Trip B-2

VARIATIONS IN L- AND S-TECTONITE ON THE NORTHERN BOUNARY OF THE PISECO LAKE SHEAR ZONE, ADIRONDACK MOUNTAINS, NEW YORK

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INTRODUCTION

The subject of this field trip is the variation in deformation fabrics along the northern margin of the Piseco Lake shear zone (Gates et al., 2004) with special emphasis on the development of L-tectonite domains at various scales. To some extent, but on a much more regional scale, this was also the emphasis of field guide for the 76th NYSGA field conference (Valentino et al., 2004). The current field guide covers a geology field trip that is a continuation of the earlier field trip with overlap of a few field stops.

The Piseco Lake shear zone (Figure 1) is a major Grenvillian structure that is 10 to 20 kilometers wide and strikes generally east -west in the southern Adirondacks. Kintematic analysis in the zone demonstrated dominately low-angle sinistral shear (Gates et al., 2004). For the current study, an area of 42 square kilometers was mapped in detail and the study area spans the northern limit of the Piseco Lake zone in the area of the West Canada Creek basin (Figures 1 & 2). The objective of this study was to document the detailed rock fabric variation within the shear zone, within the transition zone and within the wall rocks to the shear zone. This study was designed to better understand the strain and metamorphic history associated with this major Adirondack structure, and document the geographic distribution of L- and L-S tectonites that were previously reported (McLelland, 1984; Chiarenzelli et al., 2000; Gates et al., 2004).

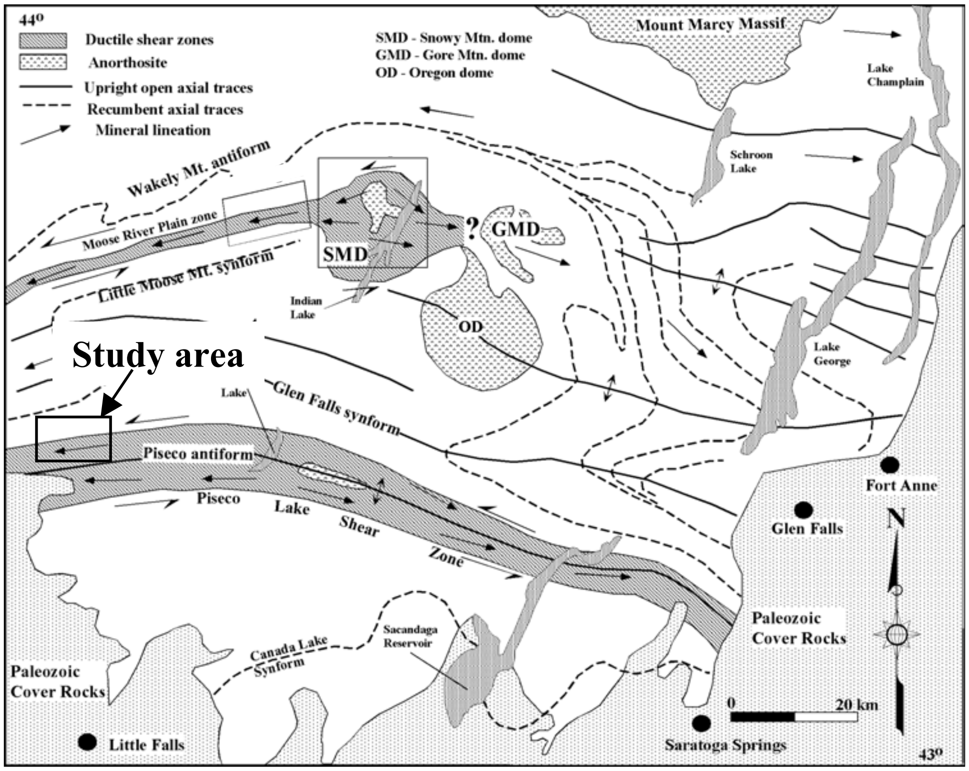


Figure 1 - Schematic structure map of the southern Adirondacks showing the Piseco Lake shear zone (modified from Chiarenzelli, et al., 2000 and Gates et al., 2004). Study area shown with box.

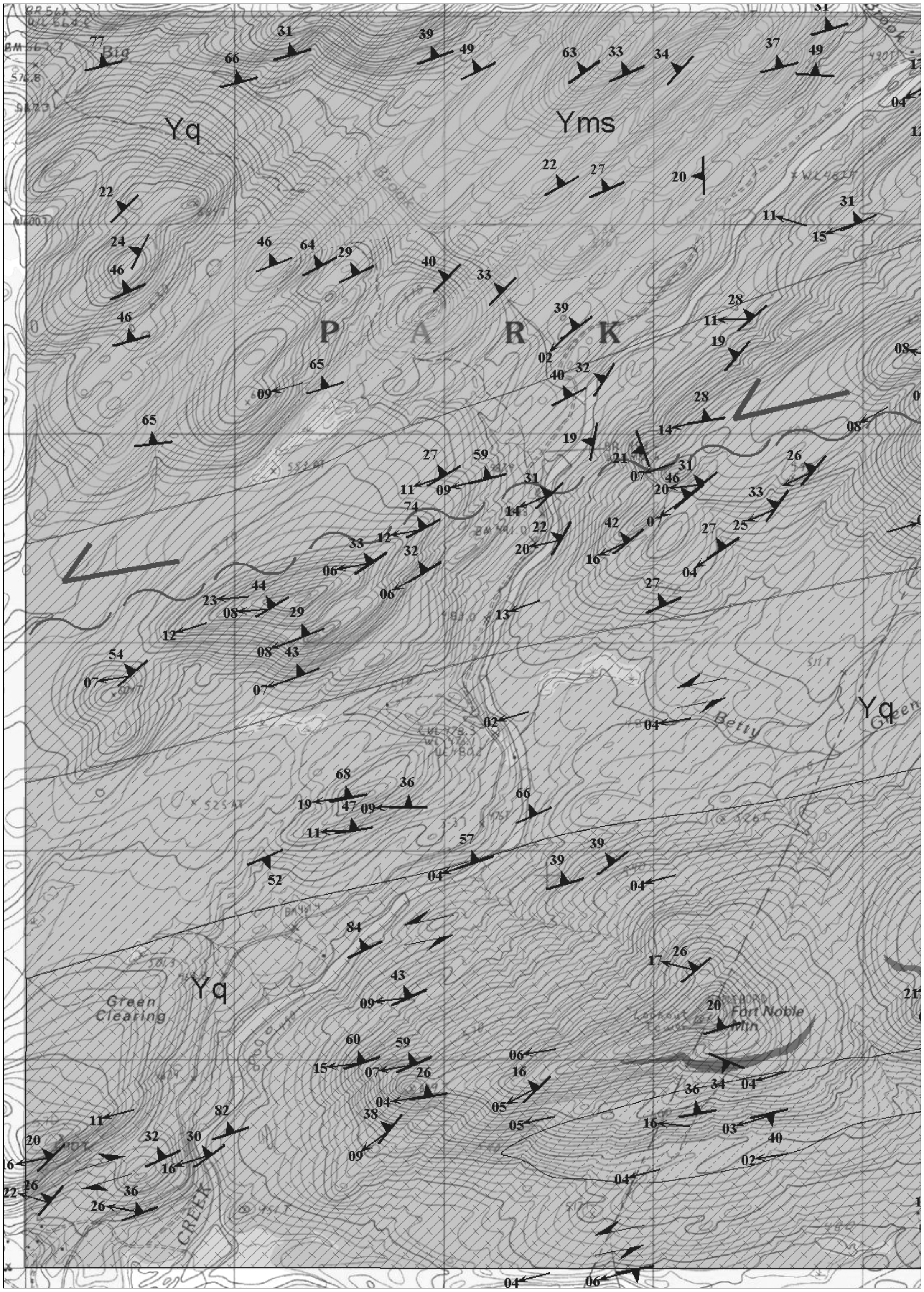


Figure 2 - Bedrock geologic map of the West Canada Creek basin in the southwestern Adirondacks. The map area spans the northern limit of the Piseco Lake shear zone. The base map is a provisional USGS metric topographic map with a 1 km grid. The next two pages show the eastern extension of the map area and the map explanation respectively.

