TRIP A1

PRECAMBRIAN GEOLOGY OF THE NORTHWEST ADIRONDACK LOWLANDS: A STRATIGRAPHIC VIEWPOINT

WILLIAM F. DELORRAINE
Geology Department
Zinc Corporation of America
Balmat, NY 13609

and

JAMES D. CARL
Geology Department
State University of New York
College at Potsdam
Potsdam, NY 13676

INTRODUCTION

The idea of widespread preservation of a coherent stratigraphic sequence in middle Proterozoic rocks in the Adirondack Lowlands has been challenged from several standpoints. Workers in the Adirondack Highlands, and elsewhere in high grade Grenville terrane, have drawn attention to the extent of tectonic realignment that has accompanied folding, ductile deformation and metamorphism. Rock units that were originally discordant have been swept into into parallelism to form "straight gneisses" that resemble a layered sequence. Sequences of metasedimentary rocks have been obscured by the size, volume and frequency of igneous intrusions. Contacts between intrusive and sedimentary rocks have been obliterated by tectonism, the acquisition of gneissic foliation and by metamorphic differentiation. Further complications are introduced where lithologic units have been disturbed or cut out by faulting, and where slivers of much older rocks have been thrusted into the terrane. Thrusting and stacking of crustal segments from southeast to northwest is proposed to have occurred in large parts of Grenville terrane in Canada (Davidson, 1986). For a general review of field and textural criteria used to recognize intense deformation and tectonic realignment, see the summary by Passchier and others (1990).

The Adirondack Lowlands consist chiefly of recognizable metasedimentary rocks and extensive units of fine grained gneisses whose protoliths are a matter of controversy. Metaintrusive rocks here constitute a much smaller proportion of outcrops than in the Adirondack Highlands, and the intrusive bodies are generally smaller in size. Ductile deformation has been extensive in some rock types, particularly the marbles (now annealed?), Hyde School Gneiss and the Huckleberry Mountain granitic gneisses (Tewksbury and others, 1993, and this guidebook). Nonetheless, primary features have been preserved that include stromatolites in carbonates and cross bedding in quartzites. Dikes, apophyses, aplite veins, pegmatites and phenocrysts are preserved in certain metaintrusive bodies. Highly ptygmatic and cross cutting migmatite veins have not been realigned to parallelism in Popple Hill Gneiss, and rocks in some of the fault panels mapped by Brown (1989) preserve a stratigraphic succession comparable with that elsewhere. The case for pervasive tectonic realignment that mimics, but does not represent, a true stratigraphic succession must be demonstrated for local areas in the Lowlands.

Stratigraphic principles are applicable where widespread rock units are shown to be older than the metaigneous rocks that intrude them. Zircons from the widely distributed Popple Hill Gneiss, portions of which are regarded as metavolcanic by Carl (1988), have a U-Pb age of 1214 +/- 21 Ma (Carl and Sinha, 1992) and a whole rock Rb-Sr age of 1297 +/- 41 Ma (Grant and others, 1984). Zircons from another possible metavolcanic unit, the Hyde School Gneiss, range in age from 1219 +/- 52 Ma to 1284 +/- 7 Ma, but ages of 1236 +/- 6 Ma and 1230 +/- 30 Ma for unzoned zircons from two of the bodies have been considered representative (McLelland and others, 1992). Intrusive rocks in the Lowlands generally fall into the range of 1170-1130 Ma as is the case for anorthosite, mangerite, charnockite and granite members of the AMCG intrusive series in the Highlands (McLelland, 1986).

The above remarks are made in the aftermath of a large number (more than 40!) of published U-Pb zircon ages (McLelland and others, 1988; McLelland and Chiarenzelli, 1990; 1991; Chiarenzelli and McLelland, 1991; McLelland and others, 1992) which have had great influence on the understanding of Adirondack geology, particularly in the Highlands. The paper by McLelland and others (1992) on a major Lowland rock type, the Hyde School Gneiss, is of concern because it proposes to overturn a set of stratigraphic conclusions established over decades of field mapping and mining exploration. Hyde School Gneiss, long regarded as a basal stratigraphic unit throughout the Lowlands, is now proposed to be an intrusive igneous rock with no stratigraphic significance. The possibility that metavolcanic rocks could constitute a large proportion of Adirondack rock types is relegated to the backwater of "phase II" in a three-phase summary of the history of Adirondack conceptual schemes (McLelland, 1991). That argument is the subject of a field trip to be held on the weekend following the 1993 NYSGA meeting. Interested readers can obtain copies of the guidebook from the organization known as Friends of the Grenville (FOG, which does not necessarily reflect the state of mind of its members). For the Lowlands and for this guidebook, we plan to "dress up" the corpse of "phase II" which is characterized by paradigms of stratigraphy and stratigraphic correlation. We address some of the issues in the field stops described below.

REGIONAL STRATIGRAPHY

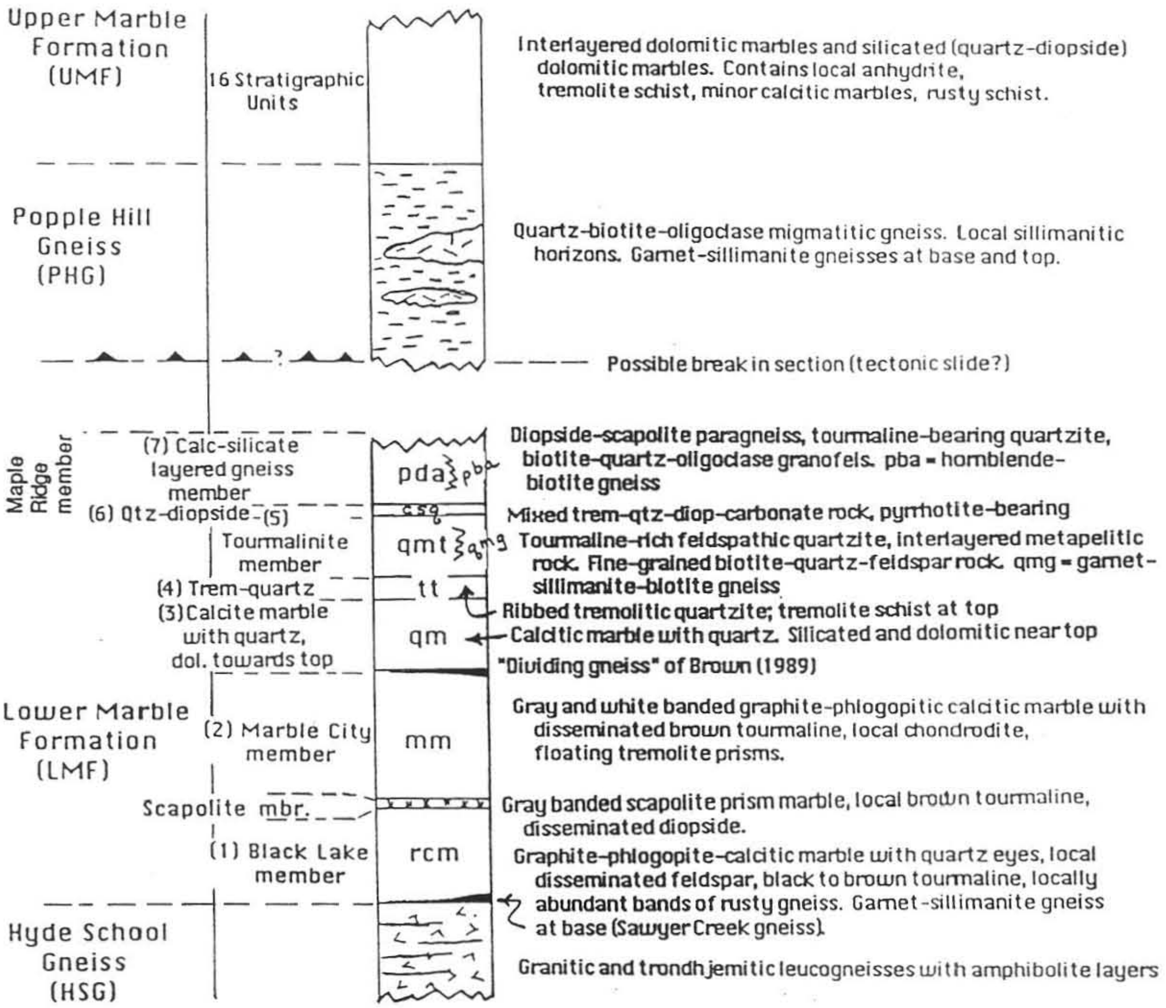
The Adirondack Lowlands represents an extension of the Canadian Grenville Province into New York State, beginning at the eastern end of Lake Ontario. The Lowlands are part of the Frontenac Axis terrane of the Central Metasedimentary belt. They are separated from the Central Granulite terrane of the Adirondack Highlands by the Carthage-Colton Mylonite Zone (also described in the 1993 FOG guidebook) and are underlain by a succession of 1.2-1.3 Ga-old platformal, chiefly carbonate metasedimentary and metavolcanic rocks that reached upper amphibolite facies metamorphism.

Four lithostratigraphic units or formations (Fig. 1) have been proposed to underlie the Lowlands (deLorraine and Carl, 1986; Carl and others, 1990). A geological fold-out map of the Lowlands (Fig. 2) utilizing the four formations will be distributed to those attending the field trip, and copies can be obtained by writing deLorraine. Whether these units constitute a lithotectonic stacking sequence or a true stratigraphic sequence is subject to scrutiny, but the continuity of the units across the Lowlands, their usefulness as a predictive tool, and the compatibility of the sense of tops with structural and geochronological data suggest that a stratigraphic model is indeed viable. Detailed mapping at scales of 1:2400 and 1:4800 has been used in local areas to determine structural relationships and to construct an idealized stratigraphic column for the region. Correlation among stratigraphic columns produced for the Lowlands is shown in Fig. 3, and an idealized NW-SE geologic section across the Lowlands is shown in Fig. 4. Note that rock units high in the section occur only in the southern and central parts of the Lowlands.

The four formations include the Hyde School Gneiss, a complex of basal leucogneisses with thin, concordant amphibolite layers (Fig. 1). The rocks are followed up section by the Lower Marble formation, Popple Hill Gneiss and by Upper Marble formation. Lower Marble formation is subdivided into members that have great lateral continuity and distinctive composition. The formation is dominated by graphitic-phlogopitic-calcitic marbles with disseminated brown to black tourmaline, whereas Upper Marble formation consists of 16 dolomitic and silicated dolomitic members that are lacking in tourmaline. The intervening Popple Hill Gneiss is a thick and variably migmatitic unit of dacitic composition that lies in apparent tectonic contact with the underlying Lower Marble formation.

We have subdivided and described members of the Lower Marble formation (Fig. 1) for several reasons. First, the structural interpretation of a highly deformed terrane with intricate map patterns necessarily begins with a reconstruction of the layering or stratigraphy of the map area. Second, the extent of *apparent* stratigraphic control on the distribution of Hyde School Gneiss needs to be evaluated through map pattern analysis. Third, very detailed geologic maps are necessary to determine the location of regional thrust faults, tectonic slides and other faults. Stratigraphic control provided by geological mapping also places constraints on the location of potential suture zones. The concept of amalgamation of microterranes along cryptic suture zones is an active area of discussion in the Lowlands, particularly in view of the discovery of a 1416 +/- 6 Ma-old leucogneiss dike on Wellesley Island by McLelland and others (1988; 1992). Lithologic successions on either side of postulated suture zones must be understood in some detail before accessments can be made.

We briefly describe the subdivisions of the Lower Marble formation because it is the most widespread formation in the Lowlands and because it directly overlies the Hyde School



Preliminary: errors and/or omissions attributable to deLorraine

Figure 1 Idealized stratigraphic column for the Northwest Adirondack Mountains, New York

Gneiss. Identical lithologies are present to the northeast in Canada and to the southeast in the Adirondack Highlands, and correlation with these areas may be possible.

STRATIGRAPHY OF LOWER MARBLE FORMATION

The basal or Black Lake member of Lower Marble formation occupies most of the terrane northwest of the Beaver Creek lineament (Figs. 2, 3) where the member appears to be much thicker than east of the lineament. The member consists of rusty graphite-phlogopite-calcite marbles with rusty gneiss bands and intercalated quartzite horizons. Coarse grained, homogeneous calcitic marble and massive diopside rock are also present. Accessory minerals include disseminated feldspar and brown to black tourmaline. Disseminated green granular diopside is common in the marble, as are quartz "eyes." Upsection are distinctive marker horizons that include a scapolite prism marble, a magnesian marble referred to as the Marble City member (Fig. 1), and a ribbed quartzite with tremolite partings. The quartzite is overlain by a tourmalinite-quartzite-biotite schist member that may constitute a unique marker horizon (Brown and Ayuso, 1985). At the top of Lower Marble formation is the Maple Ridge member that is composed of calc-silicate gneisses that may be in structural contact with the overlying Popple Hill Gneiss.

Each body of Hyde School Gneiss in the Lowlands is surrounded and overlain by the Black Lake member of Lower Marble formation (Fig. 2). Subdivisions of Lower Marble formation were first elucidated by Brown (1989; 1978; 1969) who worked out the section in the North Gouverneur area. That section was found to have excellent predictive value elsewhere and was expanded by deLorraine to produce an idealized column (Fig. 1).

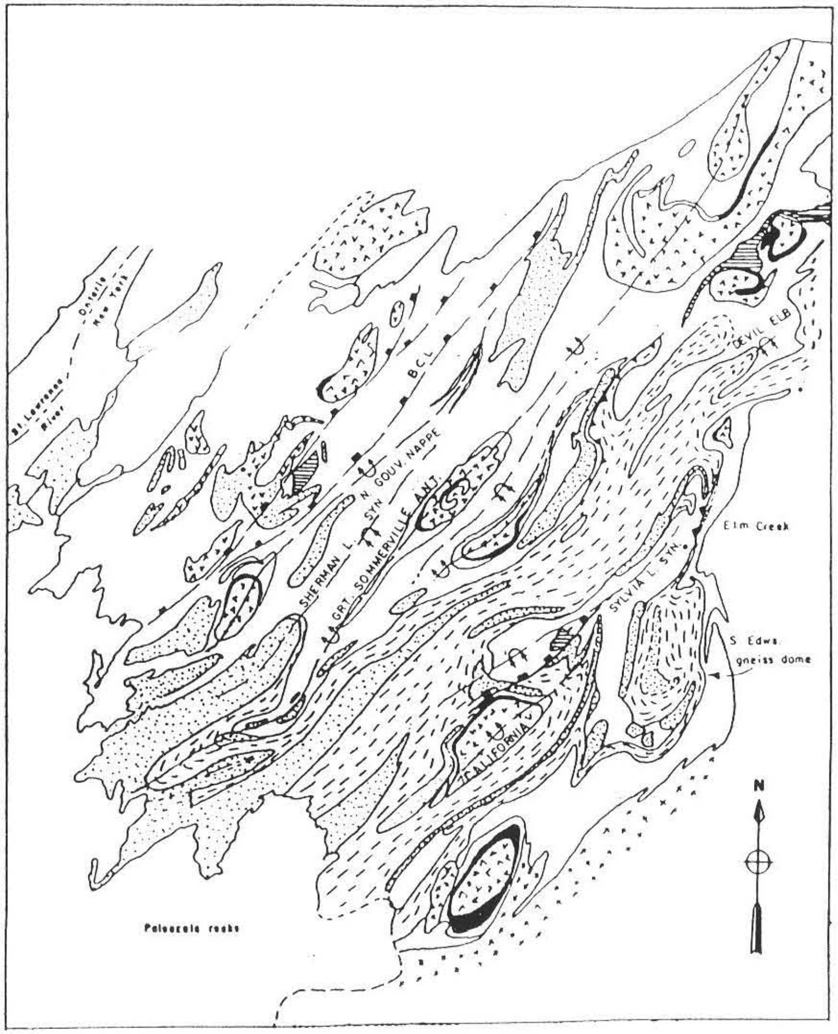
STRUCTURAL GEOLOGY

Folding

At least four phases of deformation have been proposed for the Adirondack Lowlands (Brown, 1971; Brocoum, 1971; Foose, 1974; Foose and Carl, 1977; deLorraine, 1979; Wiener, 1981; Guzowski, 1979; Weiner and others, 1984). The earliest recognized phase of deformation occurred at a high metamorphic grade to produce isoclinal folds with axial planar foliation that defines the prominent regional foliation. No unequivocal major early folds are known, and minor folds are rare. Some regionally extensive mylonites are deformed by second phase folds and are interpreted as refolded, early-phase tectonic slide surfaces.

