Structure and Rock Fabric Within the Central and Southern Adirondacks

James McLelland
Department of Geology, Colgate University, Hamilton, NY

INTRODUCTION

The area referred to as the southern Adirondacks is shown in Figure 1.
Within this region, the Precambrian is bounded approximately by the towns
of Lowville and Little Falls on the west and Saratoga Springs and Glens Falls
on the east (Fig. 2).
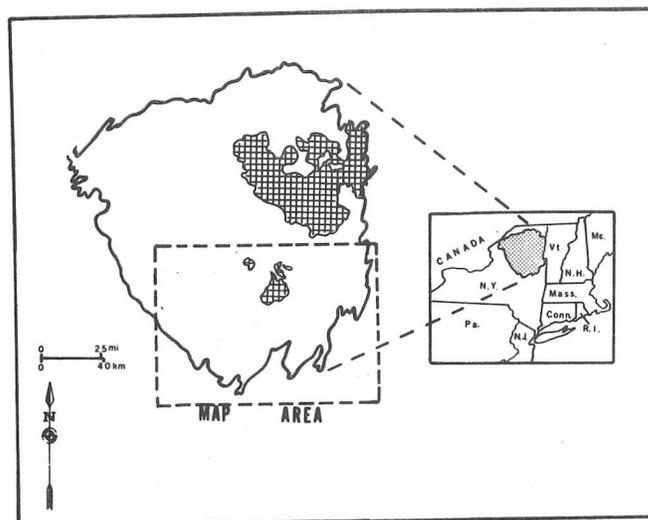
Fig. 1. Location map of the
Adirondack Mts. Major
anorthosite massifs are represented
by the grid pattern. The central
and southern Adirondacks lie within
the dashed rectangle labeled "Map
Area".

Mapping in the southern Adirondacks was done first by Miller (1911,
1916, 1920, 1923); Cushing and Ruedemann (1914); Krieger (1937); and Cannon
(1937); more recent investigations were undertaken by Bartholome (1956),
Thompson (1959); Nelson (1968); and Lettney (1969). At approximately the
same time Walton (1961) began extensive field studies in the eastern portion
of the area (Paradox Lake, etc.), de Waard (1962) began his studies in the
west (Little Moose Mt. syncline). Subsequently de Waard was joined by Romey
(de Waard and Romey, 1969).

Separately and together, Walton and de Waard (1963) demonstrated that
the Adirondacks are made up of polydeformational structures, the earliest of
which consist of isoclinal, recumbent folds. Their elucidation of Adirondack
geology set the tone for future workers in the area. In this regard one of their
most important contributions to the regional picture was that the lithologic
sequence of the west-central Adirondacks is similar to that of the eastern
Adirondacks.

Beginning in 1967 McLelland (1969, 1972) initiated mapping in the
southernmost Adirondacks just to the west of Sacandaga Reservoir subsequently
this work was extended north and east to connect with that of Walton and de Waard.
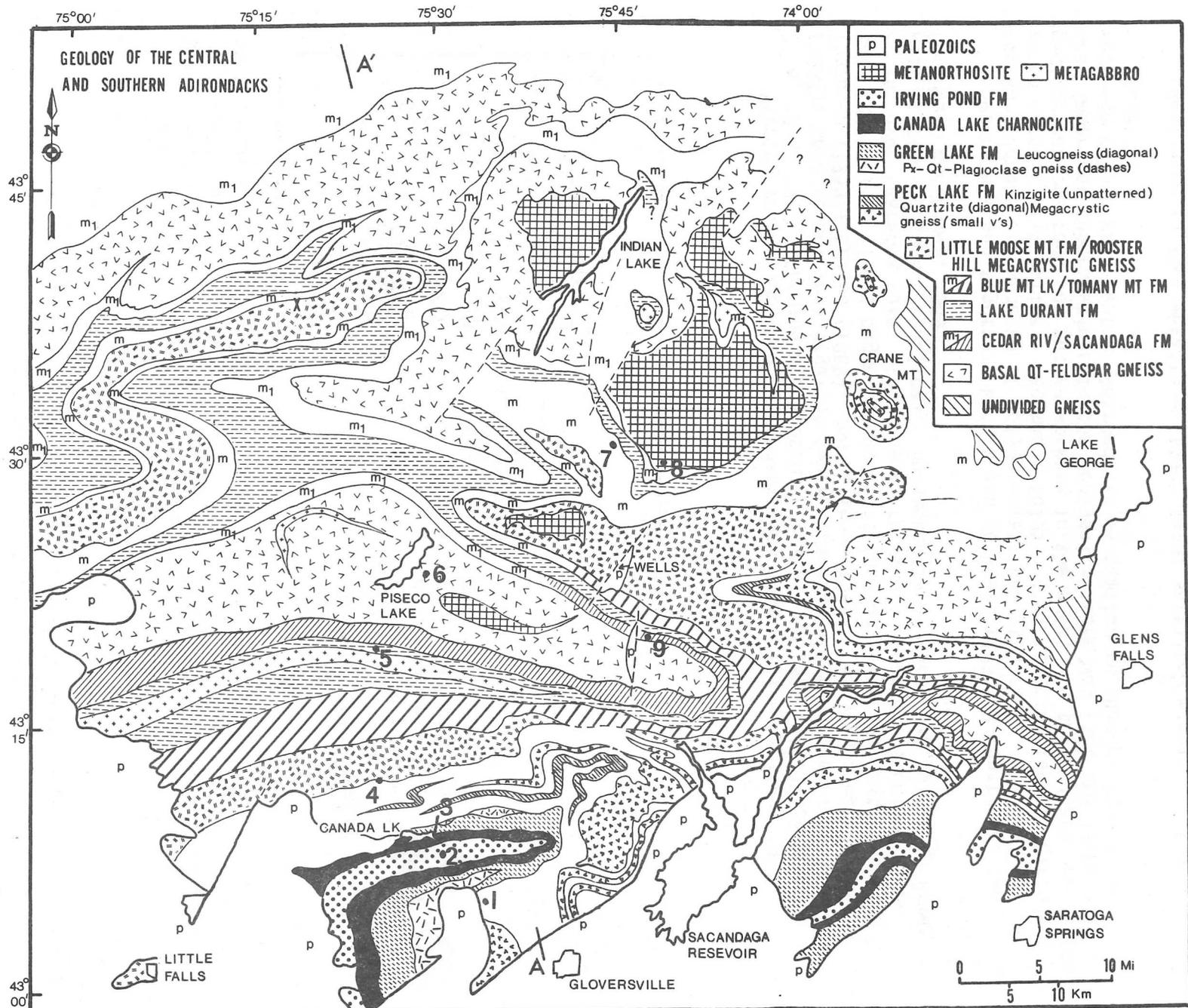
Fig. 2. Formational map and stop localities for the central and southern Adirondacks (from McLelland and Isachsen, 1980)

GEOLOGY OF THE CENTRAL AND SOUTHERN ADIRONDACKS

OLD FORGE

GLENS FALLS

LITTLE FALLS

GLOVERSVILLE

SARATOGA SPRINGS

LK CHAMPLAIN

LAKE GEORGE

44°00 lat

43°00 lat

75°00

74°00

N

0 5 10 mi

0 5 10 15 km

LEGEND

- Q– QUARTERNARY P–PALEOZOIC
- OLIVINE METAGABBRO
- META-TONALITE
- METANORTHOSITE
- MASSIVE CHARNOCKITE
- LAYERED CHARNOCKITIC GN
- STREAKY GRANITIC GNEISS
- GAR-BIOT-QT-PLAG. GNEISS
- MAFIC GRANULITE
- MARBLE RICH UNITS
- QZ'T-SILLIMANITE RICH UNITS
- CHARNOCKITE w̄ ANDESINE
- LEUCOGRANITIC GNEISS
- ALASKITIC GNEISS
- BASAL GRANITIC GNEISS
- U UNDIVIDED
- THRUST FAULT
- NORMAL FAULT

Fig. 3. Lithological map of the central and southern Adirondacks. Note that only a few high angle faults are shown.