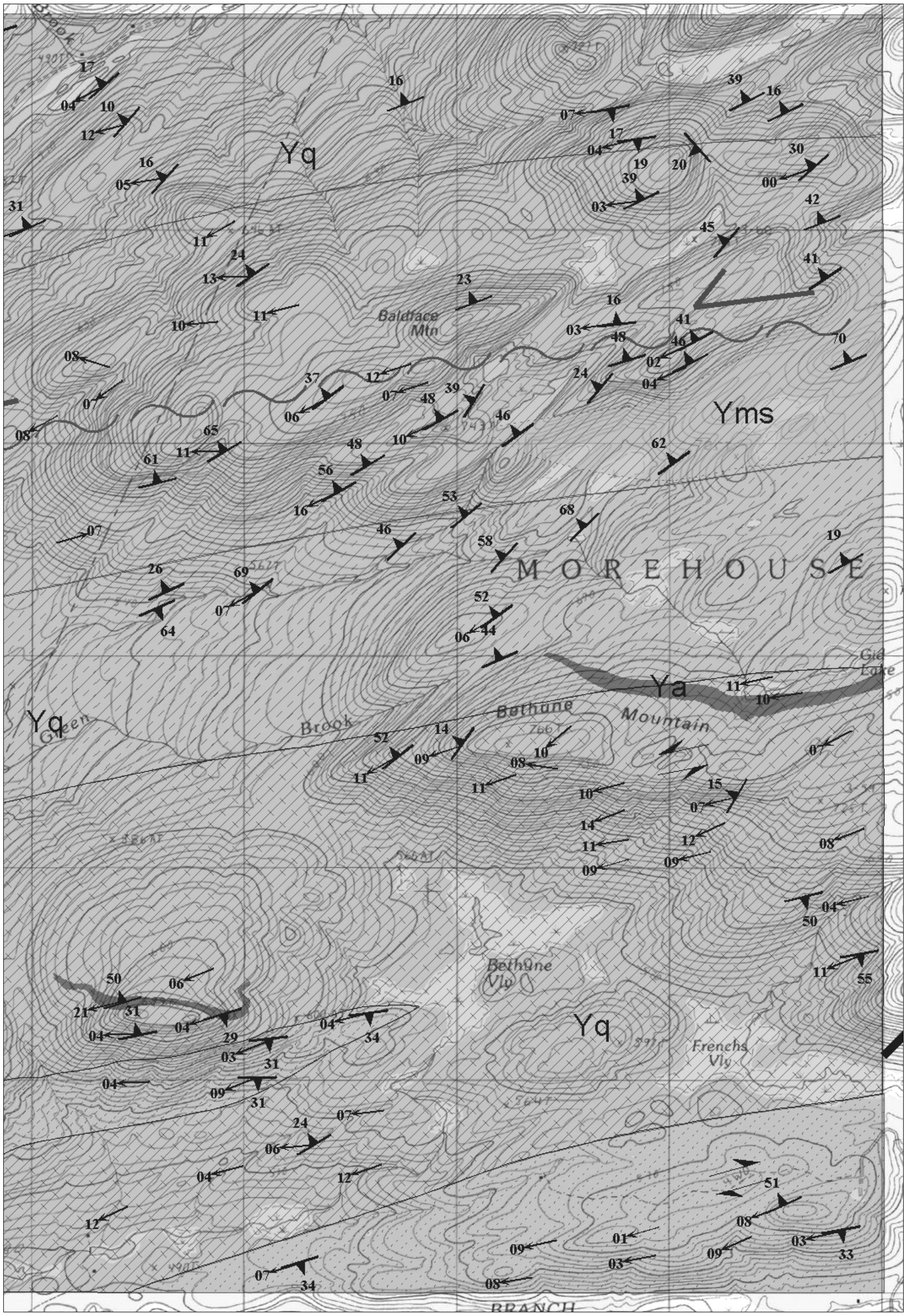
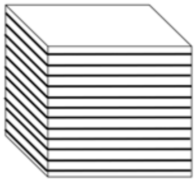
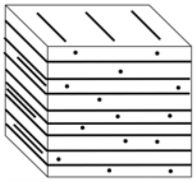
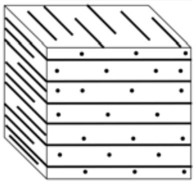
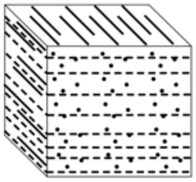
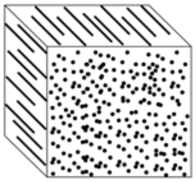


Figure 2 continued - Eastern extent of the geologic map of the West Canada Creek basin. See the next page for the map explanation.

Explanation of L and S Fabric Variation

Handsample distribution of Lineation vs. Foliation	Over print on the map	Fabric description
	S ▨	The rock fabric is almost entirely made up of foliation defined by planar aggregates of minerals. Lineations can be present but are weakly developed and difficult to find at the outcrop.
	S > L ▨	Foliation is better developed than lineation. Although the foliation is dominant, the linear mineral fabric can be observed at the outcrop.
	L = S ▤	Both the foliation and the lineation are penetrative and well developed, and easily observed at the outcrop.
	L > S ▩	Lineation is penetrative, and the foliation is poorly developed. However, the foliation is observable at the outcrop.
	L ░	The lineation is penetrative, and foliation is extremely weak or non-existant. The lineation is defined by linear aggregates of recrystallized minerals such as quartz and feldspars.

Explanation of Rock Type

Yq	Quartzofelspathic gneiss this rock type contains quartz, potassium feldspar, plagioclase, with minor biotite or chlorite, and or hornblende. Bands of micas or hornblende generally define the foliation of the quartozofeldspatic gneiss.
Yms	Meta-sedimentary gneiss this rock type contains quartz, plagioclase, hornblende, with minor biotite and garnet. Plagioclase generally defines the foliation of the meta-sedimentary rock.
Ya	Amphibolite this rock type contains hornblende, plagioclase, and biotite. Thin bands of plagioclase and zone of concentrated hornblende crystals define the foliation.

Figure 2 continued - Map explanation for the West Canada Creek basin with special emphasis on rock fabrics and lithology. Three gray shades were used to represent general rock types and the shades are overlain with patterns to represent the five categories of rock fabrics. The structure symbols on the map represent the foliation (S) and lineation (L) as described in the text.

FABRIC VARIATION IN THE PISECO LAKE ZONE

Five domains of varying fabric intensities were documented (L>>S, L>S, L-S, S>L, and S) within the Piseco Lake zone and the shear zone transition region with the wall rocks (see Figure 2 on the previous pages). The northern boundary of the Piseco zone is defined by a gradational increase in L-S fabric intensity from north to south. Both the foliation and lineation are defined by dynamically recrystallized aggregates of quartz, K-feldspar, plagioclase and minor mafic phases. This fabric transition corresponds with an increase in grain size reduction of all these minerals. Within the Piseco Lake zone the fabric variation occurs systematically from L-S dominated, to L>S and finally L>>S tectonite (Figure 2). A cigar-shaped map-scale domain of L>>S fabric, 3.5 km by 0.5 km in size, trends parallel to the linear fabric observed at the outcrop. A change in the dominate dip direction between the L>>S and L>S domains supports the presence of a foliation fold over the cigar-shaped domain.

The wall rocks to the shear zone in the study area are mostly granitic gneisses and minor dioritic gneiss containing metamorphic index minerals of hornblende and hypersthene. The granitic gneiss contains a dominant gneissocity that strikes generally east-west with very weak mineral lineations. Quartz and feldspars form course crystalline aggregates that define the gneissocity. The presence of hornblende and hypersthene, and the gneissic fabric suggest these granitic rocks were metamorphosed under granulite facies conditions as reported by earlier researchers (McLelland, 1984).

Within the zones of intense L-S deformation fabrics, the rock is generally granitic gneiss, however, it contains abundant feldspar and quartz grains up to a few cm in diameter. In places, K-feldspar grains appear to be relict igneous metacrysts. As mentioned previously, the L-S fabrics are defined by planar and linear aggregates of dynamically recrystallized quartz and feldspar grains. Additionally, the fabrics are defined by chlorite and minor biotite. This observation was previously noted by Gates et al. (2004) where they demonstrated that the occurrence of chlorite in the Piseco Lake zone to be fabric forming and parallel to the mesoscopic foliation and lineation. These rock textures and index minerals suggest two conclusions: 1. the Piseco Lake zone developed in course grained granite that is not found in the wall rocks, and 2. Cannon (1937) and McLelland (1984) described similar rock fabrics for other parts of the Piseco Lake zone, however, they did not mention the presence of low-grade fabric forming metamorphic index minerals.

Systematic look at the structural data

The structural data collected during the mapping was divided based on the fabric categories that define the five fabric domains, as shown on the map of Figure 2. These data were used to generate lower hemisphere contour diagrams for the poles to foliation and lineation. Poles to lineations are plotted at or near the perimeter of the diagram and the poles to foliation form the diffuse girdle on the interior of the diagrams. The stereogram representing the data from the L>>S domain (Figure 3E) demonstrates that the foliation is dominantly dipping to the south. But the stereogram showing the data from the L>S domain demonstrates that the foliation is dominantly dipping northward. The L-S, S>L, and S domains show foliation dominantly dipping to the north, however the general strike is consistent throughout all the diagrams.

OHIO GORGE REGION

The West Canada Creek flows through the east-west trending Ohio gorge a few kilometers south of the geologic map area of Figure 2. Nearly 90% bedrock exposure afforded the opportunity to study the fabric variation in great detail in the heart of the Piseco Lake shear zone. Access to the gorge is restricted due to private property and high water most of the year. During the Summer 2004, a detailed outcrop map was produced for the southern side of the gorge. High-resolution digital photographs were taken and assembled into a mosaic. The photo mosaic was used as the base map, and rock fabric and textural variations were overlain at the sub-meter scale. In general, the bedrock exposed in the gorge is the megacrystic granitic gneiss typical of the Piseco Lake shear zone, and there is little variation in the overall mineral content along the extent of the gorge, but, the outcrop analysis shows variation in deformation fabric at the scale of 10's of meters. Three fabric categories were observed in the gorge, L>>S, L>S and L-S tectonite as described previously. These categories demonstrated gradational and abrupt contacts between one another, and the shape of some fabric domains in the gorge show similar geometric relationships to the map-scale domains.

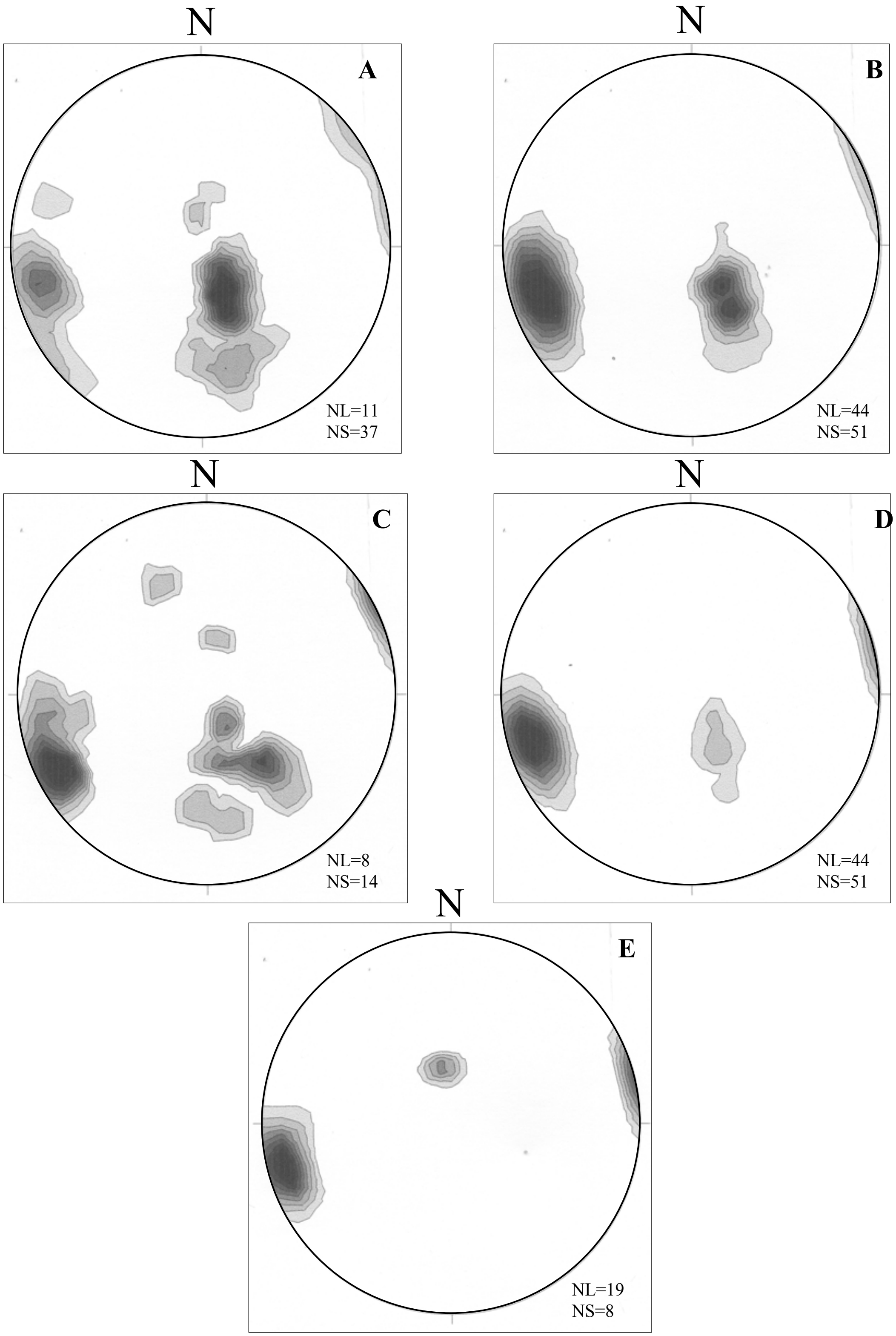


Figure 3 - Lower hemisphere contour stereograms for the L-S domains represented on the geology map of Figure 2. For each diagram above (A-E), the poles to lineations plot near the perimeter of the diagrams and the poles to foliation form the interior domains. Note the increase in the intensity of the cluster of linear data with the decrease in the occurrence of the foliation data.

Throughout the Ohio gorge there are extensive kinematic indicators consistent with sinistral low-angle shear. The L-S domains contain the best preserved porphyroclasts, with the L>>S containing few. The kinematic indicators include S-C fabrics, shear bands, asymetically broken K-feldspar grains, sigma- and delta-porphyroclasts (Lister and Snoke, 1984; Simpson and Schmid, 1983, Passchier and Simpson, 1986).

There are a number of ductile normal faults that crosscut the dominant deformation fabrics. The trace of the dominant outcrop fabric shows "drag" as a primary indicator of normal displacement. Most of these small normal shear zones contain granitic pegmatite, and there are also parallel pegmatite dikes that show no deformation. The ductile normal zone located on the east end of the Ohio gorge exhibits oblique sinistral-normal displacement, while the remaining ductile normal faults exhibit dip slip offset. Figure 4 shows a sterographic plot of the orientation of these ductile normal shear zones and other pegmatite dikes in the Ohio gorge. Both inside the ductile normal zones and within undeformed pegmatite dikes, they are composed of course grained quartz and K-feldspar with minor chlorite. These pegmatites vary in thickness from 0.5 m to 6 cm within one of the normal shear zones. Valentino et al. (2004) noted ductile normal shear zones in the upper reaches of the Ohio gorge and related it to larger-scale displacement at Speculator Mt. farther east.

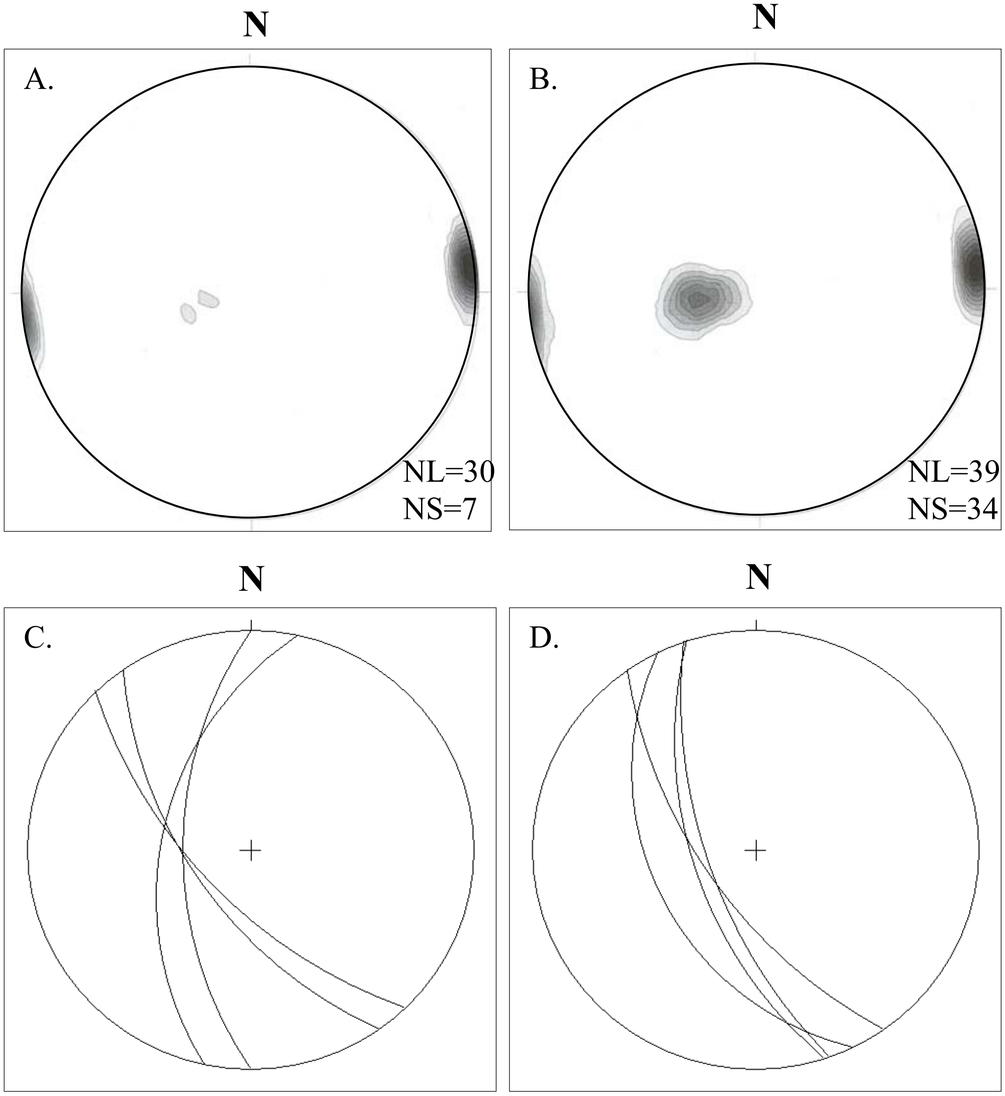


Figure 4 - Lower hemisphere sterograms for structures observed in the Ohio gorge. A. & B. Contour diagram for the poles to lineation and foliation from L>S domain (A) and L-S domain (B) parts of the gorge; C. & D. Great circle plots for ductile normal shear zones (C) and undeformed pegmatite dikes in exposed in the gorge (D).

DISCUSSION AND CONCLUSIONS

Deformation fabrics vary systematically across the northern boundary of the Piseco Lake shear zone in the West Canada Creek basin. Within the Piseco zone, all rocks contain well-formed mineral elongation lineations, however, the variation in fabric intensity appears to be controlled by the development of foliation. The attitude of mineral elongation lineations vary little, but foliation varies systematically in intensity and orientation. Rocks dominated by L-tectonite occur in a cigar-shaped domain, that occurs in broad open foliation antiform, but the foliation is only weekly developed in these areas (L>>S domain). The deformation within the zone occurs in rocks of granite protolith that are different from the high-grade granitic gneiss that occurs in the northern wall-rock to the shear zone. Geochronologic studies in the Adirondacks constrain the timing of deformation and peak metamorphism to 1090-1030 Ma. This is after the intrusion of the AMCG plutonic rocks from 1160-1100Ma (McLelland and Isachsen, 1986; McLelland et al., 1988; McLelland et al., 1996; McLelland et al., 2001). An AMCG suite age and Ottawan metamorphic age was reported by McLelland et al. (1988) for deformed granite from the core of the Piseco antiform. The location of the rock used for this analysis occurs directly along strike about 20 km east of the current study area. Although the AMCG granite within the Piseco zone is highly deformed, there is scant evidence within the study area, that it was subjected to the regional high-grade metamorphism that is preserved in the wall-rocks. It is worth considering that the gneissocity and high-grade metamorphism that occurs in the shear zone wall-rocks predates the intrusion of the granite. However, it is also possible that the low-grade dynamic metamorphism that occurred in the Piseco zone entirely overprinted the high-grade metamorphism of both rock (wall-rocks and granite) units.

ACKNOWLEDGEMENTS

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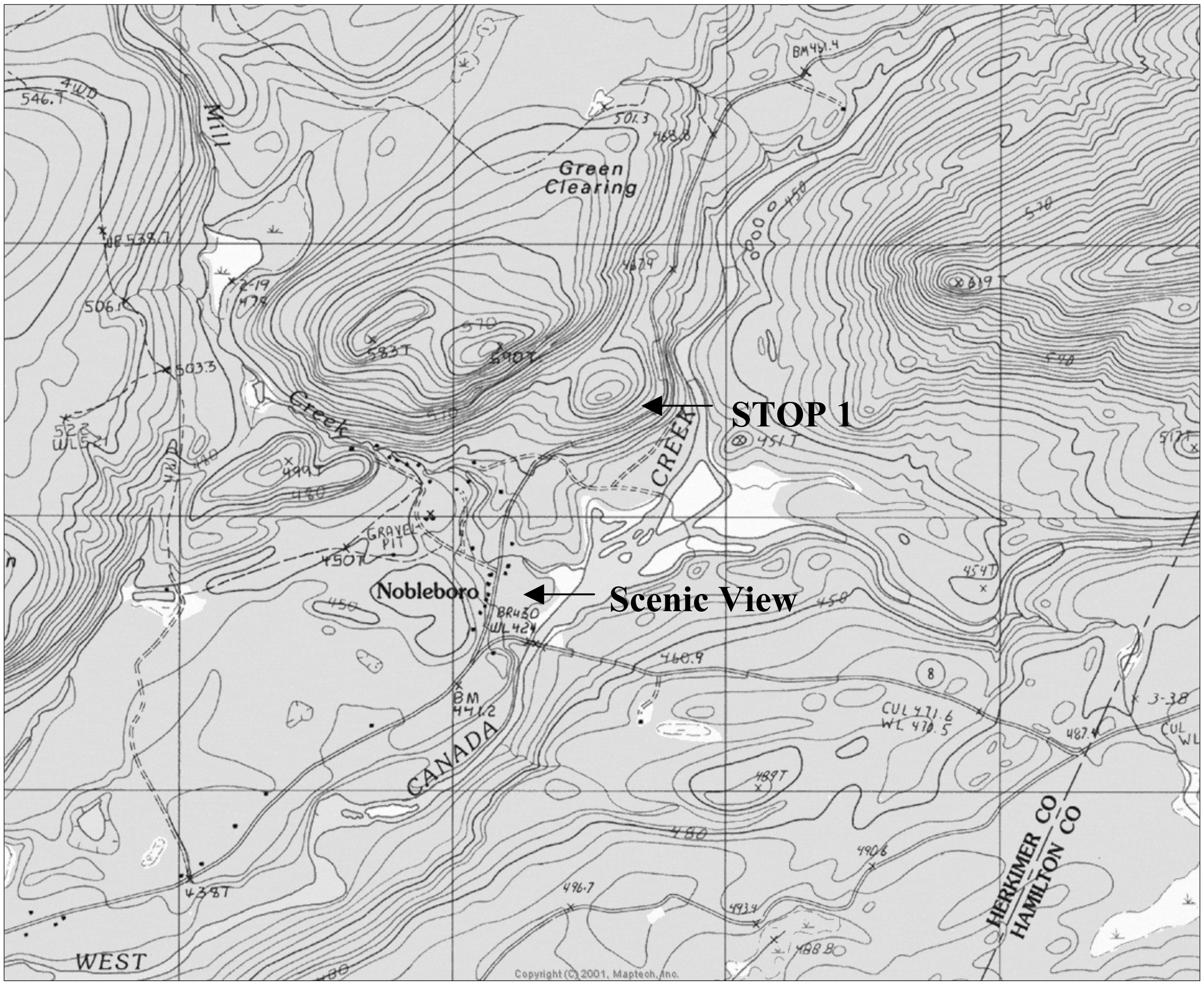
ROAD LOG AND STOP DESCRIPTIONS

Road Log:
Mileage:

0.0	The trip begins at the assembly point in the parking lot of the scenic overlook on the West Canada Creek. The scenic view is located in Nobleboro off of Route 8, between Poland and Piseco.
0.6	When exiting the driveway to the overlook, turn right on Haskell road, travel about 0.6 miles and park along the side of the dirt road. Caution the banks of the road may not be stable. Cross the dirt road and walk west to what appears to be an old quarry (STOP 1).

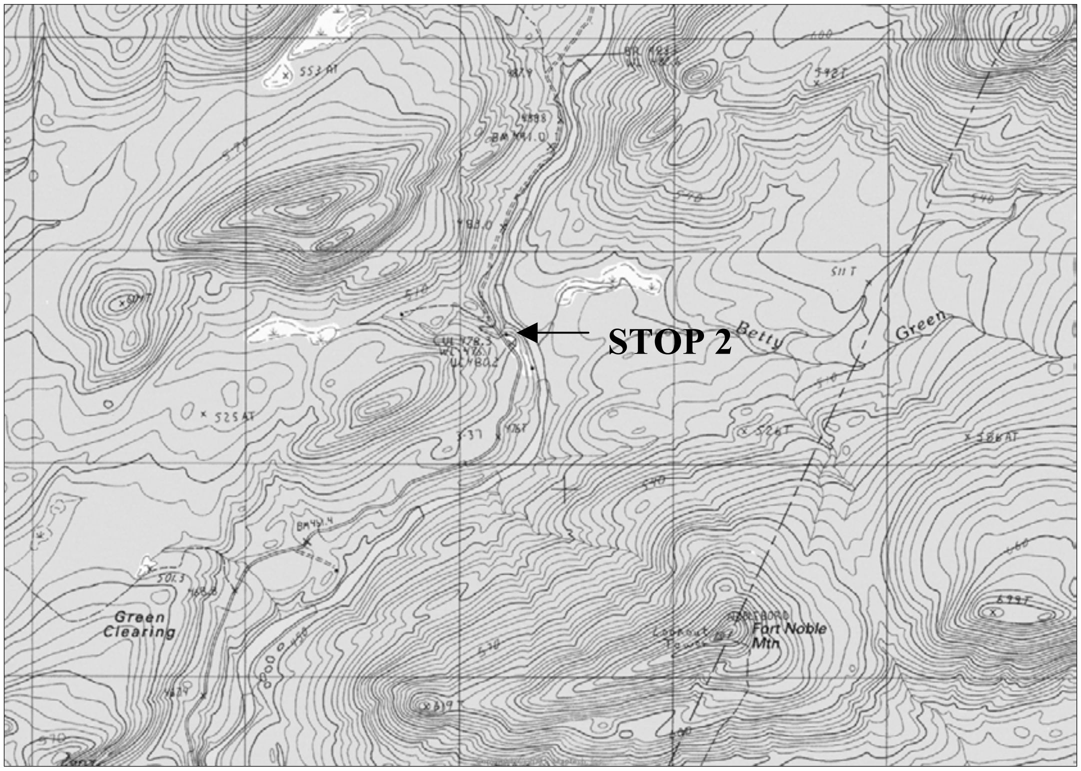


STOP 1: S>L Granitic gneiss with strong gneissic texture

Exposures of course granitic gneiss with well developed gneissocity can be seen in the high-wall of this old quarry. This stop demonstrates S>L fabric, lineation area weakly developed and foliation dominates. (Figure 5). The grain size is uniform and few kinematic indicators are present. The foliation is penetrative and is defined by planes of K-feldspar and biotite and dips to the northwest. The lineations are defined by streaks of biotite and plunge to the southwest.

Figure 5 – Photograph, view is looking north, of granitic gneiss with well-developed foliation and gneissocity. K-feldspar-rich bands define the gneissic texture. Weakly developed lineations can be observed with closer inspection, and they are parallel to the mechanical pencil in the center of the photograph.

Mileage:	
0.6	Continue northeast on Haskell road.
2.7	Arrive at a clearing, before bridge and gate turn right and park in grass. Walk east down a small hill to the West Canada Creek (STOP 2).



STOP 2: L-S and S>L Dioritic Gneiss

The southern most part of the outcrop demonstrates L-S fabric (Figure 6). Lineations are about equal to foliation in intensity. Rods of hornblende define the linear fabric, which plunges to the southwest. Plagioclase and quartz define the foliation. In thin sections of this outcrop a ceased reaction is preserved. The hornblende crystals were breaking down to form biotite in a retrograde reaction. The northern most part of the outcrop demonstrates S>L fabric with gneissic textures, similar to the previous stop. Some small faults with 15cm of displacement and boudins are also preserved at the northern end of the outcrop (Figure 6). Garnets are also visible at the northern end of the outcrop but were not observed at the southern end in hand sample or thin section.

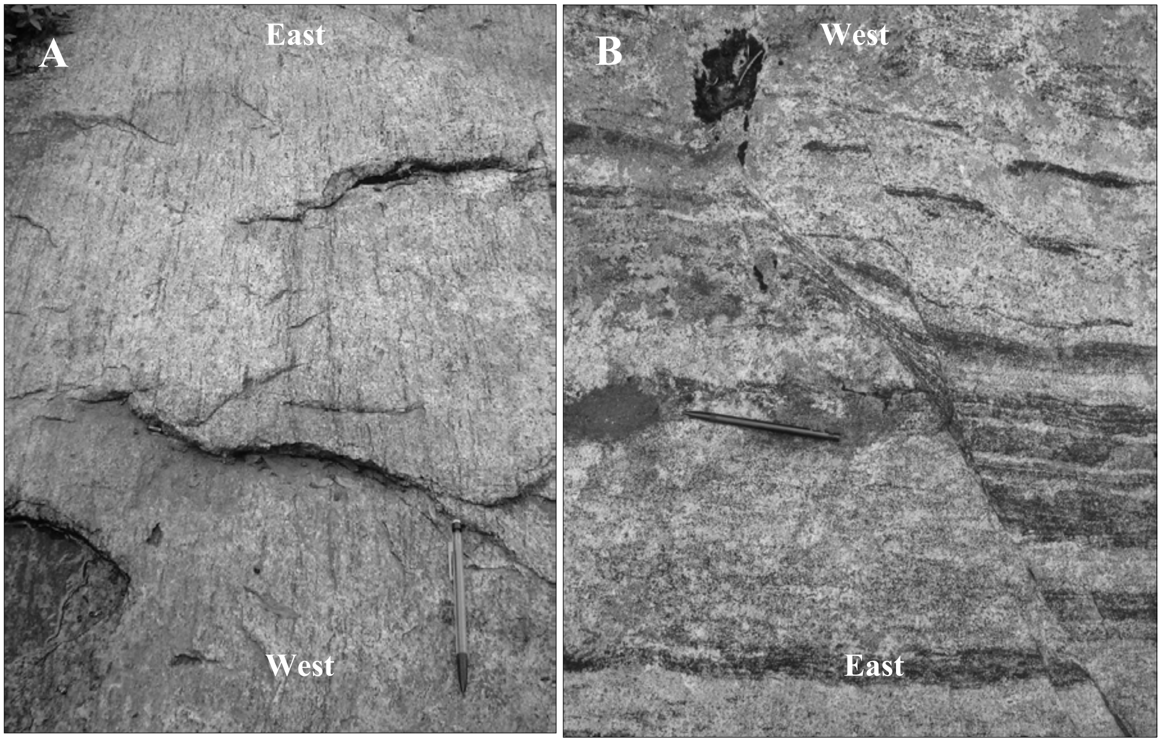
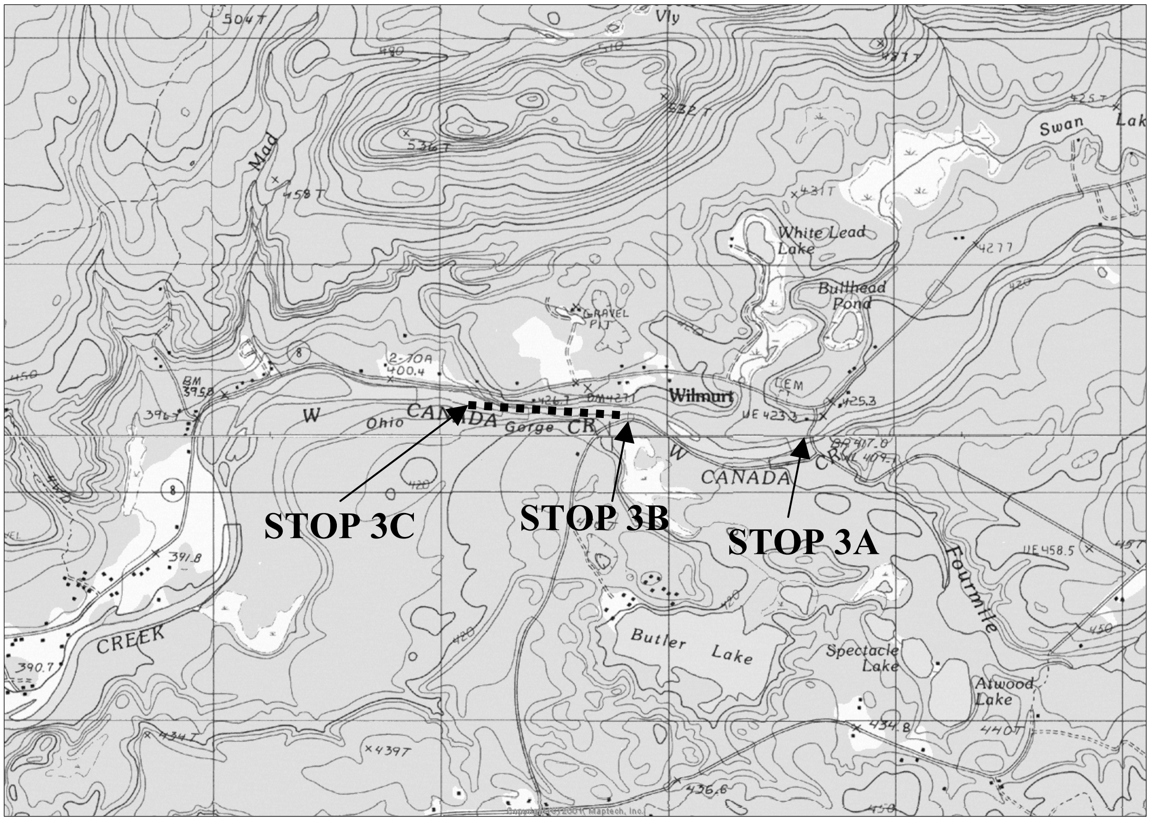


Figure 6 – (A) This is a photo of the L-S fabric at the south end of the outcrop at STOP 15. The black lines are rods of hornblende that define the linear fabric. (B) This is a photo of S>L fabric at the north end of the outcrop. A fault is shown from the top left corner to the bottom right corner. The offset of hornblende bands demonstrates a displacement of about 15cm.

Mileage:

2.7	Turn left out of the parking area heading south on Haskell road.
5.4	Pass the over look and take a right at the stop sign onto Route 8 west.
8.1	Turn left onto Gray Wilmurt Road just after right-hand curve in Rt. 8. Cross a bridge over the West Canada Creek and park at the intersection with Jones Road. Walk back toward the bridge over the West Canada Creek and down the hill to the outcrop just east (upstream) of the bridge (see location map). The outcrop forms a small waterfall on the creek. This is location 13 of Valentino et al. (2004).



STOP 3: The Piseco Lake Shear Zone at the Ohio Gorge of the West Canada Creek

The Piseco Lake shear zone traces westward through the West Canada Creek basin. Some of the best continuous exposures occur in the Ohio Gorge near Wulmurt. This stop contains highly deformed granitic gneiss in the gorge. During periods of high water, the exposures in the gorge may be covered by water. Permission is needed from the landowners at STOP 3A and 3C.

STOP 3A East of the Ohio Gorge. The West Canada Creek forms a small waterfall at the upstream part of this outcrop. Pavement exposures reveal the L-S and L>S deformation fabric in granitic gneiss (Figure 7). Foliation is gently dipping and the lineations are subhorizontal. In the region immediately down-stream of the falls, the foliation is defined by planar aggregates of recrystallized K-feldspar and quartz that alternate with dark layers containing abundant chlorite and minor biotite. The dominant fabrics are cross cut by at least three small high-strain zones. Two are steeply dipping and strike about east-west, and the third strikes south and dips moderately westward. One of the steeply dipping high-strain zones occurs in the vertical face at the southern side of the outcrop. Another occurs at the western limit of the outcrop close to the water. The north-south striking zone occurs in the low ledge near the falls. This small shear zone contains deformed pegmatite, and cross cuts the Piseco Lake shear zone foliation and lineation. Shear sense is top down to the west or normal. The other high-strain zones both contain evidence for oblique sinistral shear.

Mileage:

8.1	From the parking area head west on Wilmurt Road
8.7	Cross over a small bridge and on the first curve before driving up a hill park on the right side of the road. Walk northwest about 20 m, and STOP3B is the first outcrop on the southeast side of the Ohio gorge.

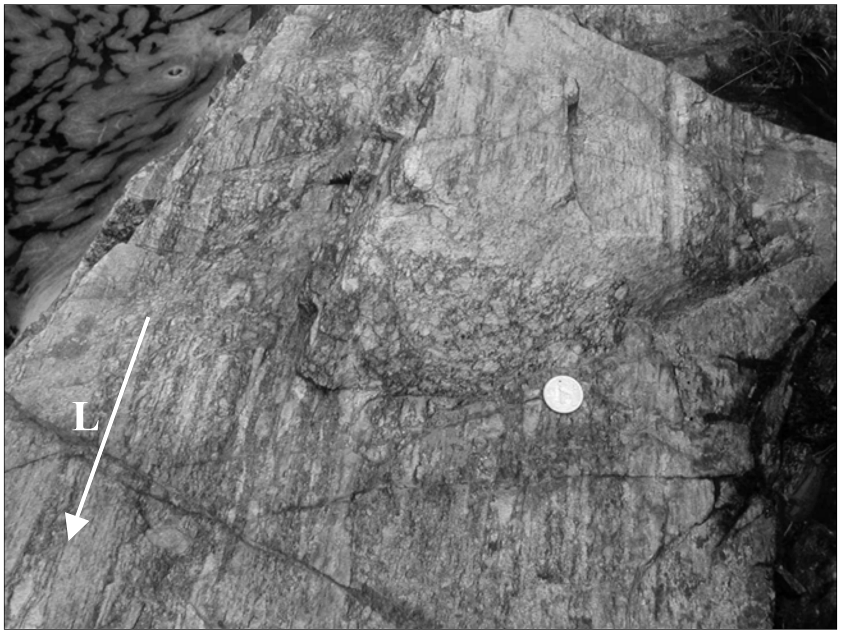


Figure 7 - Outcrop of granitic gneiss with L>>S fabric. The view is looking west. Note the textural differences in this view. The area above the coin is a subvertical surface with the ends of the mineral lineations exposed. The rest of the outcrop is broken parallel to the lineations.

STOP 3B East end of the Ohio Gorge. The east end of the Ohio gorge demonstrates L>S and L-S fabrics. The gorge contains granitic gneiss that varies only in the proportion of quartz, K-feldspar, plagioclase, biotite, and chlorite. The L-S domains have the larges grain size with numerous δ and σ shear sense indicators. The L-S domains also demonstrate lineation about 1 to 5 cm long, .5-2 cm wide, and 1-3 lineations per cm. The L>S domains have a smaller grain size then the L-S domains. The L>S domains demonstrate more lineations and less shear sense indicators, lineations are 1-6 cm long, .5-2 cm wide, and 3-5 lineations per cm. A contact between L>S and L-S can be observed (Figure 8). West of the fabric contact is an oblique left normal fault about 5 cm wide. This fault crosscuts the metamorphic fabrics strikes north south and dips to the east. Farther west is a .5 m wide pegmatite that strikes northwest southeast and dips southwest that also crosscuts metamorphic fabric. The pegmatite is composed of quartz, K-feldspar, and minor chlorite with grains about 1 to 3 cm in size.

STOP 3C requires a .75-kilometer traverse west along the ridge of the Ohio gorge. Please **WATCH YOUR STEP** because the walls of the gorge are vertical and a fall would likely result in serious injury or worst.

STOP 3C West end of the Ohio Gorge. The west end of the Ohio gorge also demonstrates L>S and L-S domains. Another ductile normal fault can also be observed. The ductile normal fault is much larger then the one observed at the east end of the gorge (Figure 9).

Mileage:

8.7	Back track to Route 8, and turn right.
12.0	Pass the scenic view where the trip began and continue east on Route 8.
16.9	Turn left onto Fayle Road.
18.5	Cross a one lane wood bridge, drive to an opening in the tree and the end of Fayle Road. Park and hike to the west about 350 meters to STOP 4A.

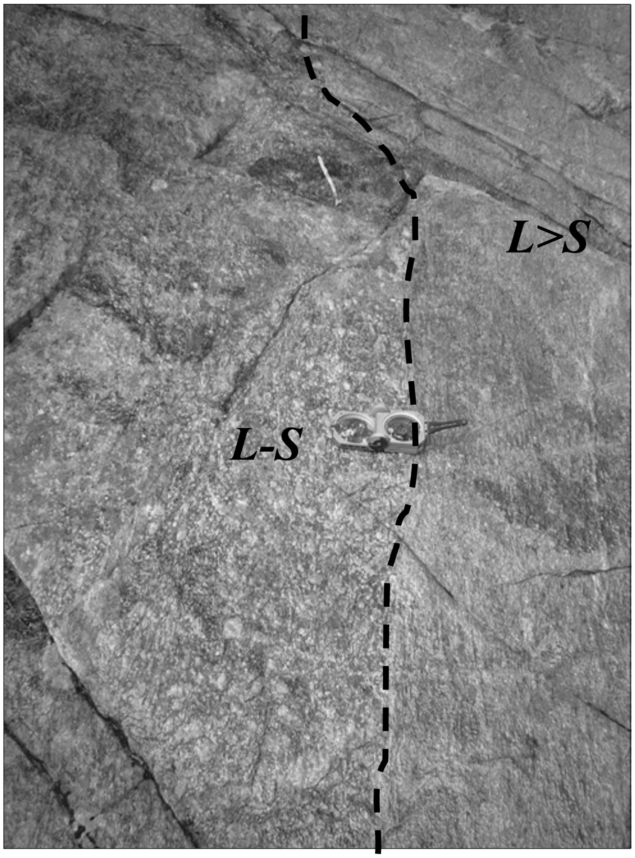


Figure 8 - This is a photo taken at the eastern end of the Ohio gorge, and the view is westward. This photo demonstrates a contact between L-S and L>S rock fabrics. In the L-S domain the grain size is larger and the lineation is less developed, while in the L>S domain the grain size is smaller and the lineations are stronger and easier to see. Note that the boundary between these fabric domains is slightly oblique to the general trend of the rock fabric. Brunton compass for scale.

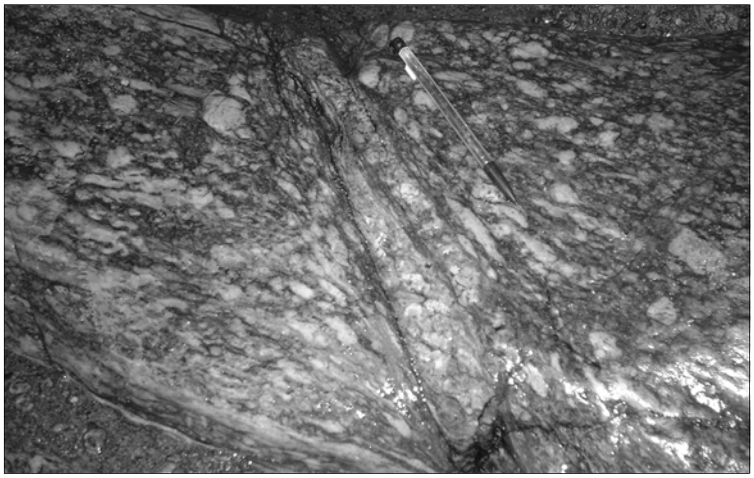
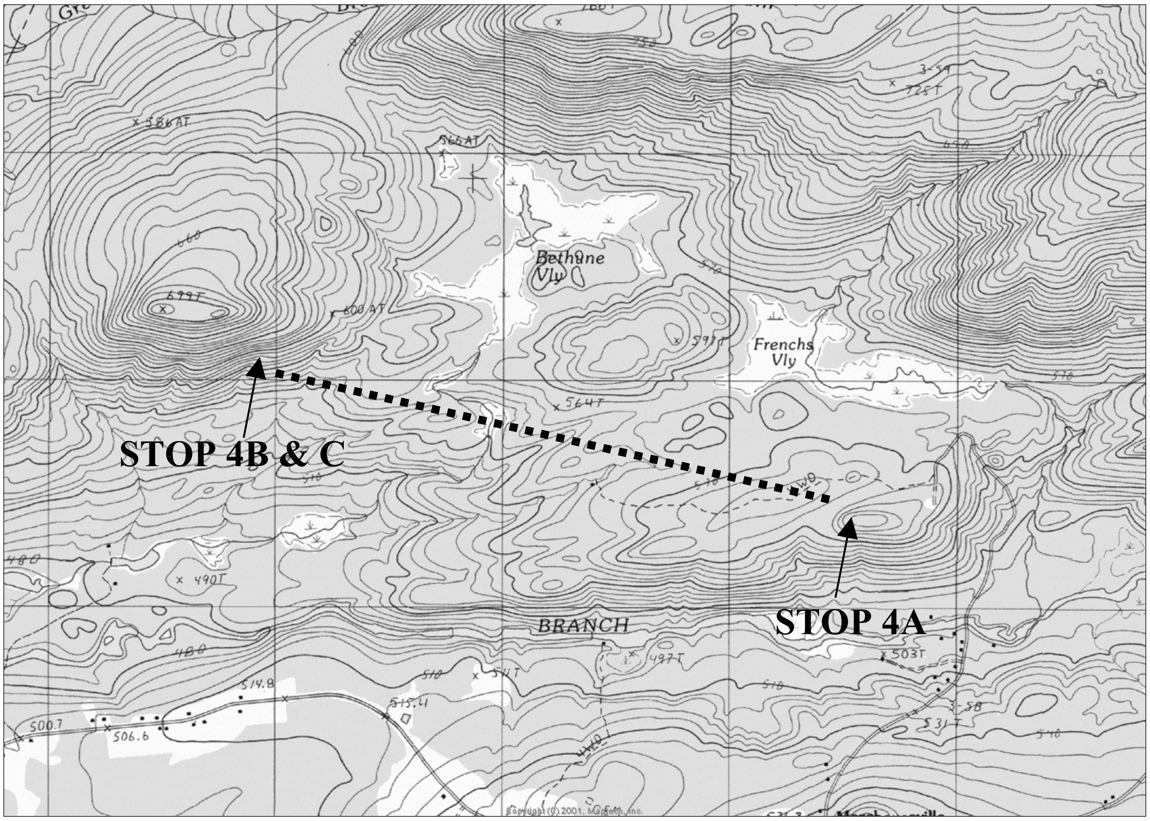


Figure 9 - This photo was taken facing south at STOP 3C. This portion of the ductile normal shear zone will only be visible if the water level is low. The small shear zone crosscuts the metamorphic fabric of the Piseco Lake zone. The footwall displays fabric drag and the hanging wall remains relatively undisturbed. The center of the zone contains deformed pegmatite with dynamically recrystallized quartz and K-feldspar.



STOP 4: L>>S Granitic Gneiss

Excellent outcrops on the northern side of a small hill just east of the parking area. Follow the dirt road to a path through the woods, and then head up hill to the south to the outcrops. This outcrop of granitic gneiss contains domains of L>S and L>>S. The L>S domains contain large and numerous σ-type shear sense indicators, some δ-type are present but are much less frequent. The porphyroclasts are large about 1-3 cm and the recrystallized porphyroclastic material is often wrapped with a quartz ribbons (Figure 10). The interpreted shear sense is low-angle and left lateral. The granitic gneiss is composed of quartz, K-feldspar plagioclase, and minor chlorite and biotite. The foliation strikes east west and dips to the south.

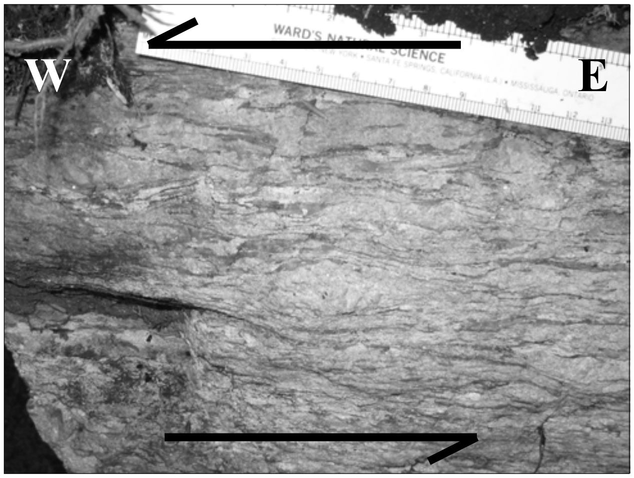


Figure 10 - The view is south at STOP 4, and looking at a surface parallel to lineation and perpendicular to foliation. Large porphyroclasts of K-feldspar and have σ-type tails which display left lateral shear sense.

STOPS 4B and 4C require about 2.5 kilometers of traverse at a bearing of about 280º. The traverse will cross a few small streams and under brush can be thick in places. There is no trail to follow, so **PLEASE STAY WITH THE GROUP**.

<u>STOP 4B Mafic Gneiss</u>. This outcrop is a rare mafic gneiss composed of biotite, hypersthene, plagioclase, quartz and ilmenite. The fabric is L>S, lineations are defined by rods of plagioclase and streaks of biotite. The grains size is very small about 0.5mm. This rock unit borders the L>>S domain which can be seen at STOP 4C.

<u>STOP 4C L>>S Cigar-Shaped Domain.</u> The final stop is a spectacular L-tectonite (Figure 11). The outcrop is granitic gneiss composed of quartz, K-feldspar, plagioclase, and fabric forming chlorite and biotite. Foliation is hard to see in hand sample but can be seen if stained for plagioclase and K-feldspar.

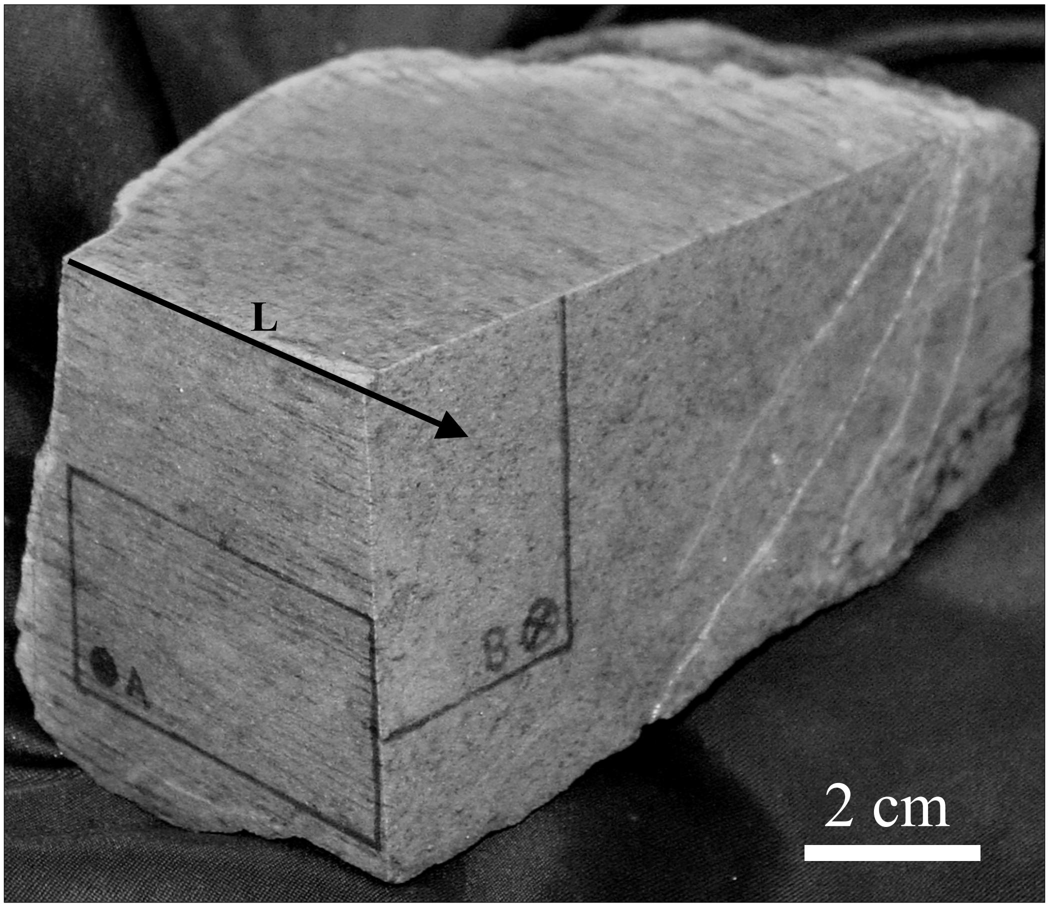


Figure 11 – Rock sample from STOP 4C with three mutually perpendicular cuts to reveal the internal fabric. Quartz rods and recrystallized aggregates of K-feldspar define the penetrative lineations, and foliation does not exist in this specimen. The dark minerals are primarily chlorite and biotite, and they too define a microscopic lineation as demonstrated by Price et al. (2003).

END OF TRIP.

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