DEFORMATIONAL AND METAMORPHIC HISTORY OF CAMPOBELLO 7.5-MINUTE QUADRANGLE, TUGALOO TERRANE, INNER PIEDMONT, SOUTH CAROLINA

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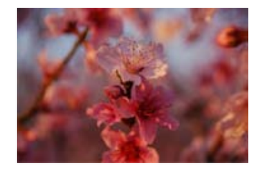
I. Introduction

Campobello 7.5-minute quadrangle (CQ) is located on the Six Mile thrust sheet within the Tugaloo terrane of the Inner Piedmont. Geologic mapping of fifteen 7.5-minute quadrangles in the Western Inner Piedmont of South Carolina by Furman University and the South Carolina Geological Survey personnel (1995-2010) has investigated the polyphase fold deformation, faulting, and metamorphic history of the region. Our mapping traces these structures into CQ.

West side of Little Mountain (Collins Mountain). This prominent ridge in southeast Campobello quadrangle has 60 m relief and is the highest peak in the area. View to the east.

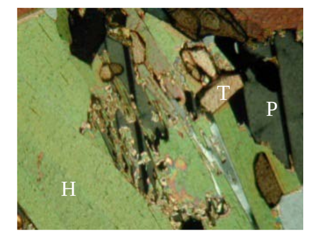
View to the northeast across peach orchards and rolling pasture land typical of northern Campobello quadrangle. Blue Ridge Front visible in the distance. View to northeast. Each year, South Carolina grows more than 200 million pounds of peaches. The state is the No. 2 peach producer in the nation, behind California. Georgia is No. 3.



II. Rock Type

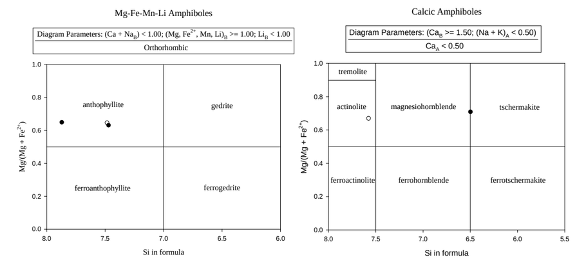
Tallulah Falls Formation gneiss (Neoproterozoic)
Interlayered biotite quartz feldspar gneiss, hornblende quartz feldspar gneiss, amphibolite, amphibole quartz feldspar gneiss, calc-silicate gneiss, and garnet biotite quartz feldspar gneiss. The different rock types are interlayered within CQ. The gneiss unit underlies ca. 95% of the quadrangle area.

Interlayered migmatitic biotite gneiss and hornblende gneiss with irregular intrusive bodies of pegmatite visible in the west wall of Lyman quarry, southeastern Campobello quadrangle. Axial planes of overturned, tight-isoclinal folds are warped by later upright, gentle folds. View to the west.



Photomicrograph (FOV 2mm) of hornblende-biotite-quartz-feldspar gneiss displaying hornblende (H), albite-twinned plagioclase (P), and titanite (T) (high relief). Crossed polars.

Pavement exposures of Tallulah Falls gneiss along Holston Creek, 2 km south of Campobello, SC. Abundant foliation and fold attitude data was collected from similar exposures in streams across the map area. View to the south.

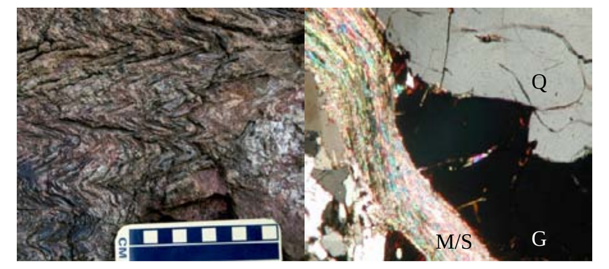

Mg-Fe-Mn-Li Amphiboles
Orthorhombic
anthophyllite
gedrite
ferroanthophyllite
ferrogedrite
Calcic Amphiboles
tremolite
actinolite
magnesiohornblende
tschermakite
ferroactinolite
ferrohornblende
ferrotschermakite
Si in formula

Amphibole plots identifying the type of amphibole based on electron microprobe analyses. The anthophyllite occurs in an amphibole quartz feldspar gneiss, the actinolite occurs in a calc-silicate, and the magnesiohornblende was identified within a hornblende metagabbro.

Tallulah Falls Formation schist (Neoproterozoic)
Interlayered schist and schistose muscovite-biotite gneiss.

The original stratigraphic order of metamorphic units in CQ is obscured by polyphase folding and faulting. Schists now lie structurally above the Tallulah Falls Formation gneiss. Schist and gneiss in the map unit have either biotite or muscovite or both present. Common lithologies include garnet (up to 5 mm)-mica schist; mica schist interlayered with pegmatite; fine-crystalline, limonitic-stained and beige-weathered, leucocratic, muscovite-sillimanite schist with sheared quartz lenses, 1-3mm thick and 0.5-2cm long; and a fine-crystalline, darker limonitic stained, muscovite schist.

With a decrease in modal mica and an increase in quartz and feldspar, schist grades into gneiss. The gneiss varieties include muscovite-biotite-garnet-quartz gneiss, with garnet comprising up to 40% of the rock composition and muscovite-biotite-quartz-plagioclase (oligoclase) gneiss.

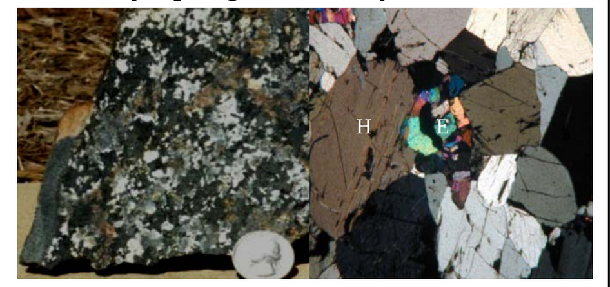


Schist with tight chevron folds (F_2) that deform cm scale isoclines (F_1). Exposure lies north of the Beaverdam fault and is structurally on the north limb of an F_2 synform. View to south.

Photomicrograph (FOV 2mm) of chlorite-garnet-muscovite schist showing isotropic garnet (G), fine-crystalline mix of fibrous sillimanite (S) and muscovite (M), and anhedral quartz crystals (Q), some with undulose extinction. Crossed polars.

Holly Springs Hornblende Metagabbro
A hornblende metagabbro body (3 x 0.5 km) is located between Lyman Lake and Holly Springs, SC. It is partly truncated and offset by east-northeast faults. Metagabbro is largely hornblende and plagioclase, the latter altering to epidote and scapolite in thin section. Some textures suggest the rock retains an original igneous texture. In float samples, zones of foliated amphibolite several cm wide with sharp contacts may represent original thin basaltic dikes in the gabbro.

The hornblende metagabbro body is surrounded by Tallulah Falls gneiss, but the contacts of the body are not exposed. Based on limited field data we tentatively suggest the hornblende metagabbro lies in the core of an F_2 synform (see cross section D-D'). If true, it is probably a fairly thin intrusive body. In addition, the hornblende metagabbro outcrop area between the North and Holly Springs faults may be a horst.



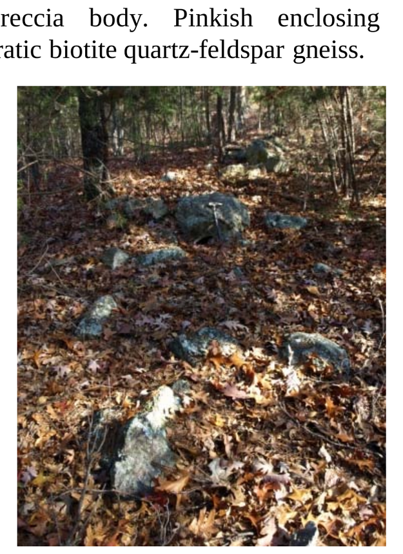
Slabbed coarse-grained hornblende metagabbro specimen with relict igneous texture (?) cut by thin amphibolite dikes (?) (left and right margins).

Photomicrograph (FOV 2mm) of recrystallized hornblende metagabbro. Hornblende (H) surrounds epidote (E) grains in the center of the image.

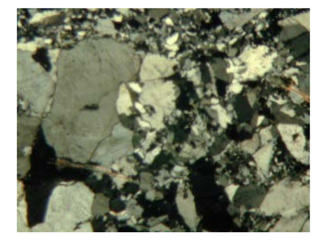
Silicified cataclastic rocks
Microbreccia, cataclasite, and syntaxial quartz veins ("comb quartz") form narrow zones of outcrop, boulders, and resistant float. Discontinuous cataclastic rock bodies up to 1.3 km in length and trending N 60°-70°E adjacent to the Pax Mountain Fault have been traced across the entire Campobello quadrangle. On a ridge 1.6 km northeast of Liberty Church, two main zones of outcrops and boulders of microbreccia and comb quartz are 10m and 25m long. In general, linear cataclastic rock bodies are a few meters long and up to 3m high.

Microbreccia body 12 m wide of Pax Mountain fault zone and enclosing leucocratic biotite quartz-feldspar gneiss is exposed along Rt. 176 in Campobello, SC. View to northeast.

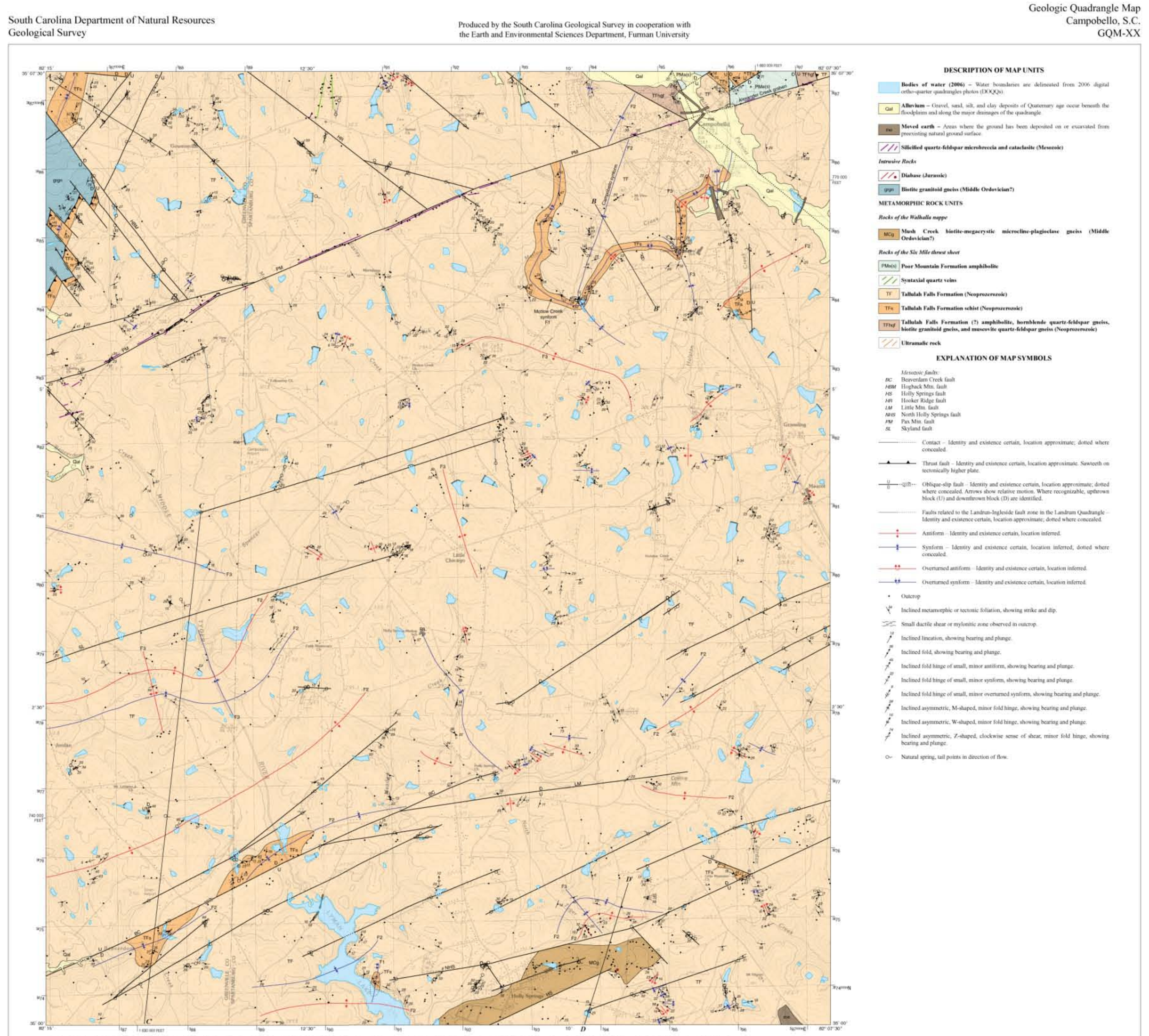
Thin, criss-crossing microbreccia and "comb quartz" veins (striking N40 -80 E and N 18 W) are exposed over a 17m zone south of the 12m-wide Campobello microbreccia body. Pinkish enclosing rock is leucocratic biotite quartz-feldspar gneiss.



Continuous zone of microbreccia exposures and float (32 ft long) trends N45°E along Pax Mountain fault. Ridge 1.6 km northeast of Liberty Church.

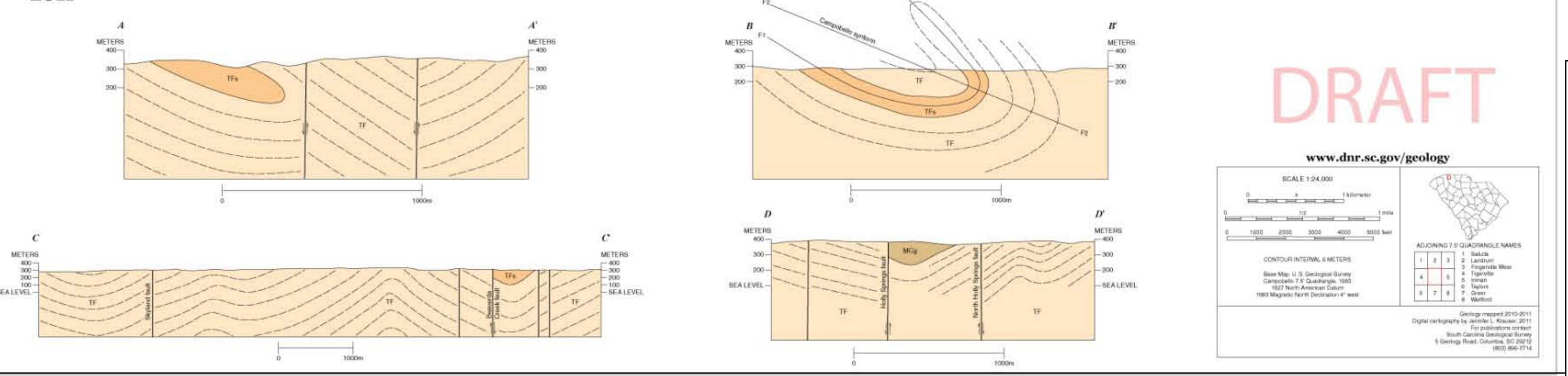


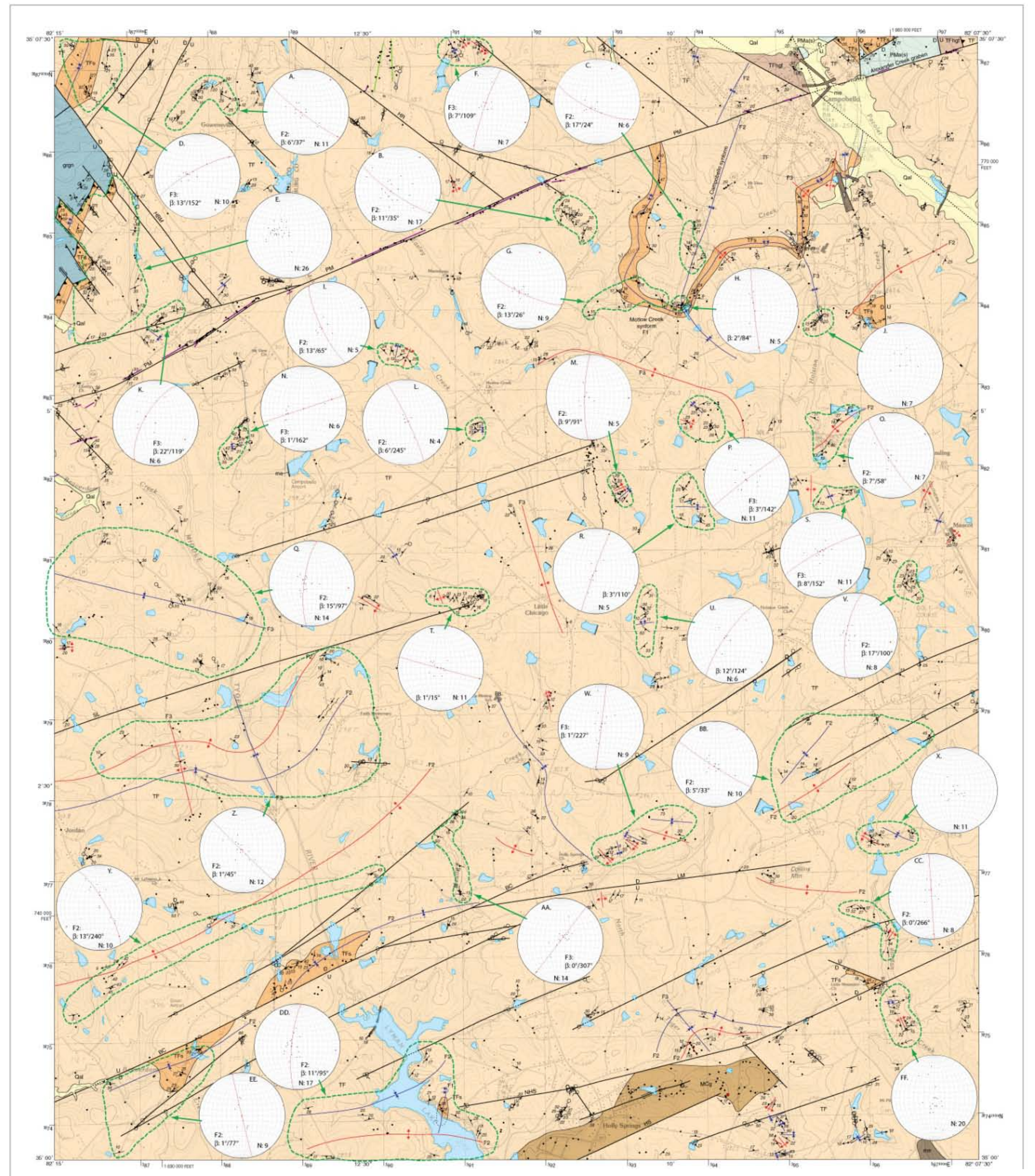
Photomicrograph (FOV 2mm) of microbreccia texture displaying clasts of quartz and feldspar of various sizes. Crossed polars.


South Carolina Department of Natural Resources
Geological Survey
Produced by the South Carolina Geological Survey in cooperation with
the Earth and Environmental Sciences Department, Furman University
Geologic Quadrangle Map
Campobello, S.C.
GQM-XX
DESCRIPTION OF MAP UNITS
Bodies of water (2006)
Alluvium
Moved earth
Silicified quartz-feldspar microbreccia and cataclasite (Mesozoic)
Intrusive Rocks
Diabase (Jurassic)
Biotite granitoid gneiss (Middle Ordovician?)
METAMORPHIC ROCK UNITS
EXPLANATION OF MAP SYMBOLS

GEOLOGIC MAP OF THE CAMPOBELLO QUADRANGLE, GREENVILLE AND SPARTANBURG COUNTIES, SOUTH CAROLINA

John M. Garihan, Alyssa K. Wickard, Rhonda Chan Soo, William A. Ranson
2011


METERS
SEA LEVEL
TF
TFs
MGg
Skyland fault
Beaverdam Creek fault
Holly Springs fault
North Holly Springs fault
1000m
DRAFT
www.dnr.sc.gov/geology
CONTOUR INTERVAL 6 METERS
ADJOINING 7.5' QUADRANGLE NAMES
1 Saluda
2 Landrum
3 Fingerville West
4 Tigerville
5 Inman
6 Taylors
7 Greer
8 Wellford
Geology mapped 2010-2011
Digital cartography by Jennifer L. Krauser, 2011



SOUTHERN HEMISPHERE, EQUAL AREA STEREOPLOTS OF POLES TO FOLIATION. SURFACES ARE USED TO DETERMINE STATISTICAL FOLD HINGE ORIENTATIONS (BETA) OF F_2 AND F_3 FOLDS

Broadly folded synform plunges 19 /188 in the west bank of Motlow Creek. Exposure is of biotite quartz feldspar gneiss.

Recumbent isoclines in migmatitic Tallulah Falls gneiss, Lyman quarry. View to the west. Drill holes are 2-3 feet apart.

Two views of isocline in Motlow Creek of garnet biotite quartz feldspar gneiss.

Broad synformal warping of foliation in Tallulah Falls gneiss, Lyman quarry of Vulcan Materials, southeastern Campobello quadrangle.

III. Cross Sections

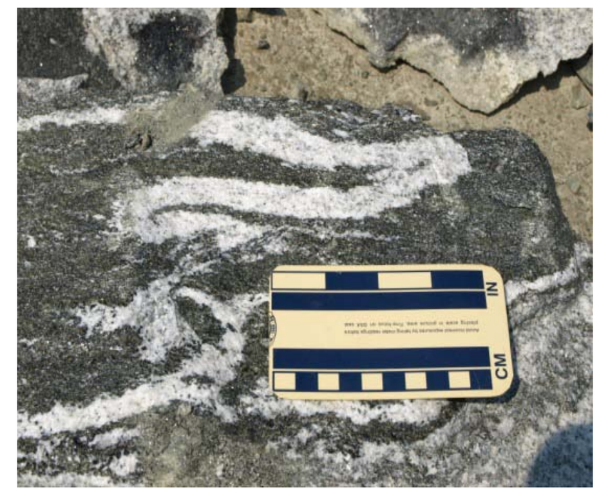
A-A': In the northwest of CQ, Tallulah Falls schist lies structurally above Tallulah Falls gneiss in the nose of an overturned synform. The synform is truncated by a vertical fault.
B-B': In the northeast of CQ and to the southeast of the Pax Mountain fault, schist forms a long, sinuous belt which has been deformed by F_1, F_2, and F_3 generation folds. The cross section shows part of this schist belt, which is structurally an overturned synform and consists of interlayered Tallulah Falls gneiss and schist. The earlier F_1 isoclinal fold was later refolded by F_2 folding.
C-C': The Beaverdam Creek Fault, trending N55 E, in southeastern CQ truncates the schist unit, which occurs in the nose of a synform. The gneiss unit displays broad synforms and antiforms and is faulted by vertical faults.
D-D': Hornblende Metagabbro body which is located in the southeast of CQ between Lyman Lake and Holly Springs, SC.

IV. Metamorphic History

Although metamorphism peaked in the sillimanite zone of the upper amphibolite facies, we observe a range of metamorphic conditions in the rocks of the CQ. Most notably, chlorite is developed in most of the amphibole quartz feldspar gneiss lithologies in which the amphibole is altered to chlorite. Microprobe data indicate that several amphiboles exist, which indicates a range of temperatures and pressures from the greenschist facies to the upper amphibolite facies. On the geologic map of Campobello quadrangle a trend appears for four of the locations of retrograded amphibole gneiss at N50 E and is a similar strike with nearby faults mapped in Campobello quadrangle. This similarity in trends suggests that the faults might have served as avenues for fluids, which then produced the retrograded mineralogy in localized regions.

V. Deformation: Faults and Folds

Folds in Campobello quadrangle
F_1 – Isoclinal folds are found at all scales. The F_1 designation is used for the oldest folds we observed in CQ. Foliation and compositional layering are affected by F_1 folding. Hence it is unknown whether the compositional layering in gneiss is in fact axial planar to a fold set older than our F_1 set. Macroscopic F_1 folds were probably overturned (recumbent?) originally, with a northwest-vergence consistent with Griffin's nappe emplacement concepts for the Inner Piedmont (Wetmore, C.C., and Griffin, V.S., 1977; Griffin, V.S., 1971; Griffin, V.S., 1967). Aligned sillimanite needles may have formed during F_1 deformation. In rock exposures a transposition foliation has been observed.



Small isoclinal fold in biotite gneiss, Lyman quarry.

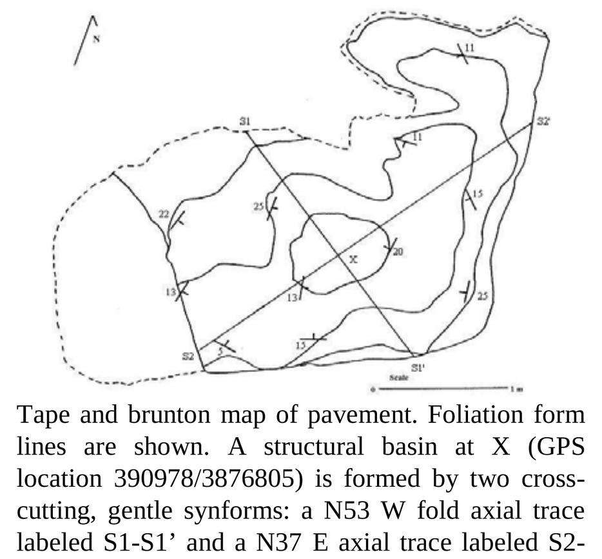
F_2 – Inclined to overturned macroscopic and mesoscopic F_2 folds deform earlier folds.

Overturned F_2 synform in interlayered biotite quartz-feldspar gneiss and amphibolite, Motlow Creek. Hammer lies on the gently dipping upright fold limb; to the right, layers abruptly bend and are overturned in the background at the narrow ledge crossing the creek. F_2 fold hinge plunges to the upper left at 30°/N59°E

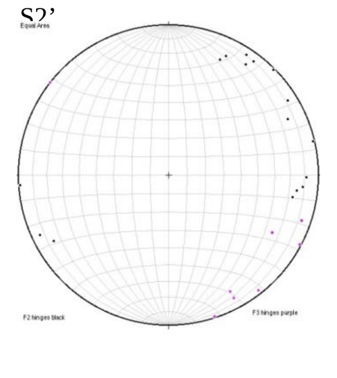
F_3 – Inclined to overturned macroscopic and mesoscopic F_3 folds deform earlier and F_2 folds.

F_4 and F_5 – Upright gentle folds. Not known from macroscopic map patterns

Pavement of biotite quartz feldspar gneiss along Meadow Creek, displaying a Type I interference fold pattern due to polyphase deformation. The white tape measures mark the axial traces of two gentle synforms which trend northwest and northeast.



Tape and brunton map of pavement. Foliation form lines are shown. A structural basin at X (GPS location 390978/3876805) is formed by two cross-cutting, gentle synforms: a N53 W fold axial trace labeled S1-S1' and a N37 E axial trace labeled S2-S2'

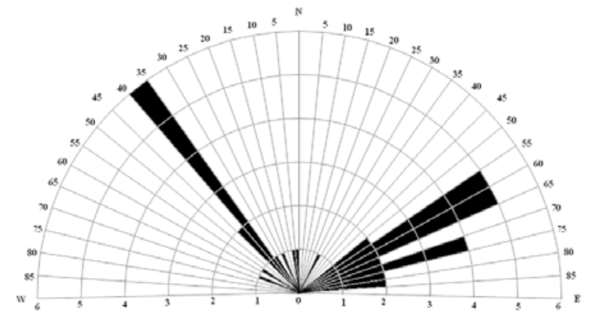


Synoptic stereoplot analysis of 24 hinge orientations of F_2 and F_3 hinge data display two hinge orientations. The hinges for F_2, in black range in azimuths of 025° to 100° and 240° to 270°. The hinge for F_3, in purple range in azimuths of 100° to 170° with just one point plunging northwest. Our interpretation of this distribution is F_2 folds being folded about F_3 with a gentle plunge southeast.

Polyphase folding in Campobello quadrangle
Campobello quadrangle has experienced five generations of folding resulting in polyphase deformation. The Motlow Creek F_1 isocline outlined by the schist unit located in the northeast of CQ has been deformed by the macroscopic Campobello F_2 synform. Other F_2 folds are seen as tight chevron folds found in schist and have deformed F_1 aligned sillimanite needles, as evident from hooks that are visible in chevron folded schist. F_3 macroscopic inclined to overturned folds trend northwest and warp F_1 and F_2 folds. This can be seen clearly in the Campobello synform (F_2), which is cross folded by F_3 folds. F_2 and F_3 together create Type-2 interference folding. The final two generations of folding are mesoscopic F_4 and F_5, two generations of gentle folding that appear 90° to each other in stream pavements creating Type-1 interference folding.

Faults in Campobello quadrangle
The chronology of faulting in CQ is northeast (oldest), northerly, northwest, and east-northeast to easterly faults. Dominant fault sets consist of older and shorter N35 -40 W striking faults and younger but longer N55 -75 E striking faults.

Zones of microbreccia boulders lie along the Pax Mountain fault and trend N30 -60 E, with individual sets trending N30 E, N40 -50 E, N55 E and N60 E. In an exposure of microbreccia in a roadside ditch at GPS location 387668/3883602, near Morrow Road and less than 10m north of the trace of the Pax Mountain fault, extensional veins up to 1ft long were oriented N25 E 68 NW, N50 E 60 NW, and N55 E 82 NW. Northeast of this microbreccia exposure and still less than 10m from the Pax Mountain fault, the orientation of syntaxial veins was measured as N50 E, E-W, and N40 -70 E. Two separate, north-trending syntaxial quartz veins (0.5-1 km long) lie 2 km northeast of Gowensville.



Rose Diagram showing fault strike frequencies for CQ

N60°-70°E fault in gently folded Tallulah Falls gneiss, Lyman quarry, southeastern Campobello quadrangle. View to the southwest.

N60 -70 E normal fault (F) next to a nose of a fold, which are both delineated by white granitic material.

VI. Summary

- The metamorphic peak is in the sillimanite zone of the upper amphibolite facies for the rocks in Campobello quadrangle. Localized retrograde fluids along faults trending N50 E metamorphosed rocks to greenschist facies, leading to chlorite replacement of amphiboles.
- Campobello quadrangle has experienced multiple deformational events resulting highly faulted and polyphase deformed geologic units.
- The fold chronology consists of five fold generations. F_1 mesoscopic and macroscopic isoclinal folds, F_2 inclined to overturned mesoscopic chevrons and macroscopic folds, F_3 gently inclined to overturned mesoscopic and macroscopic folds, and F_4 and F_5 gentle folds.
- The faulting chronology is (oldest-youngest): northeast, northerly, northwest, and east-northeast to northerly faults.
- Dominant fault trends are N35º-40ºW and N55º-75ºE and faults are assumed to be vertical.

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