Second phase folds are isoclinal in style and moderately to strongly overturned to the southeast. They deform early axial planar foliations and have curvilinear hinges that "porpoise" within their axial surfaces. Axial surface traces trend NE-SW to define the prominent regional grain. These have been described as sheath folds (deLorraine and Carl, 1986; deLorraine in Bohlen and others, 1989; Tewksbury and others, 1993). Good examples of second phase isoclinal sheath folds include the Sylvia Lake syncline (Fig. 2) that hosts the

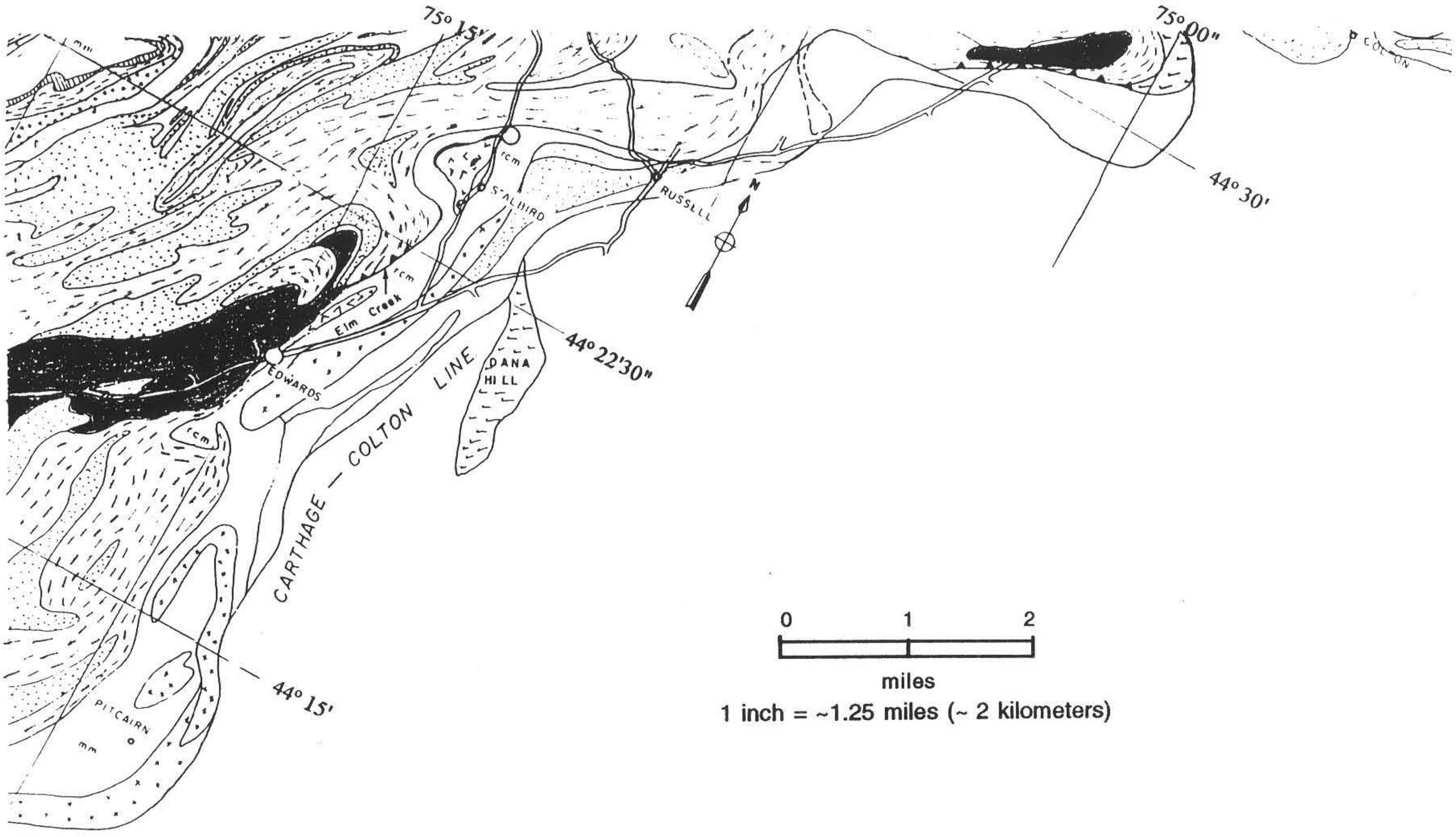
▲	Antwerp – Rossie granitoids
✓ ✓	Amphibolite – metagabbro
⁘	Hermon and other granites
x x	Syenite
■	Upper Marble
∽	Popple Hill Gneiss
- -	5, 6, 7. Udif. px. calc-silicate; biot; tour. gneisses
▨	Tremolitic quartzite
mm	Bndd magnesian mbl, "Marble City" mbr.
rcm	Rusty cal mbl, "Black Lake" mbr
■	Sill – garnet gneiss "Sawyer Creek gneiss"
^ v ?	Hyde School Gneiss




75° 30'
44° 30'
44° 22'30"
75° 45'
44° 15'
FISH CREEK
12
HICKORY LAKE
EDWARDSVILLE
11
10
POPE MILL
rcm
HYDE SCHOOL
9
BRASIE CORNER
Beaver Creek Lineament
mm
GOUVERNEUR
GOUVERNEUR
RESERVOIR HILL
H DOZ
Black Creek Fault
Grass Creek Fault
ROSSIE
16
SOMERVILLE
CHIPPEWA BAY
ST. LAWRENCE COUNTY
JEFFERSON COUNTY
DODS CREEK
PAYNE LAKE
Pleasant Lake Fault
CANADA
UNITED STATES
CHIPPEWA BAY
ROCKPORT
ALEXANDRIA BAY
REDWOOD


LOWER PALEOZOICS
75° 00"
POTSDAM
44° 37'30"
COLTON
44° 30'
WEST POTSDAM
CANTON
75° 15'
N.R.
SQ. PYRITES
rcm
HERMON
RUSSELL
CANTON
SALBIRD
44° 22'30"
rcm
mm
75° 30'
CKORY
LAKE
EEK


GOUVERNEUR
RESERVOIR HILL
75° 30'
44° 15'
75° 15'
44° 7' 15"
ST LAWRENCE COUNTY LINE
HARRISVILLE
KELLOGG CORNERS
CALIFORNIA
SOMERVILLE
JEFFERSON COUNTY
LEWIS COUNTY
CLARK POND
ANTWERP
PHILADELPHIA
75° 45'
44° 00'
LOWER PALEOZOICS
THERESA
NORTH WILNA
CARTHAGE
N
mm
fcm


75° 15'
75° 00"
44° 30'
44° 22'30"
44° 15'
mm
rcm
S'ALBIRD
RUSSELL
N
Elm Creek
EDWARDS
DANA HILL
CARTHAGE — COLTON LINE
PITCAIRN
COLTON
0
1
2
miles
1 inch = ~1.25 miles (~ 2 kilometers)

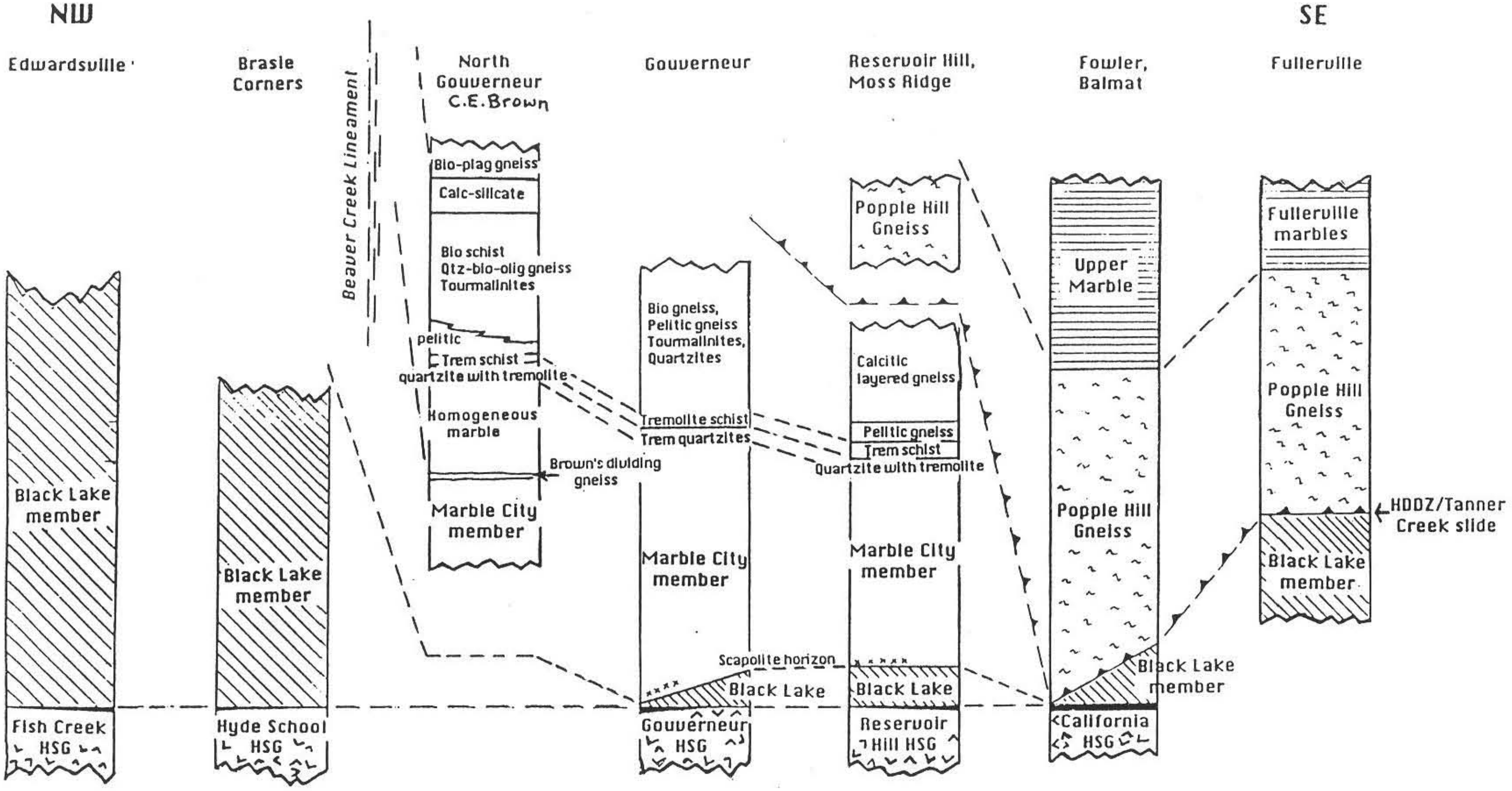


Figure 3 Proposed stratigraphic correlations from NW to SE across the Northwest Adirondack Mountains

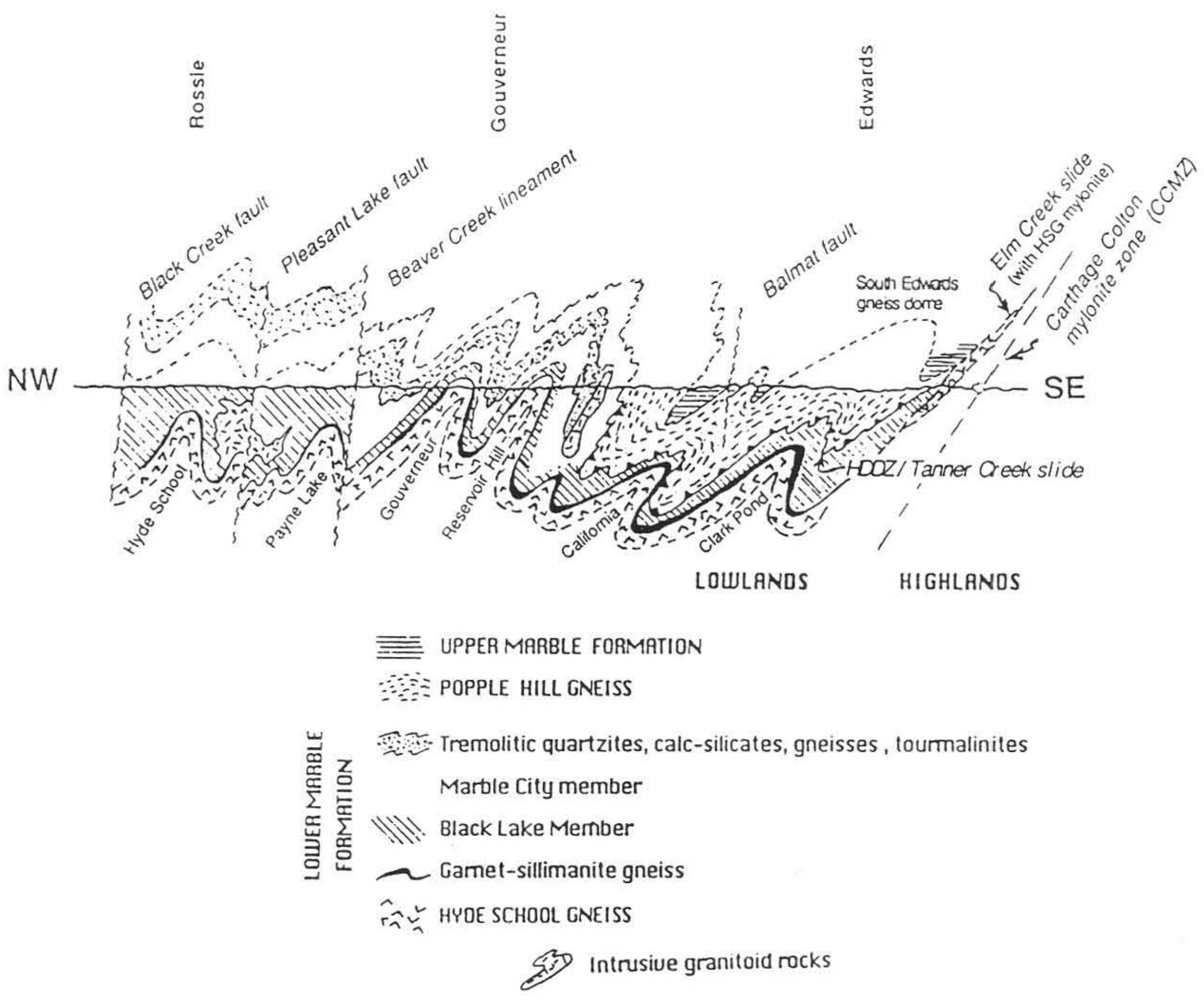


Figure 4 Proposed cross section from NW to SE across the Northwest Adirondack Mountains

zinc orebodies of the Balmat-Edwards district. The geometry of this structure is fairly well understood from diamond drilling and zinc mining. Also included are the California anticline, the Great Somerville anticline, the Sherman Lake syncline, and the North Gouverneur nappe that is cored by the Payne Lake body of Hyde School Gneiss.

Third phase folds are more or less co-planar with the local second phase folds in the Balmat mines, and the trends are also N-NE. Third phase folds tend to be open to tight in style and are recognized where they refold axial surfaces of second phase isoclines. Fourth phase folds are gentle warps to open folds with NW trends that have been recognized locally (Brocoum, 1971; Foose, 1974; deLorraine, 1979; Wiener, 1981; Brown, 1989).

Interference of fourth phase folds with earlier NE-trending folds was previously thought to have produced the dome and basin map pattern throughout the Lowlands (Foose, 1974; Foose and Carl, 1977; deLorraine, 1979; Wiener, 1981; Wiener and others, 1984). Detailed analysis of the Sylvia Lake syncline and the Pierrepont sigmoid, in conjunction with zinc mining at Balmat-Edwards, led to the suggestion that these doubly plunging synclines were sheath folds, and that "domes" cored by Hyde School Gneiss were actually the apical projections of complimentary anticlinal sheath folds (deLorraine and Carl, 1986; deLorraine, in Bohlen and others, 1989). Detailed mapping and fabric analysis by Tewksbury provided evidence for major sub-horizontal shear regimes that later D2 deformation amplified into sheath folds.

Fold interference, thus, is seen by recent workers to have played a relatively minor role in the formation of the regional dome and basin pattern. Although cross folding is capable of explaining the pattern, it cannot easily explain the ovoid outcrop patterns made by overturned bodies of Hyde School Gneiss. Heart and anchor patterns would be expected for these bodies unless the movement line of the NW-trending folds was contained entirely within the axial surfaces of the earlier, NE-trending folds. Hyde School Gneiss may be more susceptible to ductile shear, but the same folding occurs in metasedimentary envelopes around the bodies of Hyde School Gneiss, suggesting that they too were sheath folded.

The top and base of Popple Hill Gneiss are mylonitic, suggesting that ductile shear was heterogeneous and limited to discrete surfaces at contacts with the carbonates. But Popple Hill Gneiss must also be involved in the sheath folding because its contact with the Upper Marble formation defines the Sylvia Lake syncline. The question arises as to whether stratigraphic continuity can be maintained under conditions of high strain associated with sheath folding. The answer, in part, is that folds such as the Sylvia Lake syncline, Great Somerville and California anticlines, are regional folds whose overall geometry *approaches* that of sheath folds in that the hinge lines are recurved and doubly plunging. Extension and elongation has produced local stratigraphic discontinuities, but large-scale continuity across the NW Adirondacks can be demonstrated.

Faulting

Brittle Faults:

Two broad classes of faults, "brittle" and ductile, occur in the Lowlands, some in conjunction with high grade metamorphism and folding in ductile regimes, such as thrust faults, tectonic slides and shears. Others of a brittle nature occur where the offset may have been post-metamorphic.