Fig. 4. Axial trace map of the central and southern Adirondacks. For lithological map symbols see Fig. 3. Abbreviations not on map: CHS - Canada Hill syncline; GHN - Green Hill nappe; GM - Glidden Marsh syncline; HL - Hullett's Landing; OD - Oregon Dome; PD - Piseco Dome; PL - Piseco Lake; SL - Schroon Lake; SLA - Spruce Lake anticline; SMD - Snowy Mt. Dome; WS - Warrensburg syncline

Geraghty (1973) and Farrar (1976) undertook detailed mapping in the eastern half of the North Creek 15' quadrangle, and tied into investigations in the Brandt Lake region by Turner (1971). Recently, Geraghty (1978) completed a detailed study of the structure and petrology in the Blue Mt. Lake area. Current investigations by McLelland and by the N.Y. Geological Survey are going forward in the general region surrounding Lake George.

The foregoing investigations have increased our knowledge of the southern Adirondacks, and this fieldtrip is designed to show as many examples of the region's structure, lithology, and petrology as time permits.

STRUCTURAL FRAMEWORK OF THE SOUTHERN ADIRONDACKS

The southern Adirondacks (Figs. 2-5) are underlain by multiply deformed rocks which have been metamorphosed to the granulite facies. The structural framework of the region consists of four unusually large fold sets, $F_2 - F_5$ together with an early set of isoclines represented solely by intrafolial minor folds with associated axial planar foliation (Figs. 2-4). Relative ages have been assigned to these fold sets, but no information exists concerning actual time intervals involved in any phase of the deformation. It is possible that several, or all of the fold sets, are manifestations of a single deformational continuum.

The earliest and largest of the map-scale folds are recumbent, isoclinal structures (F_2) -- for example the Little Moose Mt. syncline (de Waard, 1962) and Canada Lake nappe (McLelland, 1969) (Figs. 2 and 5). These isoclines have axes that trend approximately E-W and plunge within 20° of the horizontal. As seen in Figures 4 and 5 the axial traces of each of the F_2 folds exceeds 100 km. They are believed to extend across the entire southern Adirondacks. Subsequent useage of the terms "anticline" and "syncline," rather than "antiform" and "synform," is based on correlations with rocks in the Little Moose Mt. syncline where the stratigraphic sequence is thought to be known (de Waard, 1962).

Close examination reveals that the F_2 folds rotate an earlier foliation defined principally by platets of quartz and feldspar and axial planar to minor intrafolial isoclines. Although this foliation is suggestive of pre-F_2 folding, such an event does not seem to be reflected in the regional map patterns (Fig. 3). However, it is possible that major pre-F_1 folds exist but are of dimensions exceeding the area bounded by Figure 3. If this is the situation, their presence may be revealed by continued mapping. The existence of such folds is suggested by the work of Geraghty (1978) in the Blue Mt. area. In the vicinity of Stark Hills charnockites of the Little Moose Mt. Fm. appear to be identical to supposedly older quartzo-feldspathic gneisses (basal) which lie at the base of the lithologic sequence. Given this situation, then the Cedar River and Blue Mt. Lake Fms. are identical, and there emerges a pre-F_2 fold cored by the Lake Durant Formation. However, careful examination of the Lake Durant Formation has failed to reveal the internal symmetry implied by this pre-F_2 fold model. It is possible, of course, that the pre-F_1 foliation may not be related directly to folding (e.g. formed in response to thrusting, gravity sliding, etc.; Mattauer, 1975). Currently the

origin of the pre-F_2 foliation remains unresolved. In most outcrops the pre-F_2 foliation cannot be distinguished from that associated with the F_2 folding.
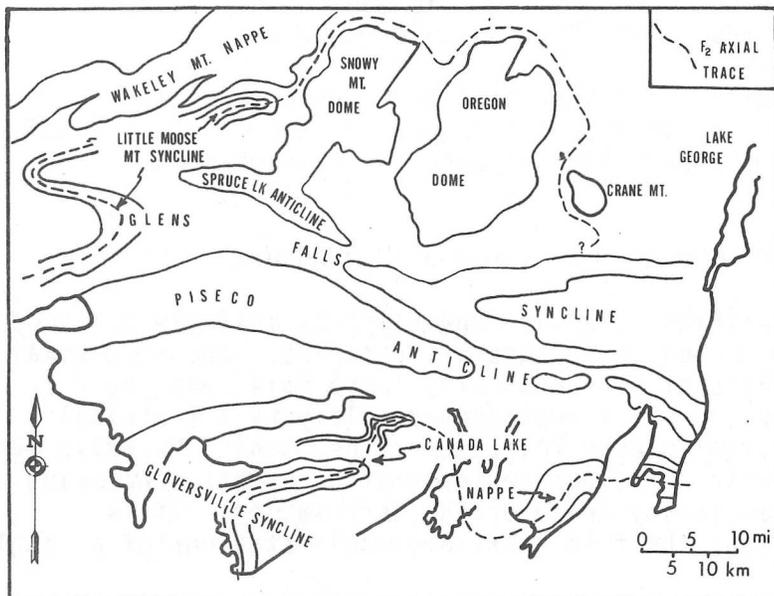
Fig. 5. Blocked out major folds of the central and southern Adirondacks (from McLelland and Isachsen, 1980).

Following the F_2 folding, there developed a relatively open and approximately upright set of F_3 folds (Figs. 2-5). These are coaxial with F_2. In general the F_3 folds are overturned slightly to the north, the exception being the Gloversville syncline with an axial plane that dips 45°N. The F_3 folds have axial traces comparable in length with those of the F_2 set. The Piseco anticline and Glens Falls syncline can be followed along their axial traces for distances exceeding 100 km until they disappear to the east and west beneath Paleozoic cover. The similarity in size and orientation of F_2 and F_3 suggests that both fold sets formed in response to the same force and field.

The fourth fold set (F_4) is open, upright, and trends NW. Within the area these folds are less prevalent than the earlier sets. However, Foose and Carl (1977) have shown that within the NW Adirondacks, northwest-trending folds are widespread and play an important role in the development of basin and dome patterns.

The fourth regional fold set (F_5) consists of large, upright NNE folds having plunges which differ depending upon the orientation of earlier fold surfaces. The F_5 folds are observed to tighten as one proceeds towards the northeast.

The regional outcrop pattern is distinctive because of the interference between members of these four fold sets (Figs. 2-5). For example, the "bent-finger" pattern of the Canada Lake nappe west of Sacandaga Reservoir is due to the superposition of the F_3 Gloversville syncline on the F_2 fold

191

geometry (Fig. 4). East of the reservoir the reemergence of the core rocks of the Canada Lake nappe is due to the superposition on F_2 of a large F_5 anticline whose axis passes along the east arm of the reservoir (Fig. 4). The culmination-depression pattern along the Piseco anticline results from the superposition of F_3 and F_5 folds. The structure of the Piseco dome is due to the intersection of the Piseco anticline (F_3) with the Snowy Mt. anticline (F_5). Farther to the north, Crane Mt. is a classic example of a structural basin formed by the interference of F_3 and F_5 synclines (Figs. 2 and 6).

