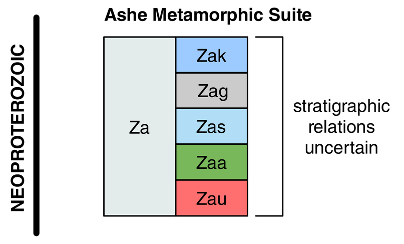
North Carolina Department of Environmental Quality
Divison of Energy, Mineral and Land Resources
Kenneth B. Taylor, State Geologist

North Carolina Geological Survey
Open File Report 2018-10

CORRELATION OF MAP UNITS



INTRODUCTION

The Mount Mitchell 7.5-minute quadrangle lies in western North Carolina in portions of Buncombe and Yancey counties, south of the city of Burnsville. Within the quadrangle are the communities of Low Gap, Pensacola, Murchison, and Eskota. A large portion of Mount Mitchell State Park is on the southeastern part of the quadrangle. The Big Ivy area in the southwest and land in the northeast belong to Pisgah National Forest. State Highway 197 and the Cane River are the only major road and river on the quadrangle. Total elevation relief is 4008 ft with a low of 2676 ft along the Cane River and a high of 6,684 ft on Mount Mitchell (highest elevation east of the Mississippi River).

GEOLOGIC OVERVIEW

Bedrock of the Mount Mitchell quadrangle consists of the Neoproterozoic to early Cambrian Ashe Metamorphic Suite (AMS) of the Tugaloo terrane (Hatcher and others, 2007). The AMS is a thick sequence 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). Numerous pegmatites occur within the AMS and are thought to be related to the 392-361 Ma pegmatites within the Spruce Pine Plutonic Suite (Kish, 1983, 1989; Johnson and others, 2001). No formal stratigraphic units are recognized in the AMS, but zones of dominant lithologies are shown on the geologic map. The kyanite gneiss and schist unit is distinct within the AMS with much of the peak metamorphic mineralogy and fabrics having been altered. This alteration may have occurred through metasomatism (fluids potentially derived from the Spruce Pine Plutonic Suite), migmatization, or an unrecognized process.

Rocks of the AMS were metamorphosed during Taconian orogenesis to kyanite- and sillimanite-grade conditions. Minimum age of prograde metamorphism is constrained by unmetamorphosed trondhjemite dikes dated at 420-405 Ma (Miller et al., 2000; Mapes, 2002) exposed east of the quadrangle. Foliations predominately strike NE-SW and are steeply dipping. The predominate strike direction of steeply dipping joints is WNW-ESE.

