

Friends of the Grenville Field Trip 2008 Indian Lake, New York

Day 1, Saturday, September 27th

The Southern Adirondack Sinistral Transpressive Shear System

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*Dave Valentino and Eric Johnson at Falls Brook, southeast flank of Snowy Mountain dome.
Photo by Lyal Harris*

Abstract

The southern Adirondack mountains of New York are underlain by metaigneous and metasedimentary rocks that were deformed in a system of mostly sinistral shear zones (the southern Adirondack shear system) during the late stage of the Ottawan orogeny. At all scales, the shear system is generally east-west striking and contains generally east-west trending (080° to 120°) subhorizontal mineral elongation lineations and variably developed foliation (shallow to steeply dipping). The shear system is identified by the Snowy Mountain dome-Moose River plain shear system in the north, and the Piseco Lake domes and shear zone (PLsz) in the south.

The Snowy Mountain anorthosite body, and related AMCG rocks, occur within a structural dome (Snowy Mt. dome, SMD) approximately 15 km across. The SMD is defined by a concentric mantle of variably foliated noritic-, gabbroic-, and charnockitic-gneisses. Kinematic analysis was performed on rocks around SMD. The northeast and northwest flanks of the dome yielded a dominant shear sense of top westward, while on the southeast and southwest flanks resulted in a top eastward shear sense. The foliation is penetrative in the dome flanks, but is progressively weaker developed toward the interior anorthosite and in the supracrustal rocks that overly the dome. The foliation that wraps around SMD, narrows into the sinistral Moose River Plain shear zone (MRPz) to the west. Opposing shear sense on opposite flanks of the SMD suggests that sinistral ductile flow occurred around the anorthosite.

The Piseco Lake shear zone (PLsz) is a trans-Adirondack east-west structure, up to 20 km wide, defined by the regional fabric including a penetrative lineation, and foliation attitude and intensity that varies across the zone. The trend of lineations within the zone are subparallel to lithologic contacts and also parallel to subhorizontal regional lineation. The zone is developed primarily within highly deformed coarse-grained granitic rocks whose chemistry suggests an arc affinity. New field results indicate that the structure has two domains including a steeply dipping (5-7 km wide) mylonite zone (southern domain) that merges across strike with a broad open foliation arch (Piseco antiform or domes, northern domain). Sinistral kinematic indicators are common in both the steeply dipping mylonite domain and the flanks of the domes. Locally, the trend of the dome axis is asymmetric to the adjacent mylonite zone, and consistent with sinistral shear. The combination of steeply dipping mylonite with transcurrent strain history and adjacent domes suggests overall sinistral transpression. Metamorphic mineral assemblages from hypersthene to chlorite define the Piseco fabrics, indicating structural development over a wide temperature range (high to low) or reactivation at lower temperature conditions. Small (dm-scale) north-striking extensional ductile shear zones occur through out the area, crosscutting the fabrics of the Piseco and Snowy Mountain structures.

The entire southern Adirondack shear system spans from a part of the Adirondacks dominated by AMCG suite rocks to a part dominated by granitoids with probable arc affinity. Based on the magnitude of the structures and the special association with rocks of different Adirondack terranes, this shear system may be a tectonic boundary separating the edge of Laurentia and older ca.1350 Ma tonalities and related arc supracrustal rocks exposed to the south. The location of the proposed suture served as a strike-slip escape structure as part of a Himalayan-type syntaxis in the late stage of the Ottawan orogeny.

Introduction

The Grenville Province forms one of the longest and most deeply exhumed areas of continental crust on Earth. Additionally, the Grenville Province exposes the deep roots of an ancient mountain range of immense portions, and records the assembly of Rodinia, one of the few recognized supercontinents. The Ottawa Orogeny (ca. 1070-1000 Ma) is often cited as a classic example of continent-continent collision and compressive thickening of the crust, with comparison with the Himalayas (Dewey and Burke, 1973; Windley, 1986; McLelland et al. 2001). This is especially true for the Adirondack massif where regional metamorphism ranges up to granulite facies (Figure 1). Oblique motion vectors between regions of the Eurasian and Indian plates has resulted in oblique collision that produced zones of transpressional strike-slip deformation in the hinterland, and belts of thrusting in the foreland (e.g. Tappionier and Molnar, 1976). Tappionier and Molnar (1977) applied a rigid indenter model to the Himalayan orogen, and proposed that zones of transcurrent strain develop syntaxes in regions of the crust

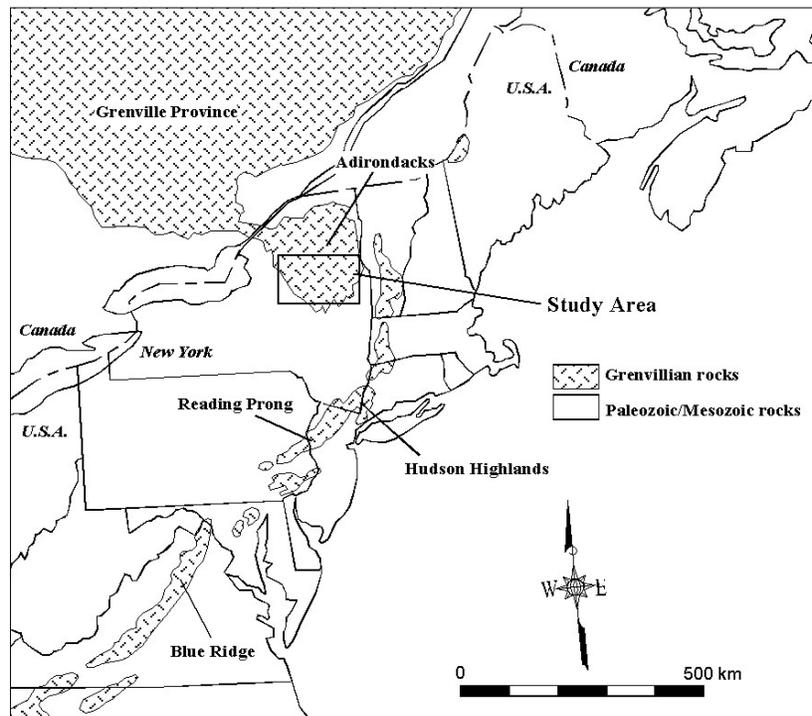


Figure 1. General map of the northeast U.S.A. and eastern Canada showing the distribution of Grenvillian basement rocks, and the study area for this field guide located in the central and southern Adirondack Mountains, New York.

undergoing horizontal escape. These structures have been almost exclusively described for rocks that were exhumed from intermediate to shallow levels of the crust. What would be the appearance of these structures deep in the crust? If a Himalayan-type plate collision is to be fully applied to the Grenville, then the presence of deformation zones other than those that exhibit contractional strain histories should be considered. A Himalayan-type tectonic model, if applied completely, should include the complex array of tectonothermal regimes found in association with the Himalayan orogen such as foreland rift basins and major zones of

transcurrent and transpressional deformation. Within these complex collision zones, the distribution of strain and the location of faults can be controlled by the presence of pre-existing structures, or by the juxtaposition of rock bodies with ductility contrasts such as decoupling of cover rocks over deforming crystalline basement (Gates et al., 1999; Valentino et al., 2004).

This field trip is based on our field and lab research on rocks of the central and southern Adirondacks over the past decade. During this trip we will present evidence that suggests a comprehensive Himalayan-type model that includes aspects of contractional, transpressional and extensional strain histories over a protracted time span.

Sinistral shear recorded in rocks of the Adirondack Highlands

In contrast to the overwhelming northeast trends throughout most of the Grenville Province, the structural grain of the south-central Adirondack Highlands is generally east-west (Figures 1 and 2). This broad zone (>60-km wide) displays general parallelism of geologic contacts, fold axes, compositional layering, foliation, mineral lineations and a series of moderate to steeply dipping mylonite zones. Several large (>20-km across) structural domes cored by rheologically rigid anorthosite lie within the zone.

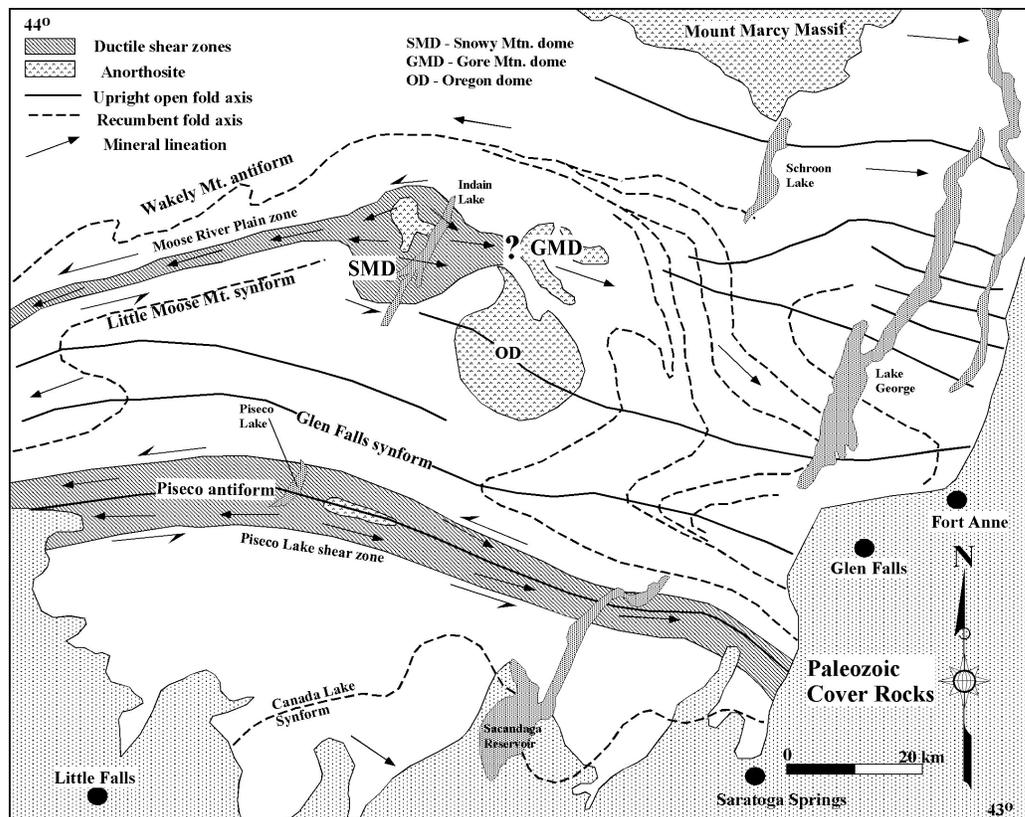


Figure 2. General geologic map of the central and southern Adirondacks showing the locations of major structures discussed in this field guide including the Moose River Plain shear zone, the Snowy Mountain dome (SMD) and the Piseco Lake shear zone.

Kinematic investigations indicate that this zone is dominated by sinistral shear strain (Chiarenzelli et al., 2000; Gates et al., 2004). There are a number of large-scale features, such as drag folds and rotated mega (giga-) clasts, which are consistent with the abundant meso- and micro-scale kinematic indicators. Kinematic indicators include S-C fabrics, shear bands, and rotated porphyroclasts (Gates et al., 2004). This east-west, broad zone is bounded by shear zones that traverse portions of the southern Adirondacks. The structure of the south-central Adirondacks has been interpreted as the consequence of transpressional modification of earlier crustal-scale recumbent folds analogous to those exposed in the Adirondack Lowlands (Chiarenzelli et al., 2000). Widespread granulite-facies mineral assemblages within substantial volumes of supracrustal rocks are consistent with compressional tectonics, and there is metamorphic mineral evidence that some shear zones outlasted high-grade conditions.

Snowy Mountain dome and Moose River Plain shear zone

A zone of high-grade intensely sheared rocks extends east-west through the Moose River Plain of the west-central Adirondacks and was thereby named the Moose River Plain shear zone (MRPSZ; Figures 2 and 3). This shear zone occurs between the Wakely Mountain antiform and Little Moose Mountain synform (Wiener et al., 1984), and it experienced sinistral shearing under granulite-facies conditions. The eastward trace of the MRPSZ intersects and is deflected around the anorthosite-cored Snowy Mountain dome (DeWaard and Romey, 1969). East of the Snowy Mountain dome, the MRPSZ, traces toward the area of Gore Mountain, but the details are not as well documented at this time. This area will be visited the second day of the field conference at Chimney Mountain.

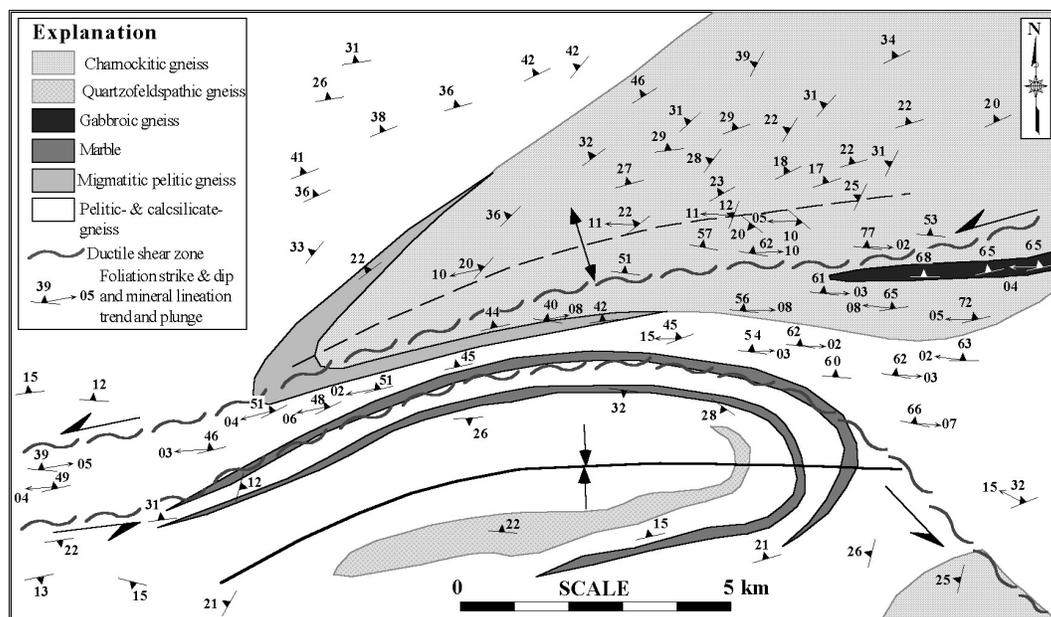


Figure 3. Detailed geologic map of the Moose River Plain shear zone in the area between the Wakely Mt. Antiform and Little Moose Mt. Synform.

Penetrative foliation occurs along a narrow belt (~2 km wide) that defines the MRPSZ. The foliation generally strikes 270° and dips moderately to steeply north. It is defined by metamorphic mineral assemblages characteristic of granulite-facies conditions. Sheared charnockitic gneiss contains the assemblage plagioclase-clinopyroxene-hypersthene, pelitic gneiss contains biotite-K-feldspar-sillimanite-garnet, and gabbroic-gneiss contains augite-hypersthene-garnet-plagioclase. Within granitic and charnockitic gneisses, foliation is defined by planar aggregates of recrystallized feldspars and quartz. Foliation in pelitic gneiss is defined by recrystallized quartz and K-feldspar and parallel alignment of biotite and sillimanite. Mineral-elongation lineations are defined by linear aggregates of feldspar, pyroxene and garnet in charnokitic gneiss, and biotite and sillimanite in pelitic gneiss. The foliation and lineation in the gabbroic gneiss is mostly defined by alternating planar aggregates of plagioclase and pyroxenes. The eastern limit of the MRPSZ is structurally continuous with the penetrative foliation that mantles the Snowy Mountain dome (DeWaard and Romey, 1969) (Figure 4).

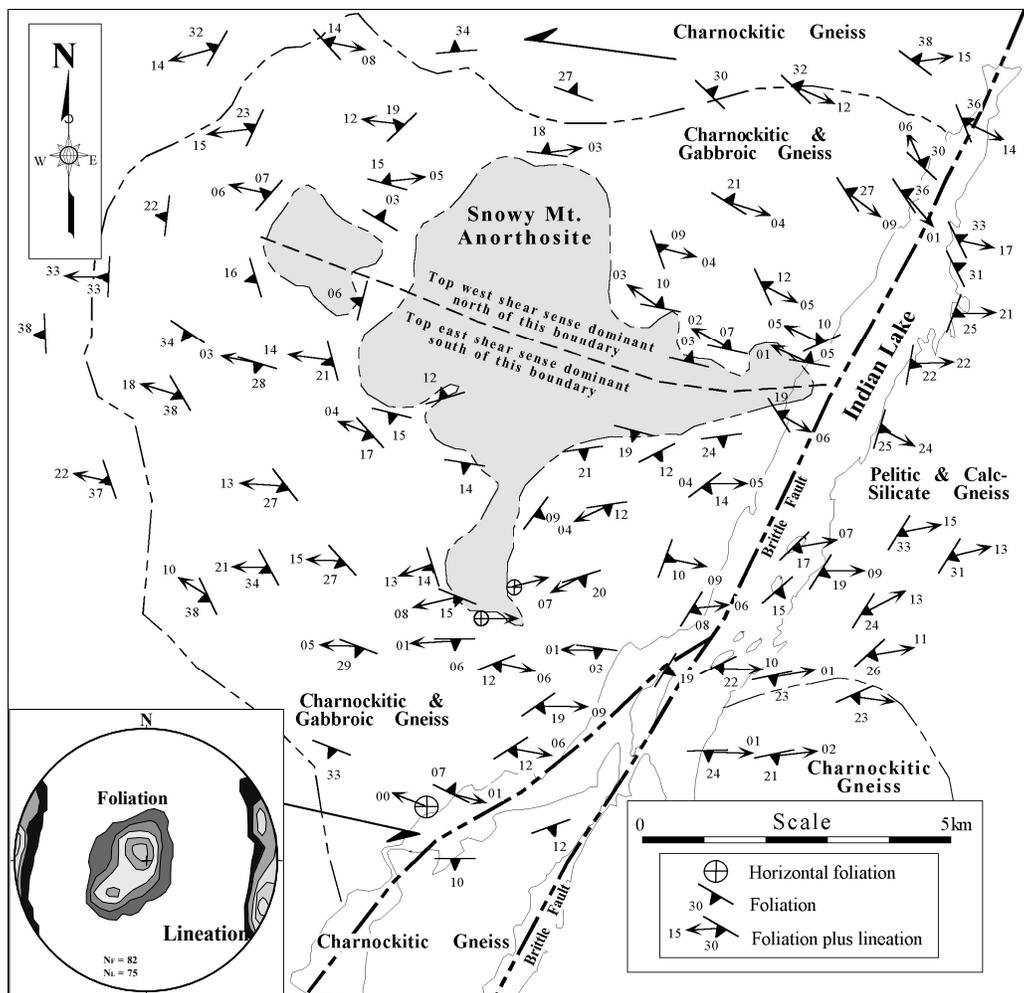


Figure 4. Structure map of the Snowy Mountain dome, central Adirondack Mountains. Geologic contacts are modified from DeWaard and Romey (1969). The inset is a stereogram for poles to foliation and lineation for the eastern half of the dome.

The zone of deformed rocks in the Moose River Plain region was interpreted as the result of shearing between the lower and upper limb of the Wakely Mountain antiform and Little Moose Mountain synform (Wiener et al., 1984). Consistent subhorizontal mineral lineations throughout the Moose River Plain shear zone are indicative of a subhorizontal transport direction and inconsistent with earlier kinematic models based solely on map-pattern folds. Kinematic indicators throughout the shear zone are consistent with left-lateral shear. Kinematic indicators include σ - and δ -type porphyroclasts (Simpson and Schmid, 1986; Passchier and Simpson, 1986) in pelitic and granitic gneiss, Type-I S-C fabrics (Lister and Snoke, 1984) in charnockitic gneiss, asymmetric foliation boudins often associated with local migmatite, and fish-structures comprised of broken garnet crystals, and small high-strain zones (Figure 5A). Locally the foliation is deflected at the margins of the MRPSZ consistent with map-scale left-lateral drag folds (Figure 3).

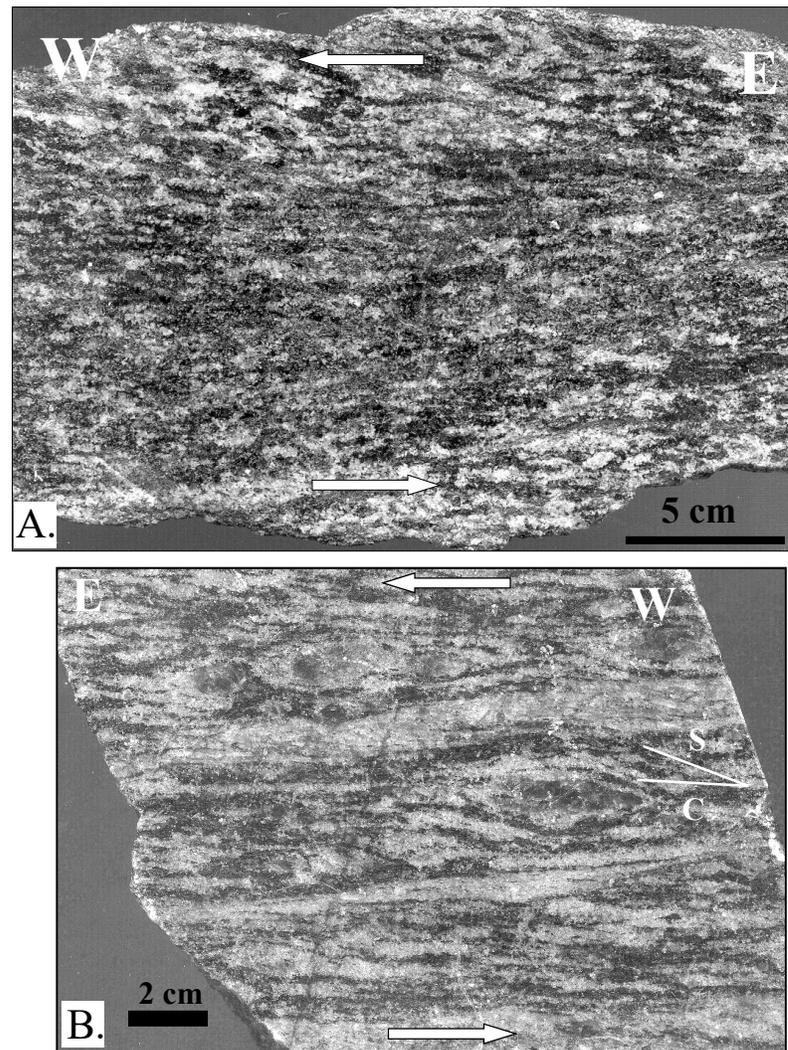


Figure 5. Examples of kinematic indicators from the Moose River Plain shear zone and the high strain fabrics that define the Snowy Mountain dome. A] Small high-strain zone from the MRPSZ showing sinistral shear; B] S-C fabric in gabbroic gneiss from the northeastern flank of the SMD.

Large (15-20-km across) structural domes cored by anorthosite in the Adirondack Highlands are interpreted to have resulted from fold interference (McLelland and Isachsen, 1986) (Figures 2). The Snowy Mountain dome (Figures 5 and 6), is underlain by AMCG suite rocks with anorthosite in the core (DeWaard and Romey, 1969). The eastern extent of the MRPSZ foliation is structurally continuous with penetrative deformation fabrics that wrap around and define the Snowy Mountain dome. The core of the dome is underlain by megacrystic anorthosite with crystals commonly up to 20 cm. Anorthosite is mantled by gabbroic- and then charnockitic- gneiss forming a semi-concentric compositional zonation (DeWaard and Romey, 1969). Although the central anorthosite is generally not deformed, the margins of the body contain dynamically recrystallized plagioclase that define well-developed foliation and lineation. As first described by DeWaard and Romey (1969), the transition from anorthosite to gabbroic gneiss is marked by more intensely developed deformation fabrics away from the dome core. Farther outward on the dome flanks, the foliation is penetrative in the charnockitic gneiss. The presence of relict plagioclase megacrysts in the charnockitic gneiss suggests a plutonic origin. Most of the unit consists of planar and linear aggregates of recrystallized plagioclase and anhedral, broken grains of clinopyroxene and hypersthene. Poles to foliation reveal that the dome has a dominant northwest-southeast-trending axis (Figure 4). The attitude of lineations vary about 30° around a general east-west trend that is roughly parallel to lineations in the MRPSZ.

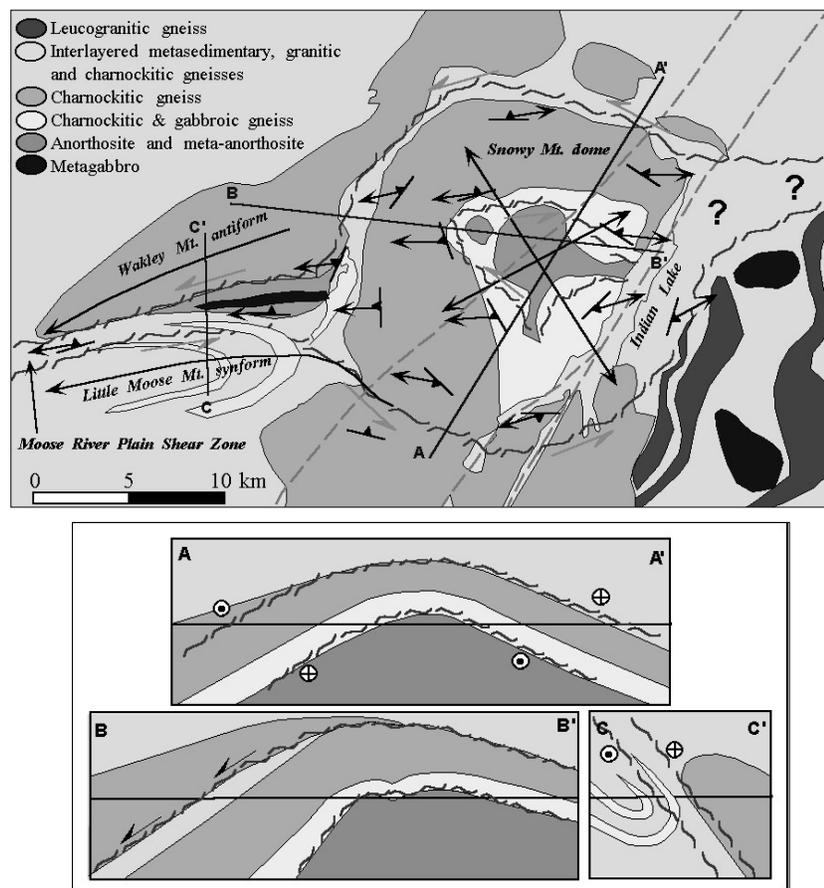


Figure 6. Schematic geologic map of the Snowy Mountain dome and the intersection with the Moose River Plain shear zone. The structure sections (A-A'; B-B'; C-C') are the same scale as the map and have no vertical exaggeration.

