FIELD TRIP NO. 4

STRATIGRAPHY, STRUCTURE, AND GEOCHEMISTRY OF GRENVILLIAN ROCKS IN NORTHERN NEW YORK

by

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Introduction

The geology of the northwest Adirondack lowlands is characterized by northeast-trending belts of highly deformed rocks, chiefly marbles and gneisses, all metamorphosed to upper amphibolite facies grade during the Grenvillian Orogeny. A clear picture of the structure and stratigraphy of this region has proven elusive due to effects of recrystallization, multiple folding, anatexis and magmatism during metamorphism.

Several different structural and stratigraphic models have been proposed which illustrate the diversity of opinion surrounding these rocks. Engel and Engel (1953) believed the stratigraphy to be part of the overturned, southeastern limb of a regional anticlinorium whose upright limb lay to the northwest in Canada. They recognized five major stratigraphic units which, from NW to SE in order of decreasing age, include the following:

1) Black Lake metasedimentary belt; 2) Gouverneur, or Lower Marble; 3) Major Gneiss belt; 4) Balmat-Edwards, or Upper Marble; and 5) Harrisville-Russell belt (see map, Figure 1 and cross-section, Figure 2).

A model by Lewis (1969) included two major marble units, separated by the Major Gneiss, which were continuous across the northwest Adirondacks but repeated in linear, northeasterly belts by tight, upright folds. More recently Foose (1974) and Wiener (1981) postulate that there is but one carbonate horizon repeated by multiply-refolded nappes.

There seems to be agreement that alaskitic gneisses (leucogneisses) which core domical structures in the northwest Adirondacks constitute a basal horizon over which marble and gneiss precursors were deposited. Geochemical data and recent field mapping reveal a relict stratigraphy consistent with an ash flow tuff origin. Geochemical data from the Major Gneiss are consistent with an origin as slightly reworked, dacitic tuff. Results of mapping by St. Joe Resources Company geologists (including deLorraine) are best interpreted as two distinct carbonate units separated by the Major Gneiss. The basal marble, here termed the Gouverneur marble