WHOLE ROCK ICP ANALYSIS[1] OF SELECTED SAMPLES

SAMPLE[2]	BC 60	NB 41	BC 195	BC 174	NB 161	NB 78	BC 233	NB 258	NB 259a	NB 259b
COORDINATES[3]	228,043N 306,752E	228,802N 305,868E	232,632N 313,013E	223,346N 310,248E	228,233N 310,683E	228,833N 307,531E	232,549N 313,894E	227,124N 307,175E	227,083N 307,157E	227,083N 307,157E
ROCK TYPE[4]	sil-ky-grt mica schist	sil-ky-grt mica schist	amphibolite	meta-sandstone	sil-grt schistose metagraywacke	altered ultramafic	quartz amphibolite	grt calc-silicate granofels	qtz, grt, hbl gneiss	sil-ky-grt schistose metagraywacke
MAP UNIT	Za	Za	Zaa	Zag	Zag	Zau	Zaa	Zaa	Zaa	Zaa
MAJOR OXIDES IN PERCENT										
SiO_2	45.97	51.91	47.41	82.57	55.75	42.07	48.91	54.3	47.27	53.14
Al_2O_3	25.25	25.98	14.18	7.34	21.05	7.53	14.47	25.51	18.16	23.31
Fe_2O_3	9.3	9.26	12.85	3.06	10.44	13.49	12.3	2.57	12.4	7.44
MgO	3.08	3.12	10.28	0.51	2.89	31.71	9.99	1.13	6.67	2.14
CaO	0.33	0.13	10.46	0.94	1.76	2.86	10.28	8.6	9.04	2.58
Na_2O	0.49	0.19	1.15	1.11	1.76	0.04	1.56	5.76	2.68	5.08
K_2O	6.35	4.55	0.64	3.07	3.1	0.01	0.54	0.06	0.2	2.55
TiO_2	1.24	1.19	0.28	0.81	1.09	0.39	0.25	0.13	1.92	0.88
P_2O_5	0.08	0.12	0.05	0.09	0.27	0.03	0.04	0.71	0.11	0.13
MnO	0.59	0.12	0.2	0.06	0.15	0.19	0.21	0.11	0.72	0.36
Cr_2O_3	0.014	0.014	0.083	0.003	0.012	0.468	0.09	0.003	0.047	0.009
LOI[5]	7	3.1	2.3	0.2	1.4	0.9	1.2	0.9	0.6	2.1
SUM[6]	99.77	99.79	99.89	99.83	99.77	99.9	99.89	99.81	99.85	99.79
ELEMENTS IN PPM[7]										
Ba	913	1111	97	686	668	9	51	52	86	765
Ni	58	<20	177	<20	30	1493	181	25	124	30
Sc	26	31	52	5	23	22	47	8	42	25
Be	5	2	<1	<1	2	<1	<1	3	<1	3
Co	62.1	5.6	56.8	4	16.1	126.3	55.8	6.1	45.4	29.4
Cs	4	1.6	<0.1	<0.1	0.9	<0.1	<0.1	<0.1	<0.1	1.4
Ga	42.9	41.4	11.6	11.1	31.2	8.3	10.6	16.8	19	28.9
Hf	7.6	6.6	0.4	13.7	12.2	0.6	0.3	0.3	3.8	5.7
Nb	31	25.2	3.1	13.7	37	0.3	3.3	1.5	3.9	11.4
Rb	241	169.3	11.5	80.4	122.1	0.4	5.6	0.6	0.6	90.8
Sn	5	2	<1	<1	1	<1	2	<1	2	<1
Sr	53	64.6	40.2	144.9	182.4	54.1	62.1	1122.1	199.2	263.8
Ta	2	1.2	0.2	1	2.6	<0.1	0.3	0.2	0.3	0.6
Th	28.2	25.9	<0.2	12.3	22.6	<0.2	0.2	<0.2	0.3	20.2
U	8.8	5.7	0.1	1.9	4.6	<0.1	0.1	0.2	<0.1	5
V	139	128	280	39	115	108	258	20	263	107
W	2.4	<0.5	<0.5	<0.5	1.6	<0.5	<0.5	<0.5	<0.5	<0.5
Zr	277.6	238.8	13.5	532.9	420.4	25.1	13.8	13.4	164.7	205.9
Y	81.8	76.9	9	25.5	74.1	6.4	8.5	15.3	35.2	58.8
La	129.1	115.4	3	30.4	81.8	1	2.7	2.1	6.4	97.8
Ce	274.4	219.7	3	64	163	1.2	6.5	5.5	19.5	227.1
Pr	32.07	28.04	0.77	8.24	20.47	0.36	0.87	0.98	3.14	23.89
Nd	121.7	105.7	3.1	32.7	77.9	1.9	3.5	5.2	15.6	89.8
Sm	22.82	19.27	0.68	6.37	15.17	0.63	0.92	1.21	4.53	16.52
Eu	2.59	2.59	0.26	1.04	2.34	0.28	0.49	1.35	1.76	4.09
Gd	19.48	16.4	1.03	5.62	14.14	0.84	1.04	1.61	5.39	13.92
Tb	2.83	2.45	0.19	0.87	2.25	0.17	0.19	0.3	0.95	2.02
Dy	15.4	14.33	1.47	4.92	13.4	1.28	1.34	2.25	5.93	11.03
Ho	3.15	3.07	0.37	0.98	2.87	0.29	0.31	0.57	1.4	2.24
Er	9.21	9.91	1.07	2.9	8.61	0.87	1.1	1.87	4.14	6.92
Tm	1.35	1.48	0.18	0.41	1.28	0.12	0.16	0.27	0.61	1.03
Yb	8.36	9.67	1.27	2.72	7.95	0.86	1.08	1.7	3.89	7.1
Lu	1.27	1.49	0.24	0.46	1.23	0.14	0.19	0.27	0.58	1.13
Mo	3	2.4	0.8	1.1	1.2	0.4	0.7	0.9	1.1	3.2
Cu	122.3	29	13.4	7.9	24.9	52.7	12.8	14.5	46.1	74.7
Pb	5.4	5.5	3.2	1.2	3.8	0.3	1.5	3	1.1	5.3
Zn	105	105	53	27	148	8	35	6	28	116
Ni	64.8	6.7	74.1	7.6	28.3	923	70.1	13.3	92	33.3
As	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.5	<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	0.5	<0.1	0.2	<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	<0.5	<0.5	1.3	<0.5	<0.5	<0.5	<0.5	<0.5
Hg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tl	0.8	1	<0.1	0.3	0.7	<0.1	<0.1	<0.1	<0.1	0.6
Se	1.7	<0.5	<0.5	<0.5	0.7	0.6	<0.5	<0.5	<0.5	1.3