Northeast striking, steeply dipping "brittle" faults have broken the Lowlands into fault panels (Figs. 2, 4), each of which ostensibly differs in structural style and stratigraphic content. "Brittle" is used advisedly in that early movements may have occurred in a ductile regime producing mylonite, whereas the latest movements were brittle and marked by brecciation. The association of these and other faults with mafic plutons is suggestive of a long, protracted history of faulting and intrusion. Important faults include the Black Creek fault, Pleasant Lake fault, Beaver Creek lineament, Oswegatchie fault and the Balmat fault (Figs. 2, 4). Brown (1989) showed that early fault movement was dominantly strike-slip and accompanied by granite and pegmatite intrusions which were later mylonitized. Evidence of late recurrent movement includes offsets of Cambrian Potsdam sandstone and the presence of breccia (Brown, 1989).

Careful mapping of units of the Lower Marble formation suggests that differences in the stratigraphy on either side of a major fault may be more apparent than real. For example, a stratigraphic breakdown on opposite sides of the Beaver Creek lineament reveals that the Black Lake member of the Lower Marble formation is not unique to that area but is exposed in various places SE of the lineament. The member dominates the terrane to the west, whereas members higher up the section are dominant to the east (Figs. 2, 4). Prior to Brown's work, marbles equivalent to the Black Lake section were not recognized east of the Beaver Creek lineament. Recent mapping by deLorraine shows that the member continues across the lineament to the east and that thin shells surround each dome of Hyde School Gneiss (Fig. 2). The member thickens abruptly west of Beaver Creek lineament where it contains more intercalated clastic lithologies such as quartzites and rusty gneisses.

We emphasize that within and across the fault-bounded panels, each body of Hyde School Gneiss is enveloped by the Black Lake member (Fig. 2). East of Beaver Creek, the upper members of Lower Marble are mapped outwardly from shells of the Black Lake member around the Gouverneur and Reservoir Hill bodies of Hyde School Gneiss. Exceptions include the Clark Pond and Stalbird bodies which lay adjacent to the Carthage-Colton line. Here local faulting has excised large parts of the Lower Marble formation. For example, rocks underlying the Pitcairn-Edwards-Stalbird areas (Fig. 2) are dominated by the Black Lake member, whereas the Clark Pond-Harrisville area is dominated by the Marble City member, and the North Russell-Pierrepont-Colton area by uppermost members of Lower Marble Formation. At Edwards, the Black Lake member is in structural contact with the Upper Marble formation; here the entire section of Popple Hill Gneiss has been excised along the Elm Creek slide (as mapped by deLorraine). Thin, mylonitized slivers of Hyde

School and Sawyer Creek gneisses occur along the contact between Upper and Lower Marble formations where they mark the trace of the slide. The lack of recognition of a tectonic contact between the two marble formations is responsible for the proposal that the Lowlands contained but a *single* marble formation (Foose, 1974; Wiener and others, 1984). The geological relationships near Edwards and Russell are consistent with a "NW side down" movement along the Carthage-Colton mylonite zone, possibly resulting from post-Grenville tectonic unroofing and extension (Heyn, 1990). Interestingly enough, Gilluly (1934) first proposed a major tectonic dislocation near Edwards.

Synmetamorphic Faults:

Synmetamorphic tectonic slides and shears are often difficult to recognize and map due to limited exposures and to the possibility of layer-parallel transport. Tectonic slides and shears are well known from the Balmat zinc mines within the Upper Marble formation. Two prominent tectonic slides within the Sylvia Lake syncline at Balmat (Fig. 5) include the Sylvia Lake slide which separates the Fowler and Sylvia Lake orebodies. These orebodies are interpreted to have been contiguous before separation by transport in a counter clockwise sense (Fig. 5). The apparent offset is on the order of 4000 ft. The Balmat slide on the lower limb of the Sylvia Lake syncline places unit 6 of Upper Marble in direct contact with Popple Hill Gneiss. Units 1 through 5 have been excised.

Only a few slides of regional extent have been reported in the literature. Foose (1974) placed the Moss Ridge slide and the Tanner Creek slide (Figs. 2, 3) at the base of Popple Hill Gneiss. Ambers and Hudson (1985) and Hudson and others (1986) described the Hailesboro ductile deformation zone, also at the base of Popple Hill Gneiss. The Tanner Creek and Hailesboro deformation zones represent the same mylonitic horizon that is isoclinally folded by a second phase isocline at Devils Elbow (near Hermon village). To the southwest, the mylonites are folded by the Great Somerville anticline and Sherman Lake syncline which also are major second phase isoclines. Thus, the Tanner Creek/Hailesboro ductile deformation zone is interpreted by us as a folded tectonic slide that may occur at the base of an early phase thrust sheet (Figs. 2, 4). Popple Hill Gneiss was emplaced over the Lower Marble formation along this slide. Its eastern contact is the edge of Popple Hill Gneiss immediately to the west of the Harrisville-Pitcairn-Stalbird-Russell marble belt. At Edwards, it is unclear whether the Elm Creek fault *is* the Hailesboro ductile deformation zone-Tanner Creek slide or a re-activation of the slide along the Carthage-Colton line.

Thrust emplacement/tectonic interleaving can account for the anomalously abbreviated sections of Lower Marble that surround the Stalbird and California domes of Hyde School Gneiss. The upper section of Lower Marble may have been cut out along the base of this postulated thrust sheet. Diamond drilling and detailed mapping (1:4800 scale) at the NE end of the California body of Hyde School Gneiss by Zinc Corporation of America show that graphitic-phlogophitic-calcitic marbles of the Black Lake member overlie the Hyde School Gneiss, separating it from Popple Hill Gneiss. Rusty gneisses also are exposed on the surface and are present in the drill core. Absent are the Marble City and higher members of the Lower Marble formation.

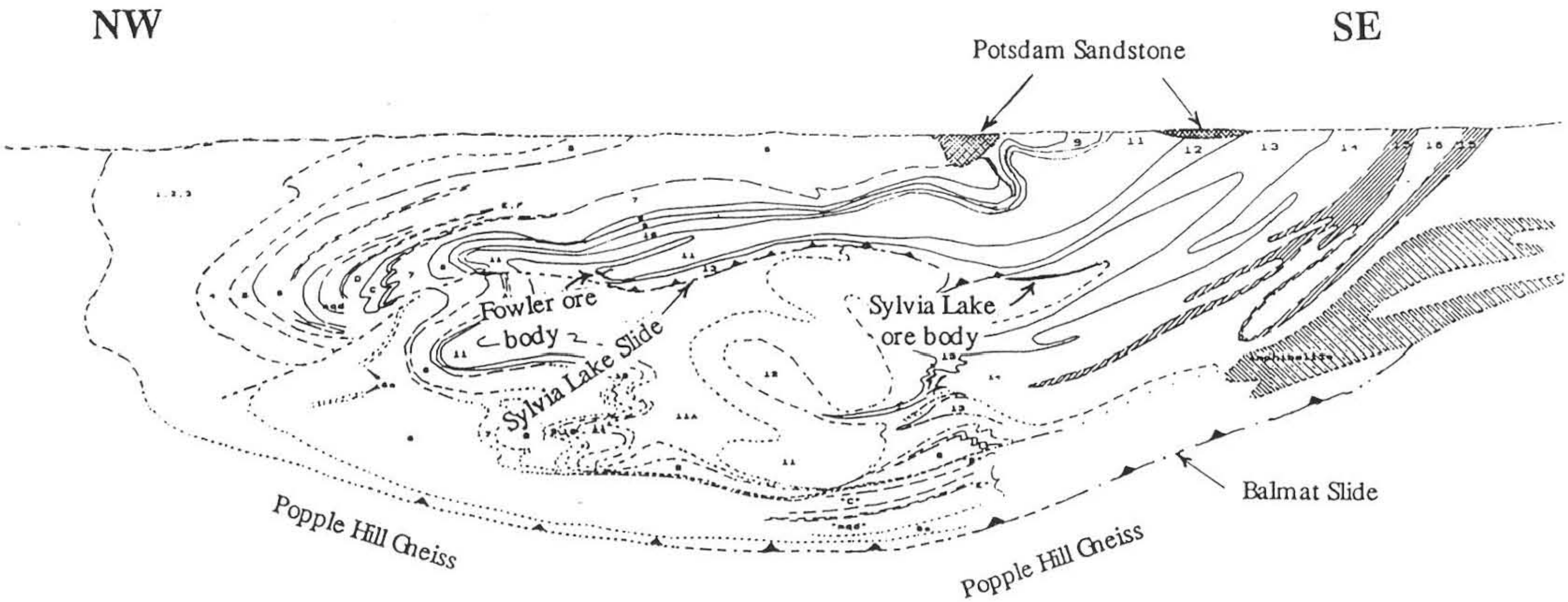


Figure 5 Generalized NW-SE cross section through the Sylvia Lake syncline showing tectonic slides within units of the Upper Marble formation. The units are described in Fig. 7.

ROAD LOG AND STOP DESCRIPTIONS

Cumulative mileage	Miles from last point	Route description
Start		Junction of Main Street (Route 11) and Park Street in the center of Canton at Canton village Park. Follow Route 11 signs out of Canton towards Gouverneur.
23.7 (38.2 km)	23.7	Gouverneur village limits. Kinney's warehouse on left.
24.7 (39.8 km)	1.0	Turn left (S) on Grove St. at the second stop light in Gouverneur, at the Community Bank and the village square.
25.9 (41.7 km)	1.2	Stop 1. Opposite the Cornell farm on Grove St. (ask permission).

STOP 1 Black Lake member of Lower Marble formation, SW end of the Reservoir Hill body of Hyde School Gneiss.

The purpose of this stop is to examine the Black Lake member of Lower Marble formation that overlies the Reservoir Hill body of Hyde School Gneiss. Marbles here are identical in lithology with those exposed west of the Beaver Creek lineament. The marble terrane west of the lineament was labelled the "Black lake Metasedimentary Belt" (Engel and Engel, 1953), and the lowermost member of Lower Marble derives its name from that area (deLorraine and Carl, 1986). Black Lake marbles are quite distinct from the marbles upsection. They are characterized by the presence of ribbed, rusty-weathered, calc-silicate gneiss bands, disseminated black tourmaline, feldspar grains, phlogopite and granular diopside (Fig. 1). Also common are coarse graphite, scattered quartz "eyes" and intercalated quartzites. Massive rusty diopside rocks and a thick, homogeneous calcitic marble unit occur west of the Beaver Creek lineament. Absent at stop 1 is the sillimanite-garnet gneiss that typically surrounds bodies of Hyde School Gneiss. It is informally labelled the Sawyer Creek gneiss after thick exposures near Sawyer Creek along the margin of the California body of Hyde School Gneiss (deLorraine and Carl, 1986).

Note the minor folds in the marbles. Are one or two phases of folds present? One might interpret an early phase defined by rootless, isoclinal intrafolial folds that are refolded by more or less upright to overturned disharmonic folds.

At first glance, one might regard Hyde School Gneiss at this locality as containing few amphibolite layers. When viewed from the rear, i. e. from the high bedrock knobs to the north, the massive outcrops of leucogneiss can be seen as steeply dipping slabs or layers, thanks to the presence of deeply weathered amphibolite layers. Foliation in the leucogneiss is folded about the Reservoir Hill anticline, suggesting that an earlier deformational fabric has been refolded. The anticline is interpreted as a doubly-plunging, southeast overturned, second phase sheath fold that is coeval with the Great Somerville anticline of Buddington and the Sylvia Lake syncline in the Balmat-Edwards mining district.

An important point to make here is the consistent and predictable appearance of Hyde School Gneiss below the Black Lake member of Lower Marble formation. Upsection of this member is a scapolite prism marble that separates the member from an overlying gray and white banded marble called the Marble City member (Fig. 1). The Marble City member will be examined in stop 3. It lacks the rusty weathering gneissic bands and disseminated feldspar observed in the Black Lake member.

We emphasize the contrasting carbonate and calc-silicate rock types because they might otherwise appear to constitute a homogeneous sea of undistinguished marbles. The marbles should not be dismissed simply as "tectonic grease." Stromatolites have been locally preserved, and the persistancy of contacts between relatively thin members for great distances has provided information about the geometries of major folds. Mapping of the thin units is the basis for structural work and zinc exploration in the Sylvia Lake syncline. Unit 6 in the Upper Marble formation, for example, has several 10 to 30 ft thick subunits of distinctive texture and composition that can be traced around the Sylvia Lake syncline by drill core from Balmat to the Hyatt mine, a distance of at least 8 miles (12.9 km). Contacts between rocks of undoubted metasedimentary origin are conformable with each other and, in many cases, with the overlying and underlying gneissic formations. These contacts are interpreted as reflecting original compositional and lithologic differences; that is, they constitute a stratigraphic sequence.

Thus, the appearance of Hyde School Gneiss at a predictable horizon is regarded as the consequence of depositional patterns modified to various degrees by metamorphism, folding, ductile deformation, ductile faulting and partial melting. Stop 12 will add basaltic intrusion to the list, but these late dikes are not to be confused with an earlier amphibolite layering.

Continue south on Grove St.

26.2 (42.2 km)	0.5	Turn right (S) on River Drive and onto the Oswegatchie River bridge.
26.7 (43.0 km)	0.5	Turn right (N) onto Main St. in Hailesboro.
27.2 (43.8 km)	0.5	Turn right (N) onto Routes 58/812.
27.9 (44.9 km)	0.5	Stop 2. Park along Route 58/812, 0.2 km south of Gouverneur village limits.

STOP 2 Scapolite marble member of the Lower Marble (with basalt dike).

Rock here overlies the carbonate and rusty gneiss of stop 1. This characteristically pitted, light gray member or horizon of the Lower Marble formation consists of scapolitebearing, graphite-phlogopite marbles with quartz segregations. It can be traced southwest of the Gouverneur body of Hyde School Gneiss to aid in defining the "Great Somerville anticline" of Buddington that parallels Route 11 through Somerville village. Scapolite is gray because of finely disseminated graphite; it varies from coarsely bladed to small elongate crystals.

The 1 m thick basaltic dike within the scapolitic marble is N 60 E, vertical and undisturbed in contrast to the highly segmented and metamorphosed dikes to be seen at stop 3. These and other NE-trending Lowland dikes may have been produced by Late Precambrian rifting and the opening of the Iapetus Ocean basin. The dikes are generally vertical, fine-grained, undeformed, amygdaloidal, and show chilled borders against the wall rock. They must have intruded brittle rocks at shallow depths. Many have undergone saussuritization and contain epidote veinlets. They intrude all Precambrian rocks in the Lowlands, but do not intrude patchy remnants of overlying sedimentary rock such as the Cambrian Potsdam sandstone. They show deep weathering (some are altered to hematite) where exposed near the pre-Upper Cambrian unconformity.

Narrow dikes like this one are likely to be strongly saussuritized and to yield unreliable directions of paleomagnetization. Seven samples from thicker, well-crystallized dikes, however, show a grouping of north-seeking poles in the southeast quadrant of the lower hemisphere of an equal area net. Books and Brown (1983) were unable to match the grouping with data from dikes in Ontario.

A hydrothermal event (phase 4 of Brown, 1983) may have reset the ages of many basalt dikes. K-Ar ages from one dike of 405 +/- 11 and 440 +/- 10 m.y. obtained on feldspar and pyroxene respectively (Brown, 1975) are not compatible with the pre-Upper Cambrian age required by field relationships. Ages for Ontario dikes ranging from 600 to 800 m.y. (Park and Irving, 1972) are likely to be representative of Lowland dikes, and the ages of 405 and 440 m.y. may approximate the time of hydrothermal activity (Brown, 1983). Hydrothermal activity is also proposed as the cause for alteration along joints that has produced epidote and reddish feldspar in some Lowland gneisses.

Badger (1993) has studied the largest of the Lowland dikes, a 14 km long, NE-trending dike that cuts Precambrian rocks including the Hyde School body of Hyde School Gneiss (see map of Brown, 1988). The dike shows alkalic affinities and has uniform chemical composition. Tectonic discrimination plots are indicative of within-plate magmatism and OIB-type (Ocean Island Basalt) mantle plume source. These dikes may be related in origin to late Precambrian, rift-related magmas of the Ottawa Graben, the eastern Adirondack Mountains and western Vermont.

Continue north to turnaround.

28.2 (45.4 km)	0.3	Turn around at intersection with old Route 58 (on right). Proceed south on Route 58/812.

29.2 (47.0 km) 1.0 Stop 3. Park along Route 58/812 near the intersection with Main St.

STOP 3 Marble City member of Lower Marble and the broken basaltic dike of the "train wreck outcrop."

The roadcut is located just south of the SW end of a major regional fold hinge, the Reservoir Hill anticline. Numerous minor folds in the marble may reflect the proximity of that anticline. Reconstruction of a refolded isocline suggests an "S" asymmetrical sense when viewed to the north; the "S" is consistent with the location of the fold on the eastern limb of the Reservoir Hill anticline. Axial surfaces of many minor folds have shallow to moderate dips to the west, perhaps giving an indication of the degree of overturning of the anticline.

This massive, coarsely crystalline, blue-gray banded calcitic to slightly magnesian marble is graphic and phlogopitic. We correlate it with Brown's (1989) unit "mm" in the northern part of the Richville quadrangle and North Gouverneur area. Marbles at stops 1 and 2 are lower in the section.