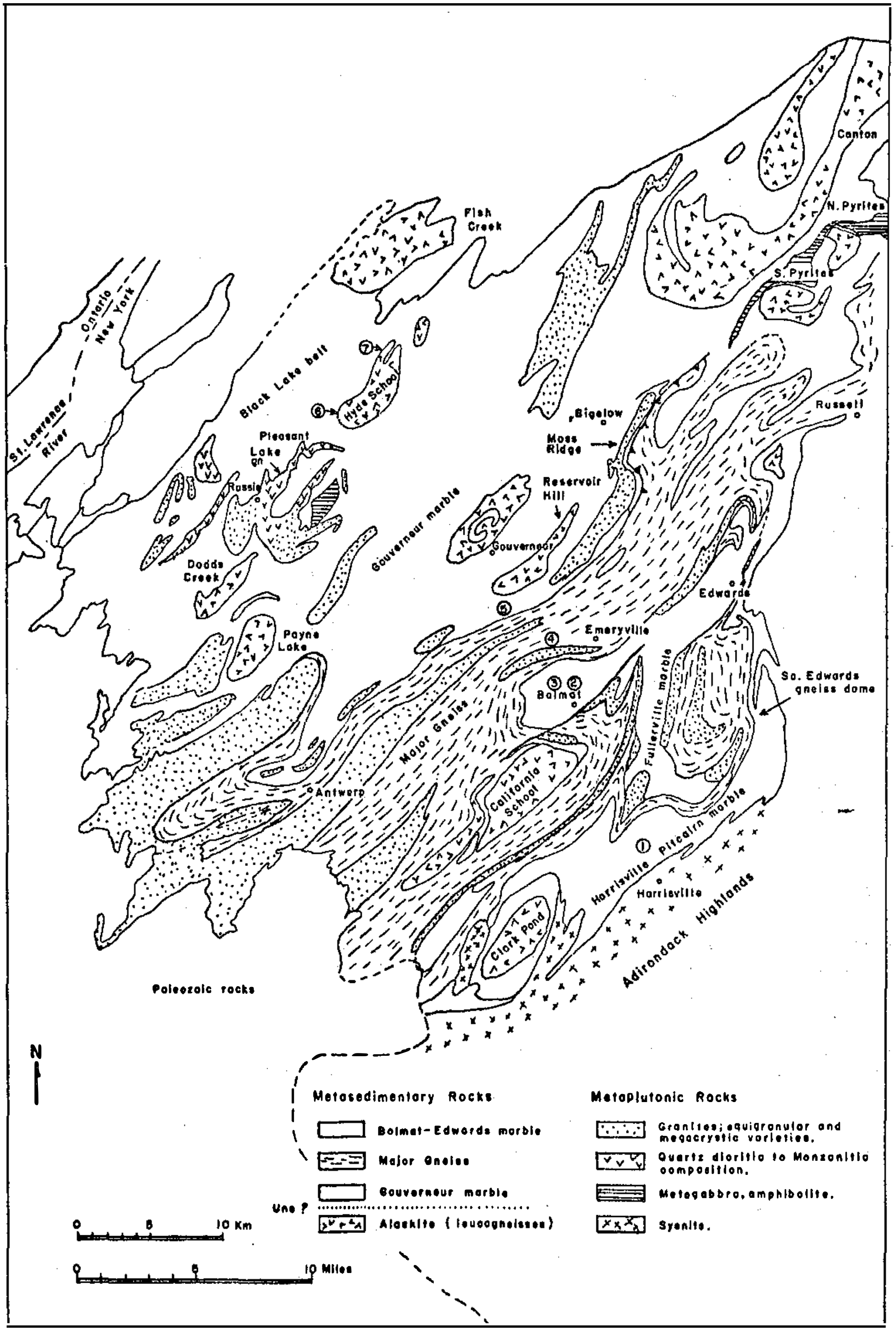


FIGURE I General geology and location of stops.