[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]Mineral abbreviations used in table: qtz-quartz; hbl-hornblende; grt-garnet; sil-sillimanite; ky-kyanite.
[5]LOI = loss on ignition in percent
[6]SUM = Sum total in percent
[7]PPM = parts per million. Ni analyzed by Bureau Veritas LF200 and AQ200 procedures.

DESCRIPTION OF MAP UNITS

Ashe Metamorphic Suite

Za — **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 metagraywacke, schist, schistose metagraywacke, kyanite gneiss and schist, conglomeratic metagraywacke, metasandstone, amphibolite, and minor calc-silicate. Thickness of layering ranges from centimeters to meters. Locally intruded by small pegmatite bodies of the Spruce Pine Plutonic Suite.

Schistose Metagraywacke — medium-gray to dark-gray; fine- to medium-grained; well foliated; equigranular to inequigranular; granoblastic to lepidoblastic to porphyroblastic; locally migmatitic; consists of quartz, plagioclase feldspar, muscovite, biotite, garnet, minor sillimanite and/or kyanite, and accessory minerals; interlayered with other Za lithologies.

Calc-silicate — light-gray; medium- to coarse-grained; weakly foliated; consists of quartz, feldspar, epidote group minerals, garnet, biotite, hornblende, pyroxene, and trace chlorite; interlayered with other Za lithologies.

Zak — **Kyanite Gneiss and Schist** — Highly altered and heterogeneous unit characterized by an abundance of kyanite and/or muscovite porphyroblasts. Typical rock is mottled light-gray to brown; coarse-grained; foliated; inequigranular to equigranular; porphyroblastic; locally migmatitic; consists of biotite, plagioclase, quartz, muscovite, kyanite and/or sillimanite, garnet, and minor accessory and trace minerals; kyanite porphyroblasts up to 15 cm; felsic interlayers may be due to metasomatism or migmatization; interlayered with other Za lithologies.

Zag — **Metagraywacke** — Medium-light-gray to medium-dark-gray; medium- to coarse-grained; weakly foliated to foliated; 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; interlayered with other Za lithologies.