DISCUSSION AND SYNTHESIS OF STRUCTURAL RELATIONSHIPS

Over a decade ago Walton and de Waard (1963) proposed that rocks of the anorthosite-charnockite suite comprise a pre-Grenvillian basement on which a coherent "supracrustal" sequence was deposited unconformably. Rocks which would be assigned a basement status in this model are designated as basal quartzo-feldspathic gneiss in Figure 3. The basal Cedar River Fm. of the overlying "supracrustal" sequence consists of marbles, quartzites, garnet-sillimanitic gneisses, and various calc-silicates. This lowermost unit is followed upward by various quartzo-feldspathic gneisses, marbles, and other metasedimentary sequences shown in Figure 2. Although our own research agrees with the generalized lithologic sequences of de Waard and Walton, two major provisos are necessary and are given here.

(1) Anorthositic rocks intrude the so-called supracrustal sequence, and therefore the anorthosites post-date these units and cannot be part of an older basement complex (Isachsen, McLelland, and Whitney, 1976; Husch, Kleinspehn, and McLelland, 1976). Isotopic evidence (Valley and O'Neill's (1983); Ashwal and Wooden, 1984) suggests that the anorthosites intruded prior to the 1.1 Ma Grenvillian metamorphism probably during a non-compressional stage (Emslie, 1978, Whitney, 1983). Angular, rotated xenoliths within the anorthosites exhibit pre-intrusion foliation and imply an earlier orogenic event(s).

(2) Within the metastratified units of the region, there exists field evidence for primary facies changes. For example, the well-layered silli-manite-garnet-quartz-feldspar gneisses of the Sacandaga Formation grade laterally into marble-rich units of the Cedar River Fm. exposed north of the Piseco anticline (Figs. 2,3). This transition along strike can be observed just south of the town of Wells, and its recognition is critical to the interpretation of the regional structure. Thus the great thickness of kinzigites (granulite-facies metapelites) south of the Piseco anticline gives way to the north to thinner units marked by marbles, calcsilicates, and quartzites. We interpret this lithologic change as due to a transition from a locally deep basin in which pelitic rocks were accumulating to a shallow-water shelf sequence dominated by carbonates and quartz sands.

Given the foregoing information, it has been possible to map and correlate structures and lithologies on either side of the Piseco anticline. In the northwest the sequence on the northern flank proceeds without structural discontinuity into the core of the Little Moose Mt. syncline. There occurs on the southern flank a mirror image of the northwestern lithologic sequence as units are traced towards the core of the Canada Lake nappe. It follows that the Canada Lake nappe and Little Moose Mt. syncline

are parts of the same fold (Fig. 6). The amplitude of this fold exceeds 70 km. and it can be followed for at least 150 km along its axial trace. The major F_2 and F_3 folds of the area are exposed through distances of similar magnitude, but their amplitudes are less than those of the F_1 isoclines. The structural framework that emerges is one dominated by exceptionally large folds.

Accepting that the Little Moose Mt. syncline and Canada Lake nappe are the same fold, and noting that the fold axis is not horizontal, it follows that the axial trace of the fold must close in space. The axial trace of the Canada Lake nappe portion of the structure can be followed from west of Gloversville to Saratoga Springs. Therefore, the axial trace of the Little Moose Mt. syncline also must traverse the Adirondacks to the north. Mapping strongly suggests that the hinge lines of this fold passes through North Creek and south of Crane Mt. (Fig. 6). From here the axial trace swings westward along the north limb of the Glens Falls syncline to a point north of Wells and thence eastward to a point south of Glens Falls. This model is depicted schematically in Figure 6 where the southern Adirondacks are shown as underlain largely by the Canada Lake-Little Moose Mt. syncline. Later folding by F_3 and F_5 events has resulted in regional doming of the F_2 axial surface and erosion has provided a window through the core of this dome. Note the western extension of the Piseco anticline beneath the Paleozoic cover. This extension is consistent with aeromagnetics of the area.

Currently attempts are underway to synthesize the structural framework of the entire Adirondacks by extending the elements of the present model to other areas. A preliminary version is shown in Figure 7 and suggests that most Adirondack structure is explicable in terms of the four regional fold sets described here. Thrust faulting has been recognized in the eastern Adirondacks (Berry, 1961) and high strain zones exist in many other areas of the Adirondacks (McLelland, 1984). Associated with these are distinctive ribbon gneisses (Fig. 8) and sheath folds (Fig. 9). These are further discussed in Stop 6, Road Log.

CONCLUDING SPECULATIONS

The ultimate origin of the structural and petrologic features of the Adirondacks remains obscure. A possible clue to the mechanisms involved is Katz's (1955) determination of 36 km as the present depth to the M-discontinuity beneath the Adirondacks. Because geothermometry-geobarometry place the peak of the Grenville metamorphism at 8-9 kb (24-36 km), a double continental thickness is suggested. Such thicknesses presently exist in two types of sites, both plate-tectonic related. The first is beneath the Andes and seems related to magmatic underplating of the South American plate (James, 1971). The second is beneath the Himalayas and Tibet and is due to thickening in response to collision (Dewey and Burke, 1973) or continental underthrusting (Powell and Conaghan, 1973). The presence of ribbon lineation, sheath folds, and subhorizontal mylonitic foliation within the region strongly suggests regional rotational strain with a dominant component of simple shear (McLelland, 1984). Rotated K-feldspar augen exhibit tails asymmetric to foliation suggesting an east side up and to the west sense of tectonic transport.