This roadcut was proposed as the type section for a single northwest Adirondack carbonate-bearing formation named the Gouverneur Marble (Wiener and others, 1984). We regard it as a member of the Lower Marble Formation. The rock was quarried throughout the area for building stone in the early 20th century. Note the small town glory that once was Gouverneur (informally called "Marble City") as preserved in the upper levels of the downtown buildings.

The dike here is metamorphosed and disrupted in contrast to the dike at stop 2, but displacement is not great in view of the extensive folding in the marble. The antiform observed in the outcrop probably existed in its present form when the dike was intruded (Schoenberg, 1974; VanDiver, 1976). The lower part of the dike appears to have been a sill, whereas the upper part cuts across the banding in the marble. Possibly the subsequent refolding, as indicated by the shallow broad syncline to the right of the dike, may have caused brecciation and displacement of the dike blocks.

The dike blocks are recrystallized and re-equilibrated near the contact with the marble. They contain little or no plagioclase, abundant diopside and meionitic scapolite with lesser microcline, sphene, tremolite, biotite, quartz, opaque, tourmaline and apatite.

Proceed south on Route 58/812.

29.5 (47.5 km) 0.3 Stop 4. Park along Route 58/812 just north of the bridge over Mattoon Creek.

STOP 4 Steer's Head outcrop where Antwerp-type granitoid gneisses have intruded the Lower Marble.

Gneisses of granite to granodioritic composition comprise a string of large, disconnected, boudin-like masses that extend from Antwerp village northeasterly for 40 km to Moss Ridge-Battle Hill near Gouverneur village. These rocks intrude chiefly the Marble City member of Lower Marble, but near Antwerp village they intrude Popple Hill Gneiss. Radiometric ages include an Rb-Sr whole rock age of 1197 +/- 53 Ma by Douglas Mose (in Carl and others, 1990), and a zircon U-Pb age of 1183 +/- 7 Ma by Jeff Chiarenzelli (in McLelland and others, 1992). These intrusions are slightly older than most anorthosite, mangerite, charnockite and granite (the AMCG intrusive suite of McLelland, 1986) in the Highlands.

Antwerp granite at this outcrop has surrounded and isolated a segment of cream colored marble that is shaped like a "steer's head" (resembling an illustration in a Zane Gray western novel). Major minerals include microcline, plagioclase, quartz, hornblende and biotite. Minor minerals include tourmaline, magnetite, ilmenite, apatite, zircon, titanite and secondary chlorite. Note the veins of quartz and tourmaline in symplectic intergrowth.

Intrusive origin is not easy to demonstrate for many Lowland gneisses, given the multiple deformation and high-grade metamorphism. Dikes and sills within marbles are especially susceptible to rupture, displacement and rotation, and many of the contacts are tectonic in origin. Selvage of scapolite, diopside, mica and quartz occurs between the metagranite and marble at this outcrop, but the presence of selvage may be indicative of regional rather than contact metamorphism. Note at this outcrop a convolute, thin band of selvage that extends from the gneiss into marble (Fig. 6). The source of components in the band may lay within the metagranite. Other features indicative of an igneous origin include aplite veins, cross-cutting relationships and the distribution of carbon and oxygen isotopes at the granite-marble contact.

Marble and granite have been analyzed for oxygen isotopes at the Steer's Head outcrop by Cartwright and Valley (1991). The marbles away from the contact have delta ^{18}O values typical for Adirondack calcite (21-24 $^{0}/_{00}$). Antwerp gneisses away from the marbles have delta ^{18}O values within the range of Grenville granitic rocks (11-12 $^{0}/_{00}$). Within a few meters of the contacts, however, delta ^{18}O values increase in the metagranite and decrease in the marble. The result is a sigmoidal shaped delta ^{18}O profile with the inflection points occurring near the contact. This steep gradient is believed to have formed by high temperature, fluid-hosted diffusion of oxygen isotopes from one rock into the other. The question is whether the profile formed during regional or contact metamorphism.

Cartwright and Valley (1991) also observe a change in marble mineralogy toward the contact with the metagranite. Phlogopite content decreases and the diopside content increases, possibly because of a shift to the right in the following reaction:

$$\textit{phlogopite} + 3\ \textit{calcite} + 6\ \textit{quartz} = \textit{K-feldspar} + 3\ \textit{diopside} + H_2O + 3\ CO_2$$

This reaction buffers XH_2O and is favored by increased temperature during contact metamorphism. Another XH_2O buffering reaction involves tremolite as follows:

$$\text{tremolite} + 3\ \text{calcite} + 2\ \text{quartz} = 5\ \text{diopside} + H_2O + 3CO_2$$

Tremolite is described as disappearing towards the contact with the Antwerp metagranite, possibly as a result of a shift to the right in this reaction.

A change in the abundance and habit of graphite also is reported in the marble. Coarse (1-2 mm) crystalline flakes of graphite more than 1 m from the contacts give way to graphite free, or finer-grained, disseminated graphite near contact with the metagranite. This change probably resulted from oxidation during intrusion of the granite. Water diffusing from the granite probably caused the breakdown of graphite with the production of methane.

Cartwright and Valley (1991) argue that isotopic exchange occurred during contact metamorphism. Evidence includes the following: (1) Antwerp metagranite would have low porosity, and it is unlikely that enough grain boundary fluid remained in the granite to allow diffusion during regional metamorphism. (2) The systematic changes in marble mineralogy are indicative of contact metamorphism. The observed mineral assemblages also are stable at conditions of regional metamorphism, and little devolatilization would have occurred then. They argue that only during the contact metamorphic event was enough fluid available in the marble.

A larger conclusion drawn from this and other isotope studies at the contacts with metaigneous rocks is that large volumes of pervasive metamorphic fluids have not infiltrated these localities during the regional metamorphism, or at any time thereafter. The sigmodal-shaped profiles would not have been preserved had this been the case (Cartwright and Valley, 1991).

Continue south on Route 58/812.

30.2 (48.6 km) 0.7	Stop 5. Park along Route 58/812 near intersection with Smith road.

STOP 5 Basal, sillimanitic Popple Hill Gneiss.

We are near the base of a thick gneissic unit called the Popple Hill Gneiss and near the contact with Lower Marble. Generally, the gneiss is migmatitic, gray and layered (see stop 6), but here it contains rod-like sillimanite up to 12% by volume (Hudson and others, 1986). Lineations defined by the sillimanite plunge 8° SW. Also present are feldspar porphyroblasts and lenticular rotated garnets with helicitic textures defined by quartz and sillimanite inclusions (Ambers and Hudson, 1985).

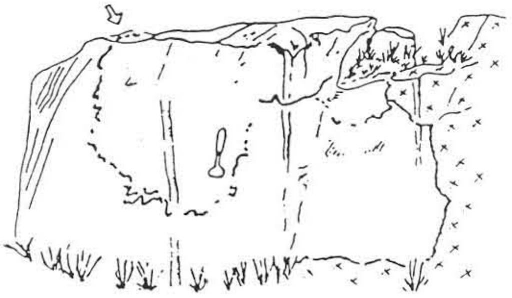
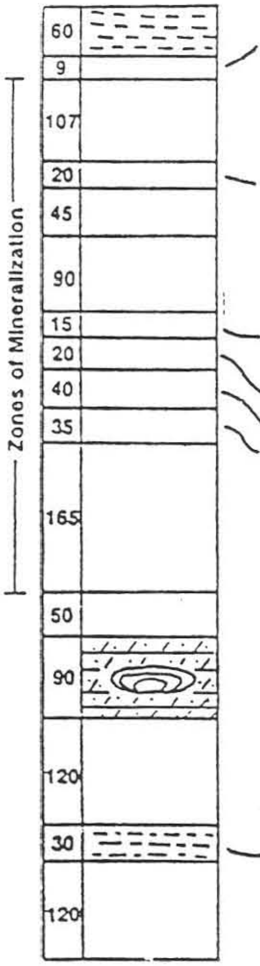


Figure 6 Antwerp metagranite (x's on right) and convolute vein that extends into the adjacent marble. Hammer for scale.



(16) Scapolitic quartz-feldspar-biotite gneiss (Median gneiss)

(15) Silicated calcitic marble with phlogopite

(14) Serpentinous calcitic and dolomitic marbles, banded quartz-diopside rock, minor calcitic and dolomitic marble, calcitic marble with quartz (quartz "mesh")

(13) Talc-tremolite schist with anhydrite

(12) Dolomitic marble, minor anhydrite

(11) Banded quartz-diopside and dolomite, minor calcitic marble, anhydrite

(10) Serpentinous, talcose diopside rock, minor biotite schist, minor anhydrite

(09) Dolomitic marble

(08) Banded quartz-diopside and dolomite

(07) Fetid graphitic dolomitic marble

(06) Siliceous dolomitic marble with diopside, quartzite, local anhydrite. Laminated quartz-diopside rock, phlogopitic calcitic marble.

(05) Dolomitic marble.

(04) Layered quartz-diopside and dolomite. Finely laminated quartz-diopside rock.

(03) Dolomitic marble

(02) Sillimanitic quartz-mica-feldspar-pyrite schist

(01) Dolomitic marble

Figure 7 Stratigraphic column for the Upper Marble

This outcrop has been regarded by some as representing a pelitic protolith whose aluminous composition was appropriate for the growth of sillimanite. The presence of carbonate seams in the gneiss at Devil's Elbow and at Philadelphia village is compatible with an interpretation of a lime-bearing protolith. Stop 5, however, is proposed to be the site of ductile faulting that occurred during or near the peak of metamorphism, with the gneiss having moved northeasterly relative to the marbles in an essentially strike-slip motion (Hudson and others, 1986). In this model the presence of stress is believed to have influenced the growth of sillimanite, perhaps by shifting the following reaction to the right:

$$2\,feldspar + 2\,H^{+} = sillimanite + 5\,SiO_2(aq) + 2\,K^{+} + H_2O$$

(Wintsch and Andrews, 1988)

The mylonites are described as Sr-depleted compared to layered Popple Hill Gneiss from which they are presumed to be derived. A whole-rock Rb-Sr isochron of 1177 +/- 40 Ma is younger than ages obtained for the layered gneiss elsewhere and is interpreted as approximating the age of ductile deformation (Hudson and others, 1986). The age also approximates that of AMCG rocks in the Highlands and the Antwerp granite at stop 4; the age falls within the 1170-1130 Ma-interval of high grade metamorphism for the Lowlands as determined by Mezger and others (1991).

This mylonite zone has been extended to connect with the tectonic slide mapped by Foose (1974) near Moss Ridge. Informally called the Hailsboro ductile deformation zone, the mylonite zone may extend across the Lowlands. The Marble City member of Lower Marble lies against Popple Hill Gneiss at this outcrop, and stratigraphically higher members are absent. The gap depicted in our stratigraphic column at the base of Popple Hill Gneiss (Fig. 1) is based on this relationship and on mapping by Foose (1974). Ductile faulting also has disturbed the contact between Popple Hill Gneiss and the units within the Upper Marble in the zinc mines at Balmat. A tectonic slide on the lower limb of the Sylvia Lake syncline places unit 6 in contact with the Popple Hill Gneiss, units 1 through 5 having been excised (Fig. 5). Drill cores penetrating the gneiss generally show blastomylonitic fabrics whereas the overlying carbonate rocks generally are recrystallized "granoblastic mylonitic marbles."

Continue south on Route 58/812.

32.2 (53.0 km) 2.7	Stop 6. Park along Route 58/812 at the intersection with the Popple Hill road

STOP 6. Type locality of the Popple Hill Gneiss.

General:

This outcrop is typical of the migmatitic phase of the gneiss, and sillimanite is much less abundant here than at stop 5. Popple Hill Gneiss lies between two carbonate-bearing units, the Lower Marble of stops 1-4 and the Upper Marble in the Sylvia Lake syncline to the south (stops 7 and 8). The gneiss outcrops in a broad loop along the outer perimeter of the

Sylvia Lake syncline and in the Balmat zinc mining district. It outcrops continuously across the Lowlands in a hard-to-farm landscape of bedrock knobs for 70 km from Philadelphia to Colton village.

Because much of the protolith may consist of volcanic ash, Carl (1988) urged that the name be changed from the Major Paragneiss (Engel and Engel, 1953) to the colloquial expression for poplar trees and the hill through which this section of Route 58 was cut (see the road sign). Here is exposed the typical gray, layered, fine grained plagioclase-K-feldspar-quartz-biotite-garnet-sillimanitic gneiss that is strewn with boudins and convolute (ptygmatic) quartzo-feldspathic veins, megacrysts of K-feldspar, layered amphibolites, sill-like bodies of leucogneiss, and other metaintrusive rocks. Even a 1 cm thick seam of orthoquartzite extends vertically through the outcrop as a fracture-filling of Upper Cambrian Potsdam sandstone.

Geochronology:

A whole rock Rb-Sr isochron of 1296 +/- 21 Ma (Grant and others, 1984) and a zircon U-Pb age of 1214 +/- 21 Ma (Carl and Sinha, 1992) have been obtained for Popple Hill Gneiss. The discrepancy between the two ages has not been resolved. Both determinations were made on suites of samples from three outcrops that included one common locality here at Popple Hill. The 1.2-1.3 Ga-age of the gneiss must also apply to the Upper Marble whose stratigraphic position above Popple Hill Gneiss is well established by drilling.

The age of Popple Hill Gneiss is particularly important in view of the 1415 +/- 6 Ma-age of a leucogneiss dike on Wellesley Island in the St. Lawrence River (McLelland and others, 1988; 1992). Host rocks there must be much older than Grenvillian, perhaps >1500 my, but the extent of their distribution is not known. If these older rocks are widely distributed, then the ca. 1230 Ma-age assigned to Hyde School Gneiss by McLelland and others (1992) would be a revelation. Hyde School Gneiss would be younger than the surrounding rocks and, therefore, intrusive in origin (McLelland and others, 1988; 1992). The previously accepted model would be rendered invalid, i. e. that the Hyde School Gneiss protolith was volcanic tuffs (Carl and VanDiver, 1975), that the bodies represented apical projections of a folded but continuous sheet, and that the gneiss lay near the base of a Lowland stratigraphic sequence (Carl and others, 1990). These recent age determinations of Popple Hill Gneiss, however, do not support an intrusive origin for nearby bodies of Hyde School Gneiss, and the argument regarding an intrusive origin has shifted to other grounds.

A 40 m thick body of metagranodiorite that we regard as intrusive into Popple Hill Gneiss occurs at the northern end of this outcrop. It has given a whole rock Rb-Sr isochron age of 1147 +/- 35 Ma (Grant and others, 1984). This age indicates that the intrusion was contemporaneous with movement along the Hailsboro ductile deformation zone (stop 5) and with intrusion of the AMCG suite in the Highlands. Evidence for intrusive origin includes the young age, the presence of K-feldspar megacrysts (phenocrysts?), amphibolite that occurs as angular blocks (xenoliths?) rather than layers, and a more mafic composition than Popple Hill Gneiss. Contacts with the gneiss have been tectonized so that cross cutting relationships are not observed, or the body may be a sill. The intrusion is cut by numerous quartzo-feldspathic veins.

Migmatite and the Availability of Fluid during Metamorphism:

The belt of Popple Hill Gneiss crosses the isotherms of regional metamorphism that signify a transition from upper amphibolite to the granulite facies, from ca. 640°C in the SW to 740°C in the NE (Seal, 1986). Popple Hill Gneiss, thus, has the potential for study of mineral and chemical change as well as the availability of fluids during prograde metamorphism. The unit has been thoroughly sampled (Engel and Engel, 1953; 1958; Stoddard, 1980; Seal, 1986; Edwards and Essene, 1988; Ehrhard, 1986; Powers and Bohlen, 1985; Hoffman, 1982; see summary in Valley and others, 1990).

Quantitative estimates of the values for water activity are based on the equilibria of reactions that include:

(1) *annite (biotite with Fe in octahedral sites) + sillimanite + quartz = almandine + sanidine + H_2O,* and

(2) *muscovite + quartz = sanidine + sillimanite + H_2O.*

Calculated values of water activity range from 0.1 to 0.5 (Valley and others, 1990). Values are uniformly low, although not as low as in higher grade rocks in the Highlands. Values decrease from Gouverneur to higher grade metamorphic rocks to the NE near Colton.

Valley and others (1990) note that the gneiss is the largest migmatite unit in the Adirondack Mountains. The type locality here is repleat with convolute quartzo-feldspathic leucosomes, some parallel to the foliation and others cross-cutting. The low values of water activity recorded for the gneiss can be used to argue that the leucosomes had formed by partial melting. Water produced during dehydration of mica and other minerals would be partitioned into the incipient melts, and the unmelted residue would be further dehydrated and made harder to melt. In support of this idea, Valley and others (1990) point to the local variability in water activity throughout the unit, suggesting that fluid compositions may have been internally buffered by solids or by melt. Buffering is consistent with the presence of migmatite and with partial melting.

Leucosomes within the gneiss, thus, may be locally derived and not introduced. Carl (1988) proposed an *in situ* origin on the basis of (1) the lack of leucosomes in either Lower or Upper Marble formation, (2) the presence of Ba-, Sr-, and Rb-rich leucosomes in Popple Hill Gneiss outcrops whose mesosome is enriched in Ba, Sr and Rb, (3) the presence of heavy REE-depleted leucosomes where mesosome is similarly depleted, and (4) the dominance of K-feldspar leucosomes in layered gneiss versus plagioclase leucosomes in the amphibolite layers. An origin by metamorphic differentiation was proposed for those leucosomes with exceptionally high K_2O content that lacked minimum melt composition (Carl, 1988).