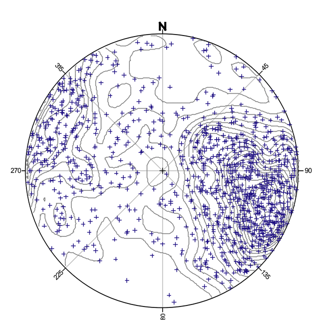
Zas — **Garnet-Mica Schist** — Very light-gray to greenish-gray to medium-gray; fine- to coarse-grained; strongly foliated; inequigranular; lepidoblastic to porphyroblastic; locally migmatitic; consists of muscovite, sericite, quartz, biotite, garnet, plagioclase feldspar, sillimanite and/or kyanite, chlorite, and trace opaque minerals; interlayered with other Za lithologies.

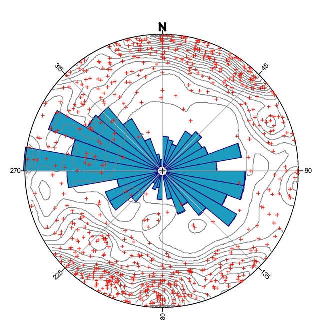
Zaa — **Amphibolite** — Where mappable it occurs as a metamorphic alteration of an ultramafic or mafic rock. Dark-green to black; fine- to coarse-grained; weakly to strongly foliated; equigranular; granoblastic to nematoblastic; consists of hornblende, plagioclase feldspar, epidote group minerals, quartz, garnet, chlorite, relict pyroxene, titanite, magnetite, and opaque minerals. Locally contains small bodies of altered ultramafic rocks not mapped at this scale. Can occur as a very minor rock type throughout the other map units, where it may represent a metamorphosed volcanic rock.

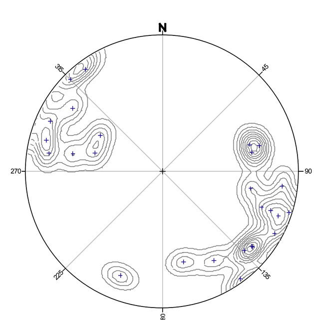
Zau — **Altered Ultramafics** — Dark-green to silvery-grayish-green; fine- to medium-grained; non-foliated to strongly foliated; equigranular; granoblastic to nematoblastic to lepidoblastic; consists of tremolite/actinolite, relict pyroxene, hornblende, chlorite, talc, serpentine, relict olivine, opaque minerals, plagioclase feldspar, magnetite, spinel, and other accessory minerals. These mineralogical variations could not be mapped at a 1:24,000 scale. Amphibolite within and adjacent to this unit occurs as a metamorphic alteration of the ultramafic or mafic rock. Thickness of amphibolitic alteration is variable. Contains inclusions of other variations of altered mafic and ultramafic rock.

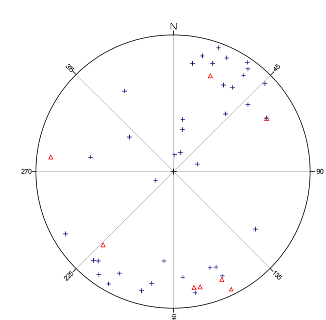
Mineral abundances are listed in decreasing order of abundance based upon visual estimates of hand samples and thin-

SCHMIDT EQUAL AREA STEREONET DATA


Equal area Schmidt Net projection of contoured poles to foliation. Foliation count 1147.


Equal area Schmidt Net projection of contoured poles to joints and unidirectional rose diagram inset. Joint count 679.


Equal area Schmidt Net projection of contoured poles to mylonitic foliation. Foliation count 26.


Equal area Schmidt Net projection of bearing and plunge directions of fold hinges in blue and mineral lineations in red. Fold hinge count 38. Mineral lineation count 8.