193

Southeastward directed subduction would be consistent with this model.
The relevant plate margin presumably lies buried beneath the present day
Appalachians.
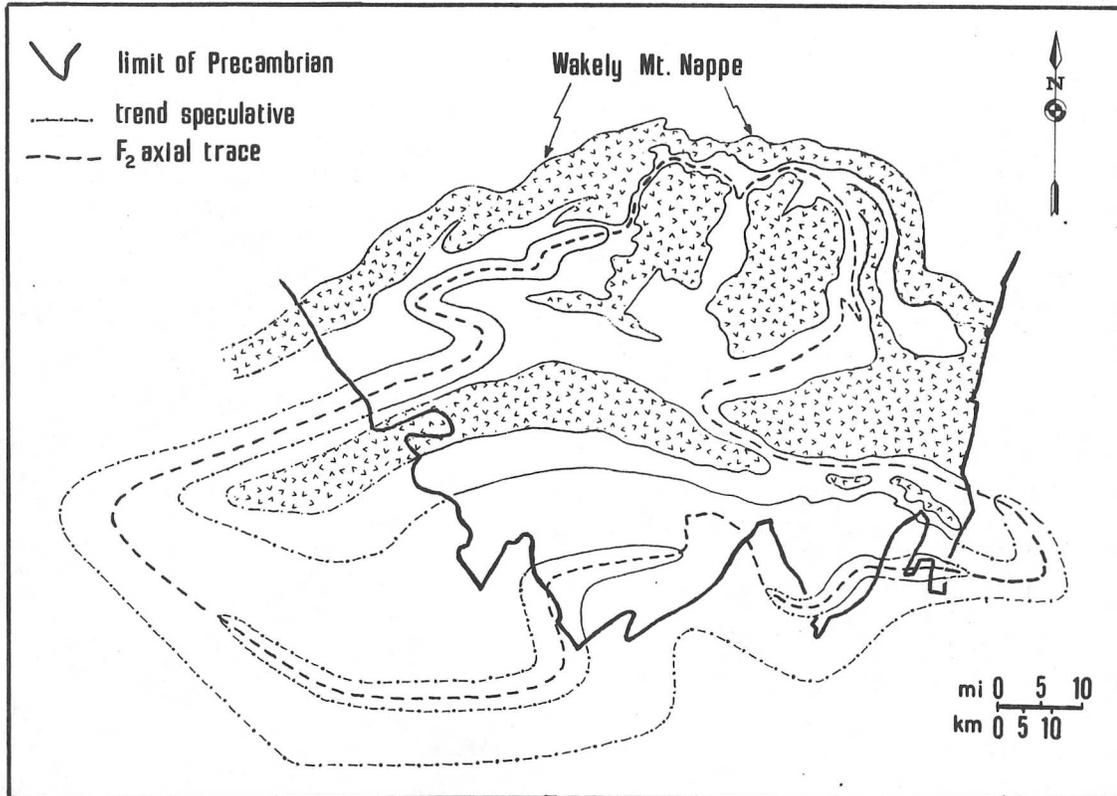
Fig. 6. Geologic sketch map showing the proposed axial trace of
the F_2 Little Moose Mt. - Canada Lake syncline. The western extension
of the Piseco anticline is inferred from aeromagnetic data (from
McLelland+Isachsen, 1980).
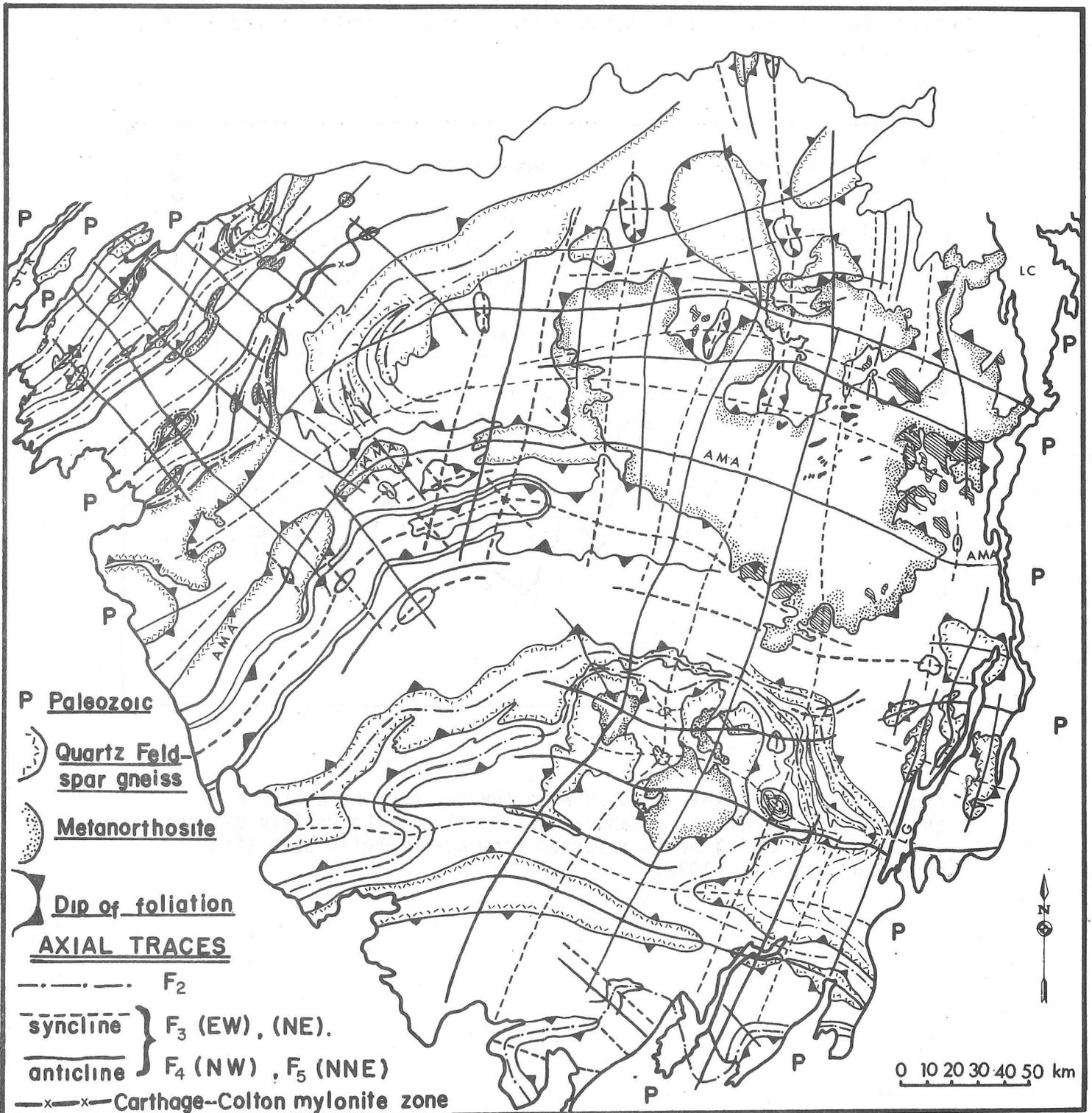
Fig. 7. Axial trace map of the Adirondack Mts. (from McLelland and Isachsen, 1980).

Legend:

P Paleozoic

Quartz Feld-spar gneiss

Metanorthosite

Dip of foliation

AXIAL TRACES

—·—·— F₂

syncline } F₃ (EW), (NE).

anticline } F₄ (NW), F₅ (NNE)

—×—×— Carthage–Colton mylonite zone

0 10 20 30 40 50 km

ROAD LOG

Mileage

0   Junction of Willie Road, Peck Hill Road, and NY Rt. 29A

1.3   Mud Lake to northeast of NY Rt. 29A

2.8   Peck Lake to northeast of NY Rt. 29A

3.6   **Stop #1**. Peck Lake Fm.

This exposure along Rt. 29A just north of Peck Lake is the type locality of the sillimanite-garnet-biotite-quartz-feldspar gneisses (kinzigites) of the Peck Lake Fm. In addition, there are exposed excellent minor folds of several generations. Note that the F_2 folds rotate an earlier foliation.

The white quartzo-feldspathic layers in the kinzigites consist of quartz, two feldspars, and garnet and are believed to be anatectic. Note that fish-hook terminations on some of these suggest that they have been transposed. It is also clear that these anatectites have been folded by F_2 indicating a pre-F_2 metamorphic event(s). In a similar fashion some garnets in the rock appear to be flattened while others do not. It is believed that the anatectites formed at the muscovite-quartz reaction and are essentially in situ melts. Further anatexis did not take place due to absence of vapor.

6.1   Junction NY Rt. 29A and NY Rt. 10

8.0   Nick Stoner's Inn on west side of NY Rt. 29A-10

8.6   **Stop #2**. Irving Pond Fm., .5 mile north of Nick Stoner's Inn, Canada Lake.

The outer portion of the Irving Pond Fm. is exposed in low cuts along the east side of Rt. 29A just prior to the crest in the road heading north.

At the southern end of the cut typical, massive quartzites of the Irving Pond are seen. Proceeding north the quartzites become "dirtier" until they are essentially quartzose sillimanite-garnet-biotite-feldspar gneisses (kinzigites).

At the northern end of the cut, and approximately on the Irving Pond/Canada Lake Fm. contact there occurs an excellent set of F_2 minor folds. Polished slabs and thin sections demonstrate that these fold an earlier foliation defined by biotite flakes and flattened quartz grains.