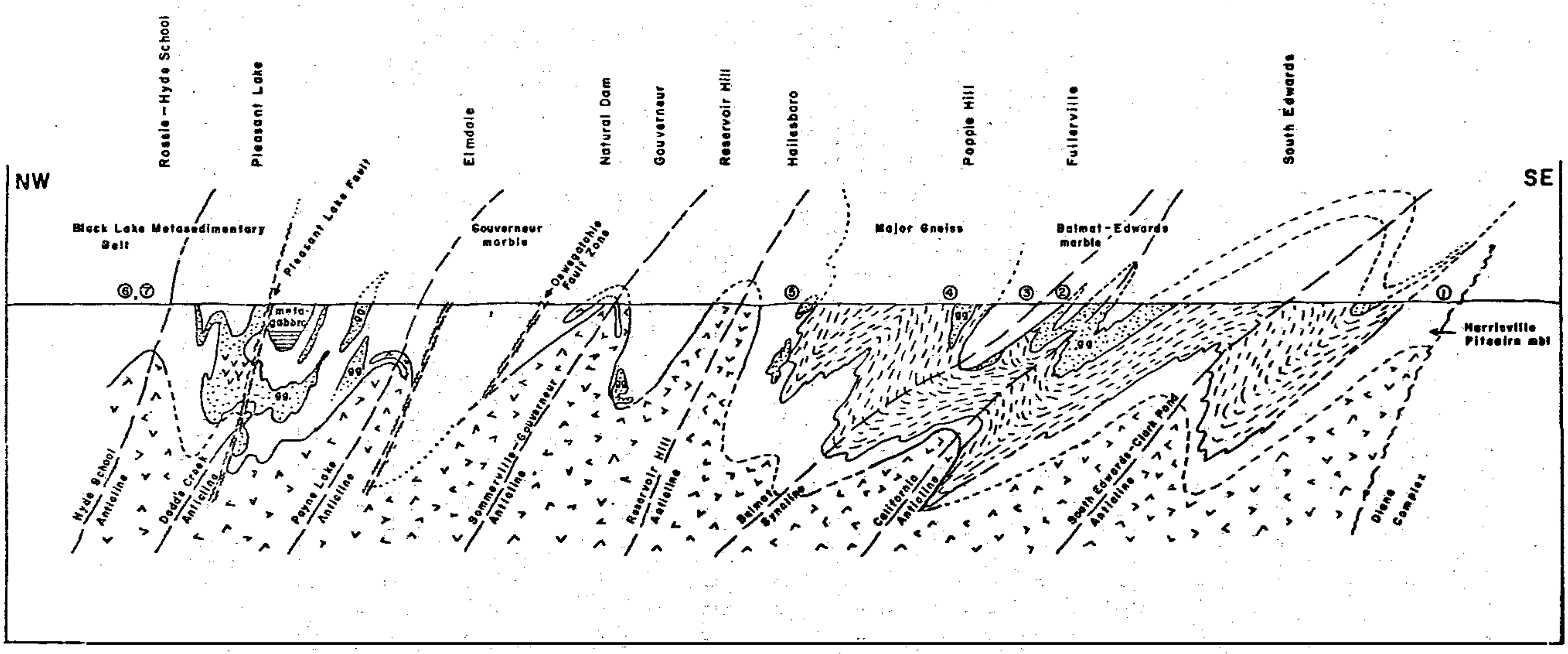


FIGURE 2. Generalized NW-SE geologic cross-section across the NW Adirondacks.

type, directly overlies the leucogneisses and comprises the Engels' Black Lake, Gouverneur (Lower Marble), and Harrisville-Pitcarin marbles (part of the Balmat-Edwards, or Upper Marble of the Engels). Major Gneiss overlies this marble and, in turn, is overlain by an upper marble, hereby called the Balmat-Edwards marble type. This model is similar in some respects to that of Lewis (1969).

The purpose of this field trip is to investigate regional stratigraphy and structure from the perspective given here. We will point out numerous areas where further investigation is needed, particularly with regard to the role of magmatism during (before?) metamorphism. We will also discuss the origin of some of the gneissic rocks in view of recent geochemical data.

Stop No. 1. New roadcut on Route 812 north of Harrisville near bridge over Oswegatchie River, Harrisville quadrangle.

We start our trip in the Harrisville-Pitcarin marble belt adjacent to the Highlands - Lowlands boundary which lies just to the southeast. Marbles here belong to the Lower marble belt (Gouveneur marble type) and overlie the Clark Pond leucogneiss body which lies to the southwest. Formerly, this belt was included in the Upper or Balmat-Edwards marble belt of the Engels. These marbles consist of coarse-grained, light gray and white, banded, graphitic-calcitic marbles with accessory brown tourmaline, local chondrodite and diopside. A thin layer of Major Gneiss between Geer's Corners and Pitcarin separates the Lower (calcitic) marble from the Upper (silicated-dolomitic) marble to the north toward Fullerville and Balmat. Note the lobate form of the intrusive body of quartz-syenite exposed on the right-hand side of the outcrop.

Stop No. 2A. St. Joe Resources Co. #2 Mine area at entrance to Balmat #2 mine, Route 812, Gouverneur quadrangle.

Exposed here in the core of the Balmat syncline is unit 14, one of 15 carbonate units comprising the stratigraphic section at Balmat. Overall plunge of the syncline (overturned) is NNW. Note the profusion of isoclinal folds, rootless fold hinges, transposed layering, and fragmented silicate layers in marble. Look for bladed tremolite clusters, diopside, quartz, serpentine, and dolomitic and calcitic marbles. Contrast the composition of this marble with that at Stop 1. Nearby is the old #2 mine-mill complex, now unused because milling operations have shifted to the new #4 mine area. However, #2 shaft still serves as an access and escape route for the #2 mining area. This is the site of original mining in the Balmat district, having begun in 1930, although sphalerite showings were reported as early as 1838 by Ebenezer Emmons.

Stop No. 2B. Area to right of gate at entrance to #2 mine area; old American Talc shaft.

Exposed here is Unit 13, a talc-tremolite-anthophyllite schist. Suggested by Engel (1962) as a shear zone metasomatically enriched in Mg, it more likely is a siliceous meta-evaporite unit. Its distinctive

Table 1: Chemistry of Popple Hill rock types (Stop No. 4)