STREAM SEDIMENT HEAVY MINERAL ANALYSIS

Stream sediment heavy mineral analysis was conducted from March 2017 through April 2017 to aid geologic mapping, better define conditions of metamorphism, and inventory minerals of potential economic significance. Procedure: In the field, approximately 13.6 kg of stream sediment material was panned to approximately 300 g of heavy mineral concentrate at each sample locality. In the laboratory, concentrate was washed and passed through heavy liquid separation using tetrabromoethane, and scanned with short- and long-wave ultraviolet illumination using an Ultra-violet Products Inc. Model UVGL-48 Mineralight Lamp. Magnetite was removed with a hand magnet. A sample split was grain mounted on a standard 27x46 mm glass slide and approximately 200 grains are identified and counted with the aid of a petrographic microscope and 1.67 index of refraction oil. Results of stream sediment heavy mineral analysis are tabulated below.

Mineral abbreviations used in table: Mg-magnetite; Ms-muscovite; Gt-garnet; Zr-zircon; Bt-biotite; Rt-rutile; Ep-epidote; St-staurolite; Sil–sillimanite; Hbl-hornblende; Ky-kyanite; Ttn-titanite; Ilm-ilmenite and other black opaque minerals; Hem-hematite and other red opaque minerals; Lx-leucoxene; Ud-unidentified.

SAMPLE[1]	COORDINATES (State Plane, NAD 83 m)	MAP UNITS DRAINED[2]	% TOTAL HM IN SAMPLE[3]	PERCENT HEAVY MINERALS IN SAMPLE[4]															
				Mg	Ms	Gt	Zr	Bt	Rt	Ep	St	Sil	Hbl	Ky	Ttn	Ilm	Hem	Lx	Ud
NB245	230,847N; 310,972E	Za, Zas, Zag	2.49	0.44	1.49	45.80	0.50	2.49	1.99	0.50	0.50	1.49	1.49	37.34	0.50	2.99	1.00	-	1.49
NB246	230,338N; 309,366E	Za, Zag, Zas	2.15	0.04	0.50	62.97	-	6.00	0.50	-	0.50	5.00	5.50	9.50	-	-	1.00	0.50	8.00
NB252	230,115N; 311,577E	Za, Zag, Zak	3.43	0.01	1.00	72.99	-	3.00	1.00	-	0.50	2.00	10.00	6.50	-	1.50	-	-	1.50
NB253	232,575N; 305,449E	Za, Zag, Zaa	1.95	0.07	0.50	42.97	2.50	1.50	1.50	-	1.00	2.50	13.99	7.99	1.50	23.48	0.50	-	-
NB263	227,612N; 306,364E	Za, Zas, Zaa	2.62	0.08	1.00	47.46	2.00	-	1.00	-	1.50	2.00	25.48	11.49	0.50	4.50	0.50	1.50	1.00

[1]Sample numbers correspond to stream sediment heavy mineral sample localities shown on geologic map
[2]Up to three most dominant map units contributing to the drainage basin, listed in decending order of map area
[3]Percentage of heavy minerals in 13.6 kg stream sediment sample
[4]Point count percentages of heavy minerals from processed samples

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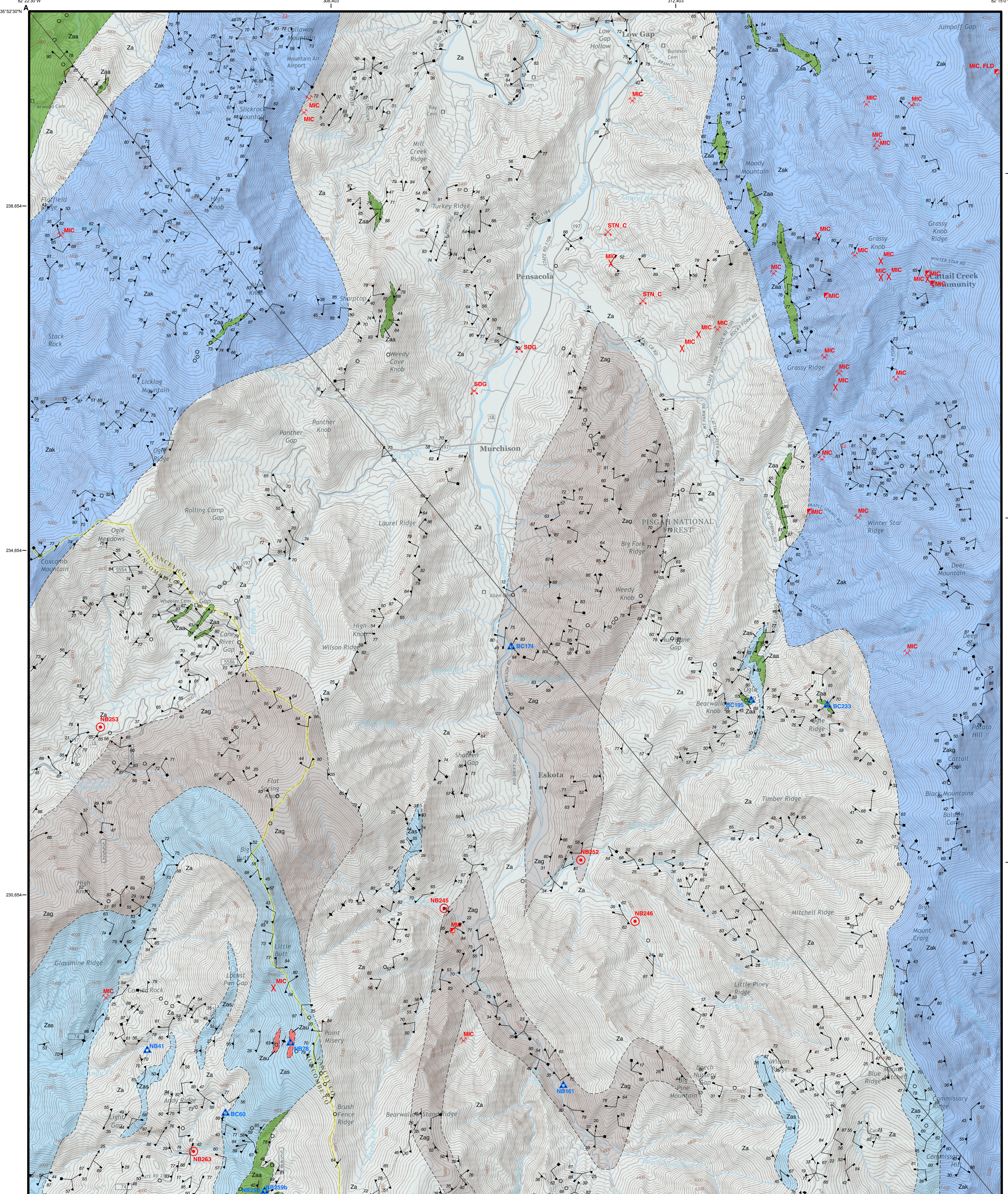
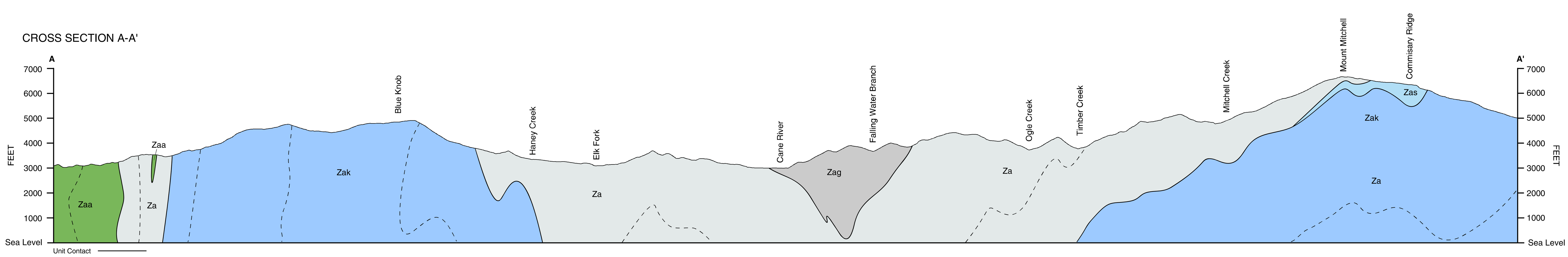


CROSS SECTION A-A'



EXPLANATION OF MAP SYMBOLS

CONTACTS

Contact—Identity and existence certain, location inferred

PLANAR FEATURES

(For multiple observations at one locality, symbols are joined at the "tail" ends of the strike lines)

- 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
- Inclined (dip direction to right) bedding, for multiple observations at one locality—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

- 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 crenulation lineation—Showing bearing and plunge

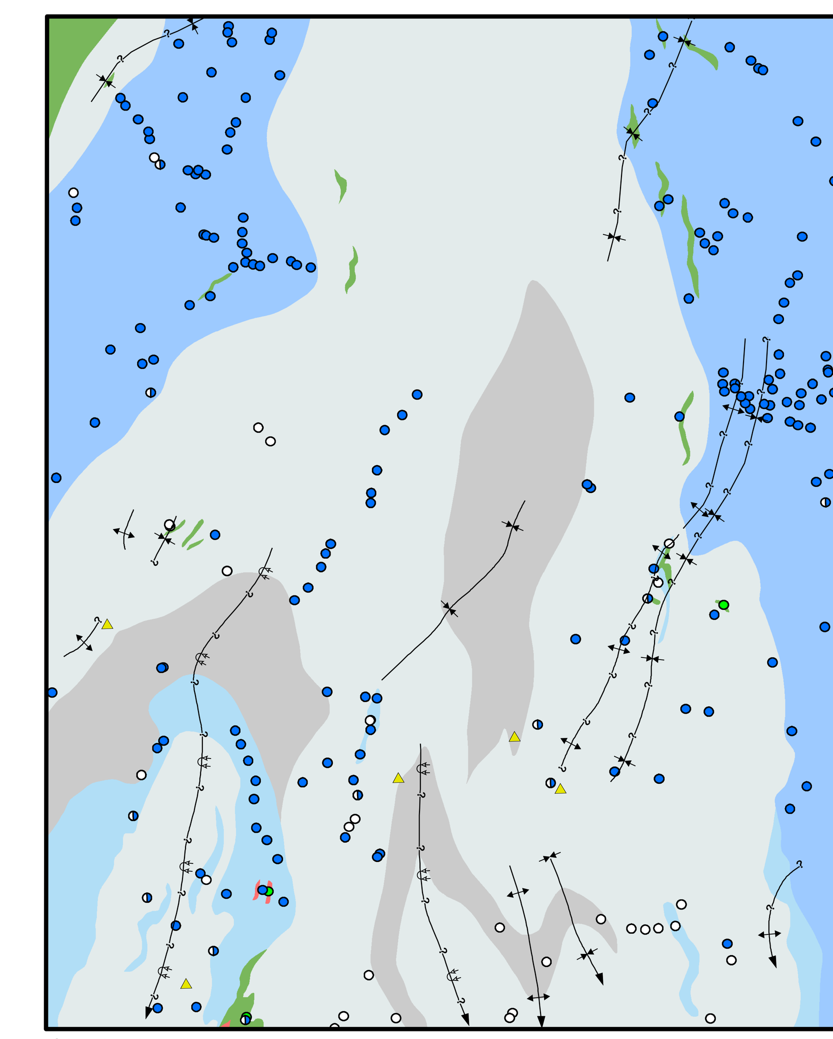
NATURAL RESOURCES

MIC - Mica
SDG - Sand and gravel
STN_C - Stone, Crushed/Broken

OTHER FEATURES

- Float station
- NB206 Thin section and whole rock analysis sample location
- NB392 Heavy mineral sample location
- Prospect (pit or small open cut)
- Sand, gravel, clay, or placer pit
- Abandoned sand, gravel, clay, or placer pit
- Open pit, quarry, or glory hole
- Abandoned open pit, quarry, or glory hole
- Inclined mine shaft

METAMORPHIC AND TECTONIC CONDITIONS

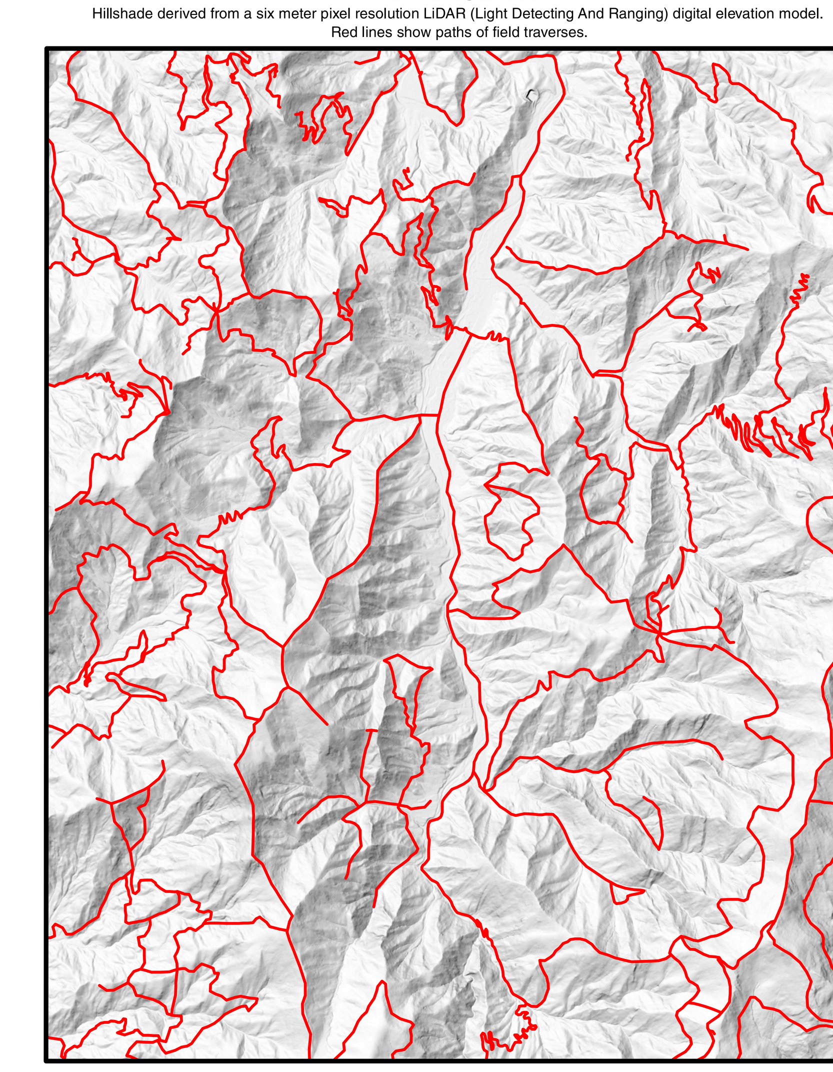


Location where sillimanite was observed
Location where staurolite was observed in stream sediments
Location where kyanite was observed
Location where chlorite was observed

Arrow—shows plunge direction of fold
Antiform—Identity or existence questionable, location accurate
Synform—Identity or existence questionable, location accurate
Antiform—Identity and existence certain, location accurate.
Synform—Identity and existence certain, location accurate.
Overturned synform—Identity or existence questionable, location approximate.

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 Mount Mitchell 7.5-minute Quadrangle, Buncombe and Yancey Counties, North Carolina

By
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Geology mapped from August 2016 to June 2018.
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