The Irving Pond Fm. is the uppermost unit in the stratigraphy of the southern Adirondacks. Its present thickness is close to 1000 meters, and it is exposed across strike for approximately 4000 meters. Throughout this section massive quartzites dominate.

8.8   **Stop #3.** Canada Lake Charnockite

These large roadcuts expose the type section of the Canada
Lake charnockite. Lithologically the charnockite consists of
20-30% quartz, 40-50% mesoperthite, 20-30% oligoclase, and
5-10% mafics. The occurrence of orthopyroxene is sporadic.
These exposures exhibit the olive-drab coloration that is
typical of charnockites. Note the strong foliation in the
rock.

Although no protolith is known with certainty for these rocks
a metavolcanic history is suggested by their homogeneity and
lateral continuity. Their bulk chemistry corresponds to
dacites.

10.0   Canada Lake Store. Good exposures of Royal Mt. member of
Green Lake Fm.

11.8   Pine Lake. Junction NY Rt. 29A and NY Rt. 10. Proceed north
on NY Rt. 10.

17.5   **Stop #4.** Rooster Hill megacrystic gneiss at the north end
of Stoner Lake.

This distinctive unit is believed to be, in part, correlative
with the Little Moose Mt. Fm. Here the unit consists of a
monotonous series of unlayered to poorly layered gneisses
characterized by large (1-4") megacrysts of perthite and
microcline perthite. For the most part these megacrysts have
been flattened in the plane of foliation as well as elongated
in an E-W direction with concomitant developed of tails of
grain-size reduced tails asymmetric to foliation. However,
a few megacrysts are situated at high angles to the foliation.
The groundmass consists of quartz, oligoclase, biotite,
hornblende, garnet, and occasional orthopyroxene. An igneous
rock analogue would be quartz-monzonite or granodiorite
depending on concentration of K-feldspar.

The origin of the Rooster Hill is obscure. Its homogeneity
over a thickness approaching 2.5 km suggests an igneous
parentage. This conclusion gains support from the presence of
localities where megacrysts appear to retain a random
orientation, and from the occasional presence of what may be
drawn out xenoliths of biotitic or amphibolitic gneisses.
However, these features may be explained by other models.
The contacts of the Rooster Hill are always conformable with
enclosing units, and this suggests a metastratified (metavolcanic?)
origin. However, the anorthosites of the region also show
conformable contacts, and this may, in part, be due to
tectonic flattening.

Recently Eckelmann (pers. comm.) has studied zircon population morphologies in the Rooster Hill and similar lithologies. His results strongly suggest an igneous plutonic origin. This would be consistent with the igneous origin assigned the Hermon granite of the northwest Adirondacks - a rock that is markedly similar to the Rooster Hill.

Mileage

20.0   Low roadcut in kinzigites of Tomany Mt. Fm.

21.4   Avery's Hotel on west side of NY Rt. 10

22.5   Long roadcuts of quartzofeldspathic gneisses and metasediments of Lake Durant Fm. intruded by metagabbro and anorthositic metagabbro.

23.6   Roadcut of anorthositic metagabbro and metanorite.

23.9   Roadcut on west side of highway shows excellent examples of anorthositic gabbros intrusive into layered pink and light green quartzo-feldspathic gneisses. The presence of pegmatites and cross-cutting granitic veins is attributed to anatexis of the quartzo-feldspathic gneisses by the anorthositic rocks.

24.0   **Stop #5.** Lake Durant and Sacandaga Fms. intruded by anorthositic gabbros and gabbroic anorthosites.

These roadcuts are located on Rt. NY 10 just south of Shaker Place.

The northernmost roadcut consists of a variety of metasedimentary rocks. These lie directly above the Piseco anticline and are believed to be stratigraphically equivalent to the Sacandaga Formation. The outcrop displays at least two phases of folding and their related fabric elements. These are believed to be F_2 and F_3. A pre-F_2 foliation is thought to be present. Both axial plane foliations are well developed here. Several examples of folded F_2 closures are present and F_2 foliations (parallel to layering) can be seen being folded about upright F_3 axial planes.

Farther to the south, and overlooking a bend in the west branch of the Sacandaga River, there occurs a long roadcut consisting principally of pink and light green quartz-perthite gneiss belonging to the Lake Durant Fm. About half-way down this roadcut there occurs a large boudin of actinolitic and diopsidic gneiss. To the north of the boudin the quartzo-feldspathic gneisses are intruded pervasively by anorthositic gabbros, gabbroic anorthosites, and various other related igneous varieties. At the north end of the cut and prior to the meta-stratified sequences these intrusives can be seen folded by upright fold axes. They are crosscut by quartzo-feldspathic material.

198

Within this general region the Lake Durant Fm. and other quartzo-
feldspathic gneisses seem to have undergone substantial anatexis.
This is suggested by the "nebular" aspect of the rocks.
Good examples of this are seen in the manner in which green
and pink portions of the quartzo-feldspathic gneisses mix.
Note also the clearly cross-cutting relationships between
quartzofeldspathic gneiss and mafic layers at the south end of
the roadcut. Here it seems that mobilized Lake Durant is
cross-cutting its own internal stratigraphy. Also note that the
quantity of pegmatitic material is greater than usual. This
increase in anatectic phenomena correlates closely with the
appearance of extensive metagabbroic and metanorthositic
rocks in this area. It is believed that these provided a
substantial portion of the heat that resulted in partial fusion
of the quartzo-feldspathic country rock.

Mileage

31.0   Red-stained basal quartzofeldspathic gneisses that have been
            faulted along NNE fractures.

31.5   Junction NY Rt. 10 and NY Rt. 8. End Rt. 10. Turn east on
            NY Rt. 8.

33.0   **Stop #6.** Core rocks of the Piseco anticline.

            Hinge line of Piseco anticline near domical culmination at
            Piseco Lake. The rocks here are typical basal quartzo-feldspathic
            gneisses such as occur in the Piseco anticline and in other
            large anticlinal structures, for example Snowy Mt. dome,
            Oregon dome.

            The pink "granitic" gneisses of the Piseco anticline do not
            exhibit marked lithologic variation. Locally grain size is
            variable and in places megacrysts seem to have been grain size
            reduced and only a few small remnants of cores are seen.
            The open folds at this locality are minor folds of the F_3
            event. Their axes trend N70W and plunge 10-15° SE parallel
            to the Piseco anticline. Co-axial F_2 isoclines are also present.

            The most striking aspect of the gneisses in the Piseco anticline
            is their well-developed lineation. This is expressed by rodding
            and ribbon fabrics. These may consist of alternating ribbons
            of quartz, quartzo-feldspathic gneiss, and biotite-rich layers.
            In some instances the rods represent transposed layering on the
            highly attenuated limbs of early, isoclinal minor folds. Near
            the northeast end of the roadcut such minor folds are easily
            seen due to the presence of more massive layers in the rock.
            Slabbed and polished specimens from this and similar outcrops
            demonstrates that these early folds are exceedingly abundant
            in the Piseco anticline. Examination of these folds shows that
            the dominant foliation in the rock is axial planar to them.