	Banded gneiss (6 samples)		Leucosome in banded gneiss (4 samples)		Massive subporphyroblastic rock (7 samples)		Leucosome in subporphyroblastic rock (4 samples)	
	average	δ	average	δ	average	δ	average	δ
SiO_2 (wt. %)	69.68 ±	1.92	71.00 ±	4.03	63.39 ±	2.30	67.45 ±	4.45
Al_2O_3	14.61 ±	0.57	15.15 ±	1.42	16.74 ±	0.74	16.37 ±	1.84
Fe_T (as Fe_2O_3)	3.66 ±	0.82	1.58 ±	0.90	6.04 ±	0.96	2.17 ±	0.82
MgO	1.18 ±	0.28	0.35 ±	0.16	2.05 ±	0.36	0.70 ±	0.39
CaO	2.11 ±	0.25	1.05 ±	0.29	3.92 ±	0.36	1.39 ±	0.26
Na_2O	3.50 ±	0.39	3.42 ±	0.88	3.50 ±	0.45	2.56 ±	0.54
K_2O	3.43 ±	0.40	7.14 ±	2.38	2.65 ±	0.63	8.27 ±	1.93
TiO_2	0.47 ±	0.11	0.12 ±	0.08	0.82 ±	0.14	0.25 ±	0.14
MnO	0.05 ±	0.01	0.03 ±	0.01	0.09 ±	0.02	0.03 ±	0.02
Total %	98.69%		99.84%		99.20%		99.19%	
Rb (ppm)	124.40 ±	13.60	161.90 ±	55.90	127.60 ±	12.60	211.30 ±	44.30
Sr	261.10 ±	59.70	264.80 ±	86.50	702.00 ±	85.80	560.00 ±	115.70
Y	24.70 ±	11.00	27.90 ±	19.70	35.00 ±	10.40	13.80 ±	14.00
Zr	194.50 ±	34.00	46.20 ±	19.20	223.40 ±	36.30	23.50 ±	19.70
Nb	11.70 ±	2.90	8.00 ±	3.00	12.50 ±	2.00	7.40 ±	5.70
Ba	581.00 ±	66.00	786.00 ±	254.00	942.00 ±	230.00	1582.00 ±	464.00
Pb	19.20 ±	4.00	39.50 ±	7.60	14.40 ±	4.30	29.60 ±	6.00
Th	4.70 ±	3.10	3.40 ±	2.80	29.40 ±	19.50	2.30 ±	2.40
Zn	77.40 ±	19.70	19.40 ±	15.20	104.00 ±	14.40	39.20 ±	23.20
Cu	5.00 ±	5.90	4.00 ±	2.80	0.00		1.90 ±	2.50
Ni	21.60 ±	3.00	14.60 ±	0.50	15.00 ±	0.50	13.90 ±	0.70

Table 2: Chemistry of Hermon porphyroblastic gneiss between Hermon and Kent Corners (Optional Stop)

	Gneiss (5 samples)		Xenolith-like dark rock within gneiss Sample number:		
	average	δ	16HR3	82-1H	82-2
SiO_2	65.95 ±	1.13	56.56	-	-
Al_2O_3	16.23 ±	0.27	18.76	-	-
Fe_T	4.43 ±	0.31	7.23	-	-
MgO	1.42 ±	0.14	2.46	-	-
CaO	2.49 ±	0.22	4.49	-	-
Na_2O	3.46 ±	0.60	5.36	-	-
K_2O	5.23 ±	0.22	3.63	-	-
TiO_2	0.64 ±	0.02	1.01	-	-
MnO	0.05 ±	0.03	0.08	-	-
TOTAL	99.90%		99.58%		
Rb	136.8 ±	5.0	117.4	108.5	105.8
Sr	405.5 ±	11.2	425.0	426.6	413.8
Y	39.6 ±	4.1	64.7	93.5	48.4
Zr	281.9 ±	16.5	459.1	447.1	287.4
Nb	13.7 ±	0.9	18.0	18.0	10.4
Ba	1047.0 ±	52.0	703.0	561.0	890.0
Pb	28.0 ±	1.3	23.4	30.1	29.4
Th	10.8 ±	2.4	6.5	11.8	15.0
Zn	57.4 ±	12.4	127.1	156.4	85.2
Cu	0.0		0.0	4.6	0.0
Ni	15.1 ±	0.9	15.9	16.9	21.3

Amphibolites are generally conformable and in sharp contact with banded gneiss. They contain biotite-selvaged leucosome that resembles its host in plagioclase content and low Ba and Rb.

Leucosome in banded gneiss is of granitic composition with K-feldspar dominant over plagioclase and 25-35% modal quartz. Like the host gneiss, leucosome is enriched in Ba, Rb and Sr. Textures range from xenomorphic granular to strongly flaser and cataclastic. Porphyroclasts are surrounded by wreaths of mortar similar to that surrounding K-feldspar augen in the Hermon gneiss. A possible mode of origin is that of partial melting along shear zones at some early stage of metamorphism and folding.

