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GUIDEBOOK

to

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Robert M. Finks, Editor

Host:

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of New York

Copies of this guidebook may be purchased from the Permanent Secretary, New York State Geological Association. Address Prof. Philip Hewitt, Department of Geology, State University College at Brockport, N. Y.

The organizer of the field trips described in this volume, and of the meeting at which they were given, is

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PREFACE

The papers brought together in this Guidebook merit comparative reading at leisure, for they often bring to bear upon problems of the local geology many independent lines of evidence. Some matters that come immediately to mind out of personal interest are:

(1) The relation of the New York City Group to the unmetamorphosed Cambro-Ordovician sequence (Trips A, C, E, H).

(2) The several phases of Taconian deformation (Trips A, G, H).

(3) The nature of the pre-Triassic basement of the Newark Basin (Trips C, E, H).

(4) Comparison of deltaic sedimentation in Devonian, Cretaceous and Pleistocene (Trips B, E, F, J).

Undoubtedly many others will occur to readers of the Guidebook.

The shortness of time available for the preparation of this guidebook made it impossible for authors to see proof of their articles and the Editor accepts responsibility for such errors as have crept in. Editorial changes were kept to a minimum.

The Editor wishes to express his thanks, on behalf of the NYSGA, to Queens College for typing the final copy which you see here reproduced by photo-offset, in particular to Mrs. Blanche J. Meixel, Supervisor of Secretarial Services, and Mrs. Helen L. Abramson, who with her staff, consisting of Mrs. Florence Altmann, Mrs. Florence Fassler, Mrs. Doretta Kaplan, Miss Marion Shapiro and Mrs. Jeanne Trush, typed and proof-read the final copy with great care, intelligence and taste.

Mrs. Lee Cogan, Editor of Official College Publications, and her assistant, Mrs. Beatrice Bergen, arranged for the printing of this volume, and provided much valuable technical advice.

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The Editor wishes to thank also Miss Carol Yanek and Mr. Nicholas F. Avignone, Geology majors at Queens College, who assisted ably with many of the tasks of editing.

Robert M. Finks,
Editor

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TRIP A: BEDROCK GEOLOGY IN THE VICINITY OF WHITE PLAINS, NEW YORK

By Leo M. Hall, University of Massachusetts

(Approved for publication by the Assistant Commissioner for the New York State Museum and Science Service.)

INTRODUCTION

Stratigraphic relations, including two unconformities, are well displayed by the bedrock in the White Plains quadrangle in Westchester County, New York. Fifteen rock units within the traditional "New York City Group" have been mapped in detail there. At the lower unconformity, Cambrian Lowerre Quartzite or Inwood Marble rest on Precambrian Fordham Gneiss and Yonkers Gneiss. Along the upper unconformity, the lower member of the Manhattan Schist rests on various units of the Inwood Marble as well as the Fordham and Yonkers. In addition, a major thrust fault may occur near the base, and locally at the base, of what has traditionally been mapped as Manhattan Schist.

There is widespread evidence for at least four, and probably five, phases of deformation in the region. The Yonkers Gneiss and Fordham Gneiss were folded at least once before the deposition of the Lowerre Quartzite and younger rocks. The pre-Manhattan rocks were deformed, at least mildly, prior to the deposition of the lower part of the Manhattan Schist. A major thrust fault, correlated with Taconic thrusting, may separate member A of the Manhattan Schist from members B and C of the Manhattan Schist. Finally, all of the rocks and previously formed structural features were involved first in major nappe-like isoclinal folds and second in folds with steeply dipping axial surfaces.

The main purpose of this field trip is to illustrate the stratigraphy of the region. In doing so, some of the main structural features will also be shown.

ACKNOWLEDGEMENTS

Field work in the White Plains quadrangle was financed by the New York State Museum and Science Service, Geological Survey. It is a pleasure to express my gratitude to the following for permitting access to their property for purposes of this field trip: East Hudson Parkway Authority, Village of Irvington, Sleepy Hollow Restorations, Inc., REA Express in Ardsley, Town of Harrison, Consolidated Edison Company, and Greenburgh School District number 8.

STRATIGRAPHY

The stratigraphy in this region can be classified into four divisions as follows:

<u>Precambrian</u>: Various gneisses and amphibolites that compose the Yonkers Gneiss and Fordham Gneiss.

Cambrian-Ordovician, Quartzite-Carbonate Sequence: Quartzites and granulites that pass upward into dolomite marbles and then calcite marbles represent a shelf or miogeosynclinal depositional sequence. The Lowerre Quartzite and Inwood Marble are included in this division.

Middle Ordovician Marble and Schist: At least the lower part of the Manhattan Schist (member A) which consists of schist and some marble represents a clastic wedge that rests unconformably on the miogeosynclinal facies.

?Cambrian-Ordovician Eugeosynclinal Sequence: An assemblage of feldspathic schists, schistose gneisses, gneisses and amphibolites that represents a eugeosynclinal depositional sequence composes this division. The Hartland Formation (Rodgers and others, 1959) and probably the portion of the Manhattan Schist here referred to as members B and C are the units that make up this sequence. Although the age of these rocks is very uncertain they are probably facies equivalents of the quartzite-carbonate sequence.