Fig. 8a. Example of ribbon lineation on a foliation surface of quartzofeldspathic gneiss of the Piseco anticline. The dark ribbons are quartz and the light ones K-feldspar.
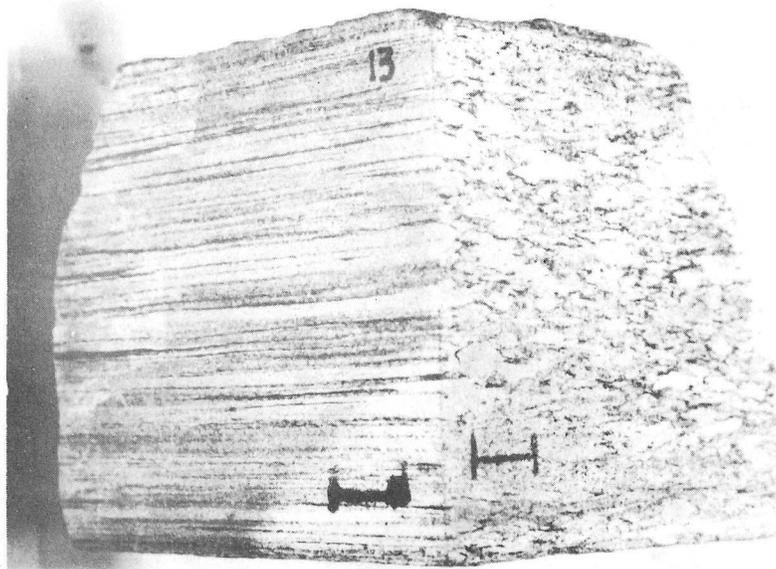
Fig. 8b. Quartzo-feldspathic gneiss of Piseco anticline cut perpendicular to foliation and parallel to lineation (left face) as well as perpendicular to lineation (right face). Note the elongation of the light colored K-feldspar augen in the direction of lineation. Bar markers are 1 cm long.

Fig. 9. The development of tails on K-feldspar augen in a gneiss less deformed than shown in Fig. 8. The face shown is perpendicular to foliation but parallel to lineation. The tails suggest a sinistral shear sense. The bar marker is 1 cm long.

Fig. 10. Sheath fold developed in calcsilicate band in marble. Steep, down dip lineation visible on right hand side. Key is 5 cm long.

The lineation in these outcrops is shown in Fig. 8a while slabbed sections are shown in Figs. 8b,c. Fig. 8b is cut perpendicular to foliation and both parallel to (left face) and perpendicular to (right face) lineation. As can be seen K-feldspar augen have been elongated in the direction of lineation. Together with elongated quartz aggregates, these grain size reduced minerals form the prominent mineral lineation that characterizes foliation surfaces (Fig. 8a). Note that the K-feldspar augen exhibit shapes closer to equant on the right hand face at perpendicular to lineation. This strongly suggests that the rock fabric is the result of rotational strain in the direction parallel to lineation, i.e., the lineation is an elongation, or stretching type. Fig. 9 shows a less deformed sample slabbed perpendicular to foliation and parallel to lineation. The development of tails on K-feldspar augen are clearly visible. These are the result of grain size reduction during ductile rotational strain. A sinistral (east over west) sense of motion is indicated. At more extreme conditions of strain the K-feldspar augen and quartz aggregates are drawn into ribbons as in the present outcrop. Long dimensions of 40-60 cm are common along with thicknesses of a millimeter, or less. Clearly strain has been extreme and elongations of 30-40 times are not unusual.

Ribbon gneiss origin by rotational strain is also suggested by the parallelism between lineation and F_2, F_3 fold axes. It is believed that these fold axes were drawn into parallelism with the lineation by ductile, rotational strain directed from east to west. The most satisfactory mechanism for this configuration is the stacking of thrust sheets and thrust nappes during plate collision. Thrusts have been recognized to the east of Lake George (Fig. 4) and others probably exist although the intense, ductile nature of the deformation has resulted in extremely subtle truncations that are difficult to recognize. Sheath folds (Fig. 10) with tube axes parallel to lineation are consistent with this model. Presumably crustal thickening during the Grenville Orogeny was caused by the stacking of these thrusts.

Mileage

43.5   Junction NY Rt. 8 and NY Rt. 30 in Speculator. Head southeast on NY Rt. 8-30.

47   **Stop #7.** Northern intersection of old Rt. NY 30 and new Rt. NY 30, 3.3 miles east of Speculator, New York.

The Blue Mt. Lake Fm. is exposed in roadcuts on both sides of the highway. These exposures show typical examples of the extreme ductility of the carbonate-rich units. The south wall of the roadcut is particularly striking, for here relatively brittle layers of garnetiferous amphibolite have been intensely boudinaged and broken. The marbles, on the other hand, have yielded plastically and flowed with ease during the defor-

mation. As a result the marble-amphibolite relationships are
similar to those that would be expected between magma and
country rock. Numerous rotated, angular blocks of amphibolite
are scattered throughout the marble in the fashion of xenoliths
in igneous intrusions. At the eastern end of the outcrop
tight isoclinal folds of amphibolite and metapelitic gneisses
have been broken apart and rotated. The isolated fold noses
that remain "floating" in the marble have been aptly termed
"tectonic fish." The early, isoclinal folds rotate on earlier
foliation.

Near the west end of the outcrop a deformed layer of charnockite
is well exposed. In other places the charnockite-marble inter-
layering occurs on the scale of one to two inches.

Exposed at several places in the roadcut are cross-cutting veins
of tourmaline and quartz displaying a symplectic type of inter-
growth. Other veins include hornblende and sphene bearing
pegmatites.

Commonly included in the Blue Mt. Lake Fm., but not exposed
here, are quartzites, kinzigites; sillimanite rich, garnetiferous,
quartz-microcline gneisses; and fine grained garnetiferous
leucogneisses identical to those characterizing the Sacandaga
Fm. These lithologies may be seen in roadcuts .5 mile to the
south.

Almost certainly these marbles are of inorganic origin. No
calcium carbonate secreting organisms appear to have existed
during the time in which these carbonates were deposited
(> 1 b.y. ago). Presumably the graphite represents remains of
stromatolite-like binding algae that operated in shallow water,
intertidal zones. If so, the other roadcut lithologies formed
in this environment as well. This seems reasonable enough for
the clearly metasedimentary units such as the quartzites and
kinzigites. The shallow water environment is much more
interesting when applied to the charnockitic and amphibolite
layers. The fine scale layering, and ubiquitous conformity
of these, strongly suggests that they do not have an intrusive
origin. Perhaps they represent the metamorphosed products of
volcanic material in a shelf like environment. Such inter-
calation is now occurring in many island arc areas where shallow
water sediments cover, and in turn are covered by, ash and
lava. Alternatively they may represent metasediments. A large
number of minerals are developed within these outcrops. Both
calcite and minor dolomite are present in the carbonate horizons.
These are accompanied by green diopside and serpentinized forsterite
as well as by tourmaline, grpahite, and variosu sulfides. In
calcsilicate horizons phlogopite, diopside (white), and
tremolite occur. Wollastonite is locally present. The presence
of tremolite and wollastonite is believed to be a function of
the relative concentration of CO_2 and H_2O in the vapor phase
(Valley et al., 1983).

47.5   Extensive roadcuts in lower part of Blue Mt. Lake Fm.
        Quartzites, kinzigites, and leucogneisses dominate. Minor
        marble and calcsilicate rock is present.

47.9   Large roadcuts in lower Lake Durant Fm. Pink, well-layered
        quartzo-feldspathic gneisses with subordinate amphibolite
        and calcsilicate rock.

49.0   <u>Stop #8.</u> One half mile south of southern intersection of
        old Rt. 30 and with new Rt. 30.

        On the west side of the road small roadcut exposes an excellent
        example of Adirondack anorthositic gneiss intermediate in
        character between the so-called Marcy type (coarse) and the
        Whiteface type (fine grained). About 50% of the rock consists
        of fine grained crystals of andesine plagioclase. Some
        of these crystals appear to have measured from 6-8" prior to
        grain size reduction. Excellent moonstone sheen can be seen
        in most crystals. In places ophitic to subophitic texture has
        been preserved with the mafic phase being represented by
        orthopyroxene.

        In addition to the anorthosite there exists a clearly cross-
        cutting set of late iron-rich orthopyroxene rich dikes containing
        xenoliths of coarse grained anorthosite. The latter may repre-
        sent a late mafic differentiate related to cotetic liquids
        responsible for the ophitic intracrystalline rest magma. This
        would be consistent with the iron enrichment trend characteristic
        of Adirondack igneous differentiation.

        Near road level there can be found several inclusions of calc-
        silicate within the anorthositic rocks. These are believed to
        have been derived from the Cedar River Fm. and are consistent
        with a non-basement status for the anorthosite.

        The upper, weathered surface of the outcrop affords the best
        vantage point for studying the textures and mineralogy of the
        anorthositic rocks. In several places there can be seen ex-
        cellent examples of garnet coronas of the type that are common
        throughout Adirondack anorthosites. These coronas are charac-
        terized by garnet rims developed around iron-titanium oxides
        and pyroxenes. Recently McLelland and Whitney (1977) have
        succeeded in describing the development of these coronas
        according to the following generalized reaction:

        Orthopyroxene + Plagioclase + Fe-bearing oxide + quartz =
                            garnet + clinopyroxene.
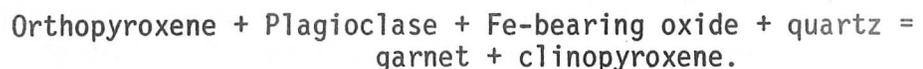
        This reaction is similar to one proposed by de Waard (1965)

but includes Fe-oxide and quartz as necessary reactant phases.
The products are typomorphic of the garnet-clinopyroxene sub-
facies of the granulite facies (de Waard 1965). The applica-
tion of various geothermometers to the phases present suggests
that the P,T conditions of metamorphism were approximately
8 Kb and 700 ± 50°C respectively.

Mileage

51.0 Cedar River Fm. Minor marble, amphibolite, and calcsilicate
rock. Predominantly very light colored sillimanite-garnet-
quartz-K-feldspar leucogneisses.

52.0 Junction NY Rt. 8 and NY Rt. 30. Continue south on NY Rt. 30.
To the west of the intersection are roadcuts in leucogneisses
of the Blue Mt. Lake Fm. A large NNE normal fault passes
through here and fault breccias may be found in the roadcut
and the woods beyond.

52.5 Entering Little Moose Mt. Fm. on northern limb of the Glens
Falls syncline. Note that dips of foliation are to the south.

54.8 Entering town of Wells which is situated on a downdropped block
of lower Paleozoic sediments. The minimum displacement along
the NNE border faults has been determined to be at least
1000 meters.

58.3 Silver Bells ski area to the east. The slopes of the ski hill
are underlain by coarse anorthositic gabbro intrusive into the
Blue Mt. Lake Fm.

60.3 Entrance to Sacandaga public campsite. On the north side of NY
Rt. 30 are quartzo-feldspathic gneisses and calcsilicate
rocks of the Lake Durant Fm. An F_1 recumbent fold trends sub-
parallel to the outcrop and along its hinge line dips become
vertical.

60.8 Gabbro and anorthositic gabbro.

62.0 **Stop #9.** Pumpkin Hollow.

Large roadcuts on the east side of Rt. 30 expose excellent examples
of the Sacandaga Fm. At the northern end of the outcrop
typical two pyroxene-plagioclase granulites can be seen.
The central part of the outcrop contains good light colored
sillimanite-garnet-microcline-quartz gneisses (leucogneisses).
Although the weathered surface of these rocks are often dark due
to staining, fresh samples display the typical light color of
the Sacandaga Fm. The characteristic excellent layering of the
Sacandaga Fm. is clearly developed. Note the strong flattening
parallel to layering and the lineation developed on many
foliation surfaces. These gneisses are similar to so-called

straight gneisses found in proximity to ductile shear zones. The Sacandaga Fm. may represent mylonitic rocks of this type and its layering may, in fact, be tectonic.

Towards the southern end of the outcrop calc-silicates and marbles make their entrance into the section. At one fresh surface a thin layer of diopsidic marble is exposed. NO HAMMERING PLEASE. Many "punky" weathering layers in the outcrop contain calc-silicates and carbonates.

At the far southern end of the roadcut there exists an exposure of the contact between the quartzo-feldspathic gneisses of the Piseco anticline and the overlying Sacandaga Fm. The hills to the south are composed of homogeneous quartzofelds-pathic gneisses coring the Piseco anticline (note how ruggedly this massive unit weathers). The Sacandaga Fm. here has a northerly dip off the northern flank of the Piseco anti-cline and begins its descent into the southern limb of the Glens Falls syncline.

No angular discordance or other indications of unconformity can be discerned at the base of the Sacandaga Fm. However, this does not preclude the prior existence of an angular discordance which may have been swept into pseudoconformity by tectonism.

Along most of the roadcut there can be found excellent examples of faults and associated pegmatite veins. Note that the drag on several of the faults gives conflicting senses of displace-ment. The cuase of this is not known to the author. Also note the drag folds which indicate tectonic transport towards the hinge line of the Piseco anticline.

Mileage

62.5-67.0	All exposures are within the basal quartzo-feldspathic gneisses at the core of the Piseco anticline.
67.0	Re-enter the Sacandaga Fm. Dips are now southerly.
68.0	In long roadcuts of southerly dipping quartzo-feldspathic gneisses of Lake Durant Fm.
70.4	Cross bridge over Sacandaga River.
74.4	Bridge crossing east corner of Sacandaga Reservoir into Northville, New York.

END LOG

REFERENCES

Ashwal, L. and Wooden, J., 1983, Sr and Nd isotope geochronology, geologic history, and origin of Adirondack anorthosite: Geochimica et Cosmochimica Acta, v. 47, no. 11, p. 1875-1887.

Baer, A.J., 1977, The Grenville Province as a shear zone: Nature, v. 267, no. 5609, p. 337-338.

Bartholome, P., 1956, Structural geology and petrologic studies in Hamilton Co., New York: unpubl. doctoral dissertation, Princeton Univ., 113 p.

Bohlen, S.R., and Essene, E.J., 1977, Feldspar and oxide thermometry of granulites in the Adirondack Highlands: Contr. Min. Petrol., v. 62, no. 2, p. 153-169.

Buddington, A.F., 1972, Differentiation trends and parental magmas for anorthositic and quartz mangerite series, Adirondacks, New York: Geol. Soc. America Mem. 132, p. 477-487.

Cannon, R.S., 1937, Geology of the Piseco Lake quadrangle: New York State Mus. Bull. 312, 107 p.