What was the protolith of the major gneiss? Perhaps dacite volcanics that were slightly weathered and reworked as proposed for paragneiss in NW Ontario by van de Kamp and Beakhouse (1978). There is at least one locality where cross bedding seems preserved. Sillimanite content is variable and may occur as thin lenses or in thin sections, but Al_2O_3 is generally low for a shale. Harker diagrams show igneous trends (except for Na and K) and the rock lacks enough CaO, Cr and Ni to represent the composition of many graywackes. An Na/K ratio of 1.0 is obtained instead of 1.2-1.4 characteristic of graywackes when leucosome is included in an assessment of average outcrop composition (Carl, 1981). The massive rock at the Popple Hill outcrop with its more mafic chemistry may represent a volcanic feeder for material now incorporated in the adjacent banded gneiss.

Stop No. 5A. Bridge over Matoon Creek, Route 58, near Hailesboro, Gouverneur quadrangle. Small outcrop on north side of road.

Gouverneur marble and gray, granitic intrusive rocks exposed here. Note the light gray inclusion of marble (shaped like a steer's head) in the darker gray granitic rocks. Similar gray granitic rocks are well exposed along Route 11 as far south as Antwerp; this string of granitic bodies extends as far northward as Moss Ridge on the Bigelo quadrangle. North of Battle Hill at the south end of Moss Ridge (Gouverneur quadrangle), the gray gneiss undergoes a transition from gray to splotchy gray and red, to pink/red granite. Its red coloration north of Battle Hill causes the unit to resemble the basal leucogneisses. We suggest that Moss Ridge is the northerly extension of the granite intrusive belt and probably constitutes a sill-like body within Gouverneur-type marbles. As such, it is unrelated to the basal leucogneisses as was proposed by Foose (1974). Moss Ridge also lacks a pronounced positive magnetic anomaly that is common to other leucogneiss bodies.

Stop No. 5B. "Train wreck" Outcrop - Fragments of "basaltic" rock in Gouverneur marble.

Clustering of blocks and their rectangular outline suggests disruption of a basaltic dike during folding. Mineralogy of the dike, however, is adjusted to metamorphic conditions. Plagioclase is absent in contact zones in the dike rock which contains meionite scapolite, diopside, microcline, sphene, tremolite, biotite, quartz, tourmaline and apatite. This roadcut also contains a basalt dike that is not disrupted.

Stops No. 6 and 7. The Hyde School "alaskite" body: leucogneiss and amphibolite at the southwest end, and tonalite at the northern edge along the Hyde road, Pope Mills quadrangle.

The Hyde School is the best exposed of several domical leucogneiss occurrences in the Northwest Adirondacks. Many years ago A. F. Buddington proposed that the gneisses represent granitic intrusions into anticlinal crests (phacoliths) during Grenville folding and metamorphism. The Hyde School body, however, is anything but a simple dome. Isoclinally folded and refolded amphibolite layers are shown to mimic the larger structures, and there is evidence that all "domes" are protruberances of a single, multiply-folded, lower stratigraphic unit present throughout the lowlands. The Hyde School body has been recently mapped by Erv Brown.

