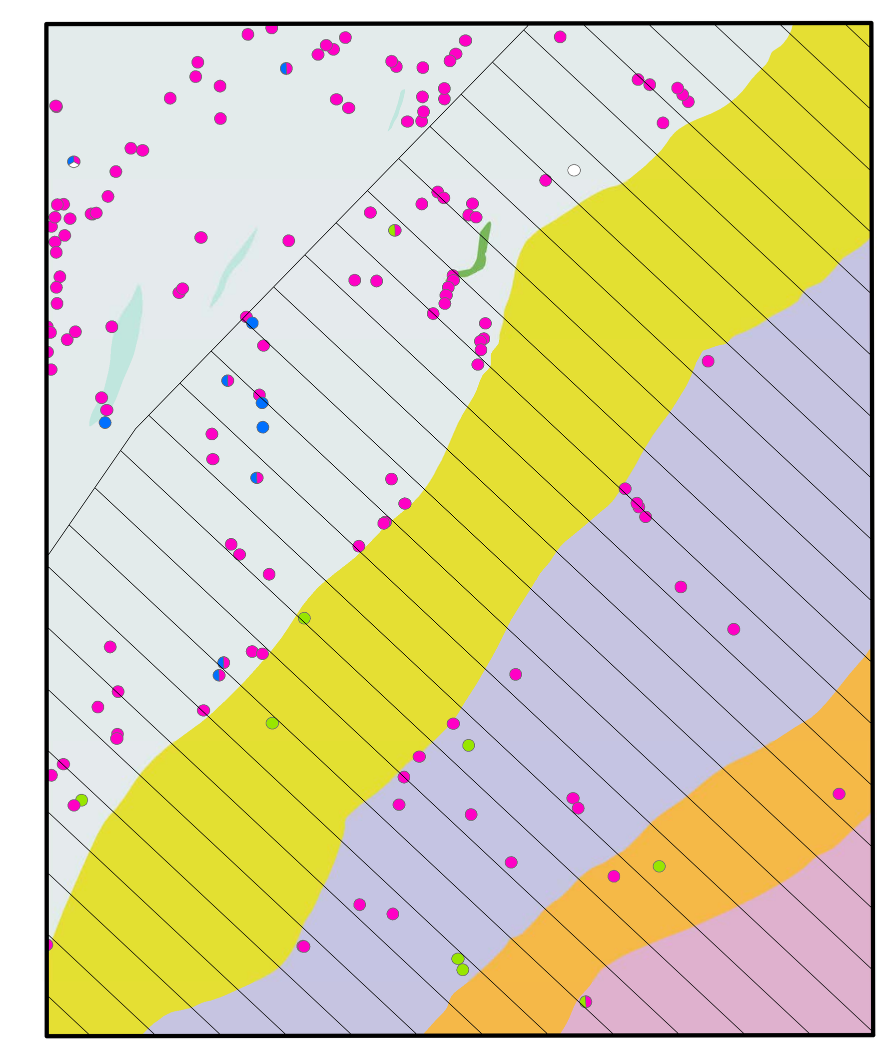
OTHER FEATURES

- Float station
- NB206 Thin section and whole rock analysis sample location
- Prospect (pit or small open cut)
- Abandoned sand, gravel, clay, or placer pit
- Abandoned open pit, quarry, or glory hole

NATURAL RESOURCES

MIC - Mica
SDG - Sand and gravel
STN - Stone

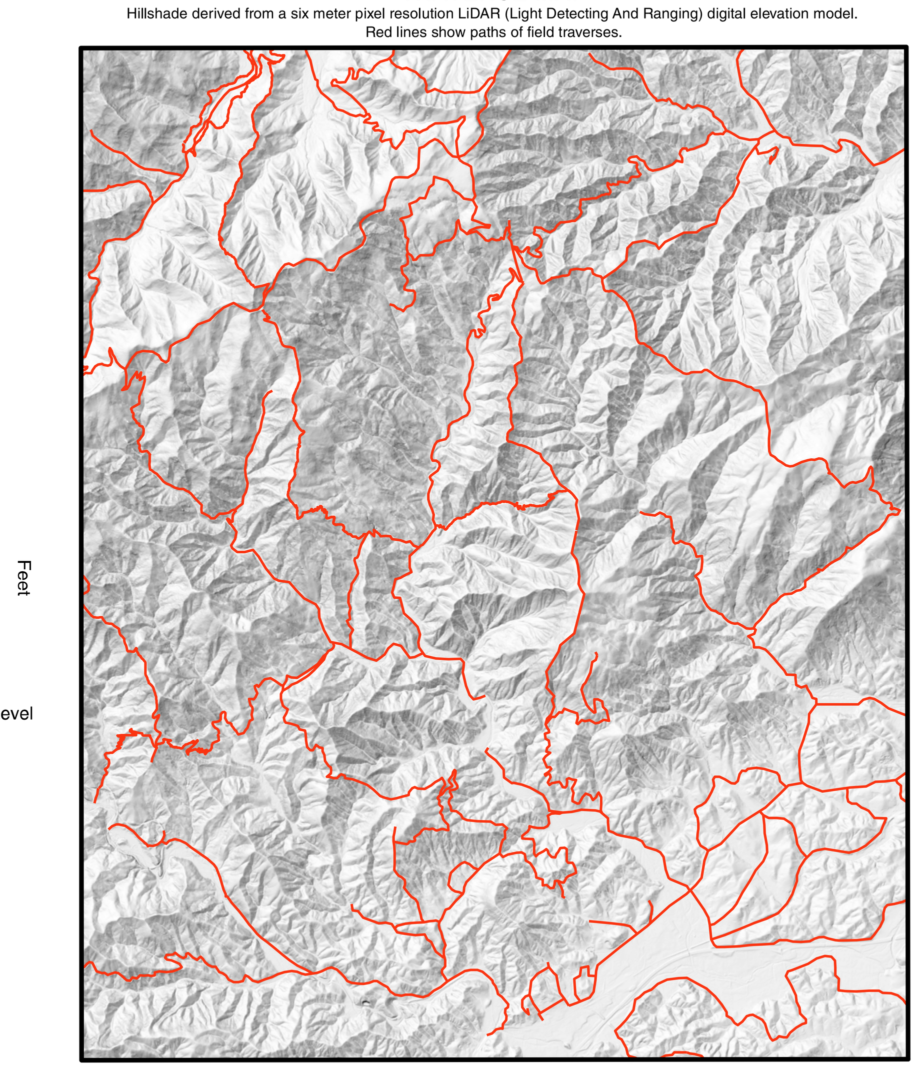
METAMORPHIC AND TECTONIC CONDITIONS



Location where sillimanite was observed
Location where kyanite was observed
Brevard Zone deformation
Location where chlorite was observed
Location where garnet was observed

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.



OLD FORT, NC
2013

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NORTH CAROLINA Department of Environmental Quality

GEOLOGICAL SURVEY N.C. 1823

Bedrock Geologic Map of the Old Fort 7.5-minute Quadrangle, McDowell and Yancey 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.