Cushing, H.P., and Ruedemann, R., 1914, Geology of Saratoga Springs and vicinity: New York State Mus. Bull. 169, 177 p.

de Waard, D., 1962, Structural analysis of a Precambrian fold - The Little Moose Mountain syncline in the southwestern Adirondacks: Kon. Ned. Akad. Wetensch., Amsterdam, Ser. B, v. 65, no. 5, p. 404-417.

de Waard, D., 1964, Mineral assemblages and metamorphic subfacies in the granulite facies terrain of the Little Moose Mountain syncline, south-central Adirondack Highlands: Proc. Kon. Ned. Akad, Wetensch, Amsterdam, Ser. B, v. 67, no. 4, p. 344-362.

de Waard, D., and Romey, W.D., 1969, Petrogenetic relationships in the anorthosite-charnockite series of the Snowy Mountain Dome, south central Adirondacks, In Isachsen, Y.W., ed., Origin of anorthosites and related rocks: New York State Sci. Service Memoir 18, p. 307-315.

Dewey, J.F., and Burke, K.C.A., 1973, Tibetan, Variscan, and preCambrian basement reactivation: products of a continental collision: Jour. Geology, v. 81, no. 6, p. 683-692.

Emslie, R.F., 1971, Liquidus relations and subsolidus reactions in plagioclase bearing systems: Ann. Rept. Director Geophys. Lab., Carnegie Inst. Washington, 1969-70, p. 148-155.

Essene, E.J., Bohlen, S.R., Valley, J.W., 1977, Regional metamorphism of the Adirondacks (abst.): Geol. Soc. America Abstracts with Program, v. 9, no. 3, p. 260.

Farrar, S.S., 1976, Petrology and structure of the Glen 7¼' quadrangle, southeast Adirondacks, New York: unpubl. doctoral dissertation, SUNY Binghamton, 241 p.

Foose, M., and Carl, J., 1977, Setting of alaskite bodies in the northwestern Adirondacks, New York: Geology, v. 5, no. 2, p. 77-80.

Geraghty, E.P., 1973, Stratigraphy, structure, and petrology of part of the North Creek 15' quadrangle, southeastern Adirondack Mountains, New York: unpubl. masters thesis, Syracuse Univ., 72 p.

Geraghty, E.P., 1978, Structure, stratigraphy and petrology of part of the Blue Mountain 15' quadrangle, central Adirondack Mountains, New York: unpubl. doctoral dissertation, Syracuse Univ., 281 p.

Hills, A., and Isachsen, Y., 1975, Rb/Sr isochron data for mangeritic rocks from the Snowy Mt. massif, Adirondack Highlands and implications from initial Sr87/Sr86 (abst): Geol. Soc. America Abstracts with Programs, v. 7, no. 1, p. 73-74.

Husch, J., Kleinspehn, K., and McLelland, J., 1975, Anorthositic rocks in the Adirondacks: basement or non-basement? (abst.): Geol. Soc. American Abstracts with Program, v. 7, no. 1, p. 78.

Isachsen, Y., McLelland, J., and Whitney, P., 1975, Anorthosite contact relationships in the Adirondacks and their implications for geologic history (abst.): Geol. Soc. America Abstracts with Program, v. 7, no. 1, p. 78-79.

James, D.E., 1971, Andean crustal and upper mantle structure: Jour. Geophys. Res., v. 76, no. 14, p. 3246-3271.

Katz, S., 1955, Seismic study of crystal structure in Pennsylvania and New York: Bull. Seis. Soc. America, v. 45, p. 303-325.

Krieger, M.H., 1937, Geology of the Thirteenth Lake Quadrangle, New York: New York State Mus. Bull. 308, 124 p.

Lettney, C.D., 1969, The anorthosite-charnockite series of the Thirteenth Lake dome, south-central Adirondacks, in Isachsen, Y.W., ed., Origin of anorthosite and related rocks: New York State Mus. and Sci. Service Mem. 18, p. 329-342.

Martignole, J., and Schrijver, K., 1970, Tectonic setting and evolution of the Morin anorthosite, Grenville Province, Quebec: Bull. Geol. Soc. Finland, v. 42, p. 165-209.

Mattauer, M., 1975, Sur le mechanisme de formation de la schistosite dans l'Himalaya: Earth Plan. Sci. Lett., v. 28, no. 2, p. 144-154.

Miller, W.J., 1911, Geology of the Broadalbin quadrangle: New York State Mus. Bull. 153, 65 p.

Miller, W.J., 1916, Geology of the Lake Pleasant quadrangle: New York State
     Mus. Bull. 182, 75 p.

Miller, W.J., 1920, Geology of the Gloversville quadrangle: New York State
     Mus. and Sci. Service, open-file maps.

Miller, W.J., 1923, Geology of the Luzerne quadrangle: New York State
     Mus. Bull., 245-246, 66 p.

McLelland, J., 1969, Geology of the southernmost Adirondacks: New England
     Intercol. Geol. Conf., Guidebook, v. 61, sec. 11, p. 1-34.

McLelland, J., 1972, Stratigraphy and structure of the Canada Lake Nappe:
     New York State Geol. Assoc., 44th Ann. Meeting, Guidebook, p. E1-E27.

McLelland, J., 1984, Origin of ribbon lineation within the southern Adirondacks,
     U.S.A.: Jour. Structural Geology, v. 6, no. ½, pp. 147-157.

McLelland, J., and Whitney, P., 1977, Origin of garnet coronas in the
     anorthosite-charnockite suite of the Adirondacks: Contr. Min. Petrol.,
     v. 60, no. 2, p. 161-181.

Molnar, P., and Tapponier, P., 1975, Cenozoic tectonics of Asia: Effects
     of a continental collision: Science, v. 189, no. 4201, p. 419-426.

Morse, S.A., ed., 1975, Nain anorthosite project Labrador: Field Report 1975:
     Contr. No. 26, Dept. Geology and Geography, Univ. Massachusetts, 93 p.

Nelson, A.E., 1968, Geology of the Ohio quadrangle: U.S. Geol. Survey Bull.
     1251-F, p. F1-F46.

Powell, C. McA., and Conaghan, P.J., 1973, Plate tectonics and the Himalayas:
     Earth Planet. Sci. Lett., v. 20, no. 1, p. 1-12.

Ramberg, H., 1967, Gravity, deformation, and the Earth's crust as studied by
     centrifuged models: Academic Press, New York, 241 p.

Silver, L., 1969, A geochronologic investigation of the Anorthosite Complex,
     Adirondack Mts., New York, in Isachsen, Y.W., ed., Origin of Anorthosites
     and related rocks: New York State Mus. and Sci. Service Mem. 18,
     p. 233-252.

Simmons, E.C., 1976, Origins of four anorthosite suites: unpubl. doctoral
     dissertation, SUNY Stony Brook, 190 p.

Thompson, B., Jr., 1959, Geology of the Harrisburg 15' quadrangle, southern
     Adirondacks: New York State Mus. and Sci. Service, open-file maps.

Turner, B.B., 1971, Structural-stratigraphic relationships among metasedimentary,
     meta-igneous, and other gneissic rocks, southeastern Adirondack Mountains,
     New York (abst.): Geol. Soc. America Abstract with Program, v. 3, no. 1,
     p. 58.

Valley, J., McLelland, J., Essene, E., and Lamb, W., 1983, Metamorphic
    fluids in the deep crust:

Walton, M.S., 1961, Geologic maps of the eastern Adirondacks: New York
    State Mus. and Sci. Service, open-file maps.

Walton, M.S. and de Waard, D., 1963, Orogenic evolution of the Precambrian
    in the Adirondack Highlands: a new synthesis: Proc. Kon. Ned. Akad.
    Wetensch., Amsterdam, Ser. B, no. 66, p. 98-106.

Zeitz, I., and King, E.R., 1977, The New York-Alabama Lineament: a possible
    plate boundary (abst.): Geol. Soc. America Abstracts with Program, v.
    9, no. 3, p. 333.