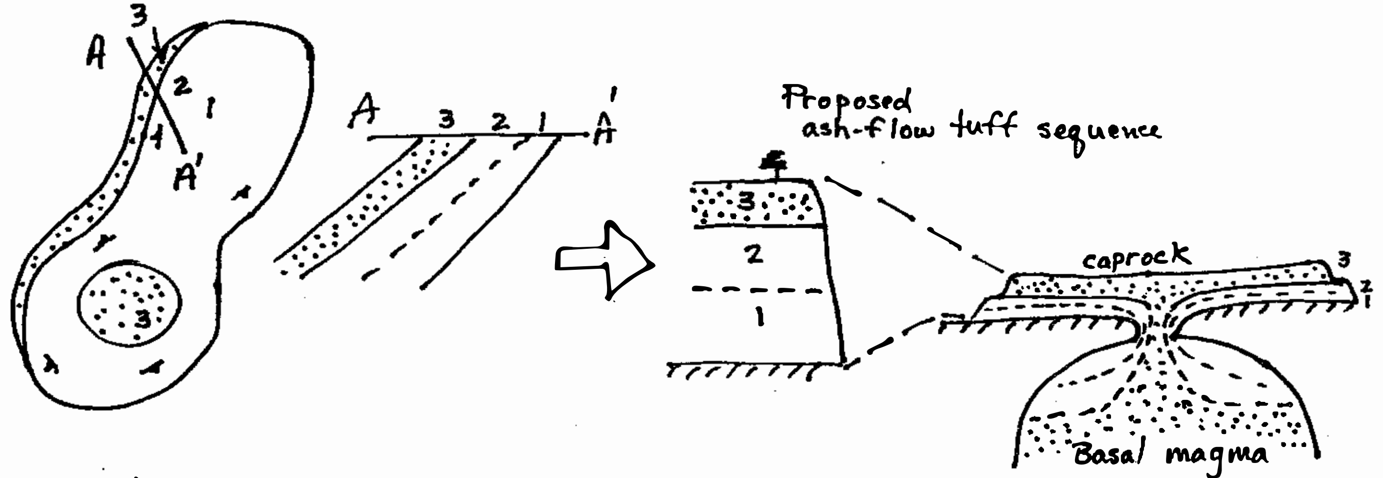
The blunt, southwesterly-plunging end of the Hyde body overlooks a solution valley in the surrounding Lower Marble unit. Amphibolites interlayered with leucogneiss (alaskite) are virtually undisturbed at this locality. Some are broken with coarse-grained quartz and feldspar occupying the break. Extension in the direction of plunge or laterally in the plane of foliation produced tension within these relatively competent layers.

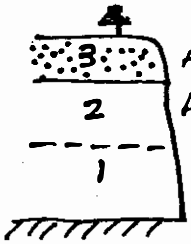
Carl and Van Diver (1975) recognized a stratigraphy of sorts within the leucogneiss and made comparisons of major element chemistry with ash flow tuffs. The presence of dark tonalite-trondhjemite gneiss units within a dominantly granitic gneiss sequence was compared to the capping of ash flow tuff sequences by later, more fluid, plagioclase-rich extrusives. The lower parts of ash flow sequences have rhyolitic tuffs derived from the uppermost, most differentiated portion of the underlying magma chamber. The plagioclase cap rock represents a later outpouring of more fluid magma at greater depth. The stratigraphic sequence on the surface, thus, represents an inversion of the zonation that existed in the underlying magma chamber (Figure 3).

Units of tonalite-troudhjemite occur along the western margin of the Hyde School exposure and in the center of the southern dome. If these are truly the cap rock of ash flow tuffs, then a walk northwardly along the Hyde road is upward in the stratigraphic sequence. It is also a look deeper into the magma chamber that gave rise to that sequence.

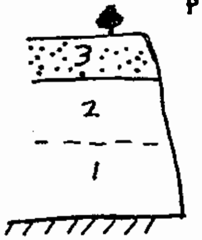
Support for an ash flow tuff origin has recently come from geochronology studies of Bob Lepak (1983) and Tom Maher (1981), students of Norman Grant at Miami University of Ohio. They find a crystallization age for precursors of the leucogneiss at 1263 ± 25 Ma and an initial $^{87}\mathrm{Sr}/^{86}\mathrm{Sr}$ ratio of 0.7033 ± 0.4. Samples with high Rb/Sr ratios give evidence for open system behavior of Sr that is proposed (by other workers) to have occurred in silicic volcanics. This Sr loss is attributed to factors such as the reordering of K-feldspar structural state during cooling of the tuffs, or by Sr loss in fluids prior to or during metamorphism.

