NORTH CAROLINA 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 MAP 2013-05

MAP UNITS

PALEOZOIC

Trondhjemite

Pzmg — Migmatite

Ashe Metamorphic Suite/Tallulah Falls Formation

NEOPROTEROZOIC (stratigraphic relations uncertain)

Zag — Metagraywacke

Zagsi — Schistose metagraywacke

Zas — Garnet mica schist

Zaa — Amphibolite

Zua — Altered ultramafic

Zah — Biotite hornblende gneiss

Earlies Gap Meta-igneous Gneisses

MESOPROTEROZOIC

Ye — Biotite gneiss

GEOLOGICAL SURVEY N.C. 1823

Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G12AC20308. This map and explanatory information is submitted for publication with the understanding that the United States Government is authorized to reproduce and distribute reprints for governmental use.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 express or implied, of the U.S. Government.

ROCK DESCRIPTIONS[1]

Intrusives

Trondhjemite – Very-light-gray to yellowish-gray; typically non-foliated; fine- to medium-grained; equigranular to inequigranular; typically granoblastic to megacrystic; occurs as thin dikes and sills ranging in thickness from centimeters to meters. Too small to be mapped at 1:24,000 scale. A trondhjemite dike near Asheville has been age dated at approximately 410-420 million years (Miller and others, 2000)[2].

Migmatite (Pzmg) – White to very-light-gray; non-foliated to weakly foliated; medium- to coarse-grained; equigranular; granoblastic; occurs commonly as thin layers and lenses (thickness of layering ranges from centimeters to meters) within other rock types and mappable bodies; locally gradational with pegmatite; consists of plagioclase feldspar, potassium feldspar, quartz, muscovite, sericite, and biotite. Migmatite (neosome) was most likely derived from local melting during regional high-grade metamorphism.

Ashe Metamorphic Suite/Tallulah Falls Formation

Metagraywacke (Zag) – Medium-light-gray to medium-dark-gray; non-foliated to weakly foliated; medium- to coarse-grained; equigranular to inequigranular; granoblastic to lepidoblastic; locally migmatitic; consists of plagioclase, quartz, biotite, muscovite, kyanite, sillimanite, opaques, epidote and apatite; thickness of layering ranges from several decimeters to several meters. Interlayered at all scales with garnet-mica schist, metasandstone and arkosic metasandstone, conglomeratic metagraywacke, amphibolite, and minor calc-silicate.

Schistose metagraywacke (Zagsi) – Medium-gray to dark-gray; foliated; fine- to medium-grained; equigranular to inequigranular; lepidoblastic to weakly granoblastic to porphyroblastic; locally migmatitic; consists of quartz, plagioclase, muscovite, biotite, kyanite, sillimanite, epidote, chlorite, and trace opaque minerals; thickness of layering ranges from several millimeters to several centimeters to several meters; commonly interlayered with metagraywacke, garnet-mica schist, conglomeratic metagraywacke, amphibolite, and minor calc-silicate.

Garnet mica schist (Zas) – Silvery-gray to medium-dark-gray; fine-to medium-grained; inequigranular; lepidoblastic and porphyroblastic; consists mostly of muscovite, biotite, garnet, and feldspar with trace amounts of epidote, chlorite, and opaque minerals. Locally migmatitic with minor and accessery amounts of sillimanite and kyanite. Interlayered with metagraywacke, schistose metagraywacke, amphibolite, altered ultramafics, and rare calc-silicate granofels.

Amphibolite (Zaa) – Amphibolite occurs as a minor rock type throughout other map units and as small mappable bodies: dark-green to black; fine-to coarse-grained; equigranular to nematoblastic; strongly foliated; consists of hornblende, plagioclase, quartz, epidote group minerals, garnet, chlorite, and minor relict pyroxene, titanite, and opaques.

Altered ultramafic (Zua) – Dark-green to silvery-grayish-green; non-foliated to strongly foliated; fine- to medium-grained; equigranular; nematoblastic to lepidoblastic; consists of 0 to 97% hornblende, 0 to 75% chlorite, 0 to 45% talc, 0 to 33% tremolite/actinolite, 0 to 19% serpentine, 0 to 15% relict olivine, 2 to 6% opaques, 0 to 1% plagioclase. These mineralogic variations could not be mapped at 1:24,000 scale. Amphibolite within this unit occurs as a metamorphic alteration of the ultramafic or mafic rock. Thickness of the amphibolitic alteration is variable. Contains inclusions of other variations of altered mafic and ultramafic rock.