The studies of Valley and others (1990) are interpreted to rule out the passage of large amounts of fluids through Adirondack rocks during high grade metamorphism. On a local level, however, fluid migration into partial melts remains a possibility, and Popple Hill Gneiss may be unusual in that it retained much of the melt as leucosome (up to 25% at some outcrops). Higher grade gneisses in the Adirondack Highlands may have lost much of their melt fraction to consist chiefly of restite.

Minor folds are abundant in this outcrop. Many display overturned "S" asymmetries as viewed to the NE, suggesting that a major syncline lies to the east. In fact, the Sylvia Lake syncline is located east of this outcrop and may have influenced the orientation of minor folds. A number of folds, however, display "Z" asymmetries. Do these folds suggest a separate or later fold event? Not necessarily. Note that many folded veins exhibit cross-cutting relationships, and recall that fold asymmetries depend upon the orientation of the veins prior to folding. Thus, it is possible to have "S" and "Z" folds in the same outcrop that are coeval.

Continue south on Route 58/812.

33.9 (54.6 km)	1.0	Leave Route 58 by turning right (S) onto Route 812.
34.1 (54.9 km)	0.2	Turn right (N) onto the Sylvia Lake Road toward the mine and mill of Zinc Corporation of America.
35.3 (56.8 km)	1.2	Stop 7. Gate entrance to Zinc Corporation of America. Park on the right side next to the marble outcrops.

STOP 7. Stromatolites in Upper Marble, units 4 and 5.

NO HAMMERS AND NO SAMPLES, NOW AND FOREVERMORE (PLEASE).

Unit 4 of the Upper Marble (Fig. 7) in the Sylvia Lake syncline contains the first known biological remains described from the Adirondack mountains (Isachsen and Landing, 1983). This stromatolite-bearing rock is exposed in the woods above the roadcut. It consists of an alternating sequence of white dolomite, serpentinous-talcose diopside rock, and quartz lenses that may represent a chert-bearing, silty, peritidal dolostone intercalated between pure dolostones. Diopside formed by reactions between quartz and dolomite, and the rims of serpentine and talc owe their origin to retrograde metamorphism. Because the sequence is upside down, unit 5 underlies unit 4 in the roadcut. Unit 5 is a white to grayish, coarse-grained dolomite that contains sparce lenses of quartz and talcose diopside. Occasionally the dolomite is fetid.

The term stromatolite is applied to laminated carbonate sediment that occurs as bulbous heads or stacks. The laminations follow the outline of the structure and may be terminated at the edge of individual heads. Individual laminae may be thicker on the top and drape over the edge of the head to make a steep angle. Stromatolites are well displayed at this outcrop, and perhaps their late recognition can be attributed to an overturned position. The delay could also be attributed to frayed wiring in the twilight zone between the eye and brain of numerous observers, including your field trip guides who did not expect to see what they saw.

Stromatolites in unit 4 are domal SH-V stromatolites that occur as simple domes up to 12 cm high and 40 cm wide (Isachsen and Landing, 1983). They are composed of broad, convex laminae that consist of dolomite and iron-poor diopside (cream-colored rather than green), and they lack structural detail in thin section. The preservation of stromatolites may be due in part to their composition. Some are incompletely preserved with laminated quartz-diopside rock making up the preserved part. Silica replacement of algal structures during diagenesis can account for the preservation, whereas the unreplaced parts would recrystallize during metamorphism to coarse dolomitic marble. Fully replaced quartz-diopside mounds would form a rigid but minor structural buttress during deformation.

This outcrop lies on the upper, overturned limb of the Sylvia Lake isoclinal syncline. The stromatolites indicate that the upper limb is inverted and that this NNE-plunging complex fold is indeed a syncline as geologists of St. Joe Minerals (now ZCA) had proposed many years ago. Stromatolites have been recognized in units 4 and 11 of Upper Marble in recent years, and deLorraine has photographed domical stromatolites and finely laminated, possibly algal mat structures at the 2500 ft. level in the Balmat mine.

Turn around in the ZCA mine entrance.

36.4(58.6 km)	1.1	Turn right onto Route 812 South.
36.5 (58.8 km)	0.1	Bonnie's Diner, famous for home made pie.
37.6 (60.5 km)	1.1	Stop 8. Park on Route 812 just south of the Sylvia Lake fishing-access road in Balmat village.

STOP 8. This newly completed roadcut (late 1992) in units 14 and 15 of the Upper Marble formation (Fig. 7) represents a rebuilding of Route 812 that followed collapse of the old road into an underground mine.

This roadcut occurs in the core of the Sylvia Lake syncline in the Upper Marble formation at Balmat. Subunits of unit 14 comprise the northern part of the cut, whereas the brownish and green rocks in the south part belong to unit 15, a phlogopite/tremolitic calcitic marble (Fig. 7). Unit 14 is composed of a variety of rock types including quartz-calcite marble (the "quartz-mesh limestone" of Buddington), thinly layered quartz-diopside rock, and serpentinous dolomite and calcitic marbles, to name a few. At the southern hinge of the Sylvia Lake syncline near Balmat, minor fold plunges are northerly or slightly west of north. Since the sides of the roadcut here are parallel to the plunges of minor folds, it is difficult to see many folds on the outcrop faces. On the southern end of the cut it is possible to see folds developed in unit 15. Minor folds associated with the Sylvia Lake syncline deform the schistosity in units 14 and 15 and, hence, the minor and major folds are interpreted as second

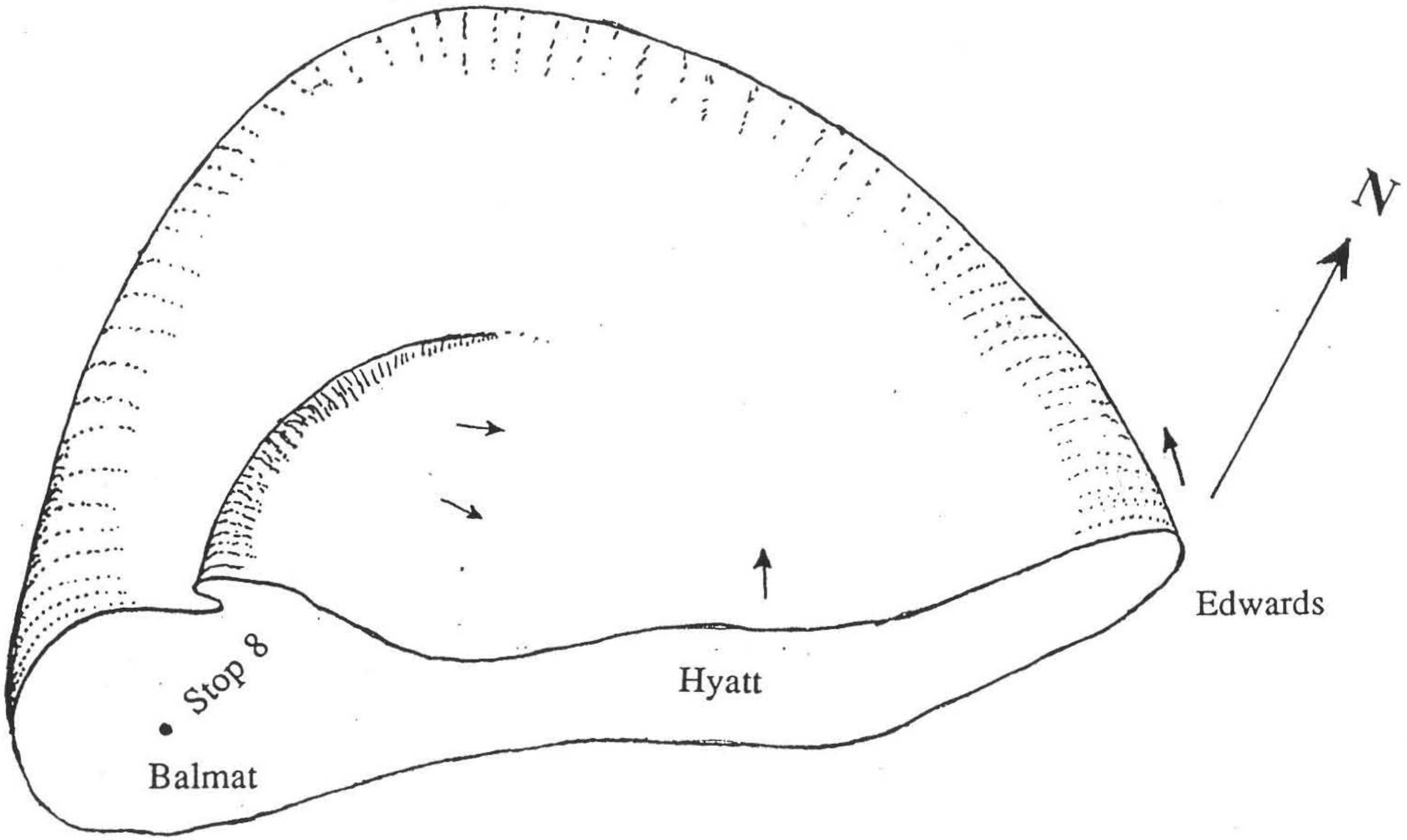


Figure 8 Sketch of the Sylvia Lake syncline as a sheath fold.

phase isoclines. Down plunge (in the mines) the fold axes swing to the NE. At the other end of the syncline at Edwards, fold axes plunge to the NW. The overall geometry of the fold, thus, is lobate, and the Sylvia Lake syncline is interpreted as a sheath fold (Fig. 8).

Turn around at the access site road. Go north on Route 812.

38.6 (62.1 km)	1.0	Bonnie's Diner (try the peanut butter pudding pie).
39.0 (62.8 km)	1.4	Intersection Route 58. Turn left (N) to Gouverneur.
45.3 (72.9 km)	6.3	Intersection Route 11 in Gouverneur. Continue straight ahead on Route 58 (N).
45.6 (73.4 km)	0.3	Sharp left turn to stay on Route 58. Proceed to Natural Dam and Brasie Corners.
47.4 (76.3 km)	0.8	The James River Corp. paper mill (on left) at Natural Dam.
50.7 (81.6 km)	3.3	Oswegatchie River bridge.
55.7 (89.7 km)	5.0	Turn right onto California road in Brasie Corners.
56.7 (91.3 km)	1.0	Flat solution valley that surrounds the Hyde School body of Hyde School Gneiss which is in view straight ahead.
59.5 (95.8 km)	2.8	Stop 9. Park on side of road.

STOP 9. Amphibolite layering in the Hyde School body of Hyde School Gneiss (Fig. 9).

Layering: Large and Small Scale

Hyde School Gneiss with numerous, thin biotitic-amphibolite layers is exposed in the smooth bedrock knobs overlooking a small pasture. We are located at the southern end of an F_2 fold that parallels the Hyde School antiform (see map of Brown, 1988). The orientation of numerous minor folds in the amphibolite layers can be related to the Hyde School antiform, interpreted here as a major, second phase sheath fold. The antiform deforms an earlier fabric, including NW-SE trending lineations and rootless isoclines that may be related to Tewksbury's early shear fabric. Nearby are isoclinally folded amphibolite layers whose axes trend NW-SE, perhaps having been rotated into parallelism with the direction of early phase, NW-directed tectonic transport.

We are near the contact between two pink alaskite units of Brown (1988), one (aa) distinguished by thin parallel layers of biotitic amphibolite, and the other (al) a massive unit with fewer layers (Fig. 9). Another mappable unit (pgd) consists of gneisses ranging in composition from biotite granite, trondhjemite, quartz monzonite, granodiorite to quartz diorite. All are foliated and contain amphibolite layers. Detailed mapping of the large-scale layering enabled Brown to interpret complex refold patterns, and we will discuss his work in the shade of a small tree.

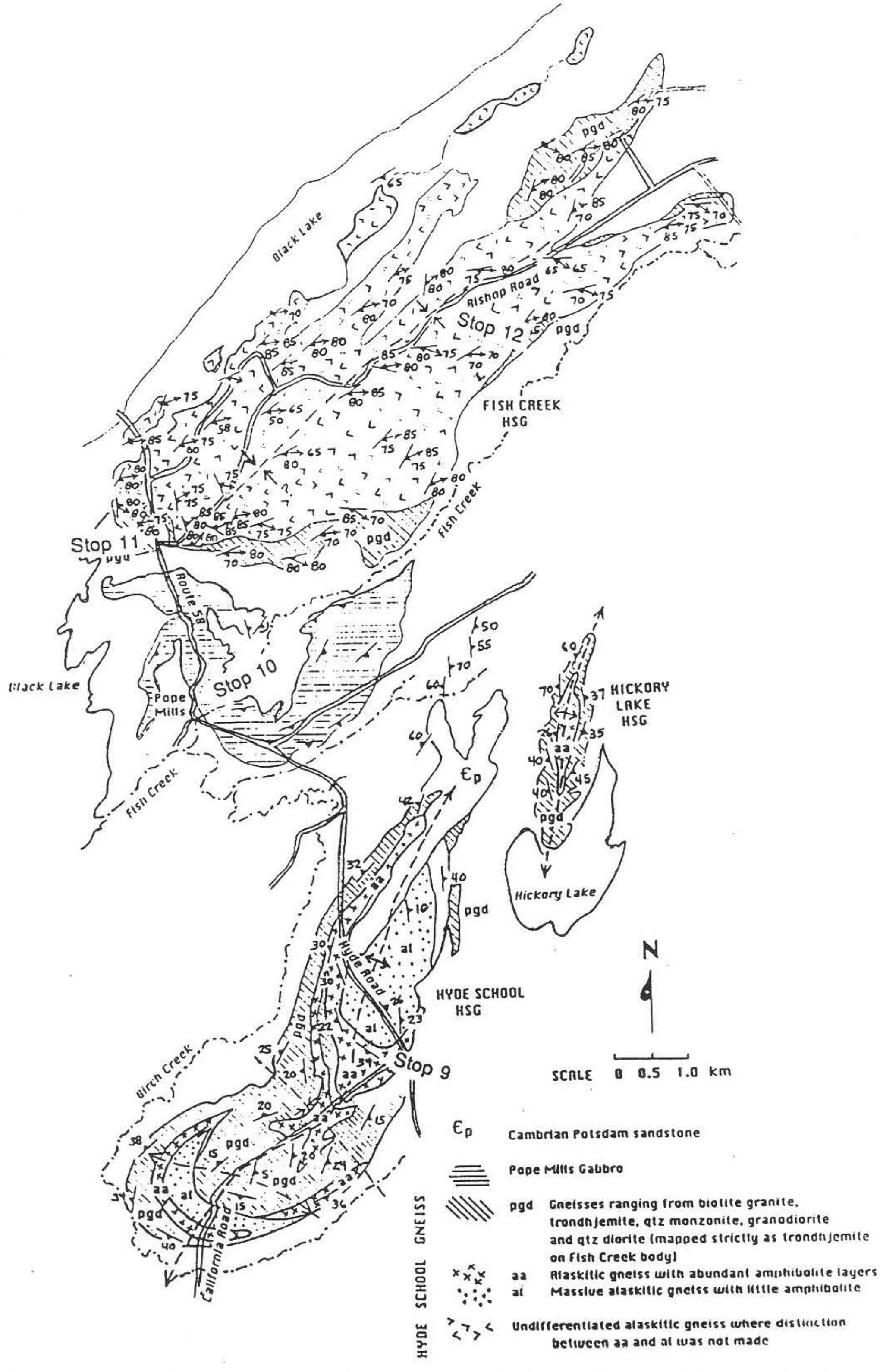


Figure 9 Location map for the Pope Mills Gabbro, Hyde School and Fish Creek bodies of Hyde School Gneiss. Data from Dietrich (1957), Buddington (1934), and Brown (1988).

Hyde School Gneiss, thus, differs from granitoid plutons of the Adirondack Lowlands in being compositionally zoned on a grand scale. Brown (1988) wrote that "the alaskite, granite, and diorite gneisses of the antiforms are a parallel-layered sequence that, despite abundant evidence of internal mobility and local melting, have not intruded each other or broken out of their elliptical structural shells as a melt." In contrast, the younger Lowland granitoid rocks show abundant evidence for intrusive origin. The Rockport granite and Gananoque syenite occur as dikes, sills and apothyses within metasedimentary rocks that outcrop along the St. Lawrence River. Even the oldest rock recorded so far, a 1415 Ma-old leucogneiss on Wellesley Island, is described as a dike within calc-silicate and tourmalinite layers (McLelland and others, 1988).

One objective of this stop is to observe the scale of the amphibolite layering, folding, and boudinage. These features are characteristic of Hyde School Gneiss. Note the absence of other lithologies or inclusions. No other granitoid bodies in the Lowlands exhibit layering like this, and most, if not all, have xenolithic inclusions of country rock attesting to their igneous provenance. Hyde School Gneiss is unique in being restricted to one stratigraphic horizon, containing layer-parallel amphibolites, and in the absence of xenolithic inclusions of the adjacent host gneisses. Feldspathic quartzites, calc-silicate and garnet-sillimanite gneiss occur within bodies of Hyde School Gneiss but, like the amphibolites, they also occur as parallel layers generally < 1 m thick.