Figure 3 Chemistry and ash-flow tuff model for the Hyde School leucogneisses (Stop no. 7)





wt %–	SiO_2	Al_2O_3	Fe_T	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	ppm– Rb	Sr	Y	Zr
Av. 3 spls:	69.89	14.14	3.33	1.68	3.22	4.51	2.44	0.53	0.05	53.5	436.3	25.0	173.4
Av. 2 spls:	74.81	10.91	5.27	0.50	0.94	3.24	4.10	0.34	0.01	88.0	124.4	96.6	735.2
Av. 2 spls:	74.36	13.27	2.75	0.10	0.55	3.71	4.55	0.19	0.02	111.0	71.7	137.5	499.5



ppm– Nb	Ba	Pb	Th	Ni	Cu	Zn
9.1	605	8.3	0.6	21.6	32.4	33.4
16.7	373	24.3	7.9	15.5	8.7	48.4
26.8	421	13.8	4.6	17.0	3.2	10.8

ppm–	La	Ce	Sm	Eu	Tb	Yb	Lu
1 spl:	19.01	31.85	4.80	0.79	0.42	1.97	0.34
1 spl:	88.28	177.03	26.45	1.99	2.84	11.05	1.43

Carl has analyzed rock samples taken along the Hyde road from granitic leucogneiss into the tonalite-trondhjemite unit. Chemistry is given with respect to lithology in Figure 2. Note the change from siliceous to more mafic chemistry toward the plagioclase unit and an "upward" increase in MgO, CaO, Na_2O, TiO_2, Ni, Cu, Sr, and Ba. There is a decrease in SiO_2, K_2O, Rb, Y, Zr, Nb, Pb, and Th. Analyses by Calvin Pride, University of Ottawa, show less total rare earth element content (and no negative Eu anomaly) in the caprock than in the underlying leucogneiss. The caprock is slightly enriched in light REE relative to heavy REE than is the underlying leucogneiss (La/Yb ratios of 9.7 vs. 8.0).

These trends are remarkably similar to those recorded in a vertical sequence of the Bishop Tuff in California by Wes Hildreth (1979). The lower, siliceous part of that sequence is enriched in the small, highly charged cations Y, Nb, Th, and La. It is also enriched in Rb and has a strong negative Eu anomaly. Ba and Sr enrichment occurs in the more mafic caprock. In contrast to the leucogneiss sequence, however, Hildreth reports the caprock enriched in K over Na (odd!) and in Zr content.

Large portions of the leucogneiss sequence must have been rapidly extruded and deposited as is the case for individual flows in a tuff sequence. Deposition of other portions, however, must have occurred intermittantly and in water because of interlayering with numerous thin amphibolites (mafic tuffs?), calc-silicates and garnet-sillimanite gneiss. Extensive compaction, recrystallization and folding evidently obliterated all textural evidence of the precursors.

Stops No. 8 and 9.

Our drive will continue northward from the Pope Mills to the Edwardsville quadrangle, if there is time and desire to do so. New roadcuts in migmatite, K-feldspar porphyroblastic gneiss and the largest roadcut (that we have observed) in an alaskite body at the Fish Creek "phacolith" await your viewing pleasure. Turn around will occur either at Stop 7 or at the Edwardsville grocery on Black Lake after refreshment and an up-date on the fishing.

Optional Stop on return to Potsdam: Hermon porphyroblastic gneiss, 2 miles southwest of Hermon toward Kent Corners, Bigelo quadrangle.

This augen gneiss is part of a mappable unit that overlies the banded paragneiss a few kilometers to the south. Contacts are both gradational and abrupt. Similar porphyroblastic units of different stratigraphic position have been labelled "Hermon granite" elsewhere in the NW Adirondacks, but we show you the locality that, in soft drink terms, is the "real thing."

The underlying major gneiss has its porphyroblastic aspects: sheets a meter thick may be interlayered with banded gneiss, or scattered K-feldspar porphyroblasts may occur in migmatite outcrops. On the other hand, the Hermon gneiss contains dark layers and xenolith-like fragments of fine-grained rock that, megascopically at least, resemble the major gneiss.

How then to regard this rock type with its close proximity to the major gneiss, its K-feldspar augen, cataclastic and recrystallized textures and its contained bits of dark rock? Engel and Buddington believed it to be "reconstituted" paragneiss to which K_2O was added. Other suggestions include a metamorphosed granitic intrusion, recrystallized mylonite, K-feldspar-rich volcanics and arkosic sediment.

Five samples taken along this road (Table 2) show uniform chemistry. The Hermon gneiss contains less silica and more Al_2O_3, K_2O, Sr (but hardly more CaO), Y, Zr, Ba, and Th than banded major gneiss at Popple Hill (Table 1). Those dark, xenolith-like fragments are more mafic than most major gneiss samples with notable enrichment in Zr, Y, and Zn.

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