Biotite-hornblende gneiss (Zah) – medium-dark-gray to dark-gray; foliated; medium- to coarse-grained; equigranular to inequigranular; granoblastic to lepidoblastic; layered; migmatitic; consists of plagioclase, quartz, biotite, hornblende, muscovite, with minor garnet, epidote, and opaque minerals. Interlayered with amphibolite, metagraywacke, schistose metagraywacke, and metasandstones.

Earlies Gap Meta-igneous Gneisses

Biotite Gneiss (Ye) - A hetrogeneous unit that includes numerous varieties of biotite gneiss and layered biotite granitic gneiss, interlayered with amphibolite, calc-silicate granofels, altered pyroxenite, minor muscovite-biotite gneiss. Biotite granodiorite gneiss to biotite tonalitie gneiss is dominant. Biotite gneisses are very light gray to medium light gray; lepidoblastic to equigranular granoblastic; locally mylonitic and migmatitic; strongly foliated; layer thicknesses range from centimeters to meters; consist of plagioclase, quartz, biotite, k-feldspar, epidote group minerals, muscovite, opaques, garnet, apatite, and chlorite.

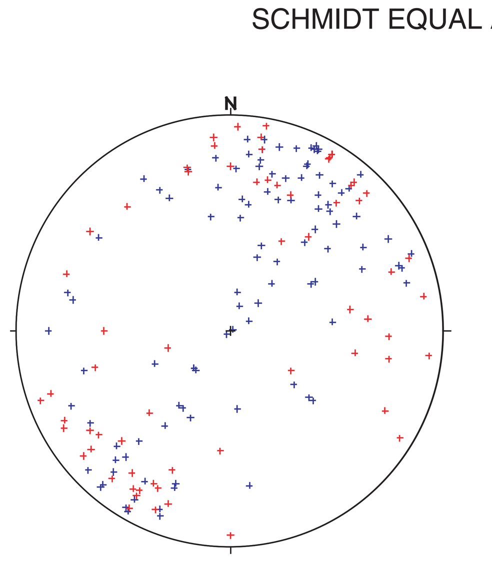
[1]Mineral percentages are based on visual estimates of selected samples.
[2]Miller, C.F., Hatcher, R.D., Jr., Ayers, J.C., Coath, C.D., and Harrison, T.M., 2000, Age and zircon inheritance of Eastern Blue Ridge plutons, southwestern North Carolina and northeastern Georgia, with implications for magma history and evolution of the Southern Appalachian orogeny, American Journal of Science, v. 300, p. 142-172.