The use of the phrase "New York City Group" is abandoned for rocks of the Manhattan Prong in the vicinity of White Plains because it is misleading with respect to the above interpretation. A brief description of the rocks along with their proposed correlations and ages is presented in columnar form in Table 1.

EVIDENCE FOR UNCONFORMITIES

Evidence for an unconformity at the base of the Lowerre Quartzite, or Inwood Marble where the Lowerre is absent, is apparent from regional mapping in the southeast corner of the Nyack quadrangle, the White Plains, Glenville and Mount Kisco quadrangles. Different varieties of gneiss are in contact with the overlying rocks from place to place (e.g. STOP 1, on this trip and Figure 1 where subdivisions of the Fordham are shown and the Yonkers Gneiss is truncated). Furthermore, some large scale folds present in the gneisses are not evident in the younger rocks (Figure 1, where members of the Fordham are indicated). Regional stratigraphic relationships indicate that this unconformity separates Precambrian rocks from Paleozoic rocks.

Member A of the Manhattan Schist is in contact with the Fordham Gneiss as well as various members of the Inwood Marble. This discontinuity at the base of member A is interpreted as representing an unconformity. The fact that marble is interbedded with schist at the base of the Manhattan is well established (Prucha, 1956; this field trip, mileages 20.5 and 29.5 as well as STOPS 6 and 7). These marble interbeds do not represent Inwood grading upward into Manhattan because they occur, with and within the schist, in contact with various members of the Inwood as well as the Fordham. Thus the marble interbedded with schist is above the unconformity. The rocks that make up member A of the Manhattan Schist are correlated with similar Middle Ordovician rocks that rest with widespread unconformity on Early Ordovician and older rocks in New York (Fisher, 1954 and 1962) and New England (Cady, 1945, p. 560; Zen, 1967, p. 40). Member B and member C of the Manhattan Schist may not be younger than member A but may be older and in thrust fault contact with the other rock units in the Manhattan Prong.

STRATIGRAPHY OF THE WHITE PLAINS AREA

AGE	FORMATION	MEMBER	BRIEF DESCRIPTION OF ROCKS	REGIONAL CORRELATION
UNCERTAIN	MANHATTAN SCHIST	C	PREDOMINANTLY BROWN-WEATHERING FELDSPATHIC SILLIMANITE-GARNET-MUSCOVITE-BIOTITE SCHIST OR SCHISTOSE GNEISS; SILLIMANITE NODULES COMMON. ALTHOUGH SILICEOUS BEDS ARE PROMINENT IN SOME PLACES, BEDDING IS NOT COMMONLY CLEARLY DEFINED.	CORRELATION OF MEMBERS B AND C IS UNCERTAIN BUT THEY MAY BE EQUIVALENT TO THE WARAMAUG FORMATION (GATES, 1952), THE HOOSAC FORMATION (HATCH AND OTHERS, 1966), AND LOWER CAMBRIAN AND CAMBRIAN (?) ROCKS OF THE TACONIC SEQUENCE (ZEN, 1967, FIG. 4).
		B	A DISCONTINUOUS UNIT OF AMPHIBOLITE AND MINOR SCHIST; ALTHOUGH THIS UNIT IS COMMONLY AT THE BASE OF MEMBER C, THERE ARE MANY PLACES WHERE IT IS WITHIN MEMBER C, SUCH AS AT STOP 10.	
MIDDLE ORDOVICIAN		A	GRAY OR DARK GRAY FISSILE SILLIMANITE-GARNET-MUSCOVITE-BIOTITE SCHIST WITH INTERBEDDED CALCITE MARBLE LOCALLY AT THE BASE.	BALMVILLE (FISHER, 1962) AND WALLOOMSAC (ZEN AND HARTSHORN, 1966).
			UNCONFORMITY	
LOWER ORDOVICIAN	INWOOD MARBLE	E	GRAY OR WHITE CALCITE MARBLE, COMMONLY TAN WEATHERING.	COPAKE LIMESTONE AND ROCHDALE LIMESTONE (KNOPF, 1962).
		D	INTERBEDDED DOLOMITE MARBLE, CALCITE MARBLE AND SOME CALC-SCHIST.	ROCHDALE LIMESTONE AND HALCYON LAKE FORMATION (KNOPF, 1962).
CAMBRIAN		C	WHITE OR BLUE-GRAY CLEAN DOLOMITE MARBLE.	BRIARCLIFF DOLOMITE (KNOPF, 1962).
		B	INTERBEDDED WHITE, GRAY, BUFF, OR PINKISH DOLOMITE MARBLE, TAN AND REDDISH BROWN CALC-SCHIST, PURPLISH-BROWN OR TAN SILICEOUS CALC-SCHIST AND GRANULITES, TAN QUARTZITE, AND CALCITE-DOLOMITE MARBLE; BEDDING ONE HALF INCH TO FOUR FEET THICK IS PRONOUNCED.	PINE PLAINS FORMATION (KNOPF, 1962).
		A	WELL BEDDED WHITE, GRAY, OR BLUE-GRAY DOLOMITE MARBLE.	STISSING DOLOMITE (KNOPF, 1962).
	LOWERRE QUARTZITE		TAN OR BUFF-WEATHERING FELDSPATHIC QUARTZITE AND GRANULITE, MICAEOUS QUARTZITE AND GLASSY QUARTZITE; DARK GRAY, BROWNISH AND LOCALLY RUSTY-WEATHERING GRANULITE AND SCHIST THAT COMMONLY CONTAIN SILLIMANTTE ARE LOCALLY PRESENT AT THE BASE.	POUGHQUAG QUARTZITE (KNOPF, 1962).
			UNCONFORMITY	
PRECAMBRIAN	FORDHAM GNEISS	E	INTERBEDDED GRAY GARNET-BIOTITE GNEISS, BROWN TO RUSTY WEATHERING BIOTITE GNEISS AND AMPHIBOLITE; AUGEN GNEISS IS LOCALLY PRESENT AT THE BASE.	UNKNOWN.
		D	RUSTY-WEATHERING SILLIMANITE-GARNET SCHIST OR SCHISTOSE GNEISS, AND SILICEOUS BIOTITE GNEISS OR QUARTZITE.	UNKNOWN.
		C	GRAY BIOTITE-HORNBLENDE GNEISS WITH NUMEROUS PINK OR WHITE QUARTZ FELDSPAR LAYERS AND LENSES; AMPHIBOLITE AND SOME PINKISH BIOTITE AND/OR HORNBLENDE QUARTZ FELDSPAR GNEISS.	UNKNOWN.
		B	GRAY GARNET-BIOTITE GNEISS AND AMPHIBOLITE.	UNKNOWN.
		A	BROWN WEATHERING GARNET-BIOTITE GNEISS, AMPHIBOLITE AND GRAY BIOTITE-HORNBLENDE GNEISS.	UNKNOWN.
	YONKERS GNEISS		PINKISH OR PURPLISH-BLUE BIOTITE AND/OR HORNBLENDE QUARTZ FELDSPAR GNEISS.	UNKNOWN.