Shear-sense indicators observed at the Snowy Mountain dome including σ - and δ -porphyroclasts (Passchier and Simpson, 1986), and type-I S-C fabrics (Lister and Snoke, 1984). Shear-sense indicators from the southern flank of the dome reveal top-to-the-east bulk shear, whereas the northwestern flank reveals top-to-the-west shear (Figure 5B). On the northwest side of the dome, where foliation dips moderately westward (Figure 4), the shear sense is locally dip-slip normal. On this basis, the dome can be divided into two domains as shown on Figure 6.

The axial obliquity of the dome with respect to the general east-west shear along the MRPSZ is consistent with development of the dome by sinistral transpression, and possibly large scale sinistral rotation. The dome does not appear to be a secondary fold defined by folded foliation as suggested in kinematic models for the Adirondacks (Weiner et al., 1984). In contrast, it appears to be a dome-shaped distribution of foliation developed in the less resistant rocks that mantle the more resistant anorthosite that cores the dome. The asymmetry of the dome axis relative to the general shear direction may reflect modification of the original dome geometry in the left-lateral shear couple. It is possible that the Snowy Mountain anorthosite and related rock suite, are part of an asymmetric giga-clast within a sinistral shear zone (Figure 6).

The Piseco Lake shear zone

In the southern Adirondacks, there is a zone (10-20 km wide) of spectacular L-S and L>S tectonite with a general east-west map pattern (Figure 2). This deformation zone was designated by Gates et al. (2004) the Piseco Lake shear zone (PLSZ) based upon its inclusion of the Piseco dome and antiform of earlier workers (Cannon, 1937; Glennie, 1973; McLelland, 1984; Wiener et al., 1984), but also upon the extent of penetrative fabrics general shear fabrics found well beyond the core of the antiform. Throughout the PLSZ, rocks of mostly granitic composition contain intense foliation and lineation, as described by Cannon (1937) and McLelland (1984). Geochemical analysis of the Piseco zone rocks reveals a calc-alkaline trend for the granitic rocks (Chiarenzelli and Valentino, 2008). Penetrative foliation and lineation are defined by dynamically recrystallized quartz (ribbons), K-feldspar and plagioclase, and alignment of muscovite, biotite and locally chlorite. Rocks within the zone consist dominantly of fine-grained aggregates of these minerals. Locally there are 2- to 6-cm-wide K-feldspar porphyroclasts supporting a plutonic origin for these rocks.

Foliation within the PLSZ defines an upright antiform (Cannon, 1937; Glennie, 1973; Weiner et al., 1984) with a subhorizontal axis that trends approximately 110° in the east, 090° in the central part, and 080° in the west. Foliation on the antiform limbs dips moderately to steeply both north and south. Lineations are penetrative in these rocks and are defined by dynamically recrystallized ribbons and rods of quartz, K-feldspar, plagioclase and streaks of chlorite, biotite, magnetite and muscovite. The plunges of the lineations are consistently shallow to subhorizontal. Overall the fabric in the antiform limb regions can be classified as L-S with the lineation and foliation both well developed. In the antiform crest, foliation is not well developed and penetrative lineations are defined by mineral rods, rods of mineral aggregates, and mineral ribbons. Lineations in the core area of the antiform are intensely developed, and in many places the linear fabric is dominant over the weak planar fabric (L>>S; Figure 7) with grain-shape aspect ratios upward of 60:1 (in the L-parallel and S-perpendicular plane).

Metamorphic index minerals are not diverse in these rocks due to the overall granitic composition. The penetrative foliation and lineation is associated with diagnostic metamorphic minerals such as biotite, chlorite and muscovite, which are indicative of lower-amphibolite to upper-greenschist facies conditions (Figure 8). Locally, anhedral grains of augite and hypersthene have overgrowths of hornblende, biotite or chlorite (Figure 9). The presence of hypersthene suggests these rocks experienced granulite facies metamorphism (McLelland, 1984), but the main fabric developed later during intense dynamic retrogression (Chiarenzelli et al., 2000).

Price et al. (2003) conducted a micro-structural study of the orientation of the chlorite and biotite grains in the L-S and L tectonites from the Piseco zone to see if the orientations are concordant or discordant with the mesoscopic rock fabrics. The inset of Figure 8 shows a domain of chlorite grains aligned parallel to a ribbon-shaped quartz aggregate. Superficially, they are parallel suggesting a genetic tie. Figure 9 shows one example from Price's orientation study of mica grains in an L>S tectonite from the area of West Canada Creek. In all three stereograms, the long axes of the mica grains are plotted relative to the macroscopic lineation in the sample. The magnitude of each plot represents the percentage of grains in specific directions. These orientations were obtained using mutually perpendicular thin sections with a Nikon universal-stage. Overall it was demonstrated that the micas have a preferred grain shape alignment with the elongate aggregates of quartz and feldspar in both the L-S and L-tectonite domains at the microscopic and macroscopic scale.

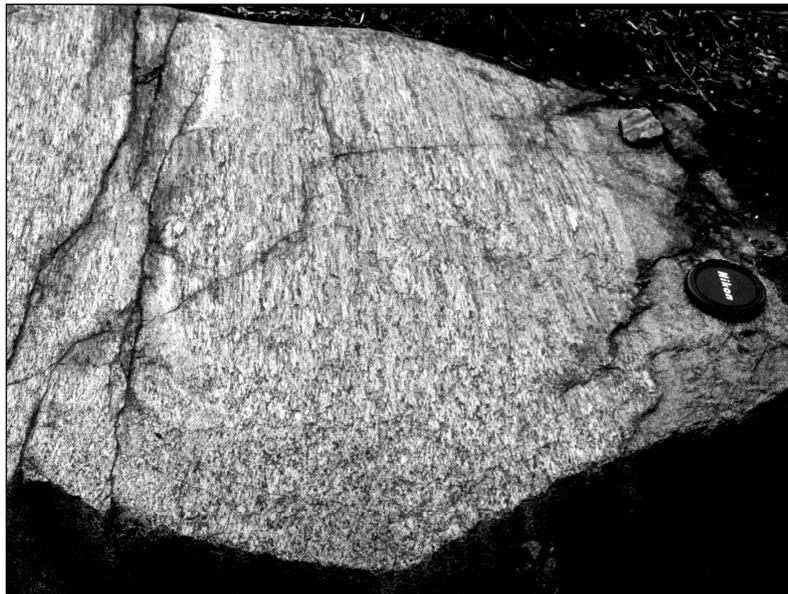


Figure 7. Outcrop of L-tectonite from the Piseco Lake shear zone. The view is looking west at an outcrop face that is subvertical in the foreground and subhorizontal in the background, revealing the ends and sides of mineral lineations respectively.

McLelland (1984) suggested that the Piseco dome developed in the constrictional part of a regional west-directed thrust, but little kinematic data was presented. Shear-sense indicators are abundant in the PLSZ, and include Type I S-C fabrics (Lister and Snoke, 1984), σ - and δ -porphyroclasts of K-feldspar (Simpson and Schmid, 1983; Passchier and Simpson, 1986), asymmetric polymineralic tails around porphyroclasts, and biotite- and muscovite-fish (Figure 11). These kinematic indicators reveal a consistent sinistral-shear sense on both the north- and south-dipping domains of the zone.

Figure 11 shows the textural transition across a southern segment of the Piseco zone, from generally moderately deformed megacrystic granite to well developed mylonite and finally domains of ultramylonite (12D).

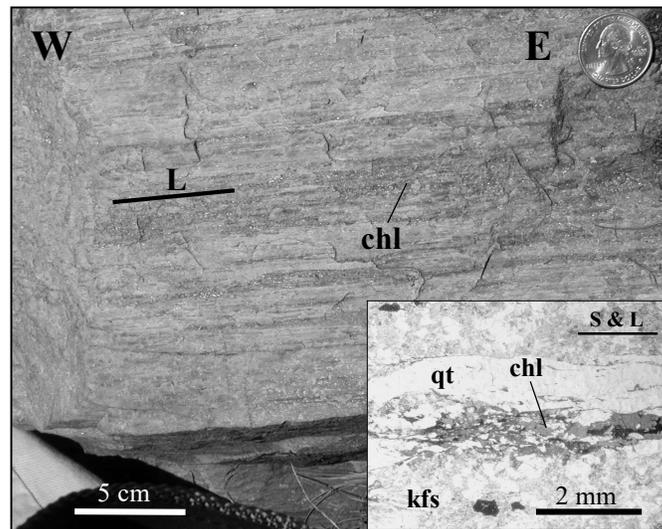


Figure 8. Outcrop of L-S fabrics in the PLSZ along Route 8 in the vicinity of Piseco Lake. The darker layers are linear aggregates of chlorite. The inset photomicrograph shows acicular chlorite (blades in three dimensions) oriented sub-parallel to the quartz ribbon.

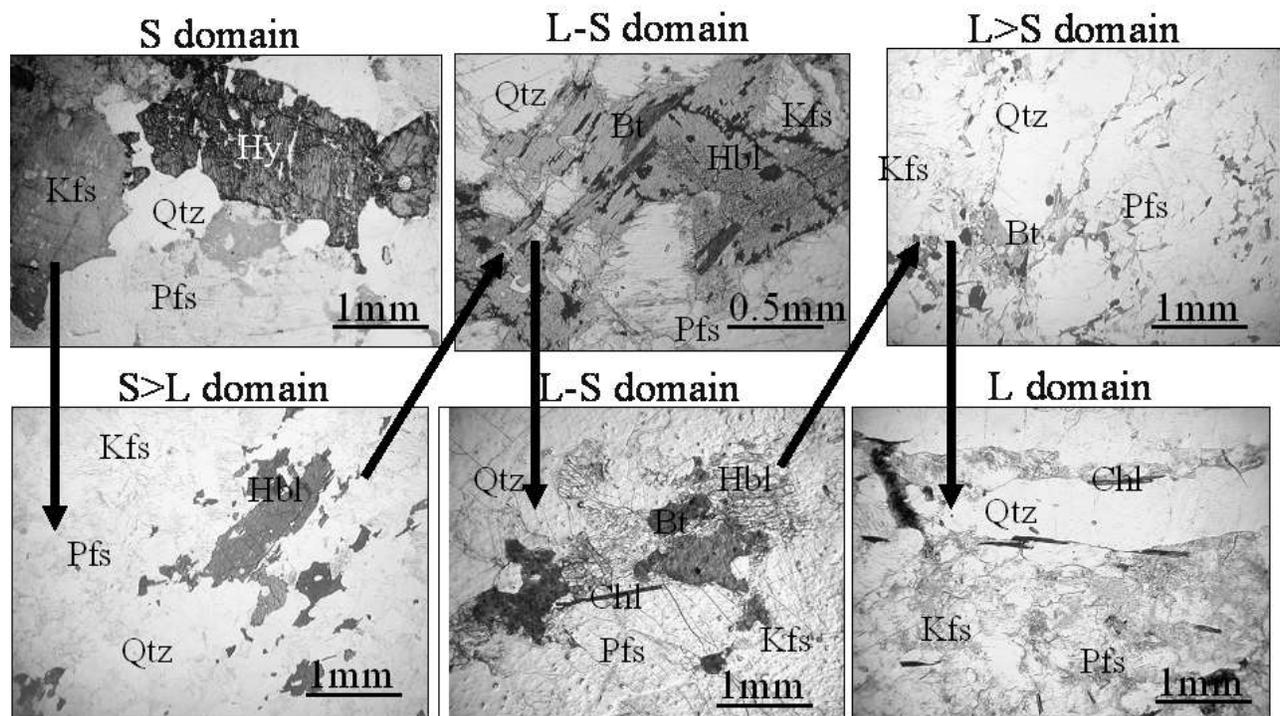


Figure 9. Photomicrographs that span various L & S fabric domains on the northern flank of the Piseco antiform. To the north and outside the L-S fabrics of the Piseco structure, the granitic rocks contain hypersthene. Rocks from the L-S, L>S and L domains show clear signs of retrograde overprint with the presence of hornblende (Hbl), biotite (Bt), and chlorite (Chl).

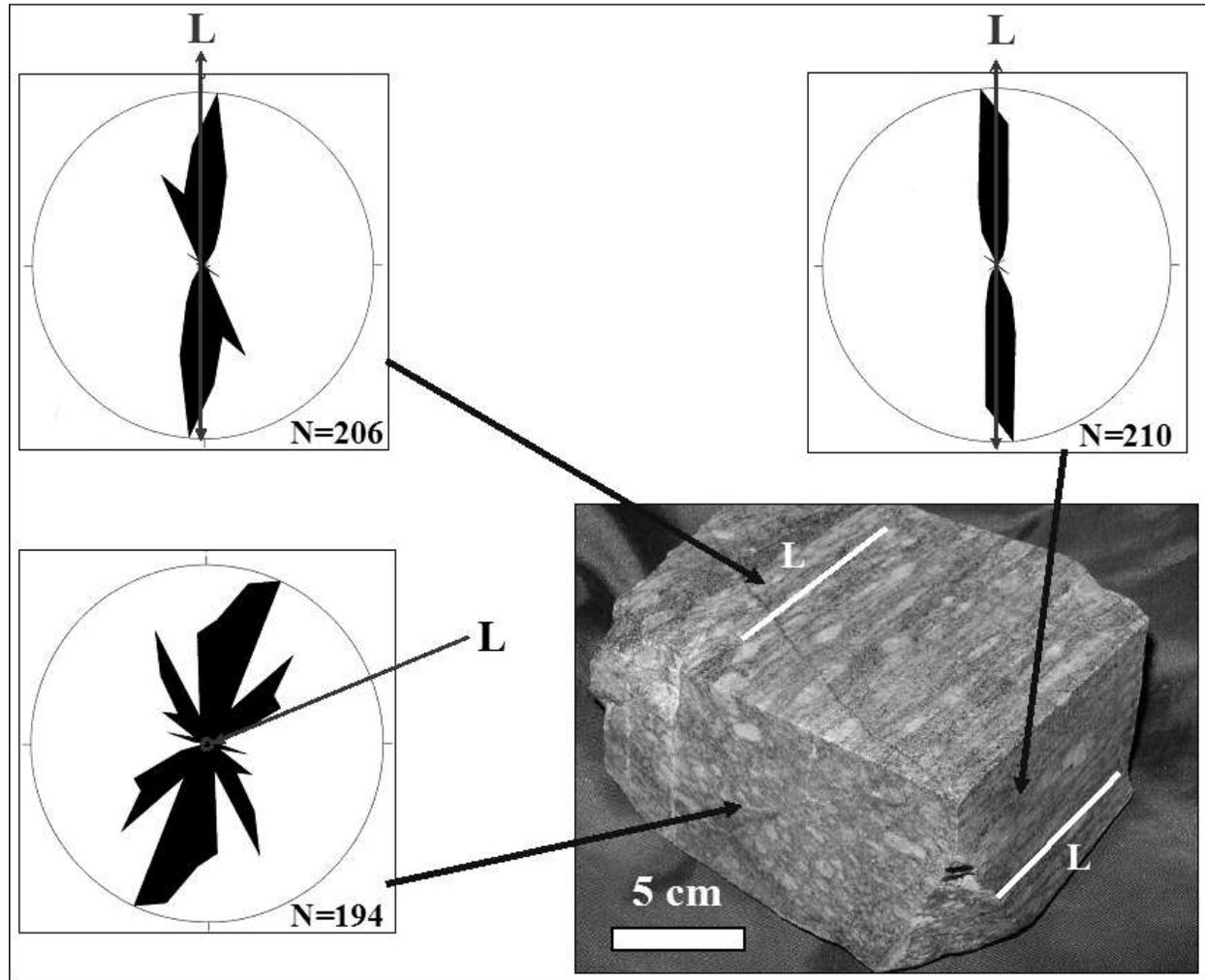


Figure 10. Photograph of a sample of L>S tectonite from the West Canada Creek area within the Piseco Lake shear zone. The three rose diagrams show the statistical orientation of the long-axes of chlorite and biotite grains relative to the macroscopic mineral elongation lineation (L) for three mutually perpendicular sections (modified from Price, 2003).

Variation in the L and S tectonite

There are two structural domains that make up the Piseco Lake shear zone: the northern domain that consists of strongly lineated, foliation domes (Piseco antiform of earlier researchers), and the southern domain that consists of moderately to steeply dipping mylonite defined by penetrative foliation and lineation. There is no apparent break in the foliation of the southern mylonite zone and the foliation in the dome region, and lineations are consistent in orientation and trend. Collectively, these structural domains make up a zone of ductile deformation that is more than 25 kilometers wide, and appears to cross the exposed limit of the southern Adirondacks. Due to the size of this structure, it has been a daunting task to produce detailed geologic maps, however, specific regions were targeted to characterize the variations in the L and S tectonite. As well, detailed field mapping projects were completed in regions of the Piseco zone through the SUNY Oswego Geology Field Program.

Cannon (1937) produced a detailed structure map in the Piseco Lake region that includes both the northern dome and the southern mylonite zone. Figure 12 shows two of Cannon's north-south cross sections through the Piseco antiform near Piseco Lake. It is interesting that that the Cannon defined the antiform by an arch-shaped configuration in the foliation, but based on his map, the pronounced lineation passes through the antiform unhindered by any apparent folding. From the more recent mapping project and consistent with Cannon's work, the foliation within the antiform is not homogeneously developed. In fact, the core of the antiform lacks any macroscopic foliation at many localities, and we argue that Cannon's cross sections are a bit misleading in that regard.

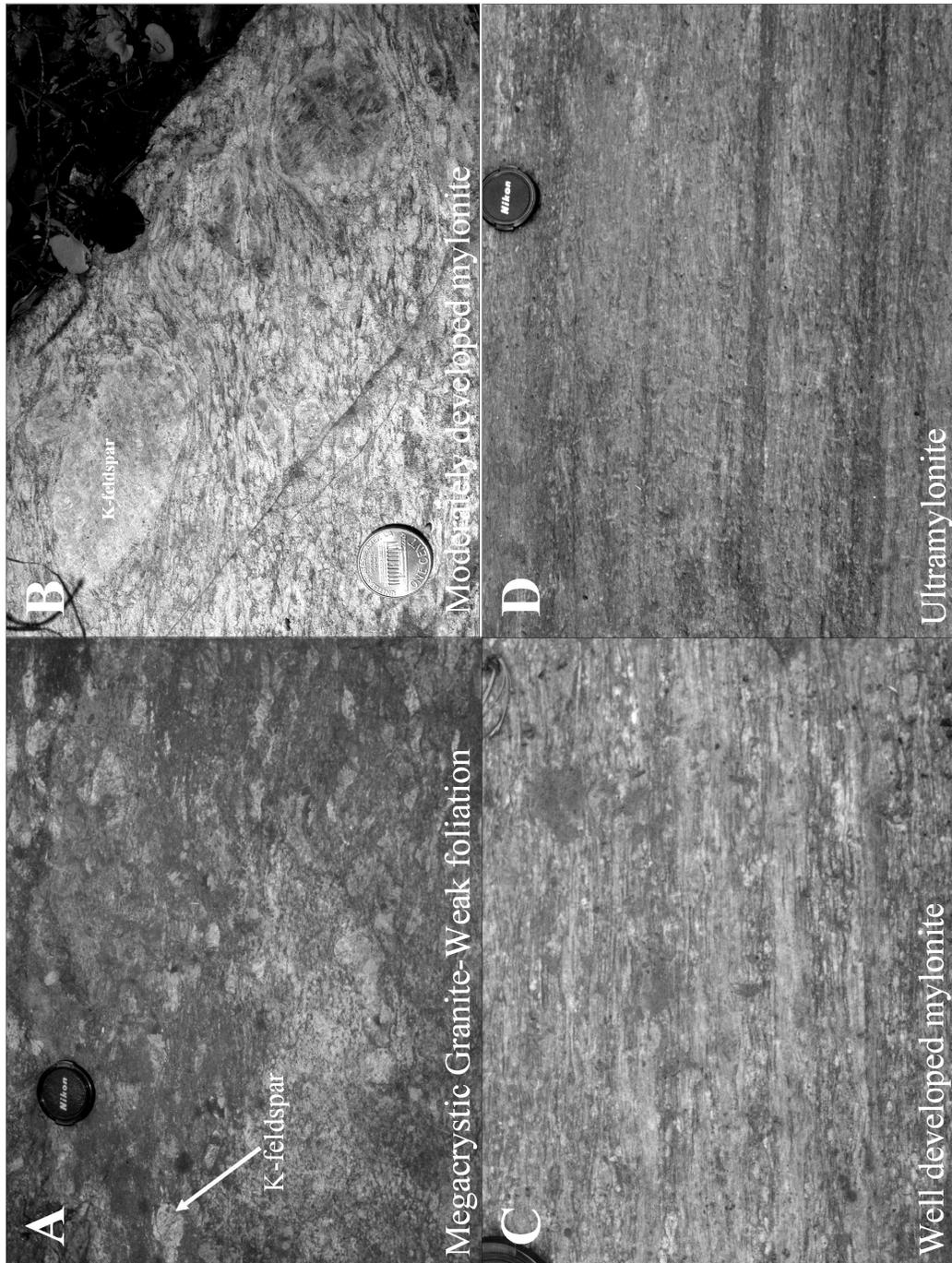


Figure 11. Collection of outcrop photographs across the southern region of the Piseco Lake shear zone in general granitic gneisses (A to D). The view for all of these photographs is into the ground with the foliation and lineation aligned left-right. Figure 13B shows large K-feldspar porphyroclasts with sinistral shear sense.

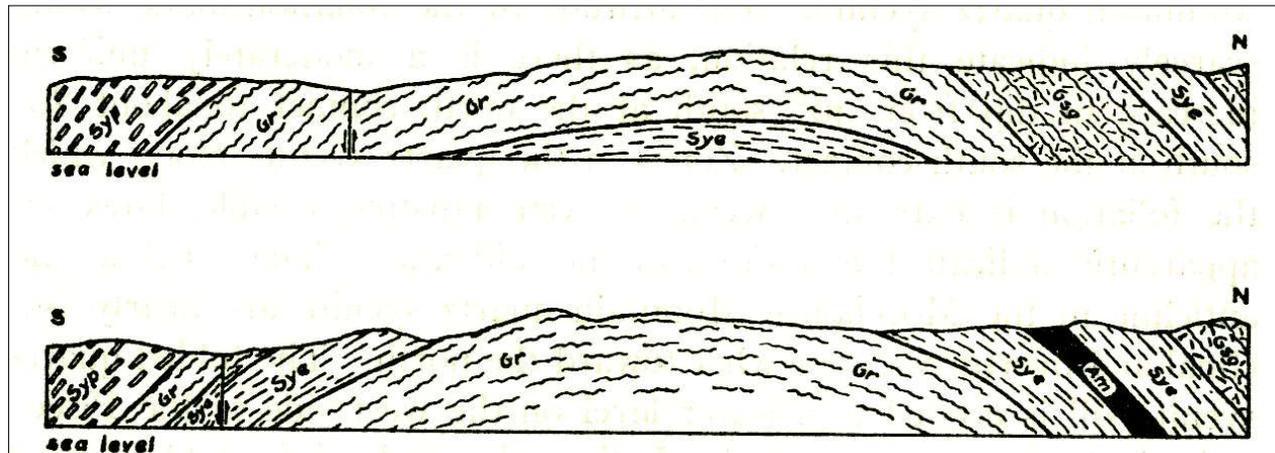


Figure 12. Cross-sections through the Piseco dome near Piseco Lake (Cannon, 1937).

A structure map was compiled based on our recent field studies integrated with the earlier work of Cannon (1937) (Figure 12). As mentioned before, most of the Piseco Lake zone resides within granitic rocks. This makes mapping the zone a bit monotonous, but provides an opportunity to discriminate rock fabrics independent of lithologic variation. In general, most of the rocks of the Piseco Lake zone would be considered L-S tectonities with the foliation and lineation well developed as in those shown in Figure 11. In the Piseco Lake area, lineations have a consistent trend of about 095° , regardless of the dip of the foliation. Isolated domains, on the scale of outcrops to kilometers, contain rocks with a dominant lineation and very weak to non-existent foliation. These rocks would be considered the L>>S category, or in some cases just L-tectonites.

The structure map of Figure 13 does not include lithologic variation because most of the area is granitic gneiss. However, structural patterns defined by the trace of foliation and lineation are represented. Most of the compiled region contains rocks with both foliation and lineation observable in hand sample, but there are map-scale domains of rocks that are dominated by lineations. The L-S domains are divided based on the steepness of the foliation dip: steeply dipping L-S mylonite (dip greater than 70°), and moderately dipping L-S mylonite. Again, the lineations throughout this region have a very consistent subhorizontal trend of about 095° independent of the attitude of the foliation. Form lines for the strike of foliation clearly delineate the geometry of the Piseco dome. The axis of the dome trends about 120° , plunges less than 5° in the area immediately west of Piseco Lake, and the axial trace is displaced by apparent Cenozoic faulting. In the northwestern part of the dome, the trace of the dome axis is more westerly. Finally, there are two domains of L-tectonite that occur near the axis of the dome. The northern flank of the dome merges with the regional shallowly dipping foliation, but the southern flank merges into a

domain of moderately to steeply dipping L-S mylonite that continues across strike for approximately 10 kilometers (Figure 14).

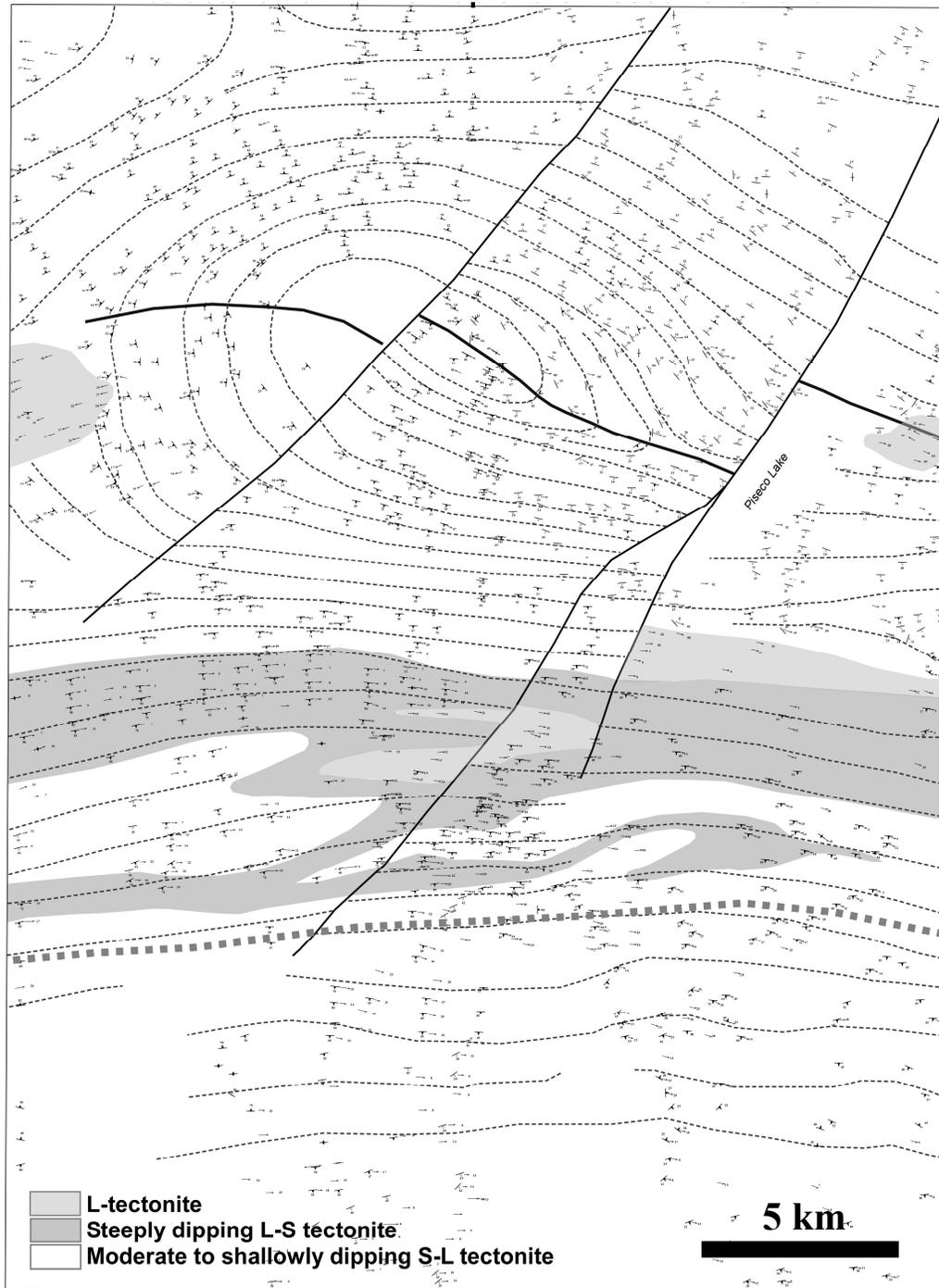


Figure 13. Structure map that crosses the Piseco Lake shear zone (type-locality of Piseco Lake) compiled from recent mapping and data from Cannon (1937). Lithologic variation is not represented on this map. The dark gray regions represents rocks dominated by L-S mylonite with a dip greater than 70° . The pale gray region represents rocks dominated by L-tectonite, and the non-shaded regions of the map represent rocks with variable L-S fabrics and shallow to moderate dip. Structure form lines are represented by the dashed lines.

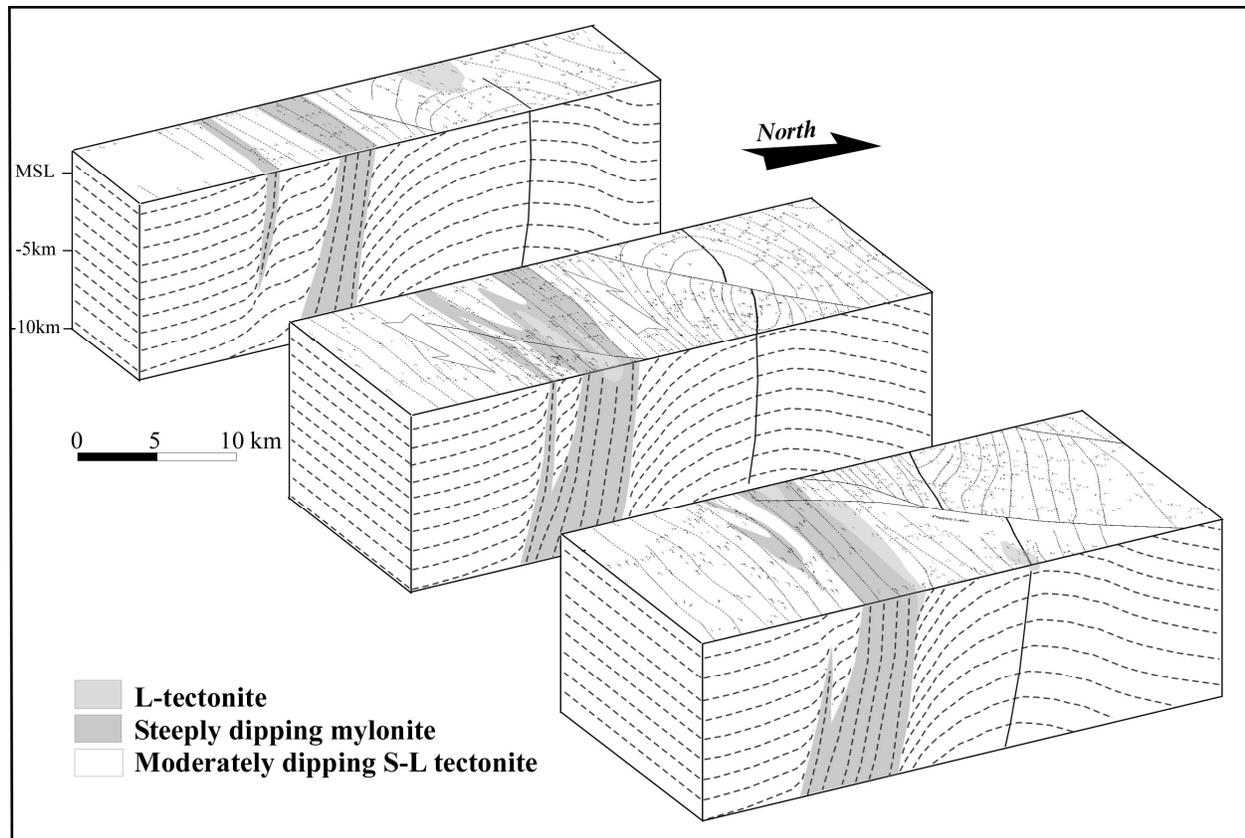


Figure 14. Structural block models for the area of Figure 14. These models include the Piseco dome in the area of Piseco Lake and the broad zone of mylonite that occurs on the southern flank of the dome.

Fabric variation in the West Canada creek basin region

In 2004, Damian Piaschyk (who was an undergraduate geology major at SUNY Oswego at that time) completed detailed mapping of 42 square kilometers area that crosses the northern boundary of the zone in the West Canada Creek basin (Figure 16), and his work was originally presented at the 2005 NYSGA field conference (Piaschyk et al., 2005). The objective of that study was to document the detailed rock fabric variation within the shear zone, the transition zone and the wall rocks to the shear zone. As well, Piaschyk's 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). Because of the high-level of detail, Piaschyk's comprehensive field work is again included as part of this field guide for the Friends of the Grenville.

Five domains of varying fabric intensities were documented ($L \gg S$, $L > S$, $L-S$, $S > L$, and S) within the Piseco Lake zone and the shear zone transition region with the wall rocks (Figure 13). 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



Figure 15. Bedrock geologic map of the West Canada Creek basin in the southwestern Adirondacks. The map area crosses the northern boundary 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.

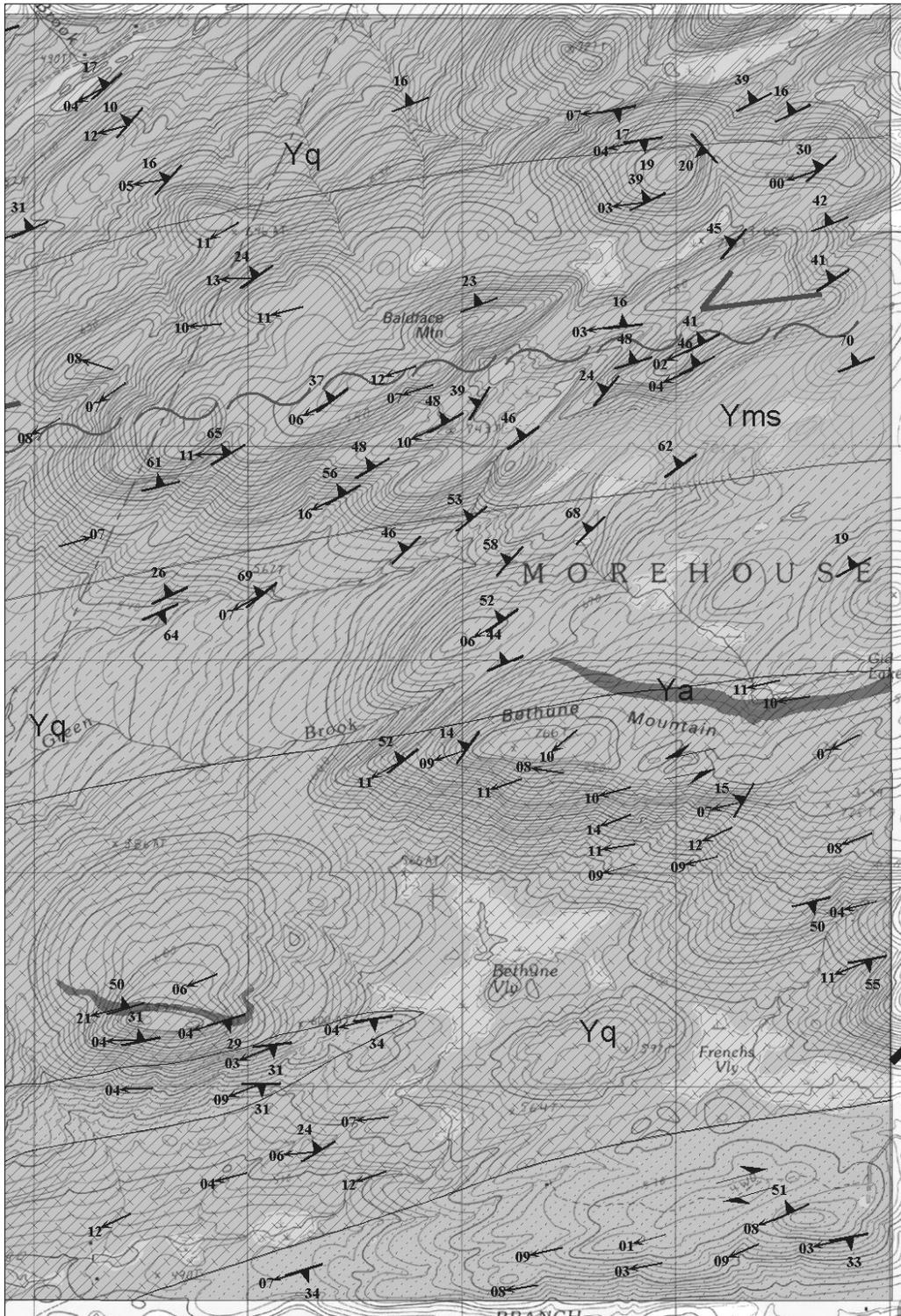


Figure 15 (continued). Eastern extent of the geologic map of the West Canada Creek basin. See the next page for the map explanation.

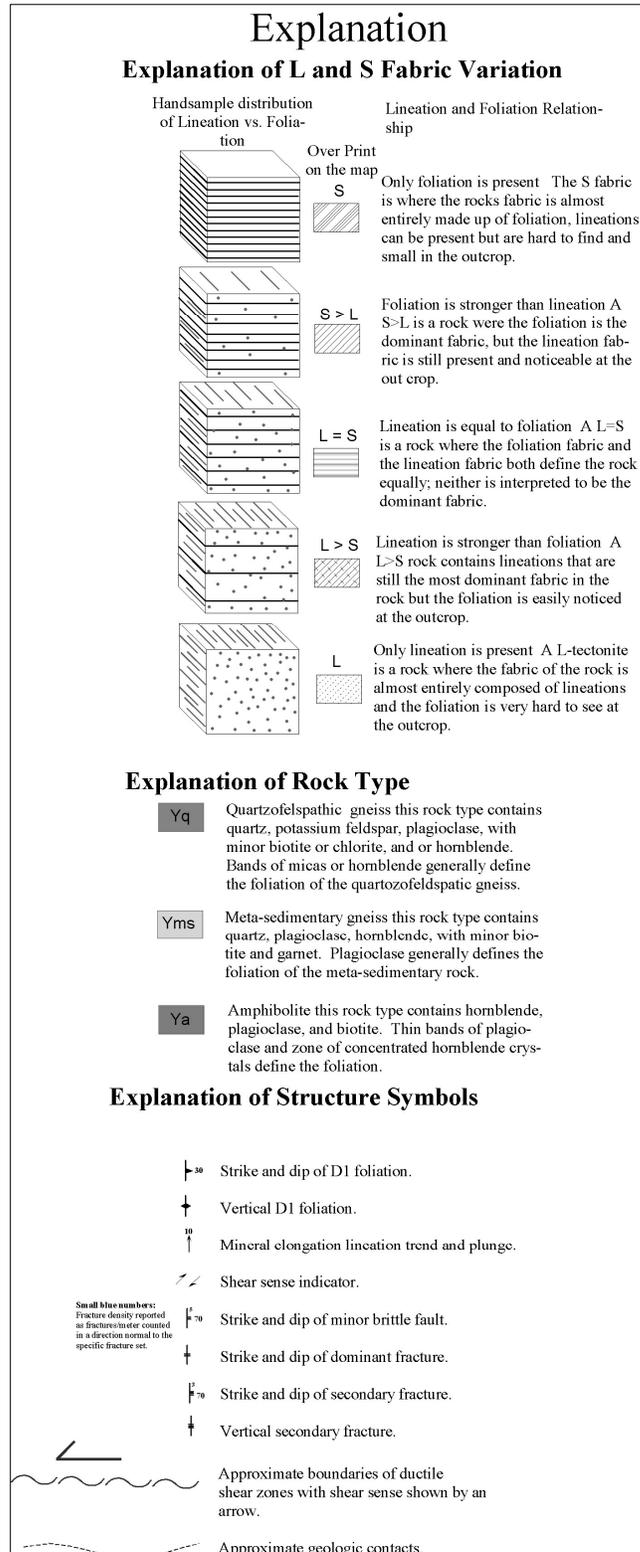


Figure 15 (continued). Map explanation for the West Canada Creek basin. Three gray shades were used to represent general rock types and the shades are overlain with patterns to represent the five categories of rock fabric.

zone the fabric variation occurs systematically from L-S dominated, to L>S and finally L>>S tectonite. 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 dominant 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 (Figure 9). The granitic gneiss contains a dominant gneissosity that strikes generally east-west with very weak mineral lineations. Quartz and feldspars form coarse crystalline aggregates that define the gneissosity. 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 megacrysts. 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. These rock textures and index minerals suggest two conclusions: the Piseco Lake zone developed in coarse grained granite that is not found in the wall rocks, and 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 in the West Canada Creek region was divided based on the fabric categories that define the five fabric domains, as shown on the map of Figure 16. These data were used to generate lower hemisphere contour diagrams for the poles to foliation and lineation. Poles to lineations plotted at or near the margin 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 16) 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 16. Nearly 90% bedrock exposure afforded the opportunity to study the fabric variation in great detail in the northern domain of the Piseco Lake 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 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.

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, asymmetrically broken K-feldspar grains, σ - and δ -porphyroclasts (Lister and Snoke, 1984; Simpson and Schmid, 1983, Passchier and Simpson, 1986).

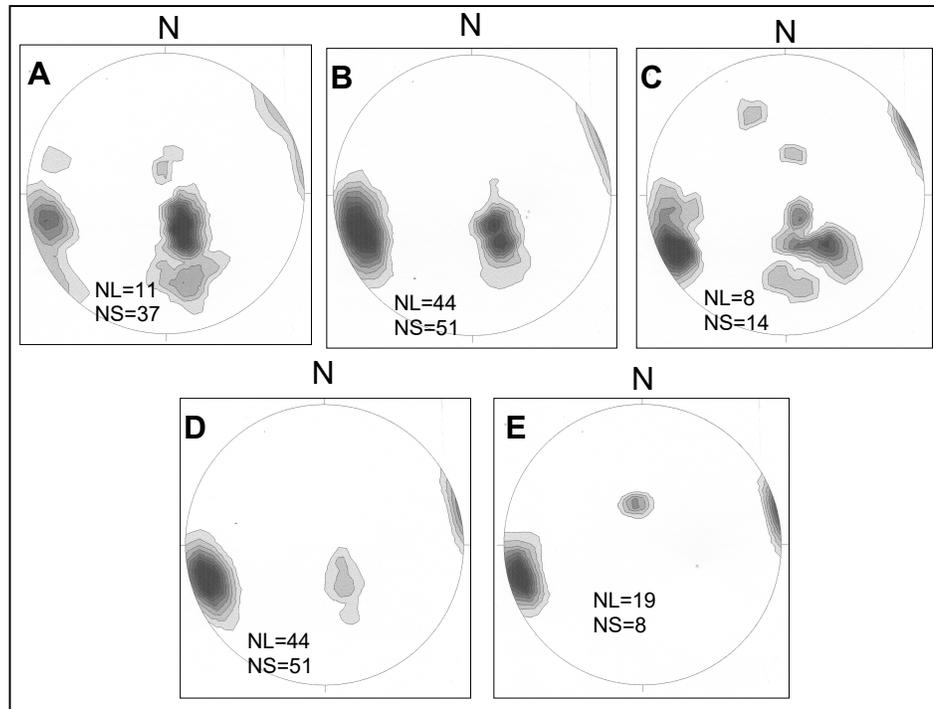


Figure 16. Lower hemisphere contour stereograms for the L-S domains represented on the geology map of Figure 2. For each diagram above (A-E), the poles to lineations plot near the perimeter of the diagrams and the poles to foliation form the interior domains. Note the increase in the intensity of the cluster of linear data with the decrease in the occurrence of the foliation data.

Cross-cutting normal shear zones

There are a number of ductile shear zones with normal shear sense that crosscut the dominant deformation fabrics of the Piseco Lake zone. Most of these shear zones are small (<30 cm thick), contain granitic pegmatite, and some 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 17 shows a stereographic plot of the orientation of these ductile normal shear zones (Figure 18) and other pegmatite dikes in the Ohio gorge. Both inside the ductile normal zones and within undeformed pegmatite dikes, they are composed of coarse 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.

Geologic mapping in the area of Speculator Mountain (excellent profile view of the mountain from Stop 5C) revealed a cross cutting ductile normal shear zone with west directed displacement (Freyer et al., 2004). The area of Speculator Mountain is underlain by a sequence of granitic-, charnockitic- and gabbroic-gneisses that contain penetrative foliation and ribbon mineral lineations. The foliation texture varies from protomylonite to mylonite in a nearly vertical stack of rocks. Near the base of the mountain, protomylonite occurs in megacrystic granitic-gneiss. Moving structurally upward, the granitic-gneiss contains penetrative mylonitic foliation and lineation. Dynamically recrystallized quartz and K-feldspar, as well as core-mantle structure in K-feldspar are evidence for ductile strain. The mylonitic foliation dips gently to moderately (20-30 degrees) westward, but in some places the foliation is locally folded about a N-S axis. Mineral lineations associated with the mylonitic foliation are defined by ribbon-shaped aggregates of recrystallized quartz, and feldspars. Biotite forms mineral streaks that parallel the ribbon lineations. The lineations trend approximately due west.

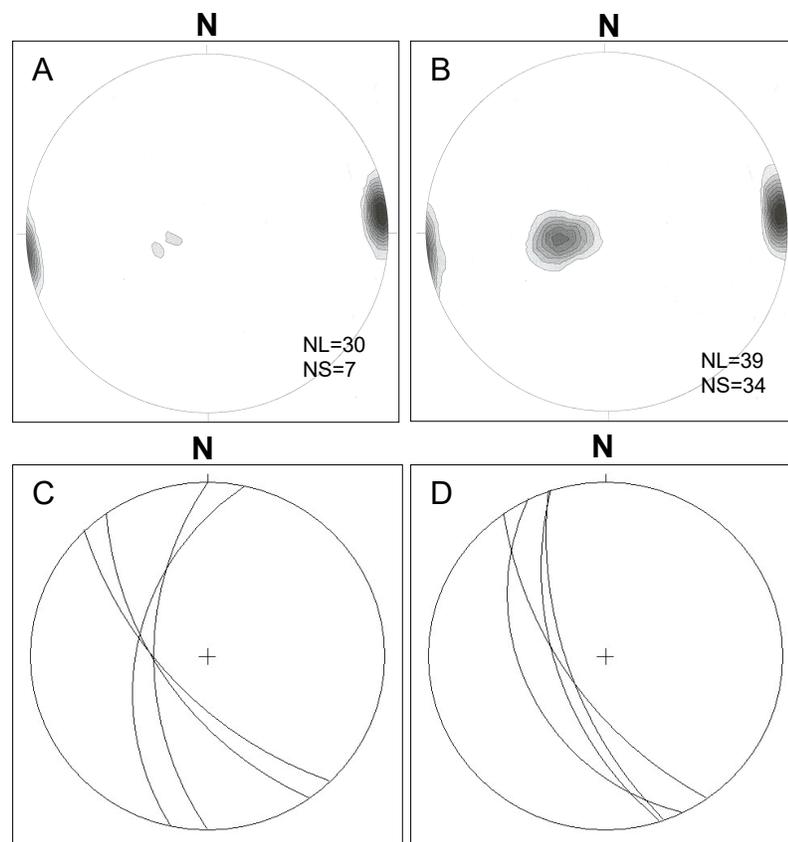


Figure 17. Lower hemisphere stereograms for structures observed in the Ohio gorge. Contour diagrams for the poles to lineation and foliation from L>S domain (A) and L-S domain (B) parts of the gorge; Great circle plots for ductile normal shear zones (C) and pegmatite dikes in exposed in the gorge (D) that are not deformed.

Kinematic analysis of granitic mylonite revealed abundant shear sense indicators such as Type I S-C fabrics, δ - and σ -porphyroclasts, asymmetric tails around porphyroclasts, and shear bands. The shear sense indicators show that the direction of displacement was top toward the west, with the charnockitic-gneiss at the top of Speculator Mountain displaced over the megacrystic granitic-gneiss

at the base. The presence of a large ductile normal shear zone was not previously documented in this area, but is consistent with displacement and relative timing of the small normal shear zones observed in the West Canada Creek area.

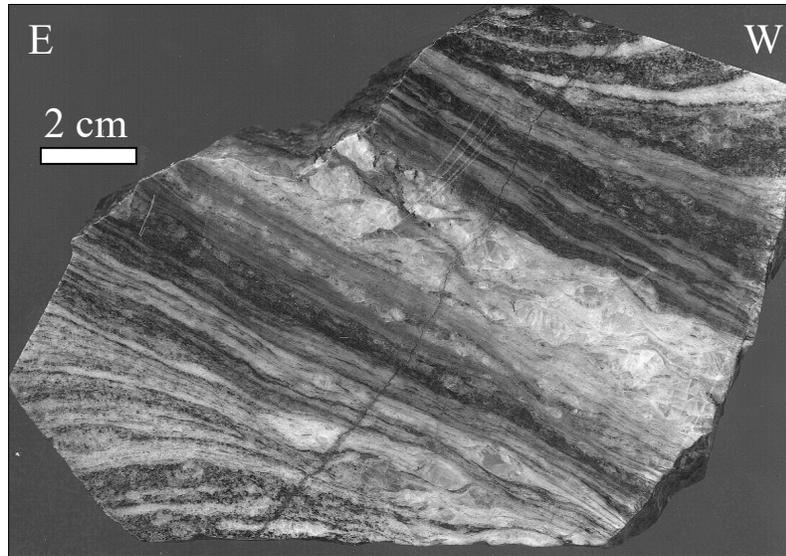


Figure 18. Polished rock slab of a small ductile shear zone that cross cuts the PLSZ fabric in the area of West Canada Creek. The view is looking south at a near vertical surface, and the shear sense is top down to the west. These small normal shear zones commonly contain parallel granitic pegmatite that is also plastically deformed.

The geochemistry and geochronology of Piseco core rocks

The Piseco core rocks, consisting primarily of strongly deformed and lineated granitic (McLelland, 1984) and charnockitic gneisses, previously described, were once thought to be part of a possible basement complex to the Grenville supracrustal sequence in the Adirondacks Highlands. However, zircons separated from a lineated granitic rock at the intersection of Routes 8 and 10 near Piseco Lake (Figure 13) yielded a three-point isochron of 1150 ± 5 Ma (McLelland et al. 1988; Chiarenzelli and McLelland 1991) placing the age firmly within that defined by numerous samples for the AMCG suite. In addition, an age of 1157 ± 8 Ma was also obtained from a three point isochron from zircons separated from the megacrystic Rooster Hill granitic gneiss (Chiarenzelli and McLelland, 1991). The Rooster Hill gneiss is exposed in an E-W-trending band about 15 km south of Piseco Lake along Route 10, but is considerably less deformed in some locations than other megacrystic rocks further to the north. A plutonic origin can be inferred with some confidence. A recent investigation of the geochemistry of the Piseco suite and reevaluation of the zircon data has called these conclusions into question (Chiarenzelli and Valentino, 2008). Here we present some of this new data but caution the reader as to its preliminary nature.

Geochemical trends

Chiarenzelli and Valentino (2008) undertook a geochemical study of the Piseco core rocks and compared them to other granitic rocks of the Adirondack Lowlands and Highlands including the A-

type granitoids of the western Adirondack Highlands (Whitney, 1992) and the megacrystic Hermon granite of the Lowlands (Carl and DeLorraine, 1997). Twelve granitoid samples, along and across strike, from the Piseco Lake shear zone one near Piseco Lake were collected and analyzed for major, trace and Rare Earth elements (Tables 1, 2 and 3). This data was pooled with twelve additional samples collected by Rachel Price (Price, 2004) who studied the Piseco core rocks to the west in the Ohio Gorge area.

Examination of geochemical data from the Piseco core rocks indicates that the rocks from both areas are very similar in composition. The dominant rock type, despite obvious textural differences, has a granitic composition (~70% SiO₂; Figure 20). In addition, the rocks are per- to metaluminous and range from subalkaline to calc-alkaline (Figure 21). Among the suite, rare earth element patterns normalized to chondritic values are similar and show enrichment in the LREE a small negative europium anomaly, and relatively flat HREE concentrations (Figure 22). A single sample shows a positive europium anomaly and appears to have a distinct geochemical signature. It also has the least amount of SiO₂ (55.76%) and may well represent a xenolithic layer within the Piseco core rocks.

On the Nb vs. Y tectonic discrimination diagram the Piseco core rocks appear to form a linear trend which extends from within volcanic arc/syn-collisional granite field to the center of the diagram (Figure 23A). Similarly, on Rb vs. Y+Nb diagram most of the rocks plot in the volcanic arc granite field; with a few samples plotting in the within plate granite and syn-collisional fields. On the AFM diagram the rock define a calc-alkaline trend (Figure 23B).

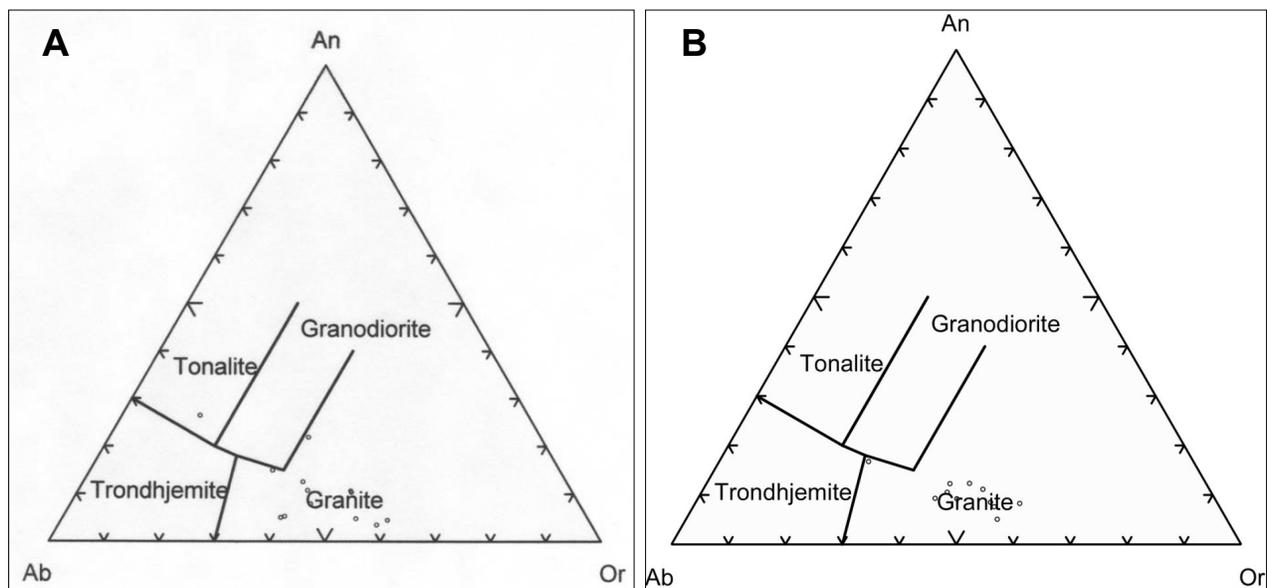


Figure 19. Ab-An-Or diagram used to classify plutonic rocks from the Piseco Lake Shear Zone near Piseco Lake (A) and Ab-An-Or diagram used to classify plutonic rocks from the Ohio Gorge, West Canada Creek (B).

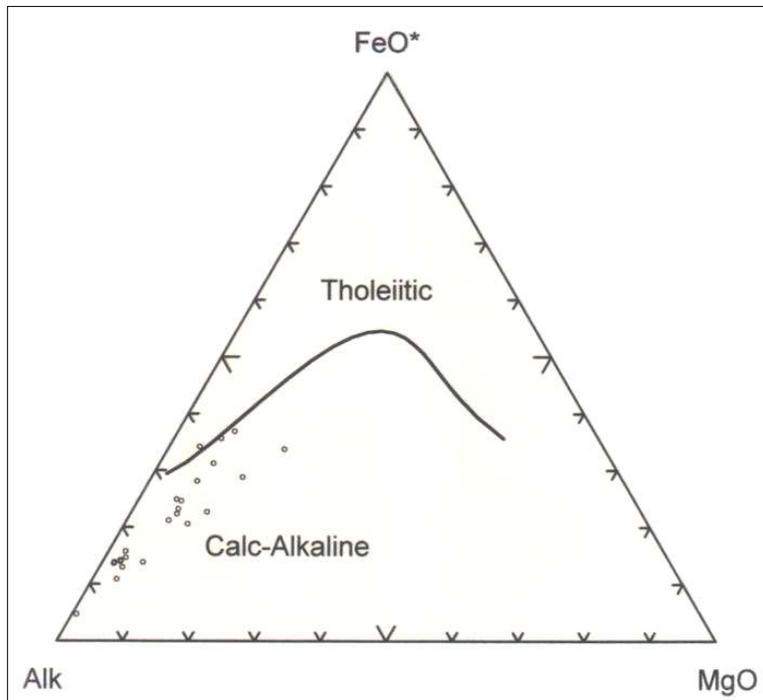


Figure 20. AFM diagram for rocks of the Piseco Lake Shear Zone.

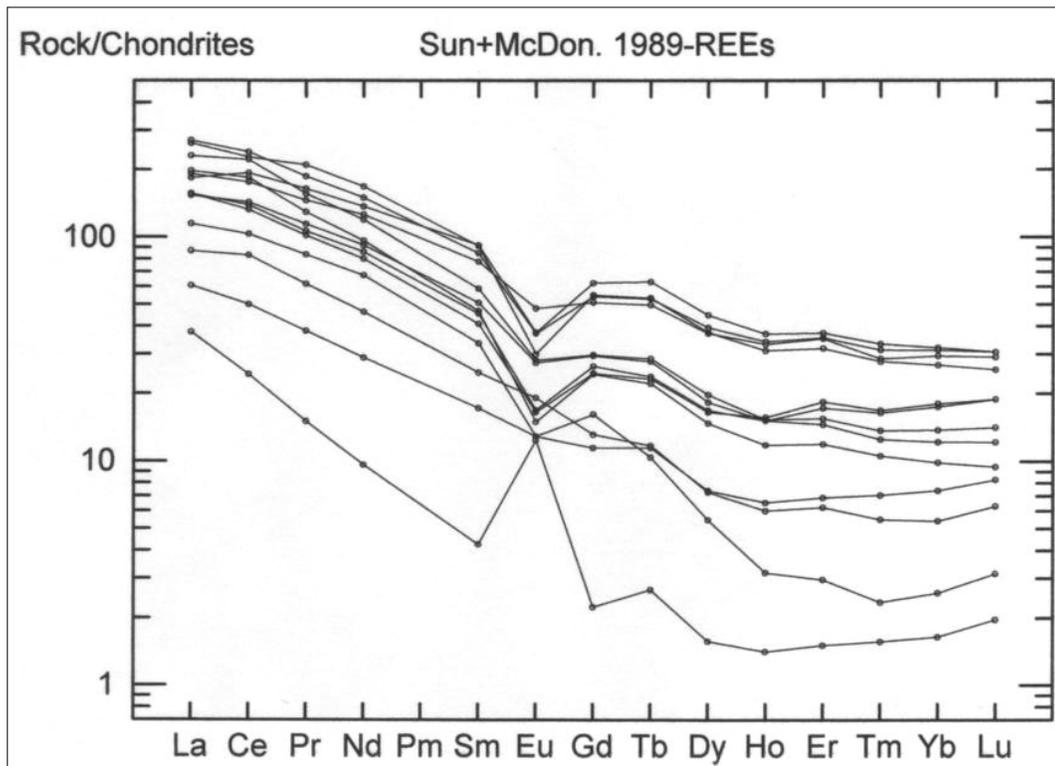


Figure 21. Rare earth element diagram for rocks of the Piseco Lake shear zone.

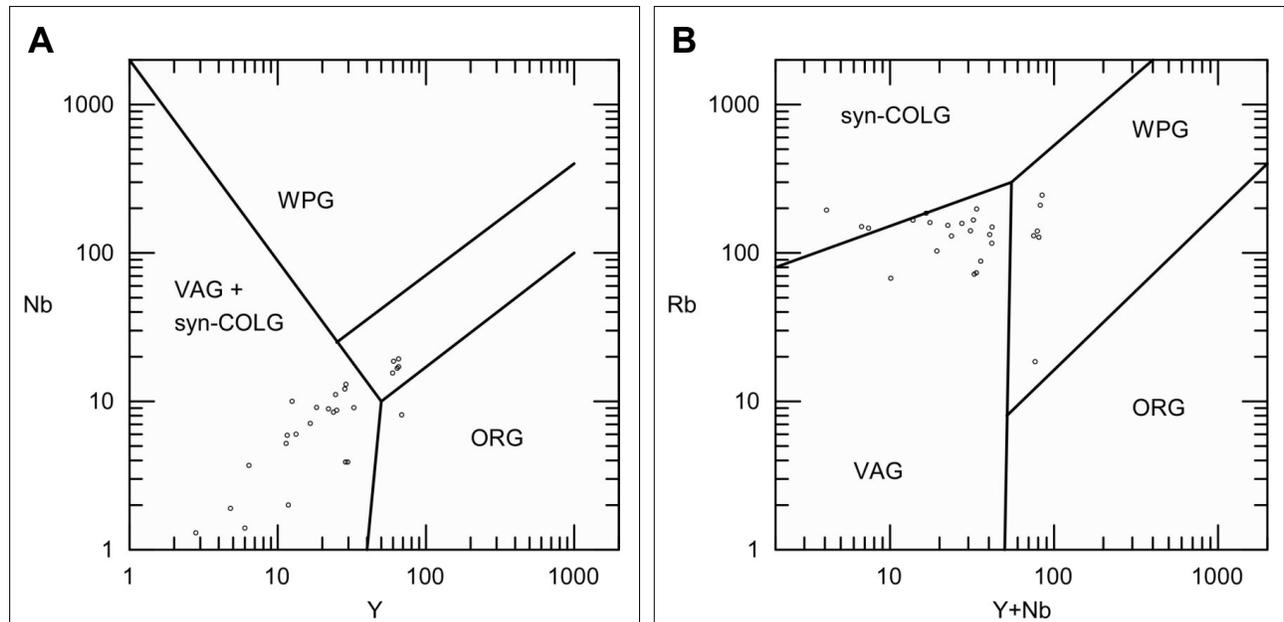


Figure 22. Nb vs. Y tectonic discrimination diagram (A) and Rb vs. Y+Nb tectonic discrimination diagram (B) for rocks of the Piseco Lake shear zone.

Plutonic rocks of the western Adirondack Highlands AMCG suite and those of the Hermon granite were utilized for comparison purposes. Whitney (1992) undertook a detailed (115 samples) geochemical study of rocks in the Western Adirondack Highlands. His work indicated that the rocks are metaluminous to mildly peraluminous and display an A-type geochemical signature. Compared I- and S-type granites he noted an enrichment in Fe, K, Ce, Y, Nb, Zr, and Ga, and a depletion in Ca, Mg, and Sr. Rare earth element patterns displayed moderate LREE enrichment and a negative Eu anomaly throughout the suite. Carl and deLorraine (1997) provided major and trace element analyses for the Hermon granite in the Lowlands. They concluded that the Hermon granite is calc-alkali to alkali and enriched in alkalis but strongly depleted in Cr and Ni. Where present, they note that the large (several centimeters) k-spar megacrysts are a distinctive. Compared to Piseco core rocks, the Hermon granite shows many geochemical similarities, whereas the western Adirondack Highland AMCG rocks are significantly different from both. On the AFM diagram (Figure 24) the Piseco core rocks and Hermon granite show calc-alkaline trends, whereas the AMCG rocks display an iron enrichment trend. In terms of the REE pattern the AMCG plutonic rocks of the western Adirondack Highlands show greater enrichment in all rare earth elements. Rocks of the Hermon granite fall within a narrow band within the field defined by the Piseco core rocks (Figure 25).

On both the Rb vs. Y+Nb and Nb vs. Y tectonic discrimination diagrams AMCG plutonic rocks of the Western Adirondack Highlands fall in small clusters within the within plate granite field or the unlabeled strip between within plate granites and orogenic granites. Conversely the Hermon granite and Piseco core rocks form linear trends that extend from well within the volcanic arc granite and syn-collisional granite field with a few samples extending into the within-plate field (Figures 26 and 27).

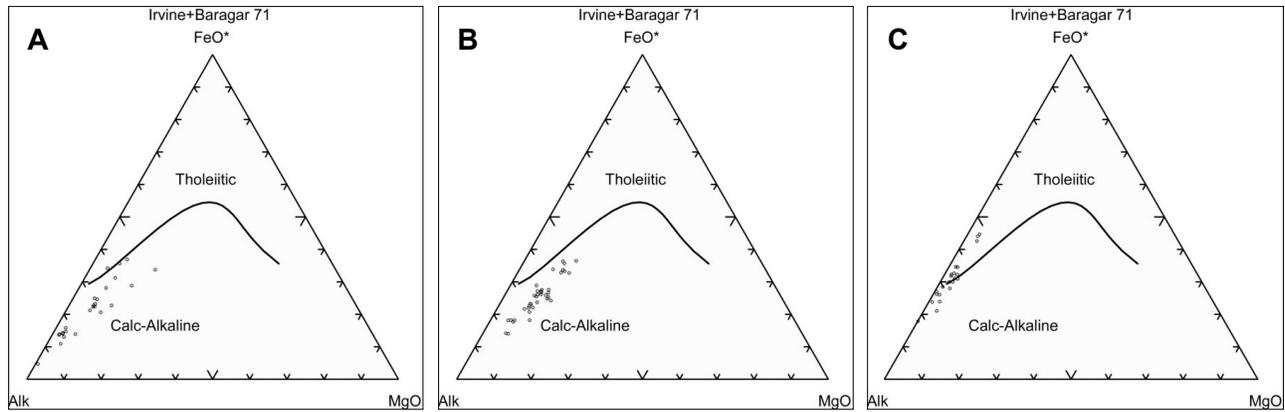


Figure 23. AFM diagram for the Hermon granite (A), Piseco core rocks (B), and AMCG granitoids of the western Adirondack Highlands (C).

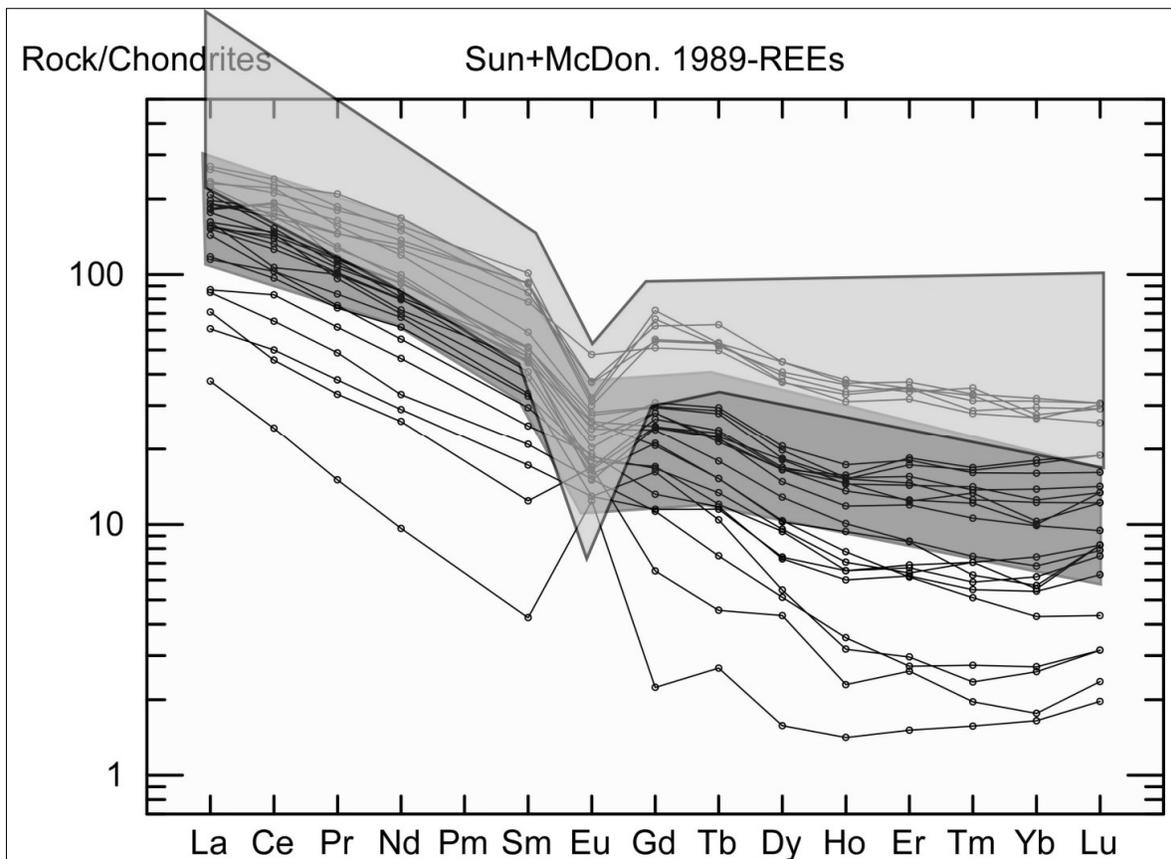


Figure 24. Rare earth element patterns for the AMCG plutonic rocks of the Western Adirondack Highlands (light gray field), Hermon granite (dark gray field), and the Piseco core rocks (individual lines).

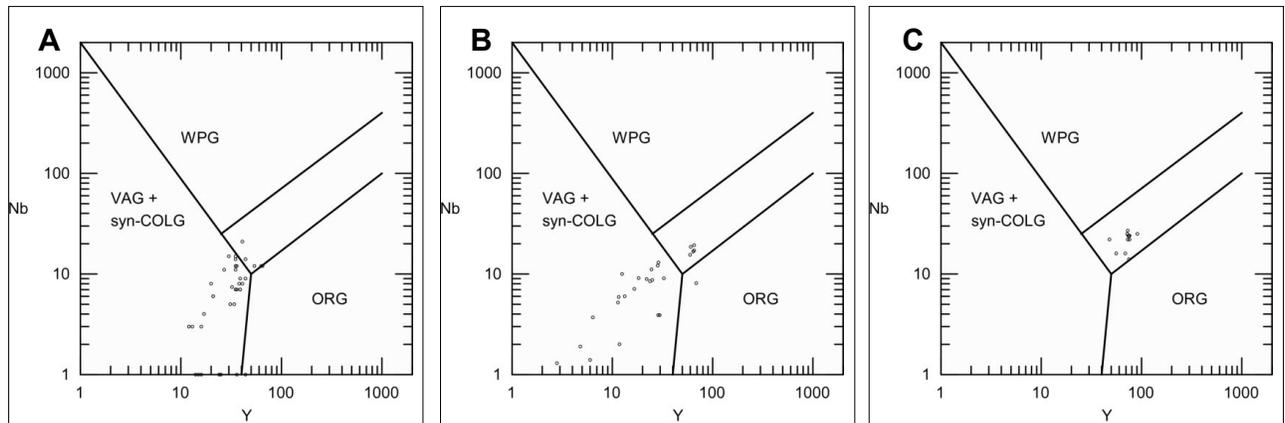


Figure 25. Nb vs. Y trace element discrimination diagram (Pearce et al., 1984) for the Hermon Granite (A), Piseco core rocks (B), and AMCG granitoids of the Adirondack Highlands (C).

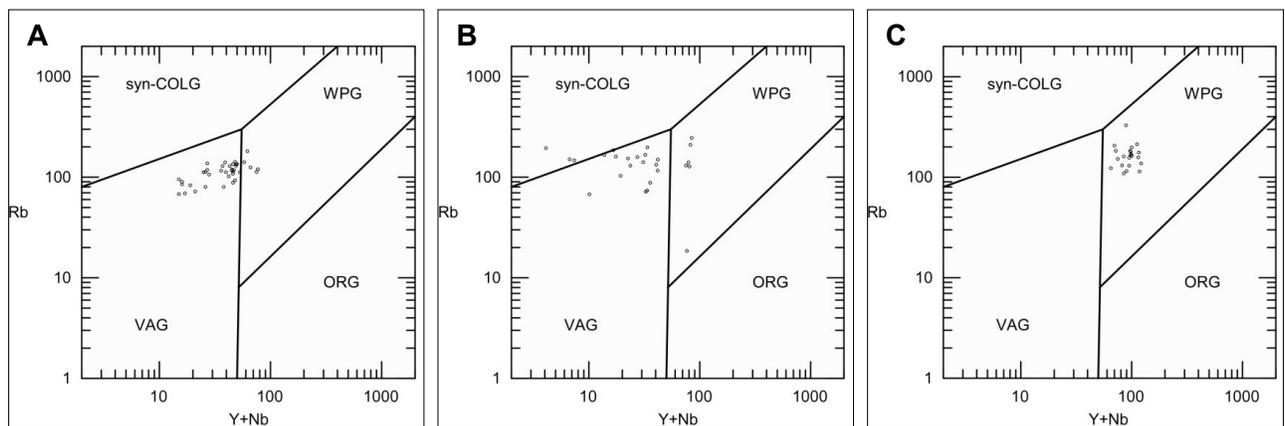


Figure 26. Rb vs. Y+Nb trace element discrimination diagram (Pearce et al., 1984) for the Hermon Granite (A), Piseco core rocks (B), and AMCG granitoids of the Adirondack Highlands (C).

Table 1. Major (ICP-OES) element concentrations for granitic rocks of the Piseco Lake shear zone.

	Units	PL-07-1	PL-07-2	PL-07-3	PL-07-4	PL-07-5	PL-07-6	PL-07-7	PL-07-8	PL-07-9	PL-07-10*	PL-07-10*	PL-07-11	PL-07-12
SiO ₂	%	67.9	72.88	74.08	68.34	66.57	72.63	66.62	65.59	55.76	76.12	76.59	73.63	74.18
Al ₂ O ₃	%	13.5	14.25	13.63	15.75	15.99	14.71	14.78	13.49	19.42	12.97	12.88	12.24	12.33
Fe ₂ O ₃	%	5.33	1.32	0.53	2.9	3.34	1.6	5.34	3.68	5.92	1.49	1.46	1.71	2.47
MgO	%	0.65	0.4	0.07	0.79	1.52	0.64	1.12	0.86	2.8	0.18	0.18	0.25	0.6
CaO	%	1.84	0.56	0.62	1.75	1.72	1.12	3.32	1.85	5.57	0.68	0.68	0.6	1.73
Na ₂ O	%	3.09	2.98	2.89	3.97	3.15	3.64	3.19	3.47	5.72	3.97	4.03	2.82	3.25
K ₂ O	%	5.49	6.33	6.72	4.94	5.57	4.66	3.92	4.14	1.95	4.17	4.11	5.12	2.96
TiO ₂	%	0.95	0.26	0.04	0.52	0.61	0.21	0.78	0.73	0.59	0.11	0.11	0.23	0.35
P ₂ O ₅	%	0.28	0.08	0.01	0.17	0.22	0.08	0.37	0.22	0.39	0.02	0.04	0.04	0.1
MnO	%	0.09	0.02	0.01	0.04	0.03	0.02	0.08	0.06	0.06	0.01	0.01	0.02	0.01
Cr ₂ O ₃	%	0.002	0.003	0.003	0.005	0.005	<0.01	0.003	0.008	0.014	0.009	0.005	0.006	0.003
Ni	ppm	10	47	11	44	<5	<5	7	20	21	33	9	14	7
Sc	ppm	9	3	<1	5	11	4	10	5	24	5	5	2	5
LOI	%	0.7	0.8	1.4	0.7	1	0.7	0.2	5.8	1.7	0.2	0.3	3.3	2
TOT/C	%	0.04	0.01	0.01	0.02	0.01	0.03	0.04	0.02	0.15	0.01	0.02	0.02	0.03
TOT/S	%	0.03	<.01	<.01	0.01	0.01	0.01	0.04	0.01	0.03	0.01	0.01	0.02	0.01
SUM	%	99.82	99.9	100	99.88	99.73	100	99.73	99.9	99.9	99.94	99.8	99.96	99.98

Table 2. Trace element (ICP-MS) concentrations for granitic rocks of the Piseco Lake shear zone.

	Units	PL-07-1	PL-07-2	PL-07-3	PL-07-4	PL-07-5	PL-07-6	PL-07-7	PL-07-8	PL-07-9	PL-07-10*	PL-07-10*	PL-07-11	PL-07-12
Ag	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
As	ppm	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
Au	ppb	0.8	0.9	0.7	<.5	0.9	0.6	0.5	0.7	<.5	<.5	0.6	<.5	<.5
Ba	ppm	933.2	937.3	312.7	718.8	970.3	393.4	639.5	569.7	355	698.2	674.9	285	244.2
Be	ppm	2	1	1	3	2	1	2	2	3	1	1	2	1
Bi	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Cd	ppm	0.1	<.1	<.1	0.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Co	ppm	5.1	1.6	<.5	4.1	7	2.1	9.8	4.6	13.8	0.9	0.7	1.3	3.2
Cs	ppm	0.4	0.9	0.9	0.7	2.3	0.8	0.4	1.2	0.2	0.1	0.1	1.1	0.1
Cu	ppm	7.5	8.7	1.7	2.3	3	0.6	24.4	14	4	1.5	1.5	19.2	1
Ga	ppm	21.3	16.2	17.9	21.2	20.9	21.2	19.6	20	27.1	15.3	16	15.9	18.4
Hf	ppm	17.5	5.2	1	7.5	6.9	2.4	11.1	9.5	3.4	6.1	6.5	6.8	4.2
Hg	ppm	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Mo	ppm	1.8	0.4	0.3	0.8	0.6	0.3	0.7	0.8	0.4	0.8	0.8	0.7	0.4
Nb	ppm	15.5	5.9	1.3	13	12.1	6	16.7	18.6	8.1	3.9	3.9	8.9	3.7
Ni	ppm	1.5	2.5	1.7	4.6	8	2.3	4.9	3	16.8	3.5	3.2	2	3.8
Pb	ppm	4.7	1.5	2.6	2.1	1.7	1	1.6	1.5	0.8	1.7	1.7	2.4	1
Rb	ppm	130.6	160.3	194.3	149.4	132.9	103	127.6	140.3	18.5	73.4	71.9	140.8	67.5
Sb	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Se	ppm	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
Sn	ppm	2	2	1	3	4	2	3	3	2	1	1	2	1
Sr	ppm	212.8	369.4	176.2	383.9	418.6	183.9	266.8	254.6	729.1	65.7	63.5	110.9	186.3
Ta	ppm	0.7	0.7	0.1	0.7	0.9	0.3	1.1	1.3	0.4	0.1	0.1	0.5	<.1
Th	ppm	1.6	12	2.4	12.1	8.1	4.1	11.1	8.2	1	11.2	11.7	13	11
Tl	ppm	<.1	<.1	<.1	0.2	0.3	0.1	0.2	0.2	<.1	<.1	<.1	<.1	0.1
U	ppm	0.7	1.9	1.7	1.8	1.6	2.1	0.9	1.9	0.3	1.1	1.2	1.8	0.9
V	ppm	28	19	7	41	62	18	65	39	137	<.5	<.5	7	27
W	ppm	0.3	0.1	<.1	<.1	0.7	0.1	<.1	0.1	<.1	<.1	<.1	<.1	<.1
Zn	ppm	107	19	4	50	47	14	68	46	57	11	12	19	16
Zr	ppm	757.6	177.8	23.9	286	283.7	80.1	426.8	357	122.1	176.5	184.3	242.4	135.7

Table 3. Rare Earth element concentrations for granitic rocks of the Piseco Lake shear zone.

	Units	PL-07-1	PL-07-2	PL-07-3	PL-07-4	PL-07-5	PL-07-6	PL-07-7	PL-07-8	PL-07-9	PL-07-10*	PL-07-10*	PL-07-11	PL-07-12
Y	ppm	59.6	11.6	2.8	28.9	28.4	13.3	64.1	60.6	68.6	29.7	28.7	22	6.4
La	ppm	45.4	20.6	8.9	54.6	36.4	14.4	63.9	62.1	43.6	37.1	37.1	46.8	27.2
Ce	ppm	107.6	50.8	14.9	135.5	87.4	30.6	146.8	139	118.2	81	85	112.6	63.1
Pr	ppm	13.86	5.86	1.43	14.82	10.85	3.61	17.71	19.9	15.6	9.67	10.1	12.27	7.94
Nd	ppm	58.8	21.6	4.5	55.8	43	13.5	69.9	78.4	63.9	37.4	40.1	45	31.5
Sm	ppm	11.9	3.8	0.65	9	7.78	2.64	12.98	13.99	14.08	6.26	6.96	7.15	5.13
Eu	ppm	2.78	1.11	0.72	1.63	1.59	0.75	2.15	1.74	2.17	0.96	0.98	0.87	0.75
Gd	ppm	10.48	2.71	0.46	6.11	6.06	2.36	11.14	11.32	12.83	5.06	5.44	5.01	3.33
Tb	ppm	1.86	0.44	0.1	1.07	1.04	0.43	1.98	2	2.36	0.87	0.89	0.83	0.39
Dy	ppm	9.43	1.85	0.4	5.03	4.66	1.88	10.01	9.51	11.38	4.21	4.29	3.76	1.39
Ho	ppm	1.88	0.34	0.08	0.87	0.86	0.37	1.93	1.76	2.09	0.89	0.86	0.67	0.18
Er	ppm	5.82	1.03	0.25	2.57	2.42	1.14	5.87	5.27	6.17	3.05	2.86	1.98	0.49
Tm	ppm	0.73	0.14	0.04	0.35	0.32	0.18	0.8	0.71	0.85	0.43	0.42	0.27	0.06
Yb	ppm	5.01	0.92	0.28	2.35	2.08	1.26	5.32	4.56	5.45	3.07	2.98	1.68	0.44
Lu	ppm	0.74	0.16	0.05	0.36	0.31	0.21	0.78	0.65	0.78	0.48	0.48	0.24	0.08

Geochronology

As mentioned above the age, and correlation with AMCG rocks elsewhere in the Adirondack Highlands, of the Piseco Lake core rocks has been inferred from a three-point U-Pb zircon isochron as 1150+/-5 Ma. This has been tentatively verified by an age (1157+/-8 Ma) on the Rooster Hill gneiss that may represent a less deformed megacrystic variant of the Piseco core rocks (Chiarenzelli and McLelland, 1991). Both samples were completed at a time (mid-1980s) when relatively large amounts of zircon were required to provide sufficient amounts of lead for analysis and to overcome the ubiquitous lead blank from the large-scale combustion of leaded gasoline. As a consequence zircon fractions were often subdivided on the basis of magnetic susceptibility and/or size. Air abrasion was routinely used to improve the concordancy of zircon fractions. SEM investigation of zircon populations was carried out, and often displayed core-rim relations, but dating of small volumes of zircon and combining visual observations and analyses was not routinely possible.

Given the constraints of the time, it is entirely possible, and in fact likely, that the zircon ages obtained from high-grade Adirondack rocks represent mixed ages influenced by zircon grown both during igneous crystallization and metamorphism events. Currently techniques such as Sensitive High-Resolution Ion Microprobe (SHRIMP) analysis is capable of focusing on individual spots as small as a few microns for analysis. Reinvestigation of Adirondack zircon suites has refined the ages determined by the original analyses by several tens of millions of years (McLelland et al., 2001). Given the state of deformation of the Piseco core rocks we began to wonder what a modern geochronological study of the original zircon suite would tell us. For this reason we obtained the original zircon fractions reported in McLelland et al. (1988) and Chiarenzelli and McLelland (1991) for the sample of the Piseco core rocks from the outcrops at the intersection of Routes 8 and 10, just south of Piseco Lake. The actual rock sampled is a strongly lineated (L-tectonite), granitic mylonite with prominent quartz ribbons formed by intense deformation (AM-86-9).

An abundant population of lavender zircons were originally separated from the Piseco core rock sample. They are several hundred microns in length and consisted of rounded to subhedral prisms with rounded terminations. They average about 500 ppm Uranium but varied from 101-1109 ppm. Uranium to Thorium ratios varied from 1.6 to 36.7 and fell into two distinct groups; >10 and <5 . Zircons ranged from 2:1 to 3:1 in aspect ratio (length to width). The zircons, from the least magnetic fraction (NM 0°) were mounted in epoxy, observed under cathodoluminescence via the scanning electron microscope, and analyzed by laser ablation multi-collector inductively coupled mass spectrometry (LA-MC-ICP-MS). This work was completed at the Laserchron Laboratory at the University of Arizona. Both 25 micron and 35 micron spot-size data was collected. Scanning electron microscope observation revealed cores and rims in most grains, suggesting, at least, a two-stage growth history. Consequently ablation pits were located in an attempt to analyze either cores or rims. Figure 27 shows some of the ablation pits on the sectioned zircon grains.

Unfortunately the results are somewhat equivocal and difficult to interpret because of the large spot size used and relatively large two-sigma errors (Table 4, Figure 28). Based on core-rim relations it appears that there may be two or, possibly, three distinct populations of zircons as some older cores are mantled by both ~ 1150 Ma and ~ 1080 Ma rims (Figure 27). In addition the bimodal distribution of the U/Th ratios shows that the older zircon core material was consistently low (<5 and generally less <3), whereas younger rims had considerable higher ratios.

Summary of geochemical and geochronological results

The preliminary nature of this work limits the interpretations that can be drawn from the available data. However, it appears that the chemistry of the Piseco core rocks is not typical of other A-type granitoids in the Adirondacks, particularly those of the western Adirondacks just north of the Piseco Lake shear zone. The visual similarity of the Piseco core rocks to the Hermon granite of the Lowlands, including the abundant population of coarse, potassium feldspar megacrysts, is also generally reflected in their major and trace element chemistry. The chemistry of the Piseco core rocks, like the Hermon granite, is also suggestive of an arc origin, likely a continental arc because of the predominance of granites.

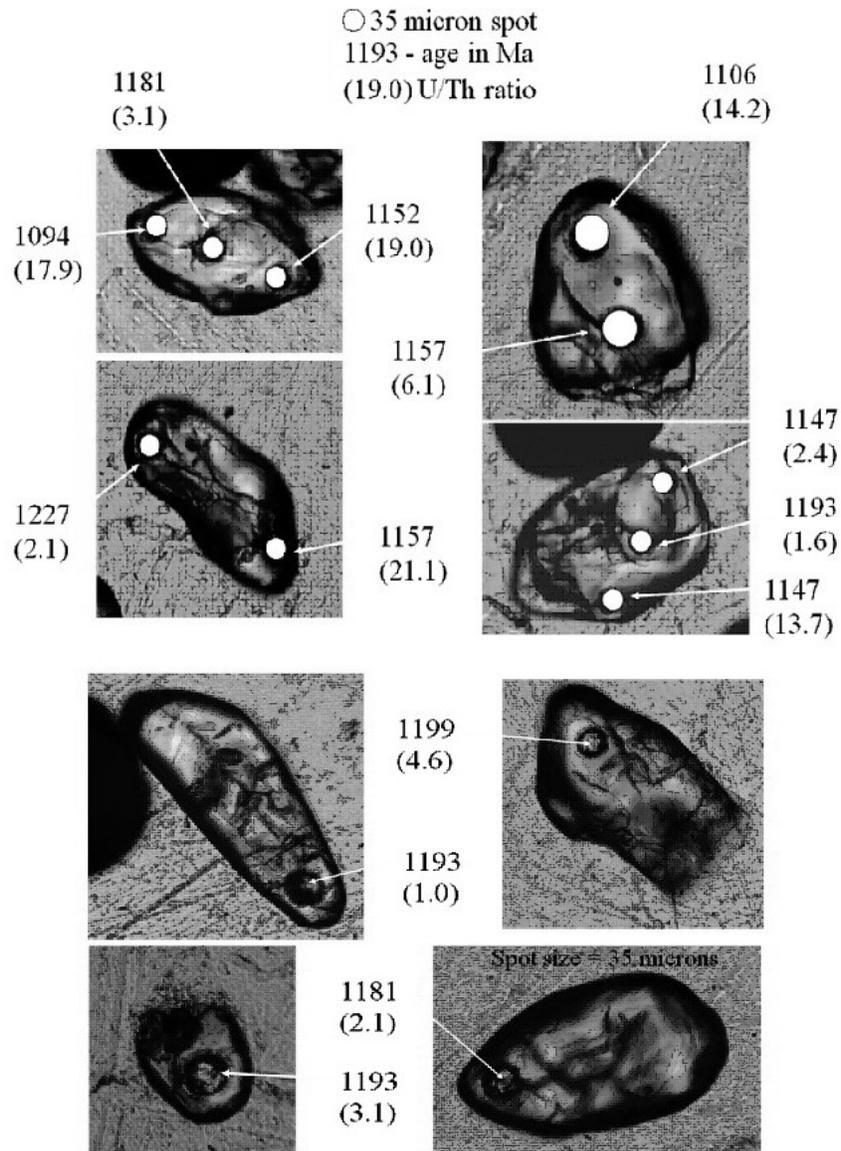


Figure 27. Photomicrographs of zircons analyzed by LA-MC-ICP-MS from the Piseco core rocks.

At this time, it is unfortunate that the geochronological results are equivocal. However, they serve to demonstrate the complexity of the zircon suite and the possibility of multiple populations. Distinct core rim relations are intriguing because the rimming material corresponds to recognized events in the Adirondack Highlands, both late Shawinigan and Ottawa metamorphism. In addition, the large difference in U/Th ratios warrants future investigation and may prove useful in distinguishing metamorphic from igneous or xenocrystic zircons. The data suggests that the oldest zircons in the Piseco core rock have typical igneous signatures (low U/Th ratios), while those of rimming material, both ~1080 and 1150 Ma, are much higher. At this point in time we believe 1169 \pm 7 Ma is a minimum age for the Piseco core rock that appears to have experienced metamorphic zircon overgrown at ca. 1150 and 1080 Ma.

Future work will involve extending geochemical and geochronological studies along the length of the Piseco antiform and the intriguing possibility that they are related to the Hermon granite of the Lowlands. As a working model, Valentino et al. (2008) have proposed that the Piseco core rocks represent a continental arc developed during subduction preceding the Shawinigan Orogen. Such an origin may explain their chemistry, spatial relationship to highly migmatized pelitic gneisses (a characteristic also shown by the Hermon Granite), and the intensity of later deformation in an orogen parallel kinematic regime (Gates et al., 2004).

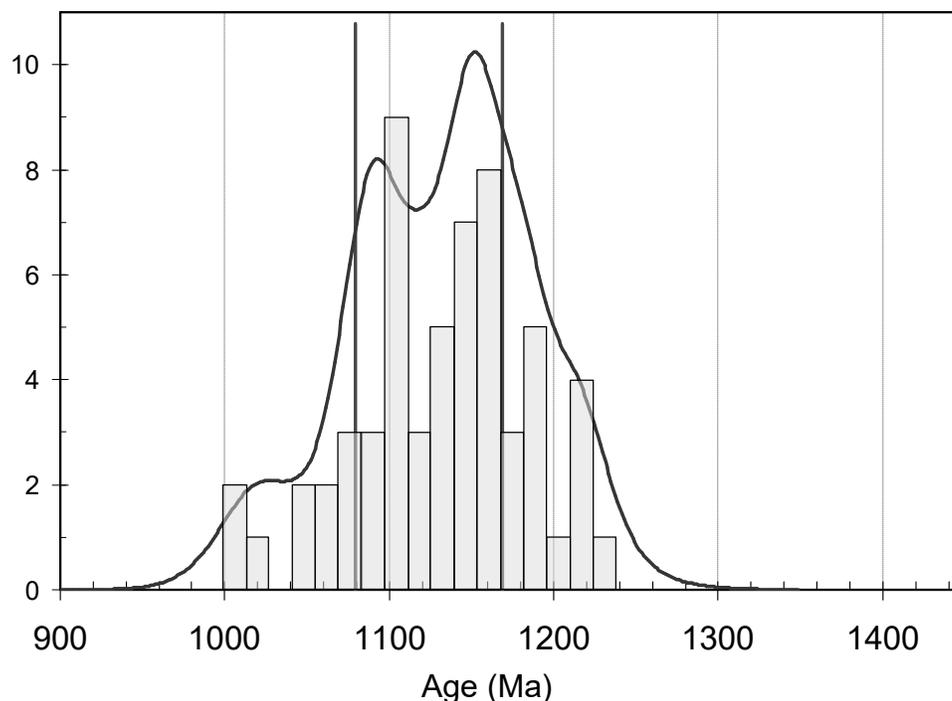


Figure 28. Histogram showing all data (56 points) from the Piseco core rock zircons. Vertical dark lines represent ages of 1079 ± 8.1 and 1169 ± 7 Ma.

Tectonic Model

Gates et al. (2004) proposed that dextral shearing in the Hudson Highlands of southern New York, and sinistral shearing in the southern Adirondacks occurred during the development of a conjugate Himalayan-type syntaxis associated with the Ottawa orogeny (Figure 29). One potential problem with this tectonic model is the distance between the southern Adirondacks and the Hudson Highlands (located in southern New York and northern New Jersey). The Proterozoic basement is covered by various Paleozoic rocks that were impacted by Appalachian deformation events, and the current geometry of the apparent Proterozoic conjugate system may have been modified. The projected intersection between the conjugate sinistral and dextral zones would occur under the area of the Taconic Highlands of eastern New York and southern Vermont. The trace of the Piseco antiform, including the highly deformed granitic rocks, varies from generally east-west to nearly north-south in the eastern Adirondacks (McLelland-personal communication 2008). The pronounced lineation that trends between 090 and 110 across most of the southern Adirondacks takes a clock-wise bend in the region of the Great Sacandaga Lake northeastern arm, and then

trends generally north-south near the Hudson River. This substantial difference in the trace of the Piseco Lake zone structures may reflect clock-wise (dextral) transposition. It is interesting that this change in trend occurs near the conjugate intersection region that was proposed by Gates et al. (2004). In effect, the Piseco Lake zone may have been deformed by dextral shearing on the north-east striking arm of the conjugate system. So, the similarity in timing and orientation of these

Table 4. LA-MC-ICP-MS U-Pb zircon data for the Piseco core rocks.

Analysis	U	206Pb	U/Th	206Pb*	±	207Pb*	±	206Pb*	±	error	206Pb*	±	207Pb*	±	206Pb*	±	Best age	±
	(ppm)	204Pb		207Pb*	(%)	235U*	(%)	238U	(%)	corr.	238U*	(Ma)	235U	(Ma)	207Pb*	(Ma)	(Ma)	(Ma)
25 microns																		
AM-86-9-5	738	45172	17.9	13.1623	1.5	1.8456	3.9	0.1762	3.6	0.92	1046.1	34.3	1061.9	25.5	1094.4	30.6	1094.4	30.6
AM-86-9-6	399	26832	3.1	12.5983	1.4	2.0714	4.6	0.1893	4.4	0.95	1117.4	45.2	1139.4	31.7	1181.5	27.3	1181.5	27.3
AM-86-9-7	601	35926	19.0	12.7875	1.4	2.0264	2.8	0.1879	2.4	0.86	1110.2	24.2	1124.4	18.8	1152.0	28.4	1152.0	28.4
AM-86-9-8	547	31880	14.0	12.9141	2.5	1.9725	2.7	0.1847	1.0	0.37	1092.9	10.1	1106.2	18.1	1132.4	49.6	1132.4	49.6
AM-86-9-9	465	29778	3.8	12.8375	2.1	1.9507	2.9	0.1816	2.0	0.68	1075.8	19.4	1098.7	19.4	1144.2	42.1	1144.2	42.1
AM-86-9-10	480	34766	12.8	12.6631	1.3	2.1062	2.7	0.1934	2.4	0.88	1140.0	24.8	1150.8	18.6	1171.4	25.9	1171.4	25.9
AM-86-9-11	681	46940	7.0	12.6688	1.4	2.1652	2.2	0.1989	1.7	0.78	1169.6	18.3	1169.9	15.1	1170.5	26.7	1170.5	26.7
AM-86-9-12	316	19752	6.2	12.6218	1.5	2.1401	1.9	0.1959	1.2	0.62	1153.3	12.7	1161.9	13.4	1177.8	29.9	1177.8	29.9
AM-86-9-13	846	60304	33.4	13.0400	1.7	1.9203	2.1	0.1816	1.3	0.61	1075.8	12.7	1088.2	13.9	1113.0	33.0	1113.0	33.0
AM-86-9-14	648	41186	36.7	13.0513	1.6	1.9401	2.0	0.1836	1.1	0.58	1086.9	11.3	1095.0	13.1	1111.3	32.0	1111.3	32.0
AM-86-9-15	500	31118	17.6	13.0670	2.9	1.9746	3.9	0.1871	2.6	0.66	1105.8	26.0	1106.9	26.0	1108.9	57.8	1108.9	57.8
AM-86-9-16	408	23172	3.1	12.5231	1.9	2.1964	2.8	0.1995	2.1	0.73	1172.6	22.0	1179.9	19.7	1193.3	38.1	1193.3	38.1
AM-86-9-17	243	15498	2.9	12.7922	1.7	2.0025	2.6	0.1858	2.0	0.76	1098.5	19.7	1116.3	17.3	1151.2	32.8	1151.2	32.8
AM-86-9-18	437	25816	4.6	12.4875	1.7	2.0988	2.9	0.1901	2.3	0.80	1121.8	23.6	1148.4	19.7	1198.9	33.9	1198.9	33.9
AM-86-9-19	483	34544	6.9	12.7869	2.1	2.0187	2.8	0.1872	1.9	0.67	1106.2	19.3	1121.8	19.2	1152.1	41.7	1152.1	41.7
AM-86-9-20	724	48670	2.4	12.7250	1.9	2.0917	3.5	0.1930	3.0	0.85	1137.8	31.0	1146.1	24.1	1161.7	36.9	1161.7	36.9
AM-86-9-21	420	24068	1.8	12.7251	3.8	2.1053	4.1	0.1943	1.4	0.34	1144.6	14.5	1150.5	28.0	1161.7	76.0	1161.7	76.0
AM-86-9-22	318	21354	2.1	12.5992	3.1	2.1432	4.3	0.1958	3.0	0.69	1152.9	31.2	1162.9	29.6	1181.4	61.1	1181.4	61.1
AM-86-9-23	247	14528	1.4	12.3272	3.4	2.2200	3.6	0.1985	1.2	0.34	1167.1	12.9	1187.4	25.1	1224.4	66.5	1224.4	66.5
AM-86-9-24	270	22194	2.2	12.6331	3.5	2.1175	3.9	0.1940	1.8	0.46	1143.1	18.8	1154.5	26.9	1176.1	68.5	1176.1	68.5
AM-86-9-25	501	23092	7.9	12.7299	2.2	2.1289	2.7	0.1966	1.5	0.57	1156.8	16.1	1158.2	18.4	1160.9	43.4	1160.9	43.4
AM-86-9-26	1109	48708	1.4	12.6904	5.2	2.2120	6.6	0.2036	4.1	0.62	1194.6	44.7	1184.9	46.5	1167.1	103.7	1167.1	103.7
AM-86-9-27	632	45106	14.4	12.6038	4.6	2.2222	4.9	0.2031	1.6	0.34	1192.1	17.7	1188.1	34.0	1180.6	90.4	1180.6	90.4
AM-86-9-28	714	43448	21.1	12.7519	2.9	2.1389	4.3	0.1978	3.1	0.73	1163.6	33.2	1161.5	29.7	1157.5	58.3	1157.5	58.3
AM-86-9-29	333	23294	1.1	12.3102	1.4	2.3248	1.9	0.2076	1.3	0.67	1215.8	14.4	1219.9	13.7	1227.1	28.1	1227.1	28.1
AM-86-9-30	322	20734	2.8	12.4839	1.5	2.2957	3.6	0.2079	3.3	0.91	1217.4	36.3	1211.0	25.5	1199.5	30.0	1199.5	30.0
AM-86-9-31	559	32420	13.1	13.2284	3.8	1.9386	4.2	0.1860	1.9	0.44	1099.6	18.7	1094.5	28.3	1084.3	76.2	1084.3	76.2
AM-86-9-33	259	17068	2.0	12.8911	3.3	2.1109	6.3	0.1974	5.4	0.85	1161.1	57.3	1152.4	43.6	1135.9	65.6	1135.9	65.6
AM-86-9-34	543	22932	1.0	12.5275	1.8	2.3006	2.6	0.2090	1.9	0.72	1223.6	20.8	1212.5	18.3	1192.6	35.2	1192.6	35.2
AM-86-9-35	593	39630	16.5	12.6967	1.8	2.0419	3.1	0.1880	2.5	0.82	1110.7	25.8	1129.6	21.1	1166.1	35.5	1166.1	35.5
AM-86-9-36	306	21784	2.6	12.5839	2.4	2.1591	2.8	0.1971	1.4	0.50	1159.5	15.0	1168.0	19.4	1183.8	47.7	1183.8	47.7
AM-86-9-37	767	48310	19.4	13.5254	1.1	1.7168	2.9	0.1684	2.7	0.93	1003.3	24.9	1014.8	18.6	1039.7	22.0	1039.7	22.0
AM-86-9-38	818	55020	24.8	13.3425	1.2	1.7544	2.3	0.1698	1.9	0.85	1010.9	18.2	1028.8	14.7	1067.1	23.9	1067.1	23.9
AM-86-9-39	692	44216	19.3	12.7910	1.0	2.0064	2.1	0.1861	1.8	0.88	1100.4	18.3	1117.7	14.0	1151.4	19.9	1151.4	19.9
AM-86-9-40	635	55224	23.7	13.2333	9.1	1.9462	9.5	0.1868	2.9	0.31	1104.0	29.5	1097.1	64.0	1083.6	182.3	1083.6	182.3
AM-86-9-41	657	38796	13.0	13.2185	2.0	1.8335	2.8	0.1758	1.9	0.68	1043.9	17.9	1057.5	18.1	1085.8	40.7	1085.8	40.7
AM-86-9-42	324	28590	2.8	13.2103	1.6	1.8991	2.0	0.1819	1.2	0.62	1077.6	12.2	1080.8	13.2	1087.1	31.3	1087.1	31.3
AM-86-9-43	251	18258	3.0	12.7315	1.7	2.1836	2.0	0.2016	1.0	0.50	1184.1	10.8	1175.8	14.0	1160.7	34.6	1160.7	34.6
AM-86-9-44	567	36520	15.9	13.2347	2.1	1.8733	4.9	0.1798	4.4	0.90	1066.0	43.4	1071.7	32.4	1083.4	42.3	1083.4	42.3
AM-86-9-45	215	13324	2.2	12.6922	2.4	2.1791	2.7	0.2006	1.3	0.47	1178.5	13.8	1174.4	19.0	1166.8	47.8	1166.8	47.8
AM-86-9-46	524	34122	10.9	12.8953	1.9	2.0539	3.5	0.1921	3.0	0.85	1132.7	30.6	1133.6	23.8	1135.3	37.0	1135.3	37.0
AM-86-9-47	510	34730	10.1	12.7826	1.6	2.0455	3.6	0.1896	3.2	0.90	1119.4	33.0	1130.8	24.3	1152.7	31.0	1152.7	31.0
AM-86-9-48	604	35066	13.1	12.7553	2.2	2.0723	3.3	0.1917	2.4	0.73	1130.7	25.1	1139.7	22.6	1157.0	44.4	1157.0	44.4
AM-86-9-49	545	33488	14.2	13.0840	1.4	1.9591	2.6	0.1859	2.2	0.85	1099.2	22.6	1101.6	17.8	1106.3	28.2	1106.3	28.2
AM-86-9-50	490	34910	6.1	12.7533	3.6	2.1082	3.8	0.1950	1.0	0.27	1148.4	10.5	1151.5	25.9	1157.3	72.0	1157.3	72.0
AM-86-9-51	1065	71116	14.2	12.7059	1.5	1.9489	3.0	0.1796	2.6	0.87	1064.7	25.8	1098.1	20.2	1164.7	28.9	1164.7	28.9
AM-86-9-52	668	64200	10.8	12.6332	2.5	2.1327	3.0	0.1954	1.7	0.56	1150.6	17.7	1159.4	20.7	1176.0	49.1	1176.0	49.1
AM-86-9-53	116	8756	4.9	12.1012	4.5	2.1994	7.4	0.1930	5.9	0.79	1137.8	61.3	1180.8	51.8	1260.6	88.4	1260.6	88.4
AM-86-9-54	101	6918	2.0	12.2708	2.0	2.2161	3.0	0.1972	2.2	0.75	1160.4	23.8	1186.1	21.0	1233.4	39.3	1233.4	39.3
AM-86-9-55	232	15482	2.6	12.8966	2.4	2.1514	3.3	0.2012	2.2	0.67	1181.9	24.1	1165.5	23.0	1135.1	48.7	1135.1	48.7
AM-86-9-56	566	38354	11.6	12.6944	1.9	2.0922	2.8	0.1926	2.0	0.72	1135.6	21.0	1146.3	19.1	1166.5	38.0	1166.5	38.0
AM-86-9-57	340	24492	2.4	12.8152	1.7	2.0888	2.9	0.1941	2.4	0.81	1143.8	24.7	1145.1	20.1	1147.7	34.2	1147.7	34.2
AM-86-9-58	638	40950	13.7	12.8150	2.0	1.9949	3.4	0.1854	2.7	0.80	1096.5	27.4	1113.8	22.9	1147.7	39.9	1147.7	39.9
AM-86-9-59	169	12056	1.6	12.5242	3.0	2.2217	4.7	0.2018	3.6	0.77	1185.0	39.4	1187.9	33.1	1193.2	59.7	1193.2	59.7
AM-86-9-60	824	61036	14.7	12.6719	3.3	2.1577	3.8	0.1983	1.9	0.51	1166.2	20.6	1167.5	26.4	1170.0	64.8	1170.0	64.8
35 microns																		
AM-86-9-1	585	28878	10.3	13.4922	2.8	1.7522	3.3	0.1715	1.7	0.52	1020.2	16.0	1028.0	21.3	1044.6	56.9	1044.6	56.9
AM-86-9-2	620	53724	14.4	12.5355	1.9	2.2573	2.5	0.2052	1.6	0.64	1203.3	17.3	1199.1	17.4	1191.4	37.5	1191.4	37.5
AM-86-9-3	555	51766	16.1	12.4381	1.9	2.2988	2.6	0.2074	1.8	0.69	1214.8	20.2	1211.9	18.7	1206.8	37.8	1206.8	37.8
AM-86-9-4	647	51884	12.5	12.6230	2.7	2.2688	3.1	0.2077	1.6	0.51	1216.6	17.4	1202.7	21.7	1177.6	52.4	1177.6	52.4

major shear zone systems in the Hudson Highlands and Adirondacks, and possible transposition of the sinistral zone by the dextral zone, strongly supports the Himalayan-type syntaxis model.

Based upon existing age constraints, this conjugate shear system was active in the core of the Ottawa orogen during and subsequent to peak metamorphic conditions. Relative to modern geographic coordinates, this conjugate system yields bulk-extension and bulk-compression directions of west-northwest and east-northeast respectively (Figure 29). These strain axes are consistent with compression directions deduced from en echelon transpressional folds in the Hudson Highlands and the en-echelon domes on the central Adirondacks (Chiarenzelli et al., 2000). This bulk strain analysis assumes that bulk rotation of the Hudson Highlands relative to the Adirondacks during Paleozoic Appalachian tectonic events (Taconic, Acadian, Alleghanian orogenies) and Mesozoic extension was minimal. The assumption is reasonable because there is no post-Precambrian penetrative deformation in the western Hudson Highlands and the major folds and faults in the surrounding Paleozoic strata are essentially parallel to those in the crystalline rocks indicating similar strain axes and minimal rotation. The Grenville Province north of the Adirondack Lowlands contains numerous Proterozoic normal faults and shear zones with an overall northwest-southeast extension direction (Streepey et al., 2000), and published age data suggest that these normal faults were active as much as 100 Ma after peak metamorphic conditions in the Adirondack Highlands. Finally, this late extensional deformation can be explained by applying the bulk-strain directions inferred from the conjugate syntaxis model (Figure 29).

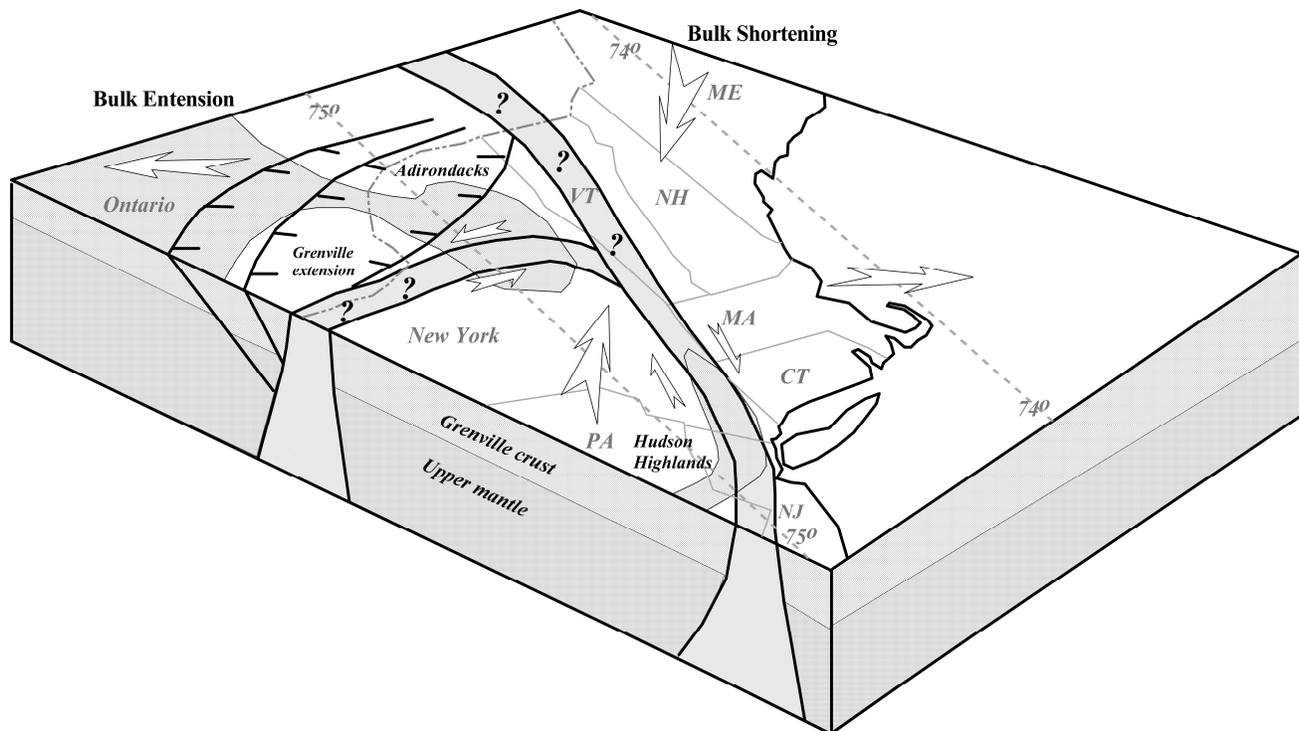


Figure 29. Block diagram depicting the crust-scale conjugate ductile shear zones forming a syntaxis. The inset shows the location of the syntaxis in a reconstruction of Rodinia (modified from Gates et al., 2004).

Acknowledgements

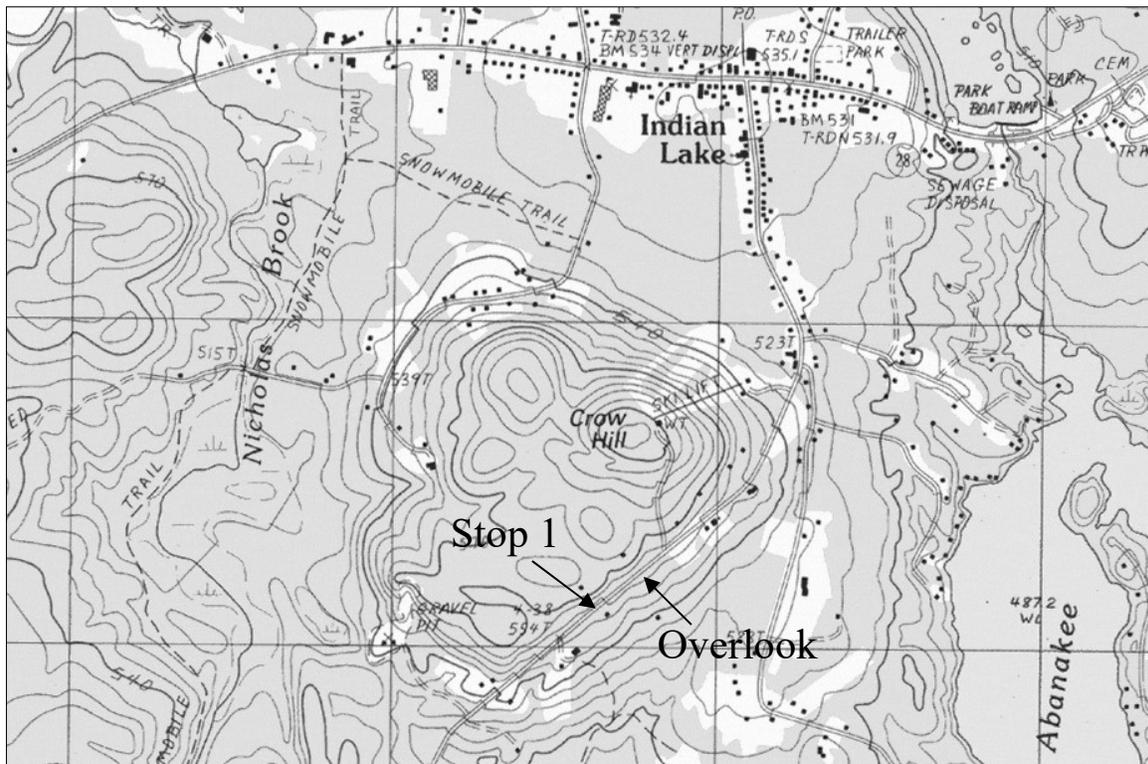
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Field Trip Description and Road Log

Road Log:

Mileage:

- 0.0 The trip begins at the assembly point in the parking lot of the super-market in the town of Indian Lake, NY, at the eastern intersection of Rts. 28 and 30. Proceed south on Rt. 30.
- 1.0 Turn left into the overlook parking lot, and walk south on Rt. 30 approximately 0.2 miles to the first roadcut on the west (right) side of the road.



STOP 1: Calc-silicate gneiss on the north side of the Snowy Mountain Dome (SMD)

Calc-silicate gneiss with penetrative foliation and folds occurs in outcrops on the west side of Route 30. The foliation is defined by planar aggregates of recrystallized plagioclase, quartz and diopside (Figure 30). Locally the calc-silicate gneiss contains quartzofeldspathic layers that define isoclinal folds, and locally there are recrystallized masses of diopside (some >10 cm in diameter).

The dominant foliation in the outcrop in most places is structurally continuous with penetrative foliation (S2) in the Snowy Mountain dome, and dips moderately northward at this location. Portions of the exposure reveal an earlier foliation (S1) preserved mostly in the hinges of the isoclinal folds (F2) (Figure 30). The S1 foliation does not occur in the rocks of the Snowy Mountain suite, and the S2 foliation dies out away from the Snowy Mountain dome. In a relative sense, the S1 foliation is either predates or is synchronous with the intrusion of the Snowy Mountain suite, and the S2 foliation is superimposed on the suite.

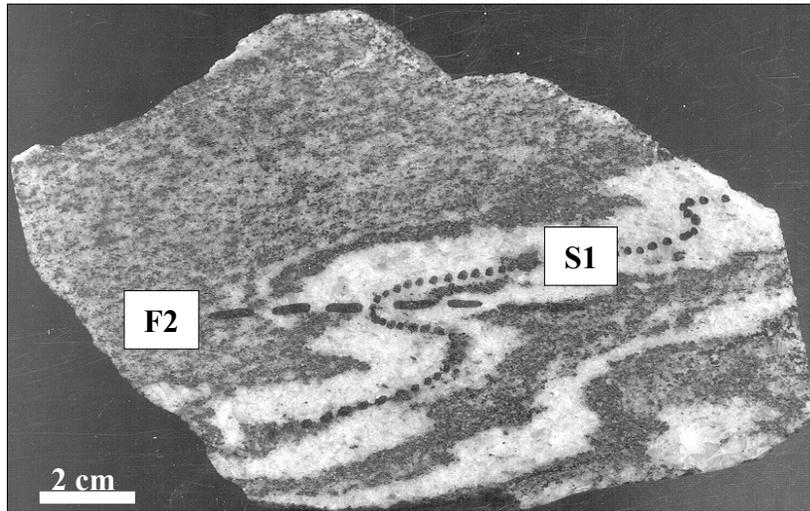
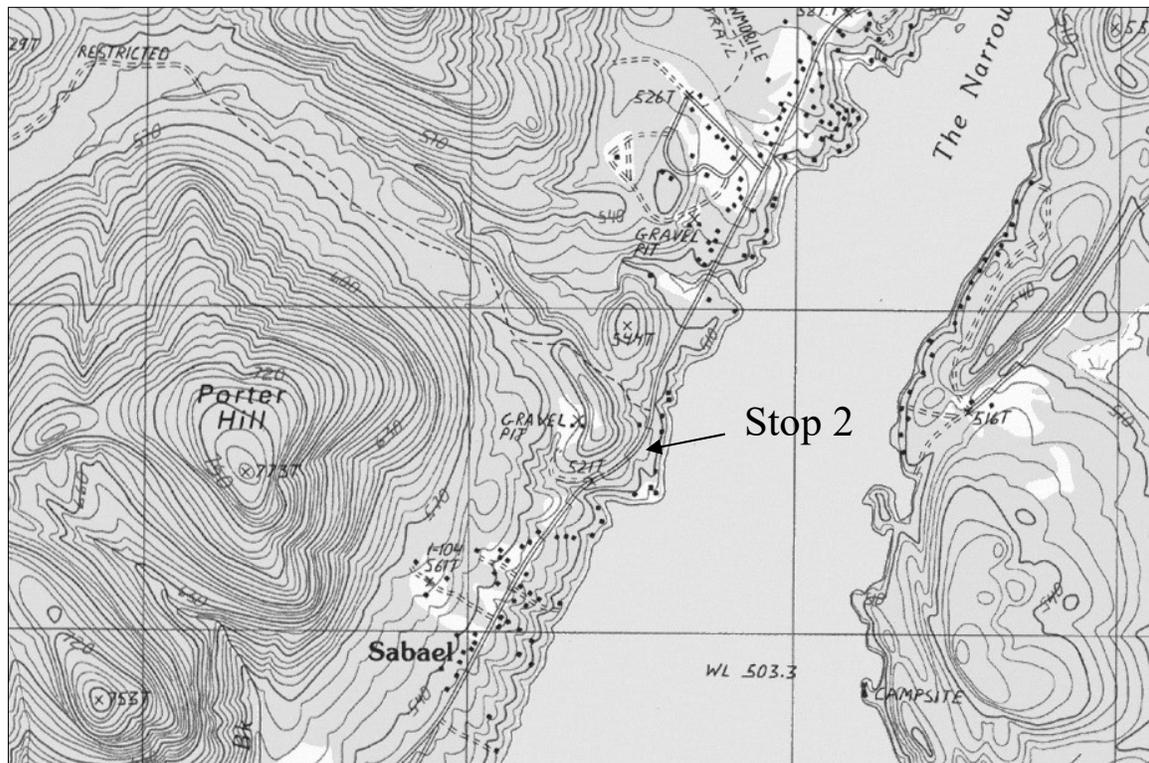


Figure 30. Rock slab of calc-silicate gneiss showing the S1 foliation defining F2 isoclinal folds.

Mileage:

- 1.0 Continue south on Rt. 30 towards Speculator.
- 2.1 Point Breeze Hotel
- 2.6 Roadcuts of charnockitic gneiss.
- 3.5 Park on the right side of Rt. 30 and cross the road to the roadcut on the east (left) side (at the “Southwinds” sign).



STOP 2: Charnockitic gneiss on the north side of the SMD

The contact between the calc-silicate gneiss of STOP 1 and charnockitic gneiss of the Snowy Mountain suite occurs approximately 1 km northeast of this location, and is concordant with the S2 foliation. Here there is exposure of highly deformed charnockitic gneiss on both sides of the road. The foliation (S2) is defined by planar aggregates of dynamically recrystallized plagioclase and broken grains of hypersthene and augite (Figure 31). The foliation dips moderately northeastward and weak mineral lineations trend shallowly toward the east. Many of the outcrop surfaces reveal augen of plagioclase with core-mantle structure. Dynamically recrystallized tails developed on porphyroclasts of plagioclase merge with the penetrative foliation. The plagioclase augen are interpreted to be relict igneous crystals, possibly original megacrysts. When viewed on outcrop surfaces that are parallel to the lineation and perpendicular to the foliation, the augen appear to be asymmetric. Domino structures and Type I S-C fabrics can be viewed on some optimum surfaces. The kinematic indicators are consistent with top toward to the west, low-angle sinistral shear.

Proceeding south across the Snowy Mountain dome, the penetrative foliation in the charnockitic gneiss progressively dips toward the east and then toward the southeast. There are numerous outcrops along Route 30 that can easily be viewed. Where the southeastern spur of Squaw Mountain intersects Route 30, there is exposure of gabbroic gneiss and megacrystic anorthosite. We will not be stopping at this outcrop during this trip due to time constraints. However, this is a good place to view the transitional compositions and deformation fabrics. The megacrystic anorthosite lacks penetrative deformation at this location, but some parts of the outcrop contain dynamically recrystallized anorthosite with well developed S2 foliation. The gabbroic gneiss contains penetrative foliation and well developed lineations at this location.

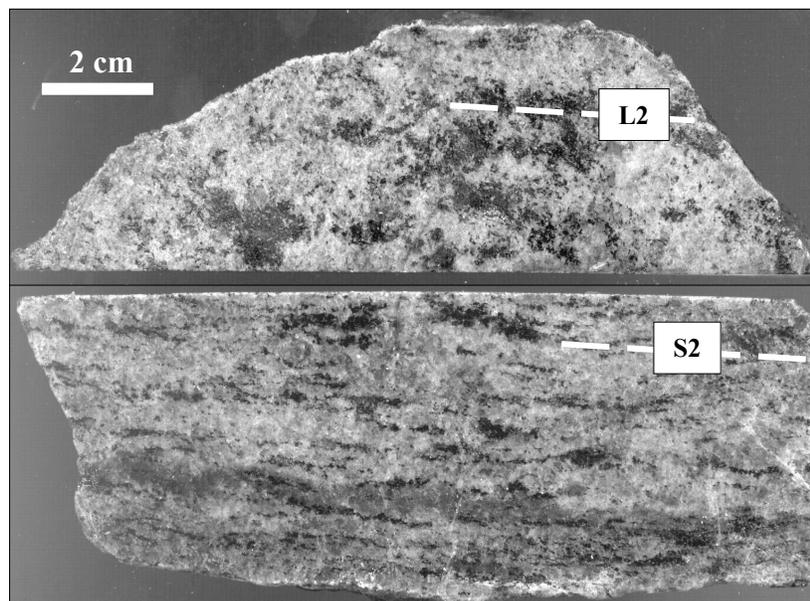


Figure 31. Mutually perpendicular rock slabs of charnockitic gneiss from the northeastern flank of the Snowy Mountain dome. The top slab is cut parallel to the S2 foliation revealing weakly developed mineral lineations. The bottom slab is cut perpendicular to the foliation and parallel to the lineation to reveal the penetrative foliation.

The transition from gabbroic- to charnockitic-gneiss occurs approximately 1000 meters northeast along the Squaw Mountain spur. This transition was documented by DeWaard and Romey (1969). Within the charnockitic gneiss branching high-strain zones can be seen (Figure 32). In places, the high-strain zones merge and have tapered terminations, and close inspection will reveal the penetrative foliation. Compositionally, the rocks in the high-strain zones are identical to the bounding charnockitic gneiss, except for the occurrence of minor quartz veins. The high-strain zones have the same general strike as the location foliation, but typically dip steeper northward in this area. Mineral lineations are better developed in the high-strain zones. Shear sense indicators are consistent with the shear sense indicators observed in the charnockitic gneiss with top toward the west ductile flow, or low-angle sinistral. The high-strain zones contain the same metamorphic minerals as the lower-strain charnockitic gneiss.

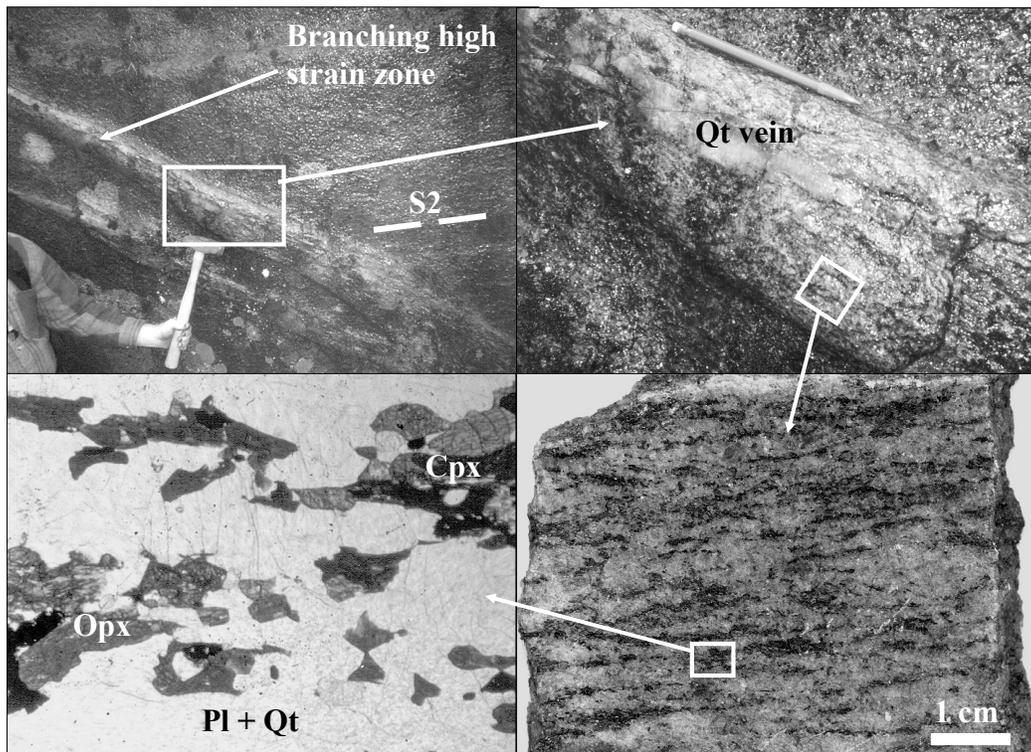


Figure 32. Example of a branching high-strain zone in charnockitic gneiss on the eastern flank of the Snowy Mountain dome in the area of Squaw Mountain.

Mileage:

- 3.5 Continue south on Rt. 30 towards Speculator.
- 5.9 Roadcuts of gabbroic metanorthosite and megacrystic metanorthosite.
- 7.1 Trailhead to Snowy Mountain. Drive slowly for the next mile or so.
- 8.0 Just after Griffith Brook, turn right into a turnout and park for Stop 3.

STOP 3: “Underview” of the Snowy Mountain Dome

From this location the crest of the Snowy Mountain dome can be viewed. Numerous slide faces expose the shallowly dipping foliation that occurs at the top of the dome (Figure 33). The

exposures at the top of Snowy Mountain can be accessed by a hiking trail that occurs about 2 km north of this location. The top of Snowy Mountain is underlain by gabbroic gneiss with penetrative S2 foliation. The foliation dips shallowly toward the north and subhorizontal mineral lineations trend nearly due east. A near vertical outcrop near the top of the mountain reveals abundant shear sense fabrics. Detailed kinematic analysis using porphyroclasts, S-C fabrics and shear bands resulted in dominant shear of top toward the west. However, some domains upward of a few meters thick showed conflicting shear sense of top toward the east. These exposures are the structurally highest part of the dome available.

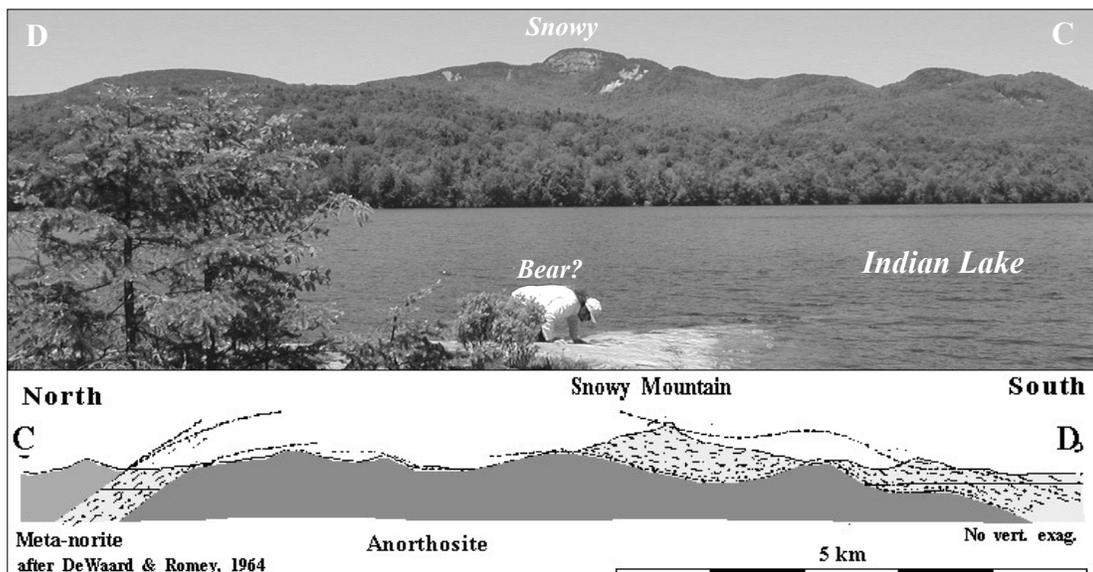
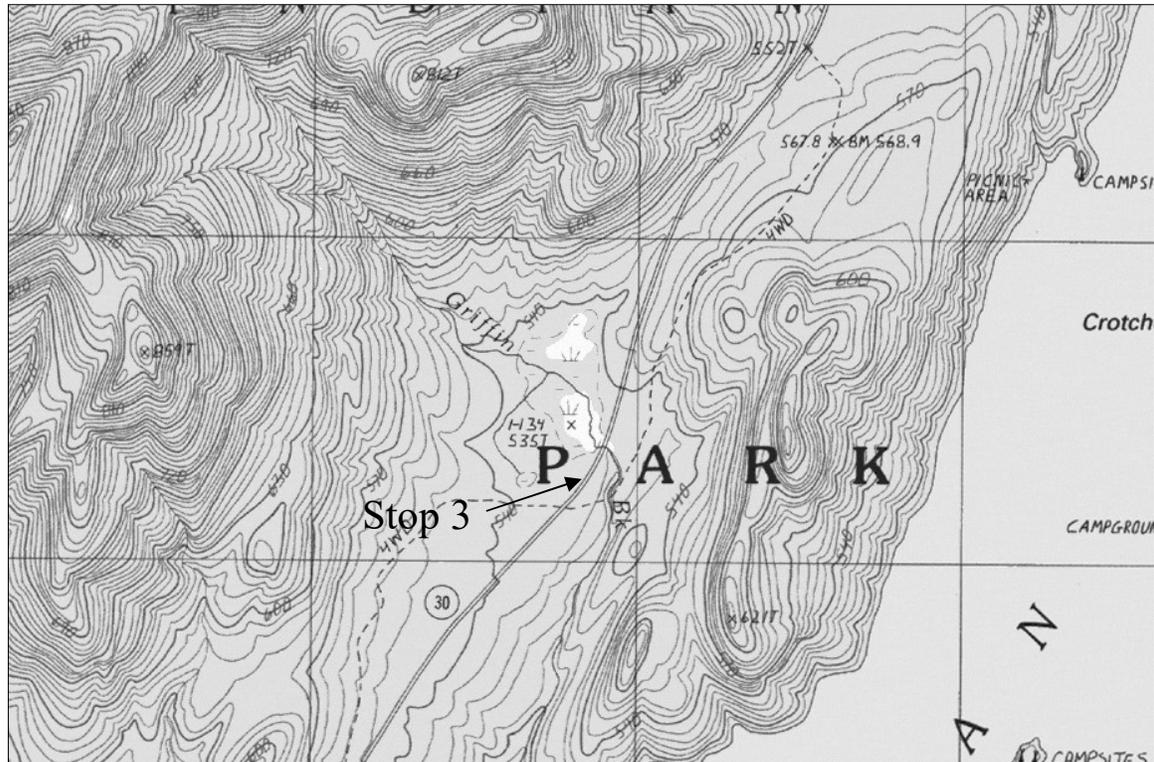
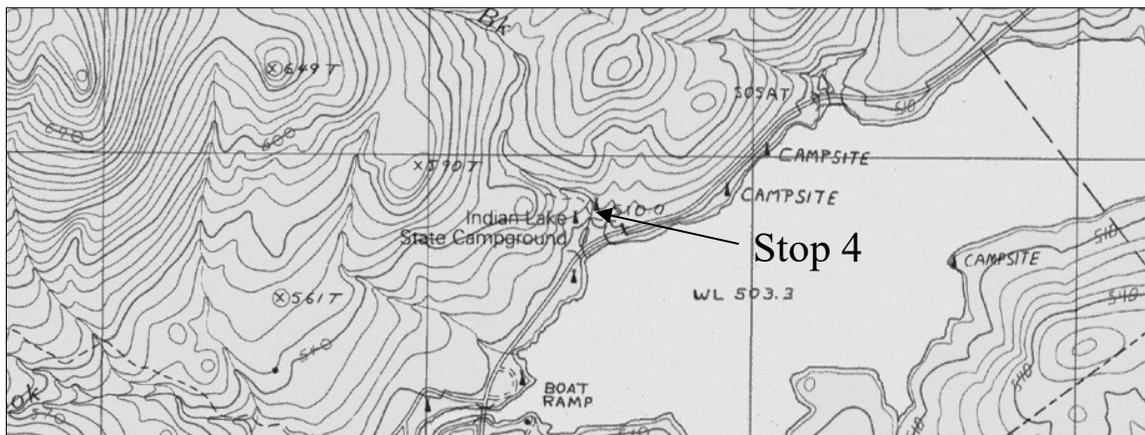


Figure 33. Westward view of Snowy Mountain from the east shore of Indian Lake (top) with the cross section of DeWaard and Romey (1964). The cross section is an eastern view of the area so “C” and “D” are reversed on the photograph. Note that Gary Solar is pretending to be a bear.

Mileage:

- 8.0 Continue south on Rt. 30 towards Speculator.
- 9.2 Access road for Timberlock resort on left.
- 10.5 Sign noting “Entering Camping Area” of Lewey Lake and Indian Lake Campgrounds.
- 11.3 Turn right onto access road for campsites. Drive this road until just into the woods, and park in the wide flat area just before the bridge over Falls Brook. Walk across the bridge and past the metal gate, then plunge into the woods on the right of the access road about 10 meters to the outcrops in the brook that form the falls.



STOP 4: Charnockitic gneiss on the southeast side of the Snowy Mountain Dome

Stop 4 is of highly deformed charnockitic gneiss, the same lithology as Stop 2. However, the penetrative foliation dips moderately toward the southeast due to the position on the Snowy Mountain dome. At this location, and as before, the foliation (S2) is defined by planar aggregates of dynamically recrystallized plagioclase and broken grains of hypersthene and augite, and weak mineral lineations trend shallowly toward the east. Augen of plagioclase have dynamically recrystallized tails often forming asymmetric kinematic indicators. As well, Type I S-C fabrics are well developed in some domains (Figure 34). Unlike Stop 2, the shear sense determined at this location is top toward the east. But, considering the dip is southerly, and mineral lineations trend easterly, the shear sense can be considered low-angle sinistral.

Mileage:

- 11.3 Return to Rt. 30, and continue south towards Speculator.
- 11.9 Lewey Lake on the right.
- 15.8 Intersection with dirt road on right (“Mountain Bike Trail”).
- 16.2 Mason Lake on the right.
- 17.6 Jessup River.
- 18.4 Roadcuts of quartzo-felspathic gneiss with granite dikes on both sides of the road.
- 19.0 Roadcut of calcite-garnet rock on the right, with a rock painted as a pig on the left.
- 21.1 Roadcut of steeply-dipping dextrally sheared rocks on the right.

- 21.3 Intersection with dirt road on right (“Mountain Bike Trail”).
- 22.4 Park on west (right) side of road at the large roadcut for Stop 5A.

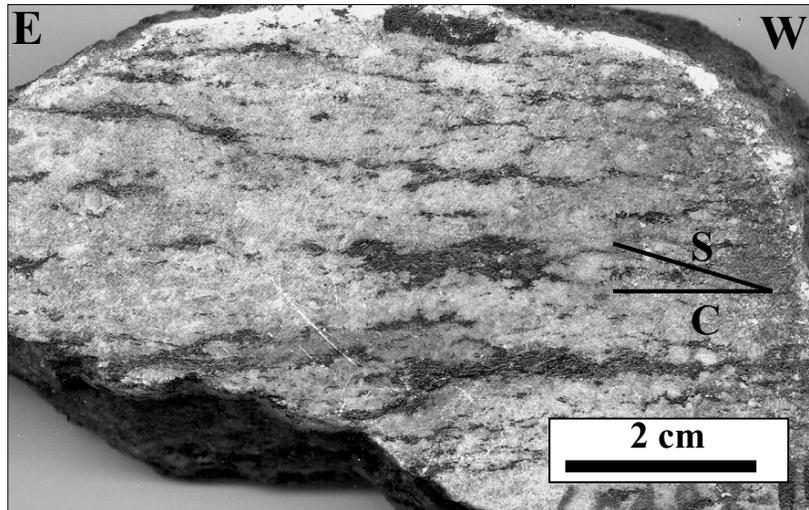
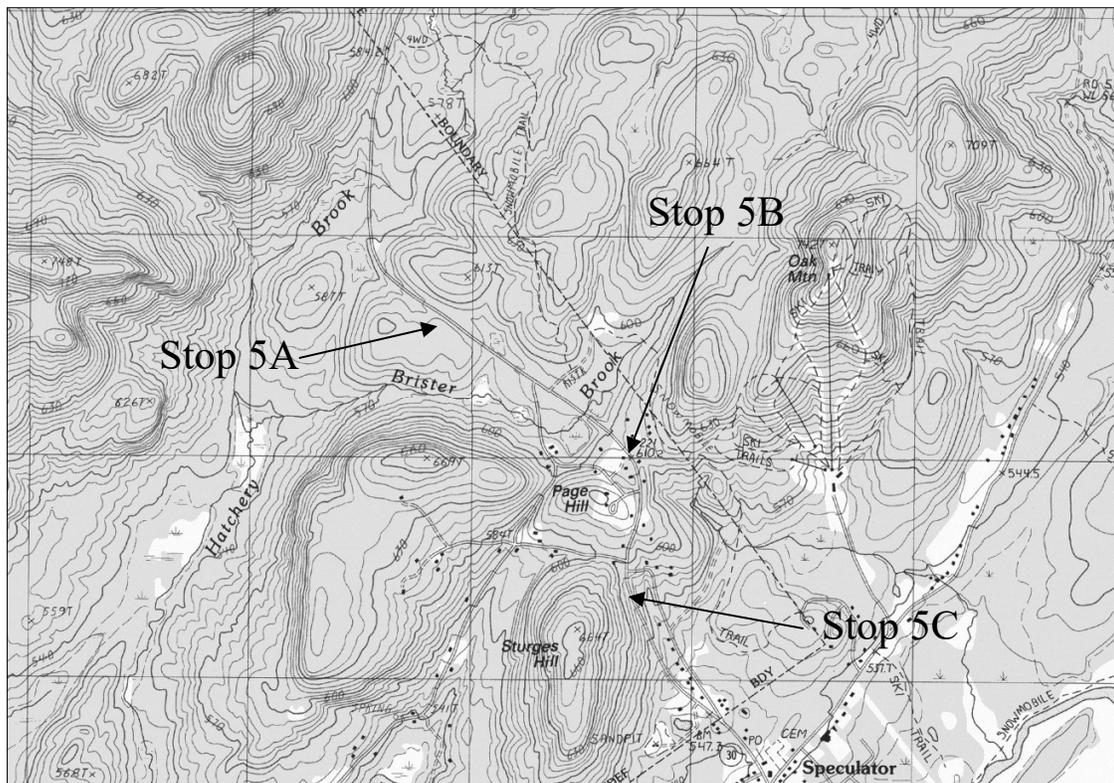


Figure 34. Rock slab of charnockitic gneiss from the falls on Falls Brook with Type I S-C fabric. The shear sense is top toward the east or sinistral. The dark minerals are broken grains of hypersthene and augite, while the lighter portions of the rock consist of recrystallized aggregates of plagioclase and quartz.



STOP 5: Rocks typical of the intervening zone between the SMD to the north and the PLSZ to the south

Rocks of each outcrop for Stop 5 are typical of rocks that occupy the zone between the SMD to the north (STOPS 1 to 4) and the Piseco Lake shear zone to the south (STOPS 6 to 13).

STOP 5A: Garnet amphibolite, calc-silicate rock and quartzo-feldspathic gneiss

Here, these three rock types and their contacts are seen. The northern $\frac{1}{4}$ of the outcrop consists of garnet amphibolite, the next $\sim \frac{1}{4}$ of the outcrop is calc-silicate rock and the southern $\frac{1}{2}$ is fine-grained quartzo-feldspathic gneiss. Complex sheath folds with sub-horizontal tight, isoclinal and sheath folds of foliation and compositional layers dominate the rock, particularly in the gneiss (trend to 110°) (Figure 17). Excellent views of the folds are seen on top of the southern part of the outcrop. The contacts between the rock types are also folded in similar fashion. Matrix minerals define lineations that are E-W and subhorizontal, but are variable in orientation due to folding.

Mileage:

22.4 Continue south on Rt. 30 towards Speculator.

23.0 Park on the right, just after the guard rail, as you ascend the north slope of Burgess Hill (see location map). The outcrop is a roadcut on the east (opposite) side of Rt. 30 just north of the sign for Lake Pleasant.

STOP 5B: Garnet amphibolite and quartzo-feldspathic gneiss

Here the garnet amphibolite and garnet-bearing quartzo-feldspathic rock is in sheared contact. The amphibolite has a distinct foliation and lineation that is folded into shallowly inclined tight folds (N-dipping axial planes) whose axes are shallowly E-W plunging. The lineation in the amphibolite is shallowly plunging to 112° . The fabric in the quartzo-feldspathic rock is distinct in contrast to the amphibolite, showing a penetrative L>>S tectonite fabric whose lineation plunges shallowly to 112° . The L>>S fabric is defined by both rods of quartz and quartz aggregates, and by tails around garnet. The highly fractured nature of the outcrop offers excellent views of this fabric. The contact between the rock types is distinct due to the color difference, but also because the amphibolite is boudinaged (foliation boudinage) due to apparent contact-parallel shear. The inter-boudin partitions are in-filled by plagioclase and amphibole (Figure 35).

Mileage:

23.0 Continue south on Rt. 30 towards Speculator.

23.2 Top of the hill (garnet amphibolite roadcuts on both sides of the road).

23.4 Park on the right side of the road just south of the intersection, and walk to the top of the large roadcut for southerly views of Lake Pleasant and Speculator Mountain, and the PLSZ.

STOP 5C: Overlook of Speculator Mountain, and the PLSZ

The rock here is sub-horizontally stratified, with the rock at the top of the hill to the north (garnet amphibolite) the lowest stratum, and the base of the outcrop is interlayered amphibolite and granitic gneiss, followed by granitic gneiss with mica 'mats' at the top (at the viewing area). Foliation is sub-horizontal here, but, again, the mineral lineation is shallowly E- and W-plunging.

The view to Speculator Mountain illustrates the structure of the late history of the PLSZ. The bench on the east side of the mountain is the top of the hanging wall block of a moderately W-dipping normal fault, and the peak of Speculator Mountain is the hanging wall block. This normal fault is defined by fabric with a distinct top-down fabric trajectory, and defines the zone to be about 100 m thick. This is one of many normal shear zones that cut the E-W fabric that defines the PLSZ, but this one is perhaps the thickest. Most identified are a few centimeters thick (as in Figure 18).



Figure 35. Pavement view of top surface of rock at Stop 5B showing the foliation boudinage in the amphibolite (bottom) and the penetratively strong fabric in the quartzo-feldspathic rock (top).

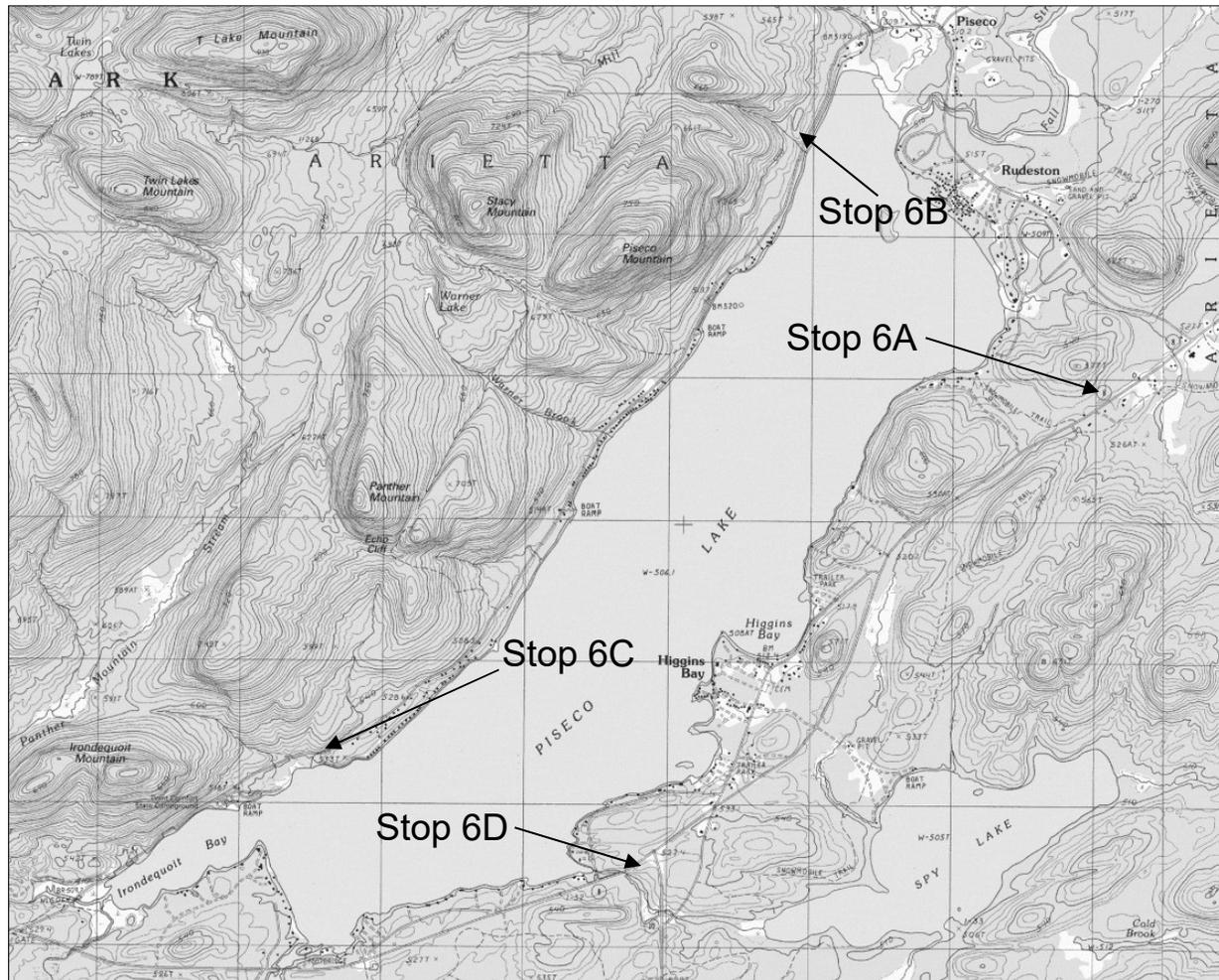
Mileage:

- 23.4 Continue south into Speculator.
- 24.1 Turn right (west) onto Rt. 8.
- 26.1 First roadcut on right is highly lineated gneiss in the margin of the PLSz.
- 27.1 Lake Pleasant
- 27.5 Lake Pleasant town center.
- 33.0 Intersection with Old Piseco Road in Piseco, NY.
- 34.0 Park on right side of the road at the low roadcut for Stop 6.

STOP 6A-D: L-S and L>S fabrics in the Piseco dome.

The Piseco Lake zone consists of the northern dome that merges with a steeply dipping shear zones to the south. This series of field stops shows variations in the attitude and type of fabrics that occur in the core of the dome. Stops 6A to 6D are a driving traverse around Piseco Lake, the type location of the Piseco antiform. At all of these localities, dynamically recrystallized feldspars and quartz form spectacular ribbon- and rod-shaped mineral lineations (McLelland, 1984), in addition to mafic phases such as biotite, chlorite and accessory magnetite. In many places, the alignment of

ribbons forms the foliation in this outcrop. Individual quartz-ribbons have aspect ratios upward of 60:1. At Stop 6A, the foliation is weakly to moderately developed, and dips shallowly southward at the eastern part of the outcrop (Figure 36), but is steeply dipping at the western end of the outcrop. The transition between these different foliation attitudes is difficult to determine because the intensity of the foliation is variable. Lineations are penetrative on all scales, and consistent in attitude (Trend: 110° ; Plunge: 05°). Stop 6A occurs on the southern flank of the map-scale dome portion of the Piseco antiform. At the western end of the outcrop there are rods of amphibolite (10-30 cm diameter) within the granitic gneiss.



There is an apparent Cenozoic fault that traces down the western side of Piseco Lake and has locally displaced parts of the Piseco dome (Figures 13 and 14). At Stop 6B, again the foliation is weakly developed with a penetrative shallowly plunging lineation. However, the foliation, where it can be observed, dips northerly. As you drive southwest along the western side of Piseco Lake, note that the foliation gradually shallows and then dips southerly. There are several outcrops that can be observed where this transition in foliation attitude occurs. The rock fabrics at Stop 6C are similar to those at Stops 6A and 6B, but again the variably developed foliation dips toward the south. Stop 6D is located at the intersection of Rts. 8 and 10, and the foliation and lineation is penetrative.

Common to all of these field stops is that both biotite and chlorite blades form microscopic lineations and foliation parallel to the macroscopic structure. Rare grains of hypersthene have been found, but they always have well developed overgrowth textures that include biotite and chlorite. The biotite and chlorite are the most abundant index minerals in the granitic gneiss, and suggest the deformation was last active under low- to moderate- metamorphic conditions, although probably began at much higher conditions to account for the relict grains of hypersthene.



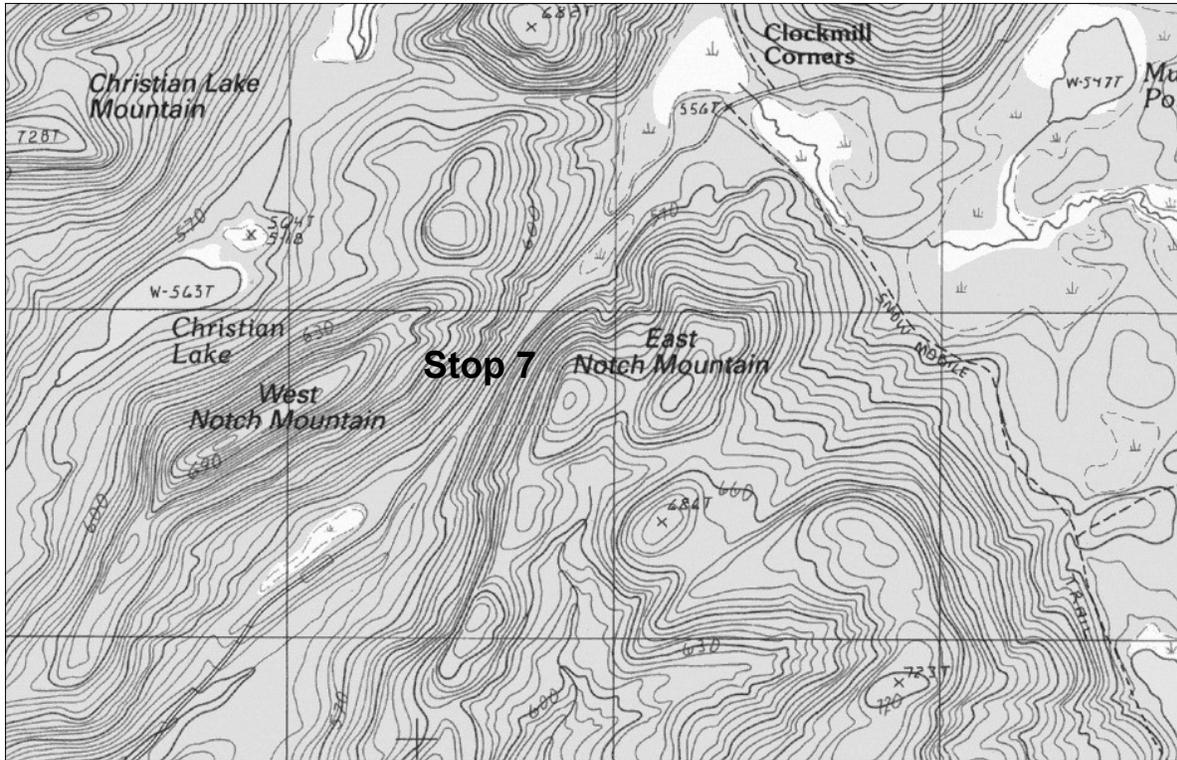
Figure 36. Pavement exposure of granitic gneiss with penetrative mineral elongation lineations defined by quartz ribbons and aggregates of dynamically recrystallized feldspar. The view is looking toward the west.

Mileage:

- 34.0 Turn around and proceed east on Rt. 8 about 0.5 mile. west on Rt. 8.
- 34.5 Turn north and follow the road around Piseco Lake to Stops 6B and 6C.
- 42.4 At the intersection with Rt. 8, turn east and proceed about 2.9 miles.
- 45.3 Turn south onto Rt. 10 and park for Stop 6D. Proceed south on Rt. 10 about 1.2 miles.
- 46.5 Turn west onto Powley Road (becomes a gravel road) and continue 4.9 miles.
- 51.4 Park where Powley Road traverses through the Notch.

STOPS 7: Steeply dipping mylonite zone of the southern PLsz

Along Powley Road, there are a sub-continuous series of pavement exposures located in the road bed, and in the gutter on the east (northeast-bound) side of the road. Due to the nature of this location, the extent of the exposed rock at this stop changes daily, so some or all of the rock described here may be viewable depending upon the time of the season in which the stop is visited (best later in the season). The best exposures occur along the road between West and East Notch Mountains.



All rocks in this region are very similar in mineral content, and vary only in detail with regard to mineral percentage and fabric type and intensity. The rock is dominantly granitic gneiss with intense subhorizontal to shallowly plunging mineral elongation lineation that trends on average about 095° , with steeply dipping generally east-west striking foliation. Both fabric elements are defined by ribbons of quartz, and ribbons of aggregate feldspar and quartz (generally 1-5 cm long depending upon grain size). Intensity of the fabric varies across strike at the 50 cm scale, with local layers of significantly coarser-grained fabrics (grains up to 1 cm in diameter). There are also places where the foliation intensity varies as seen at the field stops around Piseco Lake. Rare amphibolite bodies that are 10's of cm thick occur within the granitic gneiss (Figure 37). Shear sense indicators are abundant in the granitic rocks and consistently show sinistral shear sense (Figure 11).

Mileage:

57.4 Continue south on Powley Road about 6 miles and park.

STOP 8: Southern extent of steeply dipping mylonite

Here the granitic gneiss fabrics contain both a penetrative foliation and lineation. The foliation is steeply dipping and strikes about east-west. Mineral elongation lineation defined by linear aggregates of quartz and feldspar are subhorizontal. The extent of readily available bedrock exposure diminishes south of this location, so this may be the southern-most exposure of the Piseco Lake shear zone. Note that this location is about 21 kilometers across strike from the northern side of the Piseco dome where the pronounced lineation occurs.

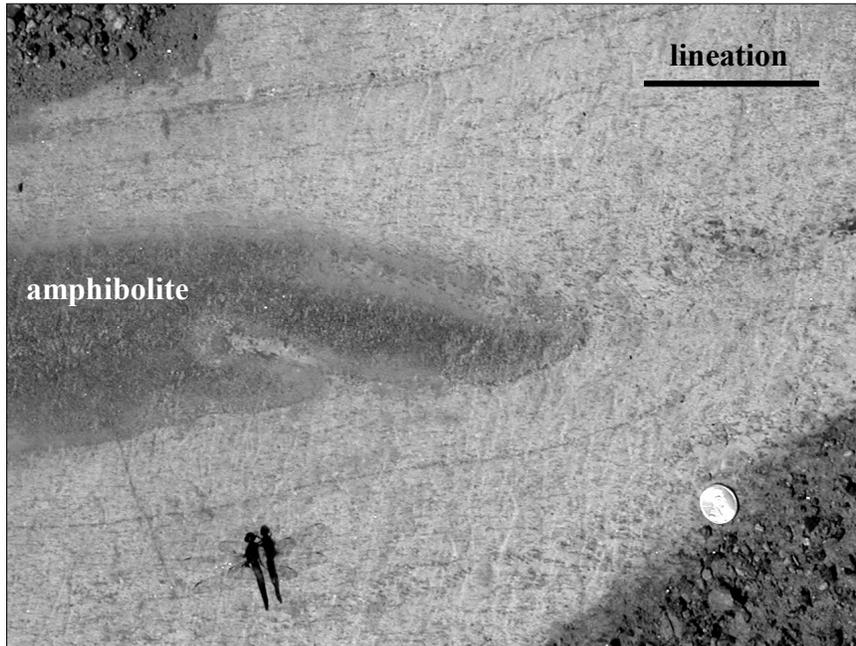
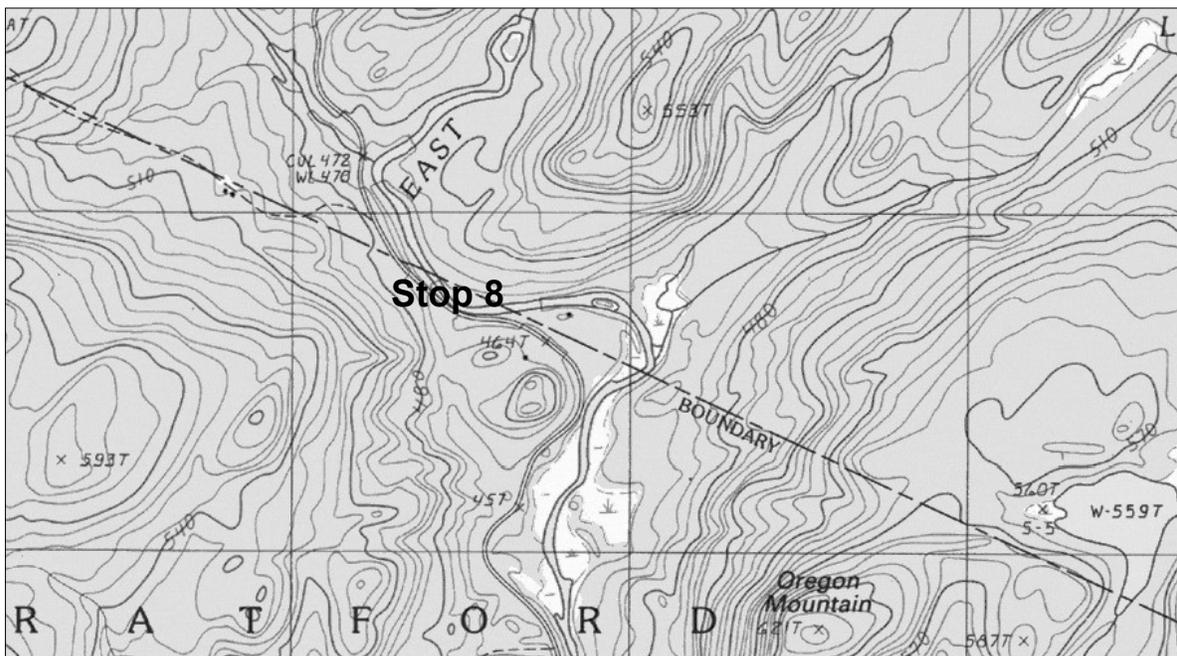


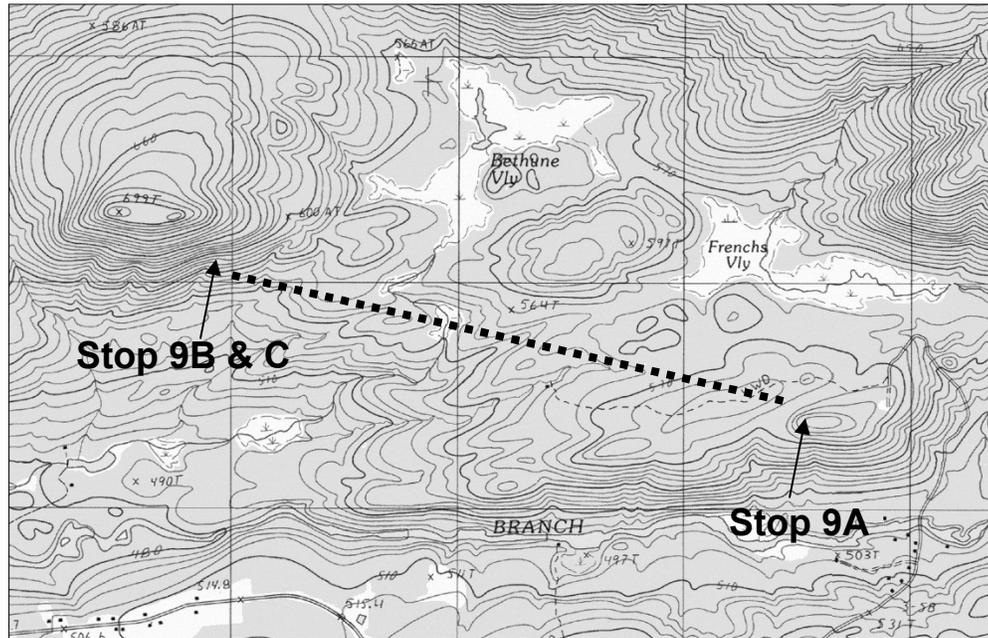
Figure 37. Pavement outcrop from the bed of Powley Road. Top is north. Note the apparent deflection of the fabric and difference in texture of the quartzo-feldspathic gneiss where it forms a ‘tail’ at the ‘nose’ of the ‘shark’-shaped amphibolite lens.



Mileage:

- 68.3 Turn around and proceed back to the intersection of Powley Road and Rt. 10, and park.
- 69.5 Continue north on Rt. 10 about 1.2 miles to the intersection with Rt. 8.
- 81.6 Turn west onto Rt. 8 and drive 12.1 miles to Moorehouseville.

83.2 Turn north onto Fayle Road, proceed north. Cross a one lane wood bridge and drive to an opening in the trees at the end of Fayle Road. Park and hike to the west about 350 meters.



STOP 9: L>>S and L-tectonite in the core of the Piseco antiform

Excellent outcrops on the northern side of a small hill just west 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 38). 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.

Stops 9B and 9C require about 2.5 kilometers of traverse at a bearing of about 280°. 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 YOUR GROUP.

Stop 9B there is an outcrop of 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 9C.

Stop 9C is a spectacular L-tectonite (Figure 39) that occurs in a cigar-shaped domain that appears on the geology map of Figure 15. 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.

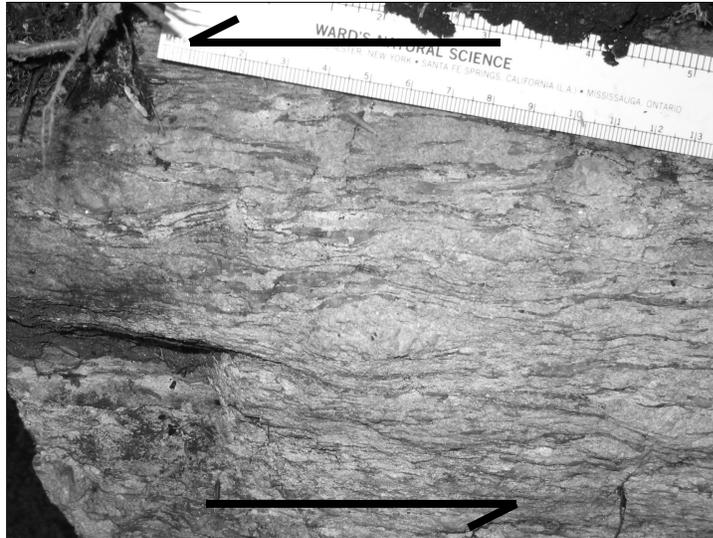


Figure 38. The view is south at Stop 9, and looking at a surface parallel to lineation and perpendicular to foliation. Large porphyroclasts of K-feldspar and have σ -type tails which display left lateral shear sense.

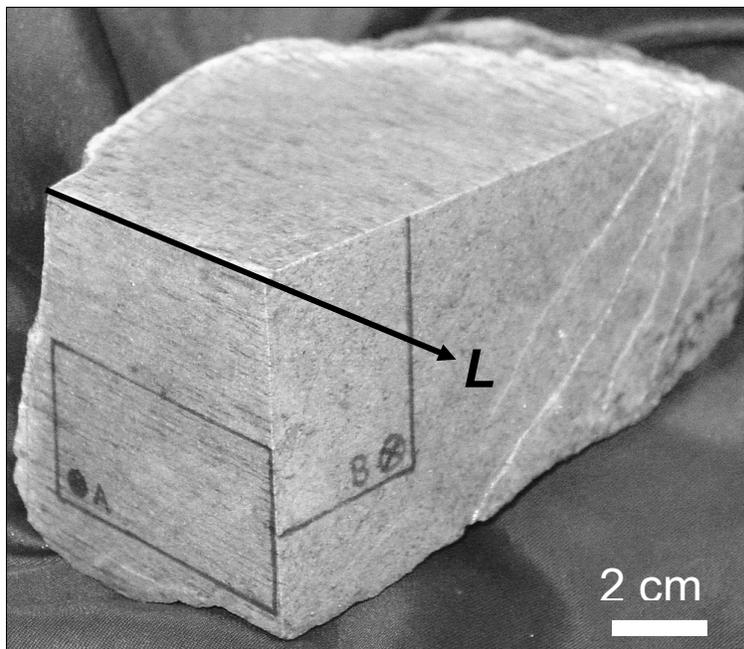
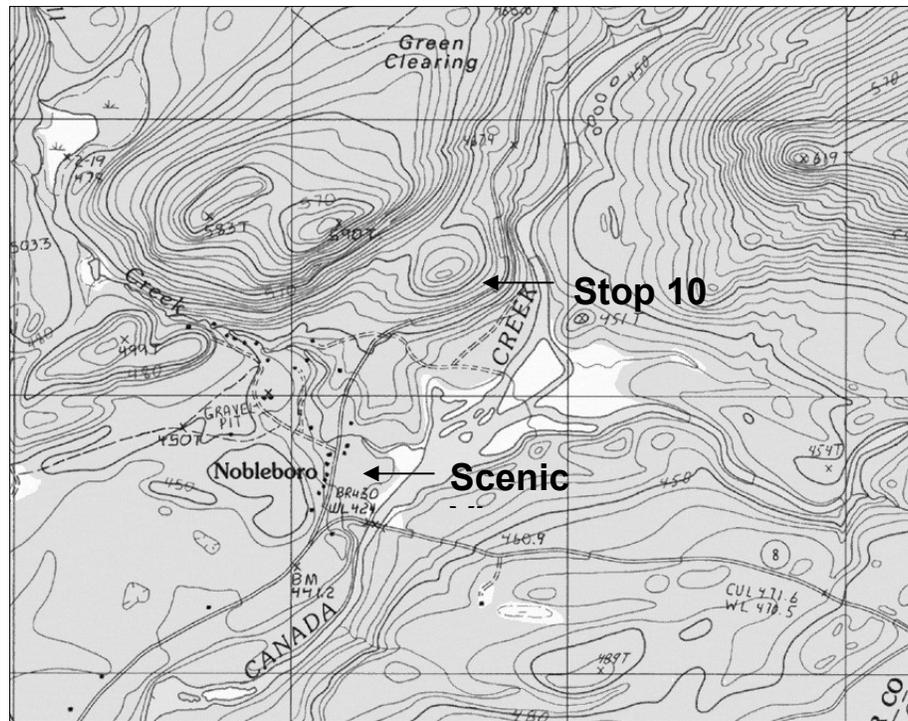


Figure 39. This photo was taken of sample from Stop 9C. Quartz rods and recrystallized aggregates of K-feldspar define the linear fabric. Dark minerals are primarily chlorite and biotite.

Mileage:

- 84.8 Return to Rt. 8 on Fayle Road.
- 89.8 Turn west on Rt. 8 and drive about 4.9 miles to Haskel Road on the right.
- 90.4 Proceed north on Haskel Road about 0.6 miles to an abandoned quarry on the left.



STOP 10. Northern limit of Piseco zone fabrics: granitic gneiss with well developed gneissocity

Exposures of coarse granitic gneiss with well developed gneissocity can be seen in the high-wall of this old quarry. This stop demonstrates S>L fabric, lination area weakly developed and foliation dominates. (Figure 40). 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.

Mileage:

93.3 Proceed north on Haskel Road.

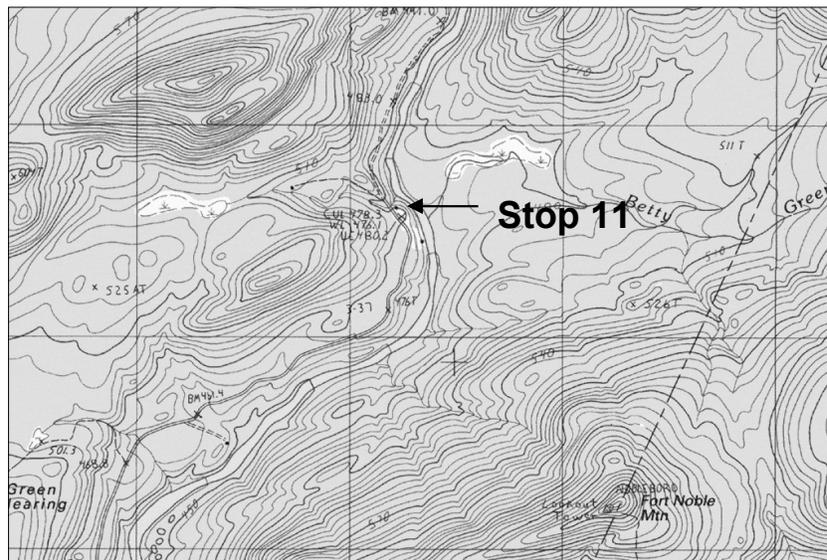
Arrive at a clearing, before bridge and gate turn right and park in grass. Walk east down a small hill to the West Canada Creek.

STOP 11. L-S and S>L Dioritic Gneiss

The southern most part of the outcrop demonstrates L-S fabric. 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 15 cm of displacement and boudins are also preserved at the northern end of the outcrop. 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 40. Photograph, view is looking north, of granitic gneiss with well developed foliation and gneissosity. K-feldspar bands define the gneissic texture. Lineations can be observed with closer inspection and are parallel to the mechanical pencil in the center of the photograph.



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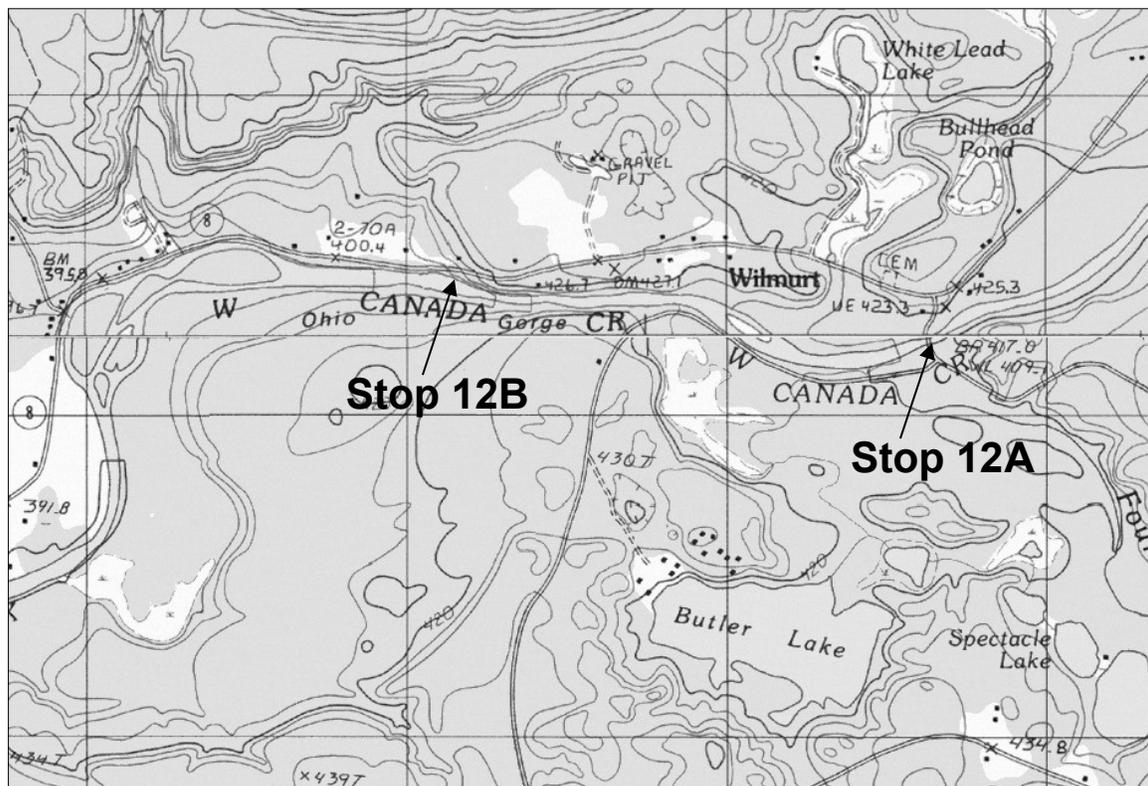
- 96.6 Proceed south on Haskel Road to the intersection with Rt. 8.
- 99.2 Turn west on Rt. 8 and proceed to the intersection with Gray Wilmurt Road on the left. Turn south onto Gray Wilmurt Road just after a sharp right-hand curve in Rt. 8. Cross a bridge over the West Canada Creek and park at the intersection with Jones Road. Walk back toward the bridge over West Canada Creek and down the hill to the outcrop just east (upstream) of the bridge (see location map). The outcrop forms a small water fall on the creek. This is private property, so make sure to get permission from the land owner.

STOP 12: The PLSZ at the Ohio Gorge of 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 Wilmurt. The last stops for this field trip are in highly deformed granitic gneiss in the gorge. During periods of high water, the exposures at the eastern and western end of the gorge may be covered or not easily accessed. Permission is needed from the landowner at Stops 12A and 12B.

STOP 12A: East of the 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 21). 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 PLSz foliation and lineation (Figure 18). Shear sense is top down to the west or normal. The other high strain zones both contain evidence for oblique sinistral shear.



Mileage:

99.4 From the parking area, turn around and back track to Rt. 8 and turn west.

100.6 Park on the right shoulder just after a steep downhill drive. Walk upstream along West Canada Creek to the first bedrock exposures for the westernmost outcrops in the Ohio Gorge. If the water level is high, it may not be possible to view this outcrop.

STOP 12B: Western limit of the outcrop belt in the Ohio Gorge

At this location the north dipping foliation of the Piseco antiform can be viewed in addition to the typical variation in L-S and L>S fabrics at the outcrop scale. Again, the foliation is defined by planar aggregates of dynamically recrystallized feldspars and quartz. Quartz also occurs in greatly attenuated ribbons, as seen at other locations during this field trip. Of particular interest at this location, are abundant kinematic indicators that are easily observed. Outcrop surfaces that are perpendicular to the foliation and parallel to the lineation reveal asymmetric augen of K-feldspar and plagioclase forming both σ - and δ -type shear sense indicators (Figure 41) with most showing top toward the west displacement. Since the mineral lineations are subhorizontal, the shear sense is considered to be low-angle sinistral at this location. The abundant large (cm-size) porphyroclasts of feldspar provide some information about the protolith for the PLsz rocks in this region. The relict grains are most likely the remains of megacrysts from an original granite.

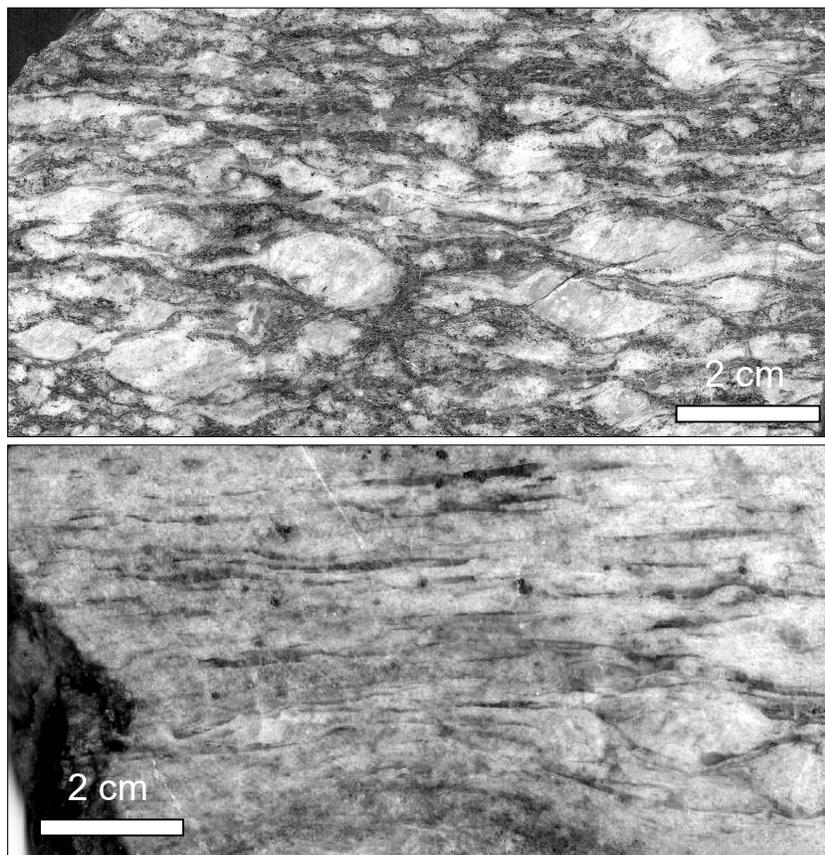


Figure 41. Rock slabs of granitic mylonite from the Piseco Lake zone. The view is into the ground at surfaces cut perpendicular to the foliation and parallel to the lineation. Note the abundant sinistral shear sense indicators developed on the feldspar grains.

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