Thus, Hyde School Gneiss consists of *conformable* lithologic layers on a large and small scale. Does the layering result from tectonism during intrusion, tectonism after intrusion, or is it a primary feature related to the deformation of ash and lava beds? Do the amphibolites represent basaltic dikes that were realigned prior to complete consolidation of the granitoid magma, so that igneous breccias and textures are preserved? Do the amphibolites represent dikes that were realigned strictly by solid state deformation? Do they represent slab-like sections of amphibolite wall rock that had been loosened during shearing and permissive intrusion of the granitoid magma? All scenarios have been proposed in one form or another.

A less complicated approach for the origin of Hyde School Gneiss begins with a layered complex of alternating ash-flow tuffs and minor metasediments, capped in some cases by outpourings of more fluid lavas and ash of trondhjemic and dioritic composition. Solid state deformation, with localized partial melting in low pressure sites, and late stage pegmatite intrusion, would account for features cited by others as evidence for intrusive origin. If the amphibolite layers were once basaltic dikes that had intruded the complex, then transposition to parallelism with the surrounding rocks had to occur *prior to* the 1170-1130 Ma period of high grade metamorphism in the Lowlands, because the amphibolite bodies were deformed after they had acquired the layered form. If the amphibolite layers represent original lithologies, e.g. protoliths of iron-rich, calcareous shales or basaltic ash, then deformation could have occurred simultaneously with high grade metamorphism.

High Temperatures and Contact Metamorphism?

The most compelling evidence for intrusive origin of Hyde School Gneiss cited by McLelland and others (1992) is the presence of perthite within the gneiss and the presence of a high grade mineral assemblage (garnet, sillimanite and spinel) in gneisses that surround Hyde School Gneiss. Perthite may form from exsolution of hypersolvus feldspar, the existence of which implies temperatures higher than those proposed for Lowland metamorphism.

It is interesting to note that the high grade mineral assemblage might have been used as evidence for higher temperatures of *regional* metamorphism had the assembly been found elsewhere than adjacent to Hyde School Gneiss. A search is underway to determine if the assemblage occurs in pelitic rocks elsewhere in the Lowlands. Given the paucity of Lowland pelitic rocks, and the remarkable selectivity that Hyde School Gneiss magma presumably has shown in intruding only pelitic horizons, we think it appropriate that the upper ranges of temperatures proposed for Lowland metamorphism be reconsidered. Also needed are U-Pb ages of garnet from the sillimanitic gneisses adjacent to Hyde School Gneiss. If the ages are >1200 my (similar to the age of the gneiss) then contact metamorphism is a possible cause. If the ages are <1200 my, then regional metamorphism is likely.

The proposal that stratigraphic principles cannot be applied in the Lowlands goes hand in glove with the model of intrusive origin for Hyde School Gneiss. Pelitic rocks can be conveniently distributed where needed as a host for granite intrusions. One may dismiss the present view of Popple Hill Gneiss as a lithologic/stratigraphic unit confined to the south-central Lowlands. It may be presumed to be distributed elsewhere, intruded by Hyde School Gneiss magma and partially melted so that the residue is left as a garnet-sillimanite gneiss that surrounds Hyde School Gneiss (McLelland and others, 1992).

On the other hand, we suggest that Hyde School Gneiss may represent a layered volcanic complex overlain by the lowest member of Lower Marble formation, whose pelitic composition was favorable for growth of garnet, sillimanite and spinel during the period of high grade regional metamorphism from 1170 to 1130 Ma.

A Stratigraphic View of Hyde School Gneiss:

The picture that emerges from detailed field mapping of members of Lower Marble formation is that the bodies of Hyde School Gneiss occur at the same stratigraphic horizon across the Lowlands. Each body is associated with the Black Lake member of the Lower Marble Formation. It is difficult to imagine how independent intrusions could acquire such similar surroundings unless the carbonate cover was deposited unconformably over each dome as proposed by Wiener and others (1984). Previous references to the gneiss appearing at various horizons across the Lowlands are incorrect. The California body of Hyde School Gneiss was cited as being in contact with Popple Hill Gneiss, with the inference being that the contact was intrusive in origin (Buddington, 1929; McLelland and others, 1992). However, the marble is exposed on the surface, and Zinc Corporation drill core shows that the Black Lake member of Lower Marble occurs between Hyde School Gneiss and Popple Hill Gneiss.

Xenoliths of adjacent metasedimentary rocks occur in Hermon-type and in most other metaintrusive rocks throughout the Lowlands, particularly at the margins of a body. Diligent search has produced few xenolithic candidates in Hyde School Gneiss other than amphibolite. Cushing (1916) observed as much when he wrote of inclusions in Hyde School Gneiss as consisting of amphibolite "no matter what the nature of the bordering Grenville rock is" (p. 18).

The conformable amphibolite layers in Hyde School Gneiss have been interpreted as slabs that were stoped and separated along foliation planes by incoming magma (Levy and others, 1993). This process requires the fortuitous convergence of the following unrelated factors: (1) The necessary presence of vast quantities of amphibolitic material immediately below the Black Lake member of Lower Marble. (2) The necessary requirement that the batholith intrude but one stratigraphic horizon and that it stoped only the amphibolite layers. Apophyses, dikes and sills of Hyde School Gneiss are non-existent in the surrounding metasedimentary rocks. (3) The requirement that the magma be extremely fluid in order to incorporate slabs that vary in thickness from 1 to 60 cm or more. Many so-called slabs have uniform thicknesses for tens of meters. (4) The requirement that magma of stock-like to batholithic dimensions was confined to one or several substrata of appropriate pelitic composition that, in turn, could be subjected to contact metamorphism to produce the ever-present garnet-sillimanite gneiss.

Continue straight ahead to intersection with Route 7 (Hyde road).

59.7 (96.1 km)	0.2	Turn left onto Route 7 toward Pope Mills.
62.7 (100.9 km)	3.0	Intersection with Route 184. Turn left (W) toward Pope Mills.
63.5 (102.2 km)	0.8	Intersection with Route 58 in Pope Mills. Continue on Route 58.
64.3 (103.5 km)	0.8	Stop 10. Park along Route 58. Do not climb the outcrop to the right (E) onto the lawn of the trailer.

STOP 10. The Pope Mills gabbro near Pope Mills village (Fig. 9).

The purpose of this brief stop is to examine a folded and metamorphosed mafic intrusion within the Lower Marble formation as a prelude to examination of the Fish Creek body of Hyde School Gneiss. The Pope Mills gabbro was interpreted by Buddington (1934) as a relatively large mass of "pyroxenic amphibolite" that had been sheared prior to intrusion of syenitic magma. The intrusion of syenite into foliation planes, with the help of mineralizers, was believed responsible for the "migmatitic character" of the body, particularly the K-feldspar megacrysts and augen that are strikingly displayed at outcrops further to the south. The body was isoclinally folded and overturned towards the northwest with the dip of foliation varying from 55 to 70° SE (Buddington, 1934).

Xenoliths of banded, greenish calc-silicate from the Black Lake member of Lower Marble occur within the metagabbro. At least three phases of the gabbro are recognized: (1) subrounded to angular and block-like forms of fine grained gabbro that are surrounded by (2) a slightly coarser grained gabbro matrix. Also present, but not at this outcrop, is (3) a biotite and K-feldspar megacrystic gabbro that Buddington regarded as a mixed rock. Examine the weathered horizontal surface on the west side of the road, and note the calc-silicate xenoliths that form a tectonically re-aligned intrusion breccia. Also note the deformed, fine grained gabbro ellipsoids whose long axes trend N 75 E.

Representative chemical analyses of the three gabbroic phases are given in Table 1. The coarser grained matrix (sample 223) is richer in total Fe, TiO_2 and P_2O_5 than the finer grained phase (sample 222). We tentatively regard the finer grained gabbro as autoliths, and the coarser grained matrix as a later, more differentiated, iron-rich phase of the same magma.

Continue north on Route 58.

65.1 (104.8 km)	0.8	Stop 11. Park on Route 58 south of the Bishop road (right) and walk northward to the outcrop.

STOP 11. SW margin of Fish Creek body of Hyde School Gneiss (Fig. 9).

Hyde School Gneiss is exposed in the hinge/axial region of the Fish Creek anticline. Nowhere could a more challenging and complex outcrop be found, because these cuts expose highly deformed alaskitic and trondhjemitic gneisses with parallel layered amphibolites in the core of a regional "anticline that looks like a syncline" (i. e. a sheath fold). Amphibolite layers may have undergone an early deformation that resulted in "chocolate-tablet" style boudinage before being refolded in the hinge of the Fish Creek anticline. Pegmatites with feldspar, green clinopyroxene and titanite assemblages intrude the suite of leucogneisses and also may appear at or near the contact with the overlying Black Lake member. Did the pegmatitic fluids derive some constituents from the carbonates upsection? Mafic dikes, probably offshoots from the Pope Mills metagabbro, are present and superfically resemble the amphibolites. Other intrusive rocks also may be present in these outcrops.

The following scenario for the Fish Creek body is proposed by deLorraine: Begin with a "normal" sequence of Hyde School Gneiss, the trondhjemite phase in contact with overlying Black Lake metasediments that are exposed at the south end of the outcrop at Bishop road. Rocks are subjected to high grade metamorphism and deformation with temperatures at the higher end of those reported in the literature. The earliest phase of deformation produced chocolate-tablet boudinage in the conformable amphibolite layers, accompanied by partial melting in the neck zones of boudins. Pegmatites are intruded, possibly channeled along the interface between Hyde School Gneiss and the Black Lake member. Offshoots of the Pope Mills metagabbro are intruded, and one wonders about contributions to the local heat budget that may have facilitated partial melting in Hyde School Gneiss.

Table 1 Representative samples of a Fish Creek amphibolite layer (190A), the Pope Mills gabbro (222 = fine grained; 223 = coarser grained; K-feldspar megacrystic = 56B), and a basaltic dike (198B) in the Fish Creek body.

	DF190A	DF222	DF223	DF56B	DF198B
SiO2 (wt. %)	48.06	51.29	48.71	51.65	48.79
Al2O3	14	15.46	15.48	16.96	16.03
Fe as Fe2O3	14.49	10.37	13.94	10.26	14.12
MgO	6.54	6.67	5.45	3.46	4.85
CaO	10.8	9.44	9.3	5.77	7.1
Na2O	3.61	3.43	3.16	3.79	4.46
K2O	0.85	1.11	1.4	4.14	1.93
TiO2	1.8	1.13	2.03	1.74	1.88
P2O5	0.29	0.28	0.56	0.91	0.32
MnO	0.24	0.16	0.17	0.11	0.15
LOi	0.17	0.73	0.59		1.45
Rb (ppm)	7	14	24	65	33
Sr	371	606	691	913	473
Ba	176	550	735	2209	581
Y	39	37	45	44	46
Zr	103	55	148	538	178
Nb	1	6	12	6	10
Cr	157	215	91	55	15
Ni	72	92	33	0	36

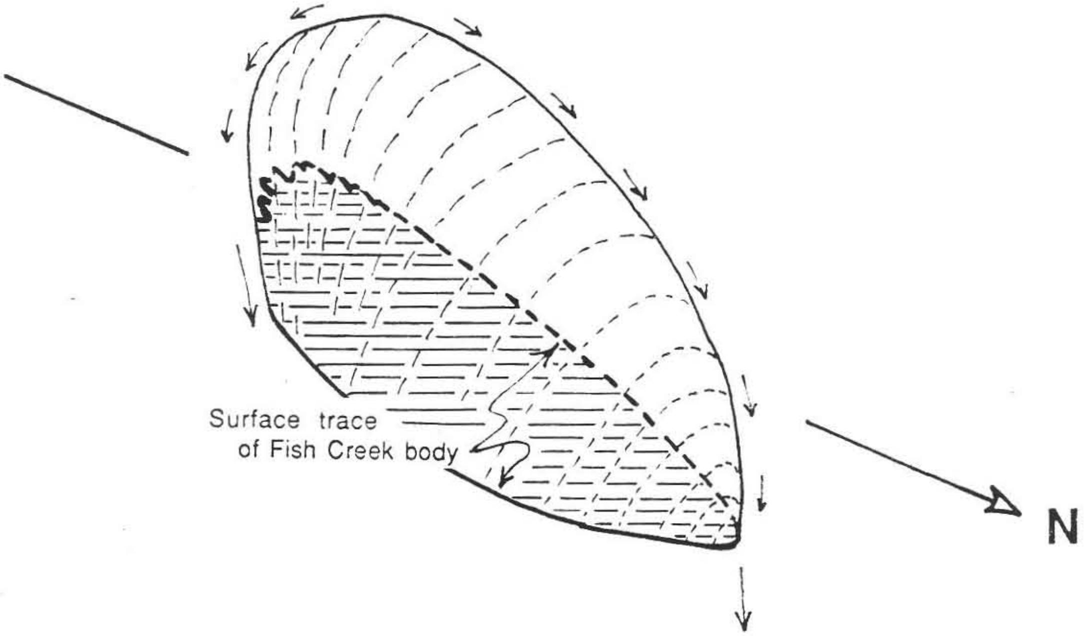


Figure 10 Sketch of a model of the Fish Creek body of Hyde School Gneiss as a sheath fold.

Phase two isoclinal sheath folding then affected the region, producing the NE-SW regional grain. The second phase, sheath fold hinge in the SW end of the Fish Creek anticline resembles an "anticline that behaved like a syncline" because of the northerly plunges of a profusion of minor tight to isoclinal folds (see proposed sketch of the structure of the Fish Creek body, Fig. 10). "M and W" minor folds in the hinge of the anticline were superimposed on amphibolite layers that previously had undergone chocolate-tablet boudinage. Partial melting would be enhanced in the core of the Fish Creek anticline because it would be a low pressure site. Magmatic heat contributions from the sill and dikes offshoots of the Pope Mills metagabbro also may have facilitated partial melting. So-called "intrusion breccias," thus, are best interpreted in a regional framework as broken, boudinaged fragments of conformable amphibolite layers which have been refolded and deformed in the solid state by "M and W" folds. The best place to verify that the amphibolite layers are not randomly or chaotically distributed is to observe them from the top of the outcrop on the west side of the road. Look to the north down the plunges of minor folds.

Turn right (E) onto Bishop road.

66.9 (109.0 km)	1.8	Intersection (left) with Mitchell road. Continue on Bishop road.
69.7 (107.7 km)	2.8	Stop 12. Park on Bishop road.

STOP 12. Mafic layers in the Fish Creek body of Hyde School Gneiss, pasture of the Yoder farm (Fig. 9).

One purpose of this stop is to distinguish late dikes that may be related to the Pope Mills metagabbro (stop 10) from amphibolite layers of the Fish Creek body of Hyde School Gneiss. Metagabbro dikes are shown to post-date the foliated amphibolite layers and an early phase of isoclinal folding. Although the dikes have been deformed and metamorphosed (as is the case with the Pope Mills gabbro), they are clearly younger than the amphibolite layers.

The dikes and amphibolite layers have been regarded as coeval. Cross-cutting relationships as observed here have been used as evidence that all mafic layers had formed as dikes which, in turn, had been transposed shortly after their emplacement within Hyde School Gneiss magma (McLelland and others, 1992). Phenocrystic plagioclase and coarse subophitic orthopyroxene have been used as evidence for an intrusive origin (Levy and others, 1993), but we believe it is the dikes that have been described rather than true amphibolite layers. The dikes have abundant orthopyroxene in various stages of alteration to hornblende. The amphibolite layers are chiefly amphibolite and biotite with little pyroxene.

The Fish Creek body was mapped by Dietrich (1954; 1957) who agreed with Buddington that the Hyde School Gneiss was intrusive in origin (he later changed his mind to an origin as

A1

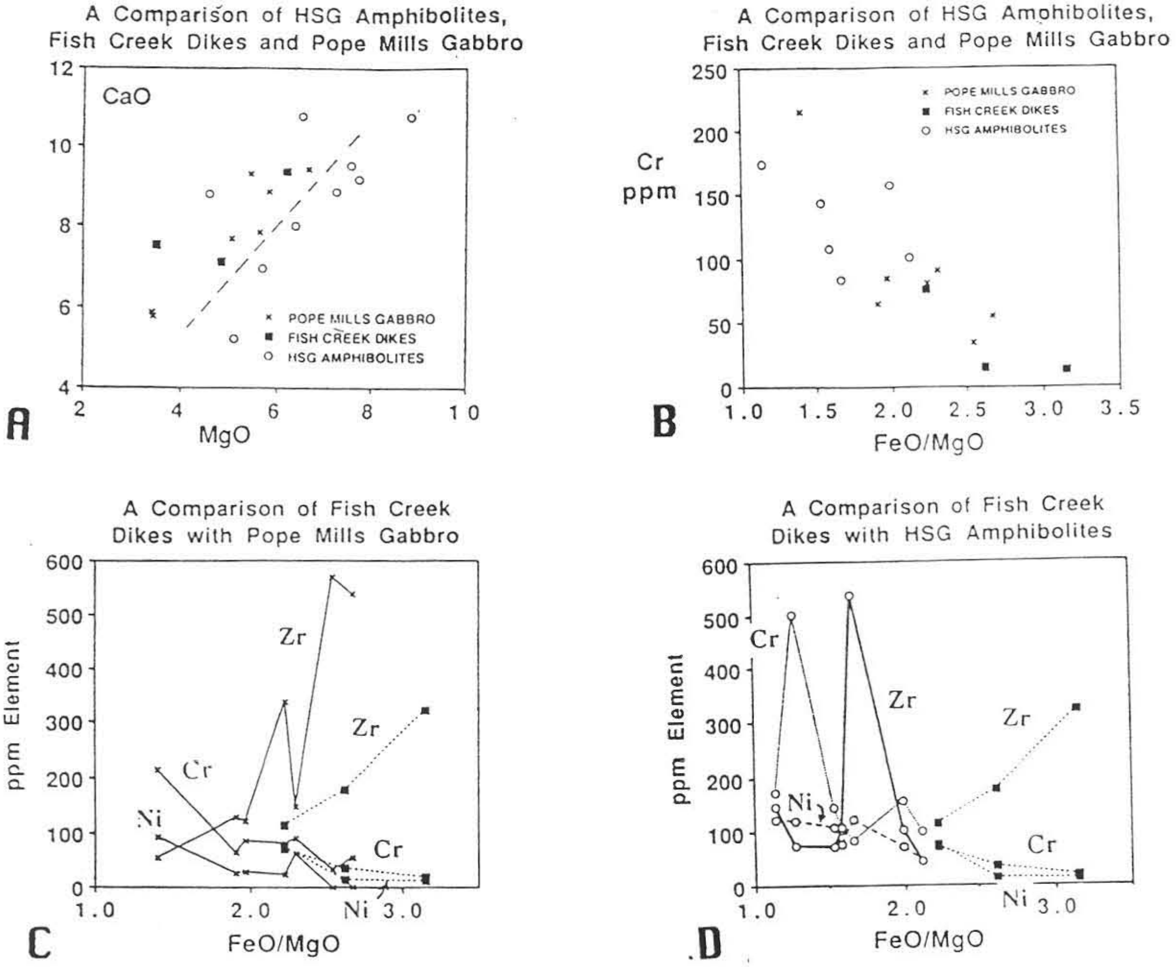


Figure 11. A geochemical comparison of mafic rocks. Pope Mills gabbro (x's), Hyde School Gneiss amphibolite layers (circles) and Fish Creek metabasaltic dikes (solid squares). (A) Pope Mills gabbro and the dikes contain less MgO than most amphibolite layers. (B) Pope Mills gabbro and the dikes are deficient in Cr relative to the amphibolite layers. (C) Trends of elemental abundances versus FeO-MgO ratios. Elemental abundances for the gabbro (x's) vary systematically with increasing Fe-Mg ratios, as is the case for the basaltic dikes (solid squares). (D) Elemental abundances for the amphibolite layers (circles), however, vary erratically with increasing Fe-Mg ratios, with the exception of Ni.

in situ anatectic magma; Dietrich, 1963). The disrupted amphibolite layers were described as xenoliths throughout the 1957 report. In addition to the amphibolite layers, Dietrich recognized 18 tabular "amphibolitized melanocratic dikes," ranging from nearly 2 ft. to a few inches in width (see photos p. 57-58 in Dietrich, 1957).

We will examine several gabbroic dikes exposed in the pastures on both sides of Bishop road. One of the dikes cuts several amphibolite layers, including one that has been isoclinally folded. The dike has been realigned to near parallelism with the amphibolite layers at one end of the outcrop. A 1 m thick dike elsewhere in the pasture cuts several amphibolite layers at an acute angle. One layer can be traced into the dike where it reappears as ruptured fragments that are true xenoliths. Clearly the amphibolite had acquired its foliation and layered form prior to intrusion of the dikes.

We have observed these dikes only in the Fish Creek and Stalbird bodies of Hyde School Gneiss. They are particularly abundant in the Fish Creek body, perhaps because of the presence of the Pope Mills gabbro.

We compare the chemistry of (1) dikes in the Fish Creek body, (2) Hyde School Gneiss amphibolite layers, and (3) Pope Mills gabbro (Table 1). In general, Hyde School Gneiss amphibolites contain more MgO, Cr and Ni than the Pope Mills gabbro. Advocates of a metaigneous origin for the amphibolite layers may regard enrichment in these elements as indicative of a lack of olivine fractionation in their source. We have used plots of MgO vs CaO (Fig. 11A) and FeO-MgO ratios vs Cr (Fig. 11B) to distinguish Hyde School Gneiss amphibolite layers from Pope Mills gabbro. Fish Creek dikes plot with the gabbro.

Fish Creek dikes resemble the Pope Mills gabbro in a tendency toward iron enrichment. Both groups show increasing Zr (and TiO_2 and P_2O_5) content and decreasing Cr and Ni (and CaO) content with increasing Fe-Mg ratio (Fig. 11C). In contrast, the amphibolite layers generally have lower Fe-Mg ratios and show relatively erratic changes in abundances of these elements with increasing iron content (Fig. 11D). We tentatively regard the dikes as fractionated, iron-enriched derivatives of the Pope Mills gabbro. More samples are needed.

Continue straight ahead to the turnaround.

70.1 (112.9 km)	0.4	Turn around in the driveway of the red barn. Retrace the route on Bishop road.
75.0 (120.7 km)	4.9	Intersection with Route 58. Turn left (S) to Pope Mills and Gouverneur.
76.7 (123.5 km)	1.7	Pope Mills. Turn right to follow Route 58.
91.3 (147.0 km)	4.6	James River Corp. paper mill at Natural Dam.
93.1 (149.9 km)	1.8	Stop sign in Gouverneur. Turn right to stay on Route 58.
93.4 (150.4 km)	0.3	Junction with Route 11. Turn left (NE) onto Route 11 toward Richville and Canton.

100.4 (161.6 km)	7.0	Abrupt right (SE) turn uphill towards Richville.
100.6(162.0 km)	0.2	Turn left (N) onto Main St. in Richville.
101.2(162.9 km)	0.6	Stop. Intersection with Route 11. Turn left (SW) and park on the right side of Route 11 adjacent to the outcrops of dark rock.

CAREFUL HERE. TRAFFIC MOVES FAST.

STOP 13. Tourmalinites and quartzites with a thinly layered appearance.

Exposed here are fine grained, gray to deep maroon, tourmaline-bearing metasedimentary rocks that include quartz-feldspar-mica-diopside gneisses, calc-silicates and quartzites. Note the inclined, 1 m thick layer of dark, glassy quartzite that contains tiny, vitreous grains of dark tourmaline. These grains could be overlooked or mistaken for biotite. We correlate the rocks with tourmaline-bearing gneisses and quartzites of unit "qmt" (Fig. 1) in the Beaver Creek area (Brown, 1989). Lithologically similar rocks have been intruded by the Rockport pluton in the Thousands Islands area, suggesting that "qmt" or its equivalents may be of widespread occurrence in southeastern Ontario.

Tourmalinite is abundant in the Lower Marble and may have crystallized from boron-rich basinal brines during diagenesis and metamorphism (Brown and Ayuso, 1985). Feldspathic quartzites and quartz-feldspar-mica granofels contain layers with up to 50% tourmaline whose composition is dravite-uvite with 0.85 to 4.25 wt.% Na_2O, 0.39 to 4.04% CaO, and up to 13.67% MgO (which is near end-member dravite composition). Li-rich compositions have not been found.

Tourmaline also occurs in sheet-like bodies of metagranite that intrude "qmt," but the tourmaline is compositionally distinct from that in the metasedimentary rocks (Brown and Ayuso, 1985). Ratios of FeO-(FeO+MgO) range from 0.55 to 0.75 in granites and pegmatites, compared to ratios of 0.15 to 0.58 for tourmalines in quartzites. Previous workers believed that the tourmaline in the metasedimentary rocks had originated from the granitic intrusions, but the reverse may be true. Intrusive rocks may have picked up (and compositionally modified?) the tourmaline from the metasedimentary rocks, as is suggested by the distribution of the tourmaline-bearing intrusions. Abundant tourmaline occurs in the metagranite that intrudes "qmt" rocks near Huckleberry Mountain (Richville quadrangle), whereas tourmaline is less common in granites that have intruded other rock units.

Some rock types within the unit "qmt" are intensely limonite-stained by the weathering of pyritic zones. Pyrite mining was carried out as a source of sulphur and sulphuric acid for the paper industry at Pyrites, Stellaville and elsewhere in northern New York in the late 19th and early 20th centuries.

Go straight ahead (SW) on Route 11.

101.7 (163.7 km)	0.5	Turn right (NW) onto the Richville Bridge road.
102.3 (164.7 km)	0.6	Cross the Oswegatchie River bridge and turn right.
103.1 (166.0 km)	0.6	Turn right onto River road.
107.0 (172.3 km)	3.9	Stop 14. Park along this narrow road.

STOP 14. Hermon-type granitoid gneiss of the Gray's School body.

At least two textural types of granitoid metaintrusive rocks were mapped in the Lowlands at the turn of the century, a fine-grained, so-called "equigranular" gneiss of the Alexandria-type that included the Hyde School Gneiss, and a coarser grained, K-feldspar megacrystic gneiss called the Hermon-type (Cushing and others, 1910). The mapping of numerous small and isolated granitic bodies throughout the Lowlands eventually led to the adoption of local names and to the abandonment of the term "Alexandria-type." But the name Hermon-type is still applied to relatively small, sheet-like and irregularly shaped, K-feldspar megacrystic plutons that are scattered throughout the Lowlands.

Hermon gneisses are generally reddish, medium to coarse grained feldspar-biotite-hornblende-quartz-titanite gneisses of syenitic to granitic composition (note the paucity of quartz at this outcrop). They contain large K-feldspar megacrysts that occasionally are oriented transverse to foliation. This coarse grained rock may give way along strike to become a fine grained equigranular gneiss. Pervasive grain size reduction may be responsible, and K-feldspar augen, flaser structure and quartz ribbons are often observed in thin section in association with a mosaic textured groundmass.

Igneous textures have survived the metamorphism and ductile deformation. Concentrically zoned megacrysts of K-feldspar are observed in thin section to contain zones of patch or speckled or "fire flake" perthite that alternate with wider zones or bands of non-perthitic feldspar. Plagioclase grains and biotite flakes lie against the perthite zones and protrude outwardly from them. We interpret these grains to be Frasel or epitatic inclusions that originally adhered to the face of a K-feldspar crystal that crystallized from a melt. The rims of fine grained pink feldspar that surround the phenocrysts were produced by ductile deformation.

Hermon gneisses generally occur as intrusions within the Lower and Upper marbles and the Popple Hill Gneiss. Conformity with the host rock, due in some cases to tectonism, has caused some to be mapped as lithologic units. They generally occur as sills and less often as dikes or apothyses. Xenoliths of amphibolite are common.

Each intrusive body of Hermon gneiss is characterized by a limited range in major element content. For example, samples from the Gray's School body (including this outcrop) are uniformly syenitic, low in SiO_2 and rich in MgO (Fig. 12; see sample 101A in Table 2). Gneisses near Hermon village are of intermediate SiO_2 content (sample 178), and samples of high SiO_2 and low MgO content (sample 124) are characteristic of the Mott Creek body. We believe that these rocks represent a common intrusive series.

We compare Hermon gneisses with another Lowland metagranite, the "equigranular" Rockport gneiss which outcrops in the islands and along the shore of the St. Lawrence River. Formerly called the Alexandria Bay Formation, this rock was cited by Wiener and others (1984) as equivalent to Hyde School Gneiss and, thus, was made to represent the basal stratigraphic unit in the NW Adirondacks. Rockport gneisses are quartz-feldspar-biotitic gneisses with less hornblende and titanite than Hermon gneisses. Fluorite is a notable accessory phase, as is tourmaline where tourmaline-bearing host rocks have been intruded (Brown and Ayuso, 1985). Rockport gneisses clearly show an intrusive origin as dikes, sills and stock-like masses. Geochemical and field differences suggest that they represent a more highly differentiated and less viscous magma than Hermon-type magma.

Hermon gneisses show a tendency toward calc-alkaline character (Fig. 13A, B) that contrasts with a pronounced alkaline character for Rockport gneisses. Both gneissic groups plot chiefly in the field of "volcanic arc" granites on an Rb vs Y + Nb tectonic discrimination

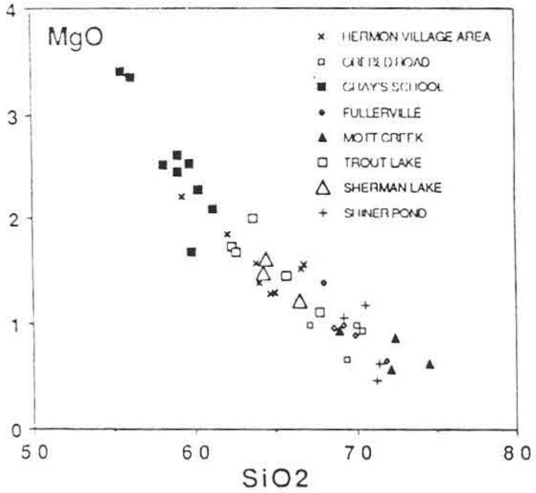


Figure 12 Plot of MgO versus SiO_2 to demonstrate that different intrusive bodies of Hermon-type granitoid gneisses have relatively consistent compositions. The syenitic Gray's School body is exposed at stop 14.

Table 2 Representative samples of Hermon gneisses (top) and Rockport gneisses (bottom). Sample 101A is from stop 14.

HERMON	#101A	#178	#124
SiO2 (wt. %)	58.99	66.78	74.56
Al2O3	16.76	16.54	14.16
Fe as Fe2O3	5.58	4.03	1.78
MgO	2.45	1.56	0.63
CaO	3.88	2.19	1.4
Na2O	4.52	2.57	3.91
K2O	5.51	5.53	4.19
TiO2	0.71	0.61	0.17
P2O5	0.4		0.06
MnO	0.08	0.01	0.06
Rb (ppm)	134	142	129
Sr	915	423	241
Ba	1018	1119	493
Y	44	35	36
Zr	415	267	114
Nb	13	12	0
Ga	18		17
Ce	192		51
ROCKPORT		#3F	#71A
SiO2 (wt. %)		68.37	73.64
Al2O3		14.42	13.62
Fe as Fe2O3		4.29	1.94
MgO		0.42	0.1
CaO		1.39	1.07
Na2O		4.24	3.49
K2O		5.45	5.17
TiO2		0.45	0.15
P2O5		0.05	0.01
MnO		0.07	0.03
Rb (ppm)		105	205
Sr		175	92
Ba		466	417
Y		49	62
Zr		571	136
Nb		10	7
Ga		21	17
Ce		269	80

A1

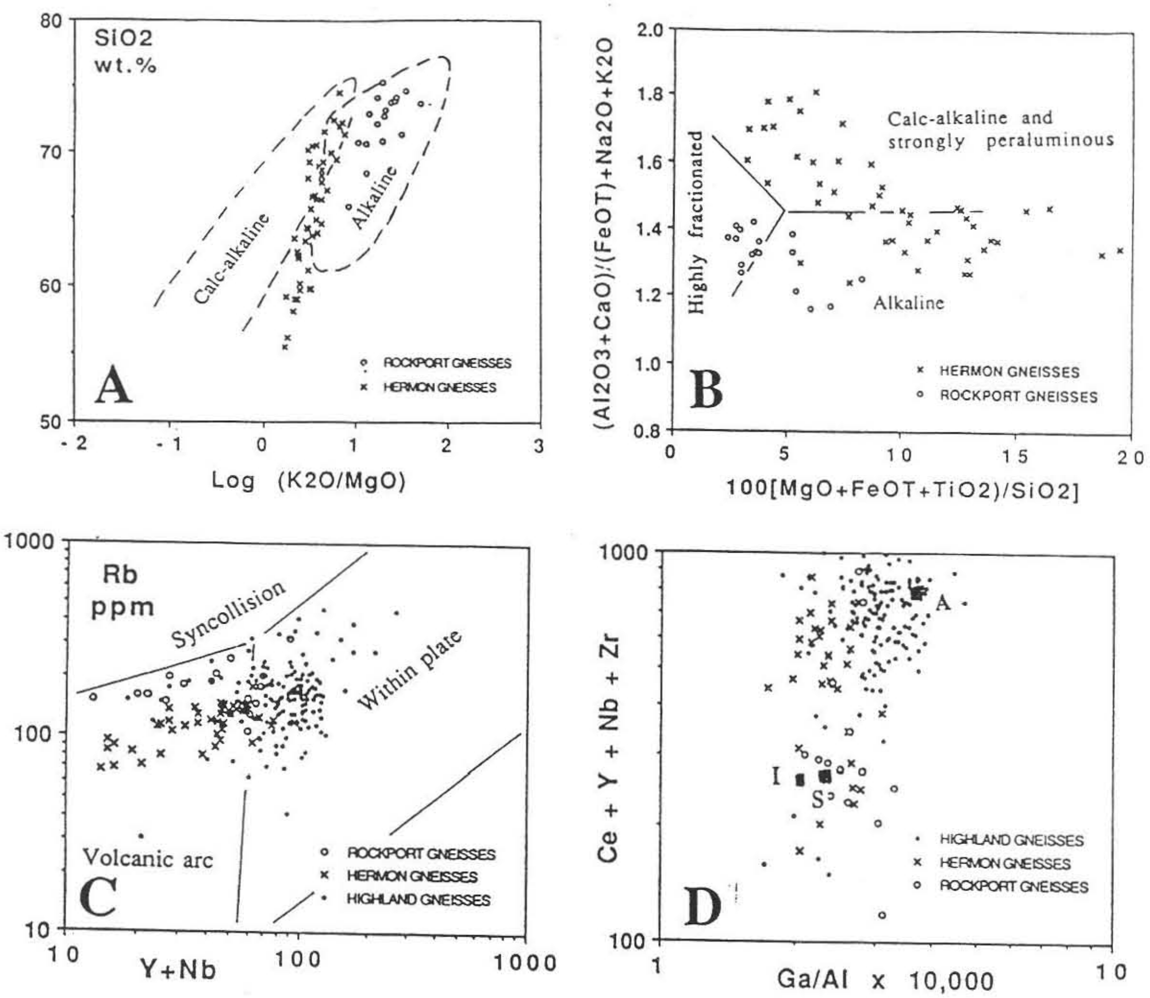


Figure 13 (A) Plots of (K2O/MgO) versus SiO_2. Hermon gneisses (x's) are transitional between calc-alkaline and alkaline. Rockport gneisses (circles) are alkaline. Fields are based on data from island arc and continental-margin suites, including the Sierra Nevada batholith, after Rogers and Greenberg (1981). (B) Major element classification of granites after Sylvester (1989) who views the "highly fractionated" category as a variety of alkaline granite. Hermon gneisses are transitional between calc-alkaline and alkaline, whereas Rockport gneisses are alkaline. (C) Tectonic discrimination diagram after Pearce and others (1984). Hermon and Rockport gneisses plot chiefly as volcanic arc granites. Highland data (dots) from Whitney (1992, and personal communication, 1991) and McLelland and Whitney (1990). Included are 12 samples taken by us from lower Lake Durant Formation in the Highlands. (D) Plots used to distinguish among I-, S- and A-type granites after Whalen and others (1987). Hermon (x's) and Rockport gneisses (circles) are widely scattered, whereas Highland granitoid rocks (dots) cluster near A-type granite.

diagram (Fig. 13C). Plots of both gneisses are widely scattered among I, S and A-type granites (Fig. 13D). In contrast, granitoid rocks of the AMCG series in the Adirondack Highlands (Figs. 13C, D) plot chiefly as alkaline, A-type "within plate" intrusive rocks (McLelland, 1986; McLelland and Whitney, 1990; Daly and McLelland, 1991).

Proceed straight ahead on River road.

108.3 (174.4 km)	1.3	First stop sign. Turn right onto Maple Ridge road.
108.5 (174.7 km)	0.2	Second stop sign. Turn right.
109.1 (175.7 km)	0.6	Oswegatchie River bridge and intersection with Route 812. Turn right on Route 812 to Dekalb.
109.3 (176.0 km)	0.2	Turn left onto Route 17 in Dekalb toward Dekalb Junction.
110.3 (177.6 km)	1.0	"Y" in the road. Keep left toward Dekalb Junction.
113.3 (182.4 km)	3.0	Intersection with Route 11 in Dekalb Junction. Turn left (NE) toward Canton.
121.9 (196.2 km) the	8.6	Intersection with Park St. in Canton. Turn right (S) to return to SLU physical plant parking lot.

WE HOPE YOU HAVE HAD A GOOD TRIP.

REFERENCES

Ambers, C.P., and Hudson, M.R., 1985, Syntectonic metamorphism in the Hailesboro fault zone, Northwest Adirondacks: Geological Society of America Abstracts with Programs, v. 17, p. 2.

Badger, R.L., 1993, Geochemical affinities of a late Precambrian basaltic dike, Adirondack Lowlands, northern New York: Geological Society of America Abstracts with Programs, v. 25, p. 4.

Bohlen, S.R., Valley, J.W. and Whitney, P.R., 1989, The Adirondack Mountains--a section of deep Proterozoic crust: Field Trip Guidebook T164, 28th International Geological Congress, 63p.

Books, K.G., and Brown, C.E., 1983, Paleomagnetic study of diabasic dikes and miscellaneous granitic gneisses in St. Lawrence and Jefferson Counties, New York: U.S. Geological Survey Open-File Report 83-226, 17p.

Brocoum, S.J., 1971, Structural and metamorphic history of the major Precambrian gneiss belt in the Hailesboro-West Fowler-Balmat area, Adirondack Lowlands, New York, [PhD thesis], New York, Columbia University, 194p.

Brown, C.E., 1989, Geologic map of the Beaver Creek area in the Grenville Lowlands, St. Lawrence County, New York: U.S. Geological Survey Miscellaneous Investigations Series, Map I-1725.

Brown, C.E., 1988, Geologic map of the Birch Creek area, St. Lawrence County, New York: U.S. Geological Survey Miscellaneous Investigations Series Map I-1645.

Brown, C.E., 1983, Mineralization, mining and mineral resources in the Beaver Creek area of the Grenville lowlands in St. Lawrence County, New York: U.S. Geological Survey Professional Paper 1279, 21p.

Brown, C.E., 1978, Reconnaissance investigation of high-calcium marble in the Beaver Creek area, St. Lawrence County, New York: U.S. Geological Survey Circular 774, 10p.

Brown, C.E., 1975, Problematical age of an alkaline analcite-bearing olivine diabase dike in St. Lawrence County, New York: Geological Society of America Abstracts with Programs, v. 7, p. 31.

Brown, C.E., 1969, New talc deposit in St. Lawrence County, New York: U.S. Geological Survey Bulletin 1272-D, 13p.

Brown, C.E., and Ayuso, R.A., 1985, Significance of tourmaline-rich rocks in the Grenville complex of St. Lawrence County, New York: U. S. Geological Survey Bulletin 1626-C, 33p.

Buddington, A.F., 1929, Granite phacoliths and their contact zones in the northwest Adirondacks: New York State Museum Bulletin 281, p. 51-107.

Buddington, A.F., 1934, Adirondack igneous rocks and their metamorphism: Geological Society of America Memoir 7, 354p.

Carl, J.D., and VanDiver, B.B., 1975, Precambrian Grenville alaskite bodies as ash-flow tuffs, northwest Adirondacks, New York: Geological Society of America Bulletin v. 86, p. 1691-1707.

Carl, J.D., 1988, Popple Hill Gneiss as dacite volcanics: A geochemical study of leucosome and mesosome, northwest Adirondacks, New York: Geological Society of America Bulletin, v. 100, p. 841-849.

Carl, J.D., deLorraine, W.F., Mose, D.G., and Shieh, Yuch-Ning, 1990, Geochemical evidence for a revised Precambrian sequence in the northwest Adirondacks, New York: Geological Society of America Bulletin, v. 102, p. 182-192.

Carl, J.D., and Sinha, A.K., 1992, Zircon U-Pb age of Popple Hill Gneiss and a Hermon-type granite gneiss, northwest Adirondack Lowlands, New York: Geological Society of America Abstracts with Programs, v. 24, p. 11.

Cartwright, I., and Valley, J.W., 1991, Steep oxygen-isotope gradients at marble-metagranite contact in the northwest Adirondack Mountains, New York, U.S.A: products of fluid-hosted diffusion: Earth and Planetary Science Letters, v. 107, p. 148-163.

Chiarenzelli, J.R., and McLelland, J.M., 1991, Age and regional relationships of granitoid rocks of the Adirondack Highlands: Journal of Geology, v. 99, p. 571-590.

Cushing, H.P., 1916, Geology of the vicinity of Ogdensburg: New York State Museum Bulletin 191, 64p.

Davidson, A., 1986, New interpretations in the southwestern Grenville Province, *in* Moore, J.M., Davidson, A., and Baer, A.J., eds., The Grenville Province: Geological Association of Canada Special Paper 31, p. 61-74.

Daly, J.S., and McLelland, J.M., 1991, Juvenile Middle Proterozoic crust in the Adirondack Highlands, Grenville Province, northeastern North America: Geology, v. 19, p. 119-122.

deLorraine, W.F., 1979, Geology of the Fowler orebody, Balmat #4 mine, Northwest Adirondacks, New York [MS thesis]: Amherst, Massachusetts, University of Massachusetts, 159p.

deLorraine, W.F., and Carl, J.D., 1986, Precambrian stratigraphy of the Northwest Adirondacks, New York: Friends of the Grenville guidebook for field trip, 37p.

Dietrich, R.V., 1954, Fish Creek phacolith, northwestern New York: American Journal of Science, v. 252, p. 513-531.

Dietrich, R.V., 1957, Precambrian geology and mineral resources of the Brier Hill quadrangle, New York: New York State Museum Bulletin 354, 121p.

Dietrich, R.V., 1963, Banded gneisses of eight localities: Norsk Geologisk Tidsskrift, v. 43, p. 89-121.

Edwards, R.L., and Essene, E.J., 1988, Pressure, temperature, and C-O-H fluid fugacities across the amphibolite-granulite transition, N.W. Adirondack Mountains, New York: Journal of Petrology, v. 29, p. 39-72.

Ehrhard, L.E., 1986, Low activities of H_2O at the amphibolite-granulite facies transition, N.W. Adirondacks: evidence for pre-Grenville melting and dehydration [MS thesis]: Stony Brook, New York, State University of New York.

Engel, A.E.J., and Engel, C.G., 1953, Grenville series in the northwest Adirondack Mountains, New York, Part 1: General features of the Grenville series: Geological Society of America Bulletin, v. 64, p. 1013-1048. Part II: Origin and metamorphism of the major paragneiss, p. 1049-1098.

Engel, A.E.J., and Engel, C.G., 1958, Progressive metamorphism and granitization of the major paragneiss, northwest Adirondack Mountains, New York, Part I: Total rock: Geological Society of America Bulletin, v. 69, p. 1369-1414.

Foose, M.P., 1974, The structure, stratigraphy and metamorphic history of the Bigelow area, Northwest Adirondacks, New York [PhD thesis]: Princeton, New Jersey, Princeton University, 224p.

Foose, M.P., and Carl, J.D., 1977, Setting of alaskite bodies in the northwest Adirondacks: Geology, v. 5, p. 77-80.

Gilluly, J., 1934, Geology of the Gouverneur talc district, New York: New York State Museum umpublished manuscript, 110 p.

Grant, N.K., Carl, J.D., Lepak, R.J., and Hickman, M.H., 1984, A 350-Ma crustal history in the Adirondack Lowlands: Geological Society of America Abstracts with programs, v. 16, p. 19.

Guzowski, R.V., 1979, Stratigraphy, structure and petrology of the Precambrian rocks in the Black Lake region, northwest Adirondacks, New York [PhD thesis]: Syracuse, New York, Syracuse University, 184p.

Heyn, T., 1990, Tectonites of the Northwest Adirondack Mountains, New York: structural and metamorphic evolution [PhD thesis]: Ithaca, N.Y., Cornell University, 203 p.

Hoffman, K.S., 1982, Investigation of the orthopyroxene isograd, N.W. Adirondacks [MS thesis]: Ann Arbor, Michigan, University of Michigan.

Hudson, M.R., Grant, N.K., Carl, J.D., and Ambers, C.P., 1986, The timing of high grade metamorphism in the northwest Adirondacks: Geological Society of America Abstracts with Programs, v. 18, p. 23-24.

Isachsen, Y.W., and Landing, E., 1983, First Proterozoic stromatolites from the Adirondack massif: stratigraphic, structural, and depositional implications: Geological Society of America Abstracts with Programs, v. 15, p. 601.

Levy, R., McLelland, J., and Ritter, A., 1993, Non-primary layering in some Adirondack orthogneisses: Geological Society of America Abstracts with Programs, v. 25, p. 33.

McLelland, J., 1991, Geology and geochronology of the Southern Adirondacks, *in* Ebert, J.R., ed., New York State Geological Association Field Trip Guidebook, p. 71-101.

McLelland, J.M., 1986, Pre-Grenvillian history of the Adirondacks as an anorogenic bimodal caldera complex of mid-Proterozoic age: Geology, v. 14, p. 229-233.

McLelland, J., Chiarenzelli, J., Whitney, P., Isachsen, Y., 1988, U-Pb geochronology of the Adirondack Mountains and implications for their geologic evolution: Geology, v. 16, p. 920-924.

McLelland, J., and Whitney, P., 1990, Anorogenic, bimodal emplaceent of anorthositic, charnockitic, and related rocks in the Adirondack Mountains, New York: Geological Society of America Special Paper 246, p. 301-315.

McLelland, J.M., and Chiarenzelli, J., 1990, Isotopic constraints on emplacement age of anorthositic rocks of the Marcy masiff, Adirondack Mtns., New York: Journal of Geology v. 98, p. 19-41.

McLelland, J., and Chiarenzelli, J., 1991, Geochronological studies in the Adirondack Mountains and the implications of a Middle Proterozoic tonalitic suite, *in* Gower, C., Ryan, B., and Rivers, T., eds., Mid-Proterozoic geology of the southern margin of Laurentia-Baltica: Geological Association of Canada Special Paper 38, p. 175-194.

McLelland, J.M., Chiarenzelli, J., and Perham, A., 1992, Age, field and petrological relationships of the Hyde School Gneiss, Adirondack Lowlands, New York: Criteria for an intrusive igneous origin: Journal of Geology, v. 100, p. 69-90.

Mezger, K., Rawnsley, C.M., Bohlen, S.R., and Hanson, G.N., 1991, U-Pb garnet, sphene, monazite, and rutile ages: implications for the duration of high-grade metamorphism and cooling histories: Adirondack Mountains, New York: Journal of Geology, v. 99, p. 415-428.

Park, J.K., and Irving, E., 1972, Magnetism of dikes of the Frontenac axis: Canadian Journal of Earth Science, v. 9, p. 763-765.

Passchier, C.W., Myers, J.S., and Kroner, A., 1990, Field geology of high-grade terrains, Springer-Verlag, 150 p.

Pearce, J.A., Harris, N.B.W., and Tindle, A.G., 1984, Trace element discrimination diagrams for the tectonic interpretation of granitic rocks: Journal of Petrology, v. 25, p. 956-983.

Powers, R.E., and Bohlen, S.R., 1985, The role of synmetamorphic igneous rocks in the metamorphism and partial melting of metasediments, N.W. Adirondacks: Contributions to Mineralogy and Petrology, v. 90, p. 401-409.

Rogers, J.J.W., and Greenberg, J.K., 1981, Trace elements in continental margin magmatism. III. Alkali granites and their relationship to cratonization: Geological Society of America Bulletin, v. 93, Part II, p. 57-93.

Seal, T.L., 1986, Pre-Grenville dehydration metamorphism in the Adirondack Mountains, New York: Evidence from pelitic and semi-pelitic metasediments [MS thesis]: Stony Brook, New York, State University of New York at Stony Brook.

Schoenberg, M., 1974, Structure and stratigraphy of the Adirondack Lowlands near Gouverneur, New York [MS thesis]: Ithaca, New York, Cornell University.

Stoddard, E.F., 1980, Metamorphic conditions at the northern end of the northwest Adirondack lowlands: Summary: Geological Society of America Bulletin, Part I, v. 92, p. 97-100.

Sylvester, P.J., 1989, Post-collisional alkaline granites: Journal of Geology, v. 97, p. 261-280.

Tewksbury, B., Culbertson, H., Marcoline, J., and Walvoord, M., 1993, Evidence for the importance of ductile shear in regional fabric development in Grenville-age gneisses of the Beaver Creek region, Northwest Lowlands, New York State: Geological Society of America Abstracts with Programs, v. 25, p. 83.

Valley, J.W., Bohlen, S.R., Essene, E.J., and Lamb, W., 1990, Metamorphism in the Adirondacks: II. The role of fluids: Journal of Petrology, v. 31, p. 555-596.

VanDiver, B.B., 1976, Rocks and routes of the north country, New York: W.F. Humphrey Press, Inc., 205p.

Whalen, J.B., Currie, K.L., and Chappell, B.W., 1987, A-type granites: geochemical characteristics, discrimination and petrogenesis: Contributions to Mineralogy and Petrology, v. 95, p. 407-419.

Whitney, P.R., 1992, Charnockites and granites of the western Adirondacks, New York, USA: a differentiated A-type suite: Precambrian Research, v. 57, p. 1-19.

Wiener, R.W., McLelland, J.M., Isachsen, Y.W., and Hall, L.M., 1984, Stratigraphy and structural geology of the Adirondack Mountains, New York: Review and synthesis, *in* The Grenville event in the Appalachians and related topics, M.J. Bartholomew, ed: Geological Society of America Special Paper 194, p. 1-55.

Wiener, R.W., 1981, Structural geology and petrology of bedrock along the Adirondack Highlands-Northwest Lowlands boundary near Harrisville, New York [PhD thesis]: Amherst, Massachusetts, University of Massachusetts, 163p.

Wintsch, R.P., and Andrews, M.S., 1988, Deformation induced growth of sillimanite "stress" minerals revisited: Journal of Geology, v. 96, p. 143-161.