WHOLE ROCK ICP ANALYSIS[1] OF SELECTED SAMPLES

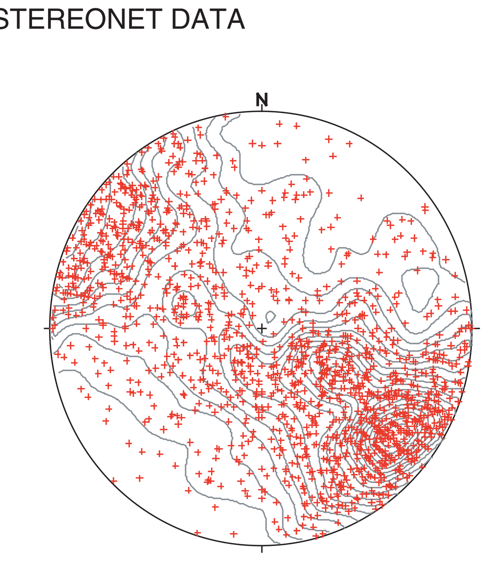
SAMPLE[2]	COORDINATES (State Plane NAD 83 m)	ROCK TYPE	MAP UNIT	OXIDES IN PERCENT SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	Cr2O3	ELEMENTS IN PPM[3] Ba	Cu	Zn	Ni	Co	Sr	Zr	Ce	Y	Nb	Sc	LOI[4]	SUM[5]
BC43	213,853N; 294,577E	calc-silicate	Zagsi	69.74	11.62	4.62	2.82	4.84	0.76	0.49	0.8	0.16	0.14	0.016	269	17	61	<20	<20	133	483	44	44	12	9	3.8	99.96
BC66	214,707N; 297,059E	metagraywacke	Zags	76.15	9.87	4.94	1.47	0.96	1.35	3.1	0.88	0.1	0.08	0.014	1029	<5	55	<20	<20	190	491	67	29	11	9	0.8	99.98
BC181	218,914N; 294,278E	ultramylonite	Zas	61.32	19	6.12	1.33	0.03	0.37	3.38	1.17	0.07	0.21	0.01	981	35	110	<20	<20	90	354	98	31	22	16	6.7	99.96
BC391	218,358N; 300,834E	kyanite-garnet-schistose metagraywacke	Zagsi	43.78	26.69	12.3	4.91	1.97	2.66	3.34	1.45	0.07	0.19	0.024	960	74	213	41	30	260	264	96	44	10	24	2.2	99.88
BC432A	214,921N; 302,460E	metagabbro	Zua	48.61	15.2	14.13	5.99	9.57	3.38	0.09	1.5	0.13	0.23	0.032	20	24	121	28	34	148	73	<30	31	<5	53	0.9	99.86
BC432B	214,921N; 302,460E	alterered olivine pyroxenite	Zua	43.57	10.72	13.22	21.5	7.85	0.5	0.1	0.55	0.04	0.19	0.235	27	116	97	1076	103	35	30	<30	10	<5	19	0.9	99.63
BC433	214,991N; 302,438E	alterered olivine pyroxenite	Zua	42.74	12.13	15.26	21.15	5.95	0.77	0.1	0.81	0.06	0.22	0.134	40	12	110	842	104	24	44	<30	16	<5	23	0.1	99.61
BC435	215,024N; 302,401E	talc-amphibole-serpentine schist	Zua	39.66	12.92	15.58	18.67	5.04	0.73	0.16	0.86	0.06	0.22	0.132	16	7	127	790	96	28	50	<30	33	<5	25	5.5	99.67
BC469	219,094N; 296,850E	metagraywacke	Zag	83.53	7.19	2.62	0.73	0.45	0.89	3.26	0.6	0.06	0.03	0.003	704	9	27	<20	<20	96	425	<30	17	10	4	0.5	100.01
RW37	213,637N; 299,084E	metaconglomerate	Zag	79.39	8.76	3.32	0.9	0.51	1.26	3.94	0.59	0.31	0.07	0.004	1134	9	42	23	<20	121	328	65	42	15	7	0.7	100
RW47	216,594N; 295,356E	kyanite-garnet-mica schist	Zas	39.22	32.49	15.44	4.41	1.5	1.41	1.56	1.5	0.06	0.55	0.016	612	58	108	60	41	226	461	274	138	33	42	1.5	99.9
RW144	218,867N; 293,706E	migmatitic metagraywacke	Zag	68.36	14.53	4.73	1.55	1.91	3.33	3.82	0.64	0.2	0.07	0.01	1023	<5	57	<20	<20	362	358	70	19	14	11	0.6	99.98
RW383	225,742N; 294,806E	migmatitic schistose metagraywacke	Zagsi	53.77	16.81	12.24	3.65	1.73	2.45	5.09	1.5	0.53	0.15	0.007	1492	13	202	25	23	230	836	52	37	28	30	1.6	99.93
RW398-A	227,199N; 293,726E	migmatitic muscovite-biotite gneiss	Zagsi	89.18	4.83	1.85	0.48	0.52	0.78	0.77	0.24	0.04	0.02	<0.002	311	<5	24	<20	<20	156	330	60	5	<5	3	1.1	99.94
RW398-B	227,199N; 293,726E	porphyritic biotite trondhjemite	Zagsi	72.79	15.41	1.44	0.37	2.21	5.55	1.4	0.15	0.06	0.02	<0.002	399	<5	32	<20	<20	585	101	<30	<3	<5	2	0.4	99.95
RW399	227,225N; 293,782E	porphyritic biotite trondhjemite and migmatite	Zagsi	73.36	14.58	1.84	0.45	1.94	5.19	1.35	0.19	0.05	0.03	<0.002	510	5	28	<20	<20	403	110	<30	5	<5	2	0.8	99.95
RW400	227,300N; 293,732E	porphyritic biotite trondhjemite	Zagsi	74.89	14.51	1.5	0.32	1.89	4.83	1.11	0.12	0.05	0.03	<0.002	369	<5	26	<20	<20	415	88	43	12	<5	2	0.6	99.95
RW405	227,444N; 293,561E	quartz amphibolite	Zagsi	55.65	13.1	11.8	5.24	7.93	1.18	2.67	0.95	0.09	0.15	0.023	480	32	130	41	38	133	111	<30	28	<5	38	1	99.92
RW406	227,422N; 293,434E	porphyritic biotite trondhjemite	Zagsi	73.15	14.83	2.08	0.66	2.07	4.41	1.28	0.23	0.03	0.02	<0.002	353	<5	41	<20	<20	614	142	30	10	<5	2	1	99.94
RW418	223,130N; 295,357E	quartzo-feldspathic blastomylonite	Zag	87.02	5.43	2.39	0.64	1.14	1.01	0.78	0.23	0.03	0.07	<0.002	175	10	18	<20	<20	80	114	<30	10	5	2	1.2	99.95
RW423	223,537N; 295,299E	biotite-muscovite meta-arkose	Zag	87.88	5.83	1.2	0.23	0.02	0.25	3.52	0.15	0.03	0.01	<0.002	1157	<5	8	<20	<20	153	255	35	4	<5	1	0.6	99.95
RW480	225,014N; 298,990E	sillimanite-kyanite-garnet mica schist	Zagsi	49.71	27.77	8.85	2.92	0.7	1.35	4.35	0.99	0.08	0.17	0.012	1031	21	185	<20	<20	175	162	190	58	19	26	2.8	99.92
BC520	224,614N; 301,802E	muscovite-biotite schistose metagraywacke	Zagsi	79.71	8.86	3.47	1.11	0.57	1.25	3.15	0.6	0.08	0.04	0.003	644	<5	41	<20	<20	86	404	63	23	12	6	0.9	99.94
BC526	224,925N; 301,594E	sillimanite-kyanite-garnet mica schist	Zagsi	64.88	17.65	6.88	2.42	0.37	0.66	3.39	0.67	0.1	0.1	0.007	1134	66	98	42	<20	82	138	129	40	14	16	2.6	99.94
BC565	224,755N; 293,404E	porphyritic biotite trondhjemite	Zas	72.73	15.42	1.38	0.29	1.86	5.43	1.64	0.12	0.07	0.02	<0.002	322	<5	36	<20	<20	631	86	<30	4	<5	1	0.8	99.93
BC578	226,645N; 294,294E	muscovite-biotite arkosic metagraywacke	Zagsi	86.06	6.28	1.99	0.49	0.13	0.5	3.46	0.32	0.05	0.02	<0.002	916	5	23	<20	<20	98	228	52	9	<5	2	0.5	99.96
BC652	225,550N; 297,705E	biotite quartzo-feldspathic blastomylonite	Zagsi	82.81	5.12	5.62	1.32	0.13	0.18	1	0.92	0.05	0.02	0.003	346	116	60	<20	<20	36	372	224	14	24	5	2.6	99.91
BC679	223,946N; 300,214E	meta-arkose	Zagsi	87.36	6.08	1.75	0.55	1.4	1.28	0.3	0.23	0.06	0.09	<0.002	84	<5	31	<20	<20	106	157	32	14	6	2	0.8	99.95
BC720	221,541N; 295,312E	meta-arkose	Zagsi	93.01	1.83	2.33	0.74	0.02	0.02	0.8	0.4	0.01	0.02	0.003	98	8	35	<20	<20	3	399	<30	<3	6	3	0.7	99.96
BC738	223,723N; 298,973E	biotite-hornblende quartzo-feldspathic granofels	Zagsi	74.1	13.48	2	1.11	4.02	3.17	0.55	0.12	0.1	0.11	<0.002	258	<5	24	<20	<20	215	75	<30	15	<5	3	1.1	99.95
BC740	223,473N; 298,825E	arkosic schistose metagraywacke	Zaa	55.46	17.03	10.09	3.83	2.97	3.2	3.72	1.21	0.41	0.13	0.006	1562	21	124	22	<20	327	873	86	23	18	19	1.5	99.94
BC743	223,422N; 298,225E	migmatitic muscovite-biotite schist	Zagsi	67.38	13.09	7.74	2.89	0.45	1.43	4.45	1.04	0.05	0.1	0.014	510	32	96	41	20	99	387	90	44	22	18	1.1	99.92

[1]Whole Rock Inductively Coupled Plasma - Atomic Emission Spectrometer (ICP) analysis conducted by Acme Analytical Laboratories, LTD., 852 E. Hastings St., Vancouver, BC
[2]Sample numbers correspond to thin section and whole rock sample localities shown on geologic map
[3]PPM = parts per million
[4]LOI = loss on ignition in percent
[5]SUM = Sum total in percent

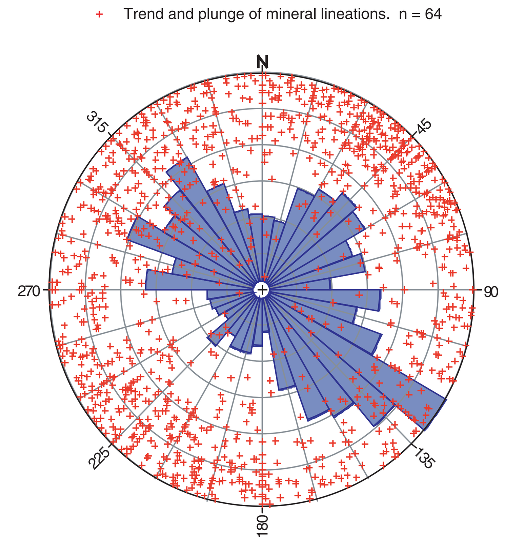
SCHMIDT EQUAL AREA STEREONET DATA



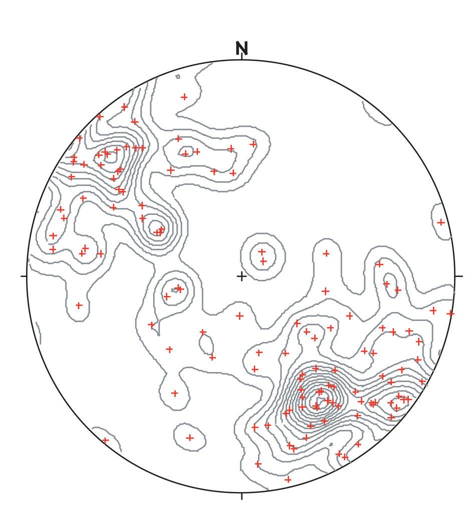
+ Trend and Plunge of minor fold axes. n = 104
+ Trend and plunge of mineral lineations. n = 64



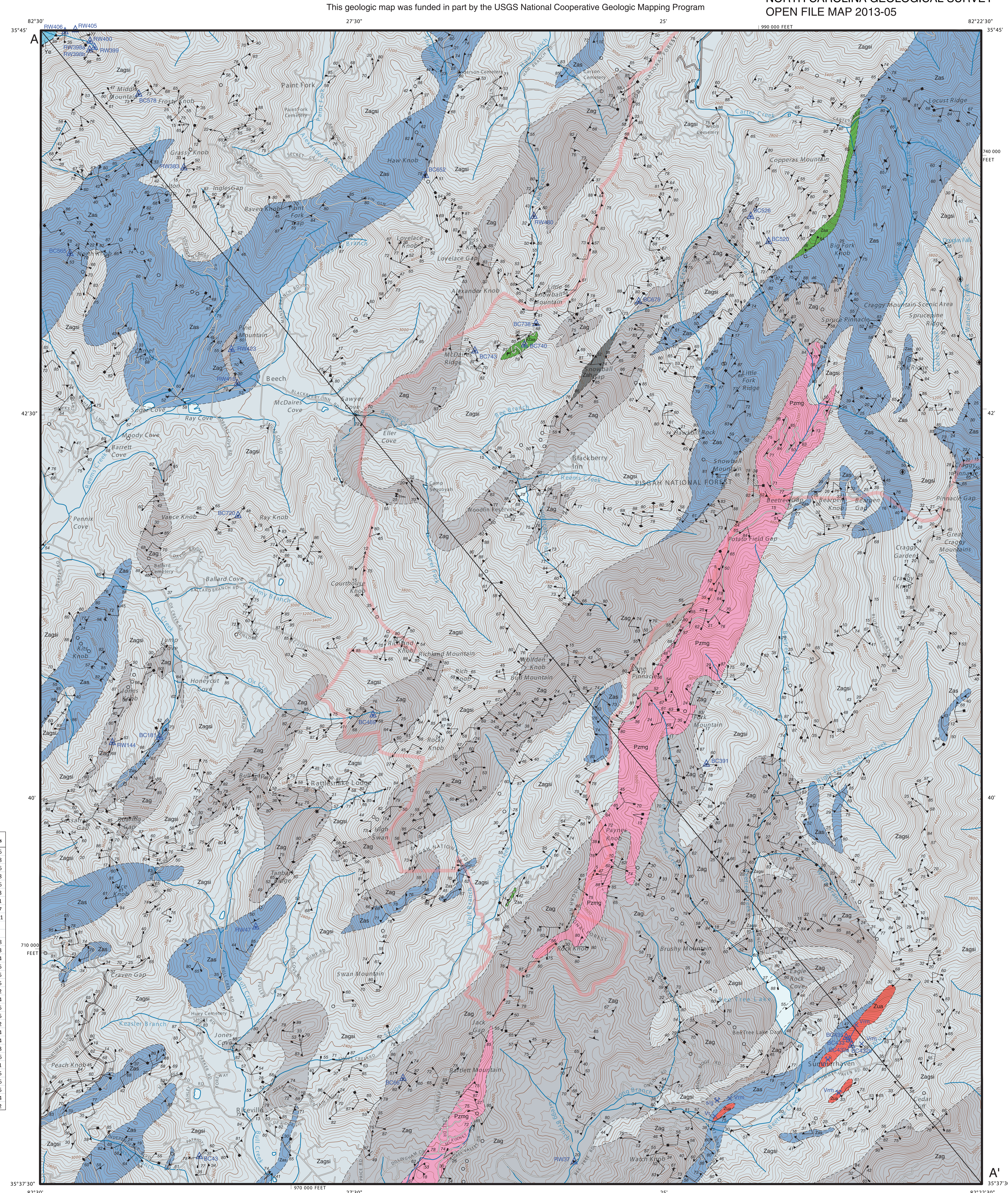
+ Poles to foliations. n = 1,618



+ Contoured poles to joints with unidirectional joint azimuth Rose diagram inset. n = 1,280



+ Poles to mylonitic foliations. n = 130



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: Universal Transverse Mercator, Zone 17S
10 000-foot ticks: North Carolina Coordinate System of 1983

Roads....©2006-2010 Tele Atlas
Roads within US Forest Service Lands....FSTopo Data with limited Forest Service updates, 2009
Names....GNIS, 2010
Hydrography....National Hydrography Dataset, 2009
Contours....National Elevation Dataset, 2008

MN GN 6° 20´ 113 MILS 0° 50´ 15 MILS
UTM GRID AND 2011 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 version 0.5.10 of the draft USGS Standards for 7.5-Minute Quadrangle Maps.
A metadata file associated with this product is draft version 0.5.12

NORTH CAROLINA
QUADRANGLE LOCATION

Mars Hill	Barnardsville	Mount Mitchell
Weaverville	Craggy Pinnacle	Montreat
Asheville	Oteen	Black Mountain

ADJOINING 7.5' QUADRANGLES

ROAD CLASSIFICATION
Interstate Route — State Route
US Route — Local Road
Ramp — 4WD
Interstate Route — US Route — State Route

CRAGGY PINNACLE, NC
2011

STRUCTURAL FEATURES

STRIKE AND DIP OF PLANAR FEATURES

Single observation at one locality (observation site at center of strike bar)
- 58 Foliation
- 75 Mylonitic Foliation
- Vertical Foliation
- Horizontal Foliation
- 65 Joint

Multiple observations at one locality (observation site at junction of symbols)
- 10 Foliation
- 72 Mylonitic Foliation
- Vertical Foliation
- Vertical Mylonitic Foliation
- 54 Joint
- Vertical Joint

CONTACTS

Short-dashed – location inferred
Thrust teeth – on upper plate

- Stratigraphic Contact
- Thrust Fault Contact

BEARING AND PLUNGE OF LINEAR FEATURES

- 10 Fold Axis
- 86 Crenulation

NON-STRUCTURAL FEATURES

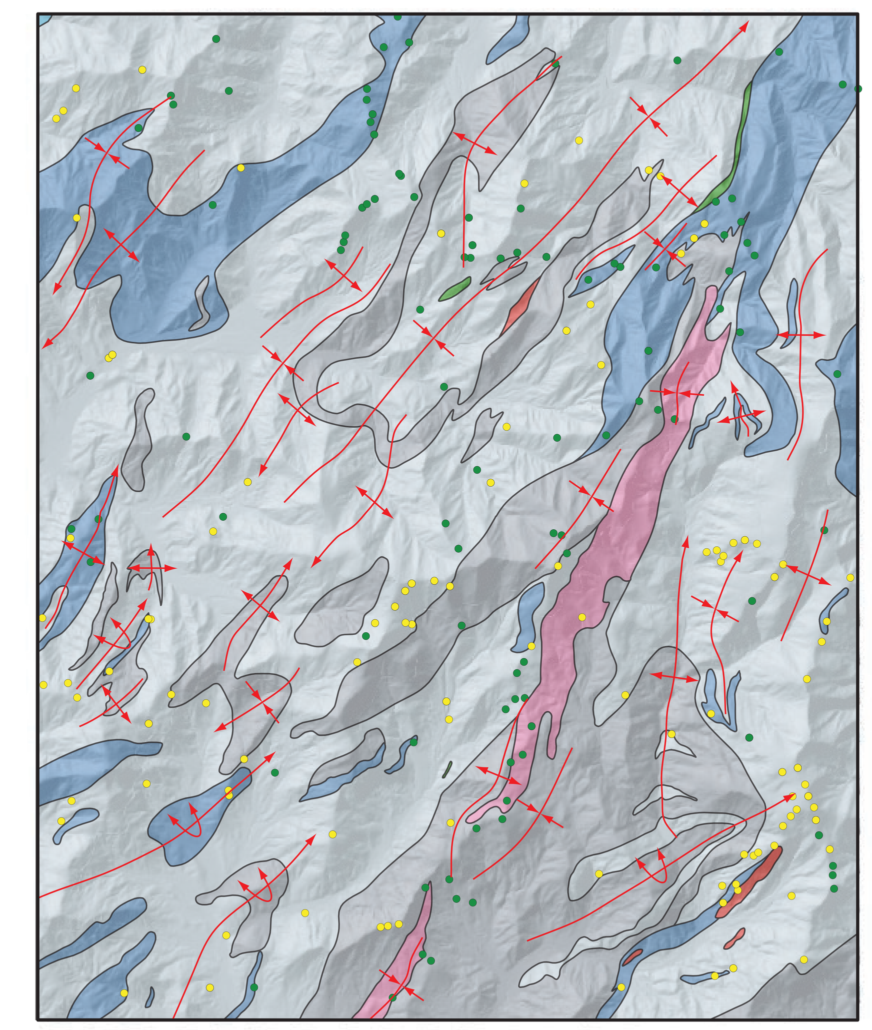
- Float Location

MINERAL RESOURCES

- BC391 Thin section sample site.
- Mine or quarry
- Prospect

COMMODITY LETTER SYMBOLS:
- Vrm Vermiculite
- s/g Sand and gravel

TECTONIC AND METAMORPHIC CONDITIONS

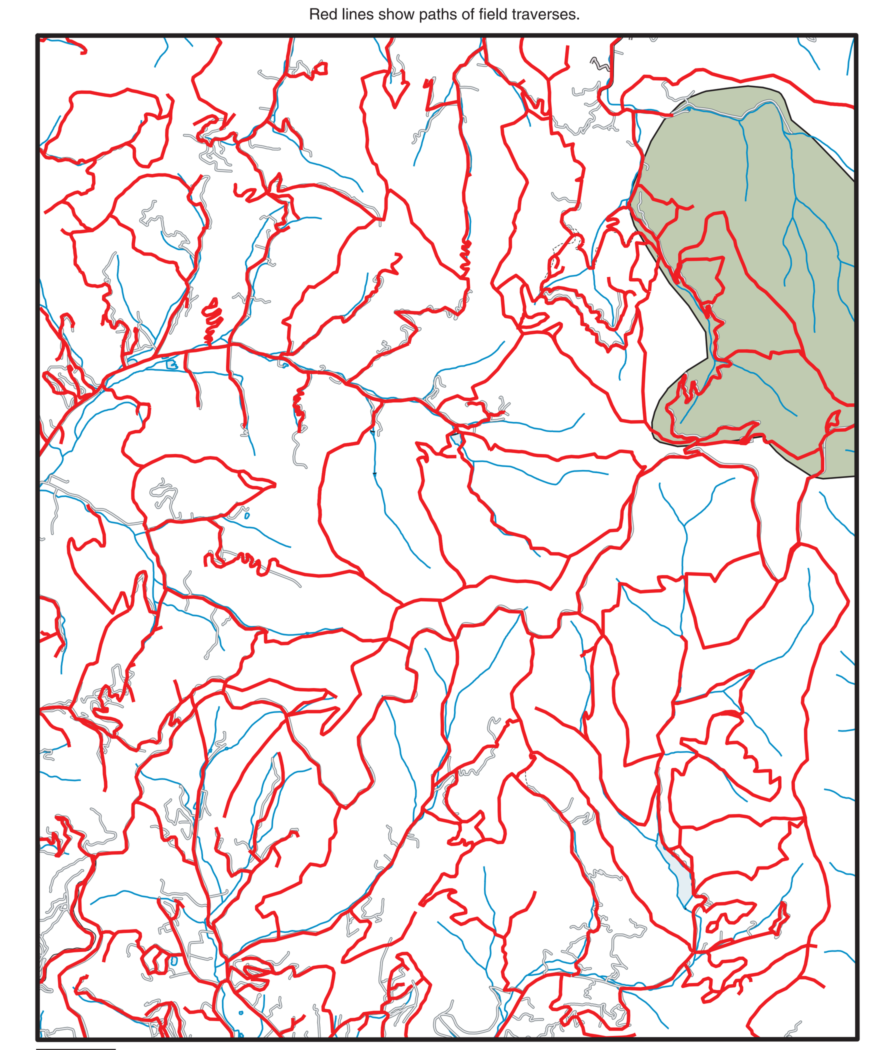


- locations where kyanite was observed in hand sample
- locations where sillimanite was observed in hand sample

antiform — synform — overturned antiform — overturned synform

TRAVERSE MAP

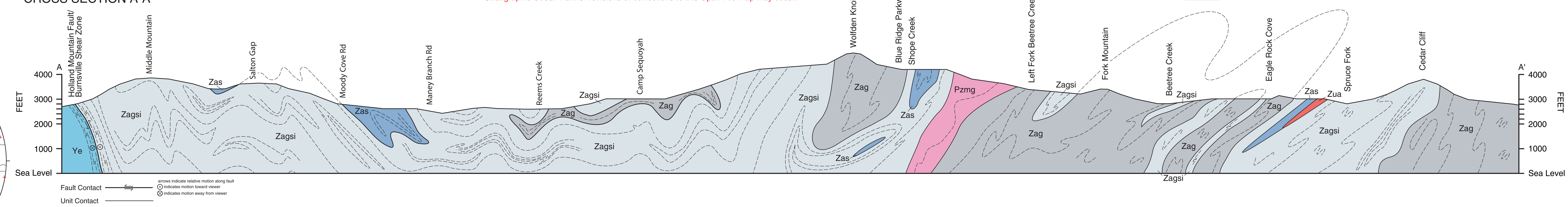
Red lines show paths of field traverses.



Additional data from United States Geological Survey Bulletin 1515: Mineral Resources of the Craggy Mountain Wilderness Study Area and Extension, Buncombe County, North Carolina; by F.G. Lesure and A.E. Grosz, United States Geological Survey, and B.B. Williams and G.C. Gazdik, United States Bureau of Mines.

This Open-File Map is preliminary. 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.

CROSS SECTION A-A'



Fault Contact — arrows indicate relative motion along fault; ⊙ indicates motion toward viewer; ⊗ indicates motion away from viewer
Unit Contact
Form Lines — interpretive patterns of subsurface foliation orientations based upon surficial structural measurements

Bedrock Geologic Map of the Craggy Pinnacle 7.5-minute Quadrangle, North Carolina

By
Bart L. Cattanach, Richard M. Wooten, G. Nicholas Bozdog and Abigail R. Bullard

Geology mapped from August 2011 to June 2013. Map preparation, digital cartography and editing by G. Nicholas Bozdog, Abigail R. Bullard, Bart L. Cattanach and Richard M. Wooten.
2013