Table 1 - Stratigraphy of the Manhattan Prong in the White Plains area.

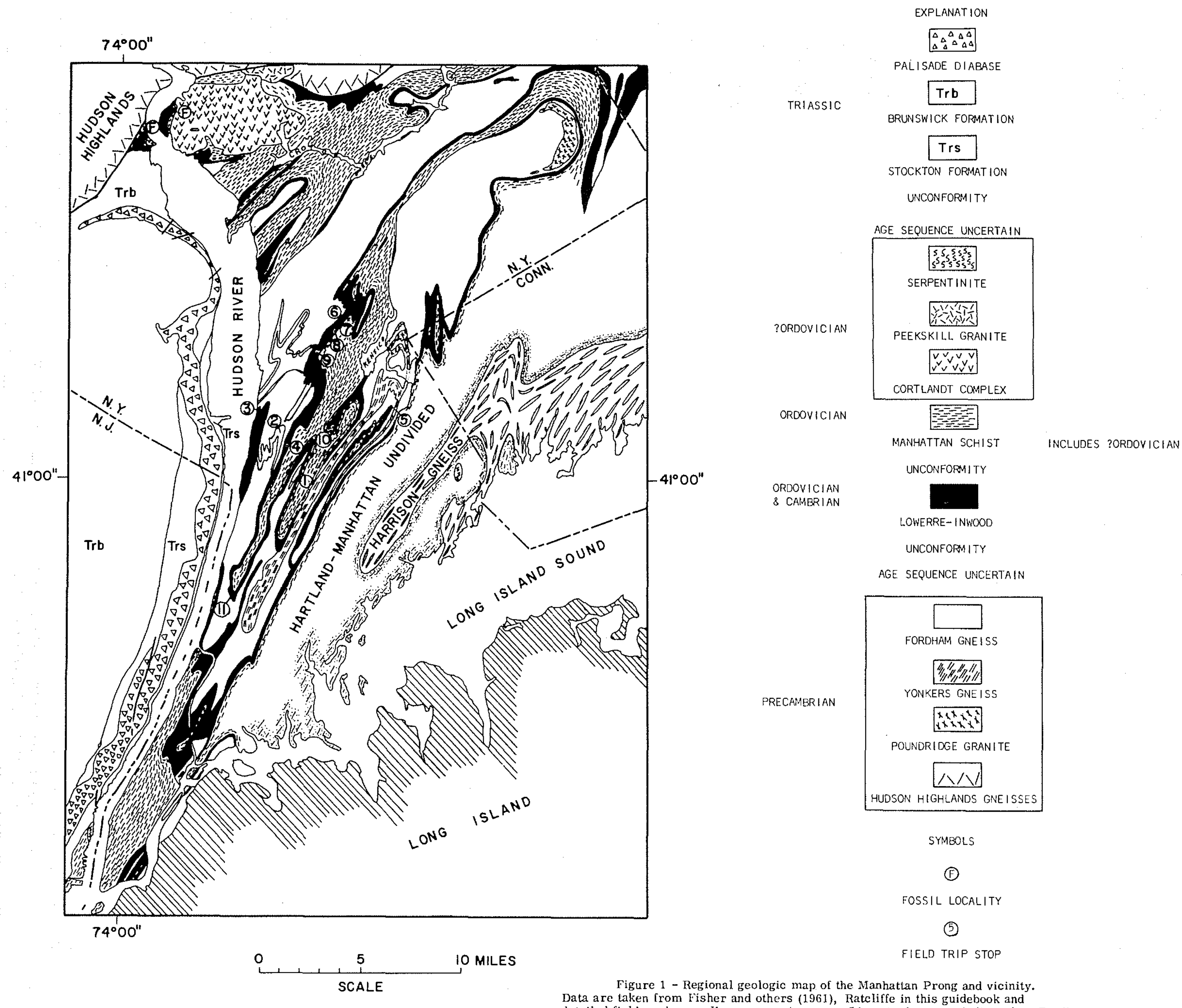

Figure 1 - Regional geologic map of the Manhattan Prong and vicinity. Data are taken from Fisher and others (1961), Ratcliffe in this guidebook and detailed field work as well as reconnaissance. Lines in the areas indicated as Fordham Gneiss represent contacts between members of the Fordham.

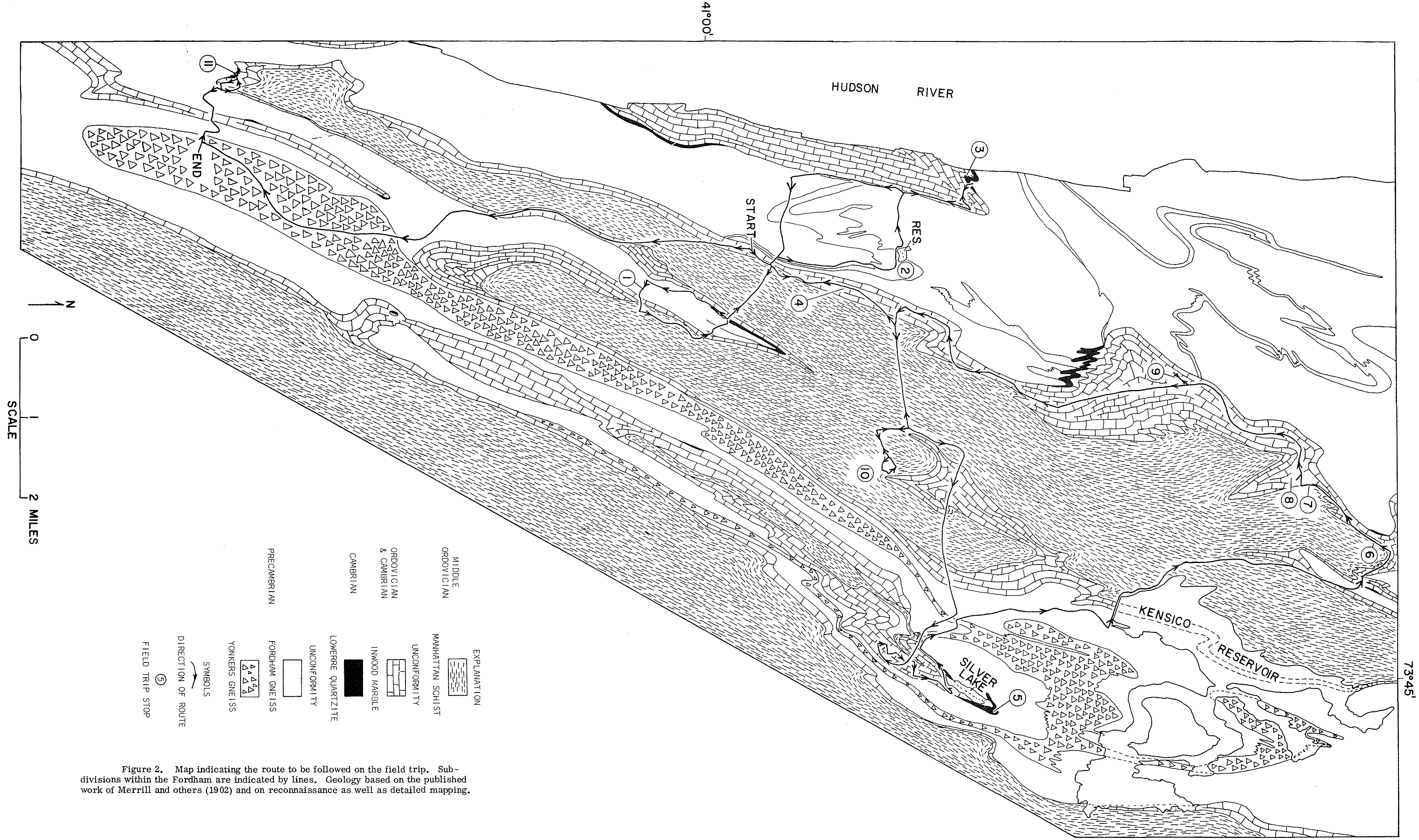

Figure 2. Map indicating the route to be followed on the field trip. Subdivisions within the Fordham are indicated by lines. Geology based on the published work of Merrill and others (1902) and on reconnaissance as well as detailed mapping.

STRUCTURAL GEOLOGY

A fold system is apparent in the Precambrian rocks where the Fordham Gneiss has been subdivided and since these folds do not involve the Paleozoic rocks they must have formed during the Precambrian. The tectonic history of the Precambrian rocks in the Manhattan Prong is extremely complex and not very well understood at present. An example of a fold in the Fordham Gneiss is displayed at STOP 2 where a steep south plunging syncline is fairly clear.

The pre-Manhattan rocks were subjected to mild deformation in the form of tilting and/or block faulting. The angular unconformity that separates member A of the Manhattan Schist from the older rocks is the evidence for this deformational episode.

All of the rocks were subjected to at least two phases of deformation in the Paleozoic as attested to by the regional map pattern as well as the many refolded minor isoclinal folds that have been observed in the Lower Paleozoic rocks throughout the Manhattan Prong. Although one phase of folding preceded the other, this does not necessarily require two separate orogenic episodes. The earliest phase of this folding resulted in the development of large scale overturned, probably recumbent, isoclinal folds that involved the basement gneiss complex and was accompanied by metamorphism. Critical evidence for this is found at STOP 5 where Paleozoic rocks extend beneath Precambrian rocks on the lower limb of an early-phase nappe-like fold. Axial plane foliation that developed in conjunction with this early phase of folding is identifiable on the local scale in minor folds. Many examples of later stage folds are found at the local (STOP 10) as well as the regional scale (STOP 5 or between STOPS 4 & 5). In fact, much of the regional map pattern (Figure 1) is very likely the result of the later phase of folding. The later stage folds are generally more open and have an axial plane foliation, locally slip cleavage, developed in association with them.

TACONIC THRUSTING?

The possibility that members B and C of the Manhattan Schist are in thrust fault contact with the other rocks in the Manhattan Prong suggests itself on the basis of the tentative correlation of members B and C with the Waramaug Formation in Connecticut (Gates, 1952) and the Hoosac Formation in Massachusetts and Vermont (Chidester and others, 1967; Zen, 1967). This somewhat tenuous correlation is based on regional mapping and lithic similarity of the rocks involved. (Percival, 1842, geologic map; Clarke, 1958, p. 22; Gates 1961) and is indicated on Table 1. The Hoosac Formation is Cambrian (Chidester and others, 1967) but the age of the Waramaug is less certain. Gates (1952, p. 14) indicated that the Waramaug is older than Stockbridge, an Inwood equivalent, and that it is probably Precambrian. Thus the relative ages of these units is apparently clear but if the tentatively proposed correlation is valid the Waramaug must be Cambrian and not Precambrian. Accordingly, Manhattan B and C would be Cambrian and thus in fault contact with Middle Ordovician Manhattan A. No direct physical evidence for thrusting has been found. The lack of such structural evidence may be due to the lithic similarity of some of the rocks involved as well as to subsequent metamorphism. Both of these would tend to obscure direct primary evidence of faulting. A relationship involving such large scale thrust faulting is similar to that found between the Taconic allochthon and autochthon (Zen, 1967).

If the proposition that major overthrusting took place in the Manhattan Prong is true, this faulting must have occurred prior to or at the beginning of the early phase of Paleozoic folding. Furthermore, if the thrusting is analogous to Taconic thrusting it very likely occurred at a time when Manhattan A was mud. Consequently, if such faulting did take place it necessitates a phase of deformation dominated by thrusting, or more likely gravity sliding, which may have been a separate deformational episode or the forerunner to the early phase of folding. Obviously, more evidence is needed to demonstrate the presence or absence of Taconic thrusting in the Manhattan Prong.

ROAD LOG

<u>Mileage.</u>

0.0	-	The road log begins at the northbound New York Thruway exit in Ardsley and the route is indicated on Figure 2. The contact between member B and member C of the Inwood Marble is exposed along the west (left) side of the exit ramp. Member C is exposed along the east (right) side of the ramp as well. The Inwood here is in the west limb of a north-plunging syncline with Manhattan Schist in the trough of the syncline underlying the hills on the east and Fordham Gneiss under the hills on the west. Leave the exit ramp and turn right (north) onto route 9A (Saw Mill River Rd.) and then proceed northward along the west limb of the syncline.
0.2	0.2	Turn right (east) onto Ashford Ave. and proceed southeasterly over the hill, across the synclinal trough. The exposures along the roadsides are Manhattan Schist.
1.0	0.8	Ashford Ave. enters Sprain Brook valley which is underlain by Inwood Marble. The ridge ahead to the east is Fordham Gneiss in the center of a north-plunging anticline. There are some small exposures of Lowerre Quartzite along the west limb of the anticline in this vicinity. The gneiss plunges out at the anticlinal nose less than a mile north of here.
1.1	0.1	Turn right (south) on Sprain Rd. and proceed southwesterly along the west limb of the anticline. The unpublished field notes of E. C. Eckel (New York State Museum and Science Service, Geological Survey files) report Lowerre Quartzite and Fordham Gneiss behind the houses on the east (left) side of the road but, apparently due to construction, only quartzite float exists there now.
2.3	1.2	Turn left (east) onto Jackson Ave.
2.4	0.1	<u>STOP 1.</u> <u>New road cuts on Sprain Brook Parkway Construction site.</u> The road cuts are along the left (north) side of Jackson Ave. on the approach to the new Jackson Ave. bridge that is now under construction and along the west side of the southbound lane of the Sprain Brook Parkway which is also presently under construction. We will walk north along the southbound lane of the Parkway and be picked up by the bus at Ardsley Rd. Those not wishing to walk may reboard the bus here and ride to Ardsley Rd. <u>Be careful of traffic on Jackson Ave.</u>

when disembarking.

Start at the west end of the road cut on the approach to the new Jackson Ave. bridge; in traversing eastward several varieties of rock types in the Fordham Gneiss will be seen in the center of the north plunging anticline. Minor structural features are abundant and many of the linear elements plunge northward apparently parallel to the anticlinal axis. Although this area has not been mapped in detail, it appears that these rocks might be grouped into three mapping units from west to east as follows:

1. Brown to rusty weathered sillimanite-garnet-biotite gneiss and smaller amounts of gray biotite-quartz-feldspar gneisses.

2. Light gray, locally pinkish, biotite-quartz-feldspar gneiss with sparse garnet. This rock looks somewhat like the Yonkers Gneiss in places.

3. Dark gray biotite and/or hornblende gneiss and amphibolite.

It would be necessary to map this area in detail to determine whether or not the above subdivision is meaningful.

After traversing to the west end of the new Jackson Ave. bridge, walk northward along the deep road cuts in subdivision 3, proposed above, and down into the Sprain Brook Valley. Walk north along the west side of the valley to Ardsley Rd. and observe several road cuts in subdivision 3. Drilling data obtained at several places along the Grassy Sprain Valley in conjunction with the highway construction now in progress reveal the predicted presence of Inwood Marble beneath the valley fill.

The contact between dark gray biotite gneiss and light gray to pinkish-gray gneiss is exposed in the road cuts at the west end of the new Ardsley Rd. bridge which is now under construction. This contact projects into the Sprain Brook Valley where it is truncated by the Inwood Marble along an unconformity. The west contact of the light gray or pinkish-gray gneisses has been mapped in detail here and it is truncated by the Inwood Marble approximately three quarters of a mile north of here. Reconnaissance indicates that these gray gneisses are very likely the same as subdivision 2 proposed above.

While the above traverse is being made, the bus will proceed as follows in order to meet the group at Ardsley Rd.:

2.4	-	Proceed east on Jackson Ave. across Grassy Sprain Brook Valley.
2.7	0.3	Turn left (north) onto Grassy Sprain Rd. and proceed along the east limb of the anticline. The road is near the contact between the Inwood Marble and Manhattan Schist. The hills to the east are underlain by the Manhattan in the trough of a syncline.

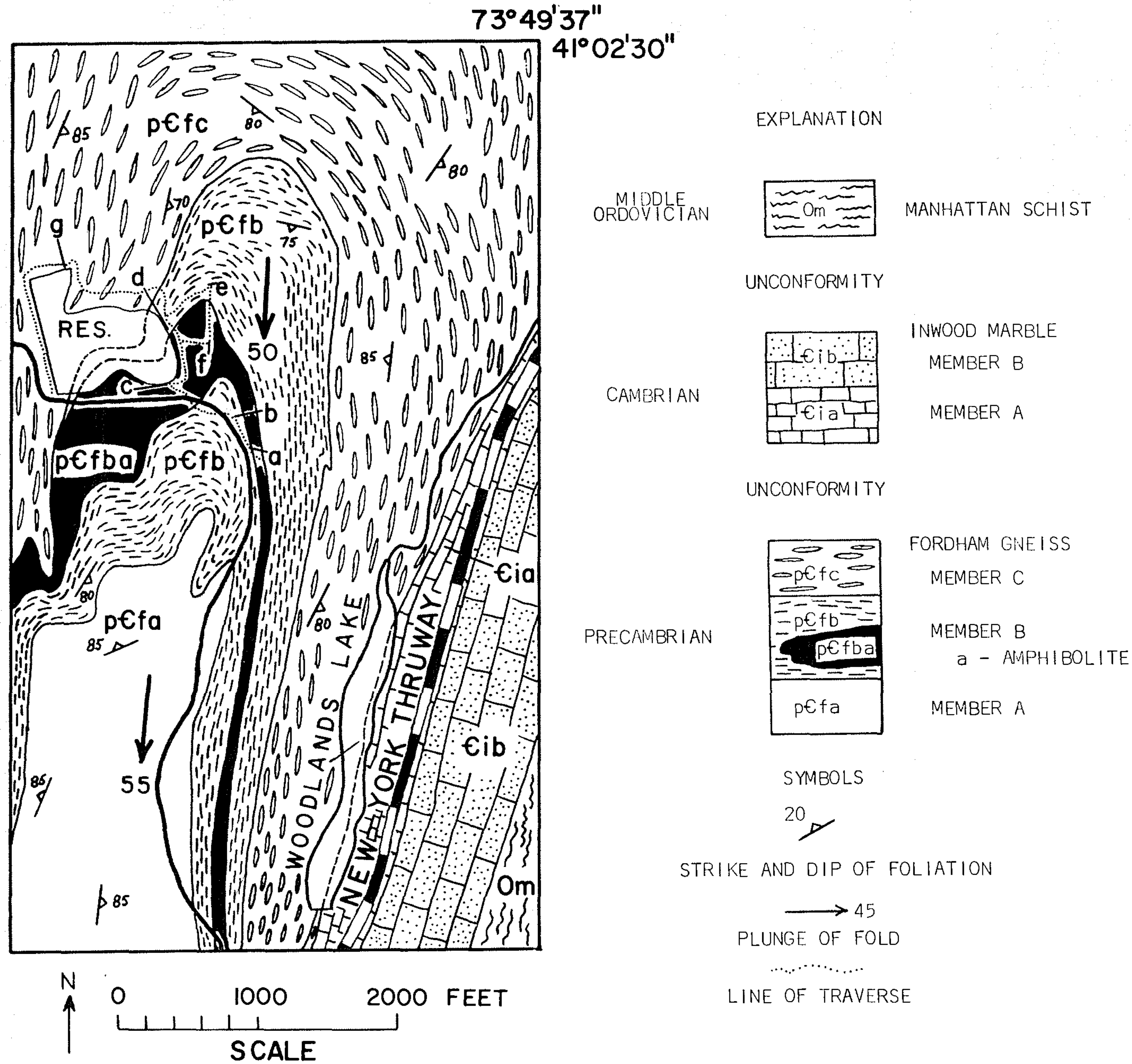

Figure 3 - Geologic map of the Harriman Road Reservoir area, STOP 2.

3.6	0.9	Turn left (northwest) onto Ardsley Rd. (A good exposure of member B of the Manhattan Schist is in the road cut along Ardsley Rd. approximately 0.1 mile southeast of this intersection.) Proceed northwest along Ardsley Rd. entering the floor of Grassy Sprain Valley.
3.8	0.2	The bus will stop here in order to allow the group to board and then will continue northwesterly on Ardsley Rd. crossing the anticline.
4.1	0.3	Proceed straight through the dangerous intersection where the street name changes from Ardsley Rd. to Ashford Ave. Continue northwesterly on Ashford Ave. re-crossing the syncline.
5.1	1.0	Proceed through the major intersection and onto the bridge that overpasses the Saw Mill River, New York Thruway, New York Central Railroad tracks, and the Saw Mill River Parkway. In so doing we have traversed from the lower part of the Manhattan Schist through members A, B, and possibly part of C of the Inwood Marble down into the Fordham Gneiss.
5.2	0.1	THIS IS AT THE IMMEDIATE WEST END OF THE BRIDGE THAT WAS JUST CROSSED. Turn right (north) onto Northfield Ave. and proceed northward. Many exposures of member A of the Fordham Gneiss are present in the hills on the west (left) side of Northfield Ave.
6.0	0.8	Turn left (north) onto Cyrus Field Rd., named after "the father of the first transatlantic cable".
6.7	0.7	Enter long left curve where the road changes from north-south to east-west and also changes names to Harriman Road.
6.8	0.1	STOP 2. Harriman Road Reservoir. Park in the driveway on the right (north) side of the road that leads into the watershed area of the reservoir. We have been allowed to visit this area through the courtesy of the Village of Irvington, Department of Public Works. This is a water supply reservoir, please conduct yourself in accordance.

This is the area of a steeply plunging structural syncline that is defined by the contacts between various members of the Fordham Gneiss (Figure 3). Minor structural features and the orientation of foliation indicates that the syncline plunges 50° to 60° toward the south. It has been possible to map a separate amphibolite within member B of the Fordham Gneiss here (Figure 3) but the amphibolite cannot be separately mapped elsewhere. We will study the syncline by traversing along and across the amphibolite-garnet gneiss contacts (see walking route, Figure 3). Disembark from the bus and proceed southeast along the northeast side of Harriman Rd. to station a.
Station a - Dark amphibolite and biotite-hornblende gneiss along with some garnetiferous gneiss are exposed here on the east limb of the syncline. The contact between the amphibolite and garnet gneiss appears gradational here and it is very difficult to map the amphibolite separately from here south. The apparent gradational nature of this

contact may be due to minor folds which are abundant here. Note the pyroxene (green-weathering) rimmed by hornblende (black) indicating retrograde metamorphism. Thin sections of similar rocks in member B of the Fordham reveal amphibole lamellae within the pyroxene and these lamellae are apparently retrograded exsolved pyroxene. The textural and mineralogical relations in this rock are open to various interpretations.

Station b - The exposure of typical gray garnet-rich gneiss in the trees on the north side of the road occupies the keel of the syncline here. Elsewhere in this rock type sillimanite is locally abundant, particularly as inclusions in garnet, but only traces of sillimanite have been observed here.

Station c - Dark amphibolite in steep south-plunging minor folds. Note the trend of the foliation here and then look toward the northeast corner of the reservoir where the amphibolite-garnet is present at station d. The strike obviously changes and this contact outlines a minor fold here on the larger syncline.

Station d - We have progressed northward along the west limb of the syncline and across the garnet gneiss-amphibolite contact. This outcrop of gray garnet gneiss is structurally beneath the amphibolite.

Station e - The garnet gneiss here is in the keel of the syncline. Note the foliation athwart the trend of the amphibolite-garnet gneiss contact. This foliation is apparently parallel to the axial plane of the syncline.

Station f - The amphibolite is in the keel of the syncline here and the foliation is parallel to the amphibolite-garnet gneiss contact.

If time permits we will walk along the north shore of the reservoir across many exposures of rocks typical of member C of the Fordham Gneiss.

Station g - This is an exposure of member C of the Fordham Gneiss that here consists of biotite and/or hornblende-quartz-feldspar gneiss, with many quartz-feldspar layers, and amphibolite. These rocks are complexly deformed with many examples of refolded folds as well as boudinaged amphibolite.

Return to Harriman Road and board the bus.

6.8	-	Proceed west along Harriman Road.
7.8	1.0	Turn right (north) onto Route 9 (Broadway) and proceed north more or less along the Fordham Gneiss-Inwood Marble contact.
8.7	0.9	Turn left (west) onto the entrance road to Sunnyside (West Sunnyside Lane). Sunnyside is the former country home of Washington Irving

who designed and remodeled the house himself and is responsible for its unique architecture.

9.0 0.3 Member B of the Inwood Marble is exposed in the stream on the right (north) side of the road.

9.1 0.1 Turn right (north) and enter the gate to Sunnyside.

9.2 0.1 STOP 3. Sunnyside. NO HAMMERING PLEASE! The contact between the Lowerre Quartzite and member A of the Inwood Marble is exposed here. This same contact is exposed at STOP 2 on Trip H (Ratcliffe, this guidebook).

Sunnyside belongs to Sleepy Hollow Restorations, Incorporated. This is a non-profit organization that has allowed us free access to Sunnyside for purposes of this field trip. Visitors are normally charged an admission fee. Please show your gratitude by being careful.

Proceed through the reception center to the outlet of the pond, "Little Mediterranean". Lowerre is exposed in the brook beneath the bridge and extends upstream. Here, the Lowerre consists of typical tan to buff weathered quartzite, micaceous quartzite, feldspathic quartzite and granulite. More Lowerre is exposed downstream from the bridge and a large fold is clearly displayed at the waterfall. This fold is large enough to be outlined by the Lowerre-Inwood contact on the regional geologic map (Figure 1.). Bedding attitudes indicate that the fold plunges 60^{o} to 65^{o} toward the southeast. A white quartz vein one to two feet thick is present in the axial region of the fold.

The contact of the Lowerre with member A of the Inwood is exposed below the waterfall and the Lowerre is relatively clean quartzite near the top. The Inwood consists of coarse white dolomite marble and a few calcite-bearing beds are also present. A bright green chromium-bearing chlorite is locally present in the coarse white dolomites. Paleontologists have assured me that the siliceous "box work" present here does not represent organic remains.

There is a fine view of the Palisades across the Hudson River. The cliffs are marked by the Palisades Sill which is in contact with the Triassic Stockton Formation at the base of the cliff a little above the surface of the river (Figure 1). An unconformity, somewhere beneath the river, separates the Paleozoic and Precambrian rocks in the vicinity of Sunnyside from the overlying Triassic rocks. This unconformity dips westward and thus projects above the ground surface at Sunnyside. Evidence for the unconformity is clear in the vicinity of Stony Point on the west side of the Hudson River, see Figure 1, Trip H, (Ratcliffe, this guidebook).

There is at least one small exposure of member A of the Inwood on the grounds of Sunnyside. We will not visit the small exposures of member C of the Fordham that are present in the wooded area north of Sunnyside, but the unconformity at the base of the Lowerre must be present somewhere in the vicinity of the northern boundary of the grounds.

Return to the parking lot and board the bus.

9.4	0.2	Leave Sunnyside passing through the gate and turning left (east) onto West Sunnyside Lane.
9.8	0.4	Turn right (south) onto Route 9 (Broadway) and proceed south to Dobbs Ferry.
12.1	2.3	Turn left (east) onto Ashford Ave. and proceed east across member A and member B of the Fordham Gneiss.
13.2	1.1	Start across the bridge that overpasses the Saw Mill River etc. and in so doing, cross the Fordham Gneiss-Inwood Marble-Manhattan Schist contacts.
13.3	0.1	Turn left (north) onto Route 9A (Saw Mill River Rd.) and proceed north along the west limb of a syncline.
13.4	0.1	Outcrops of Manhattan Schist are on the right (east).
14.3	0.9	STOP 4. REA Express Terminal. This is a good exposure of rocks that are typical of member B of the Inwood Marble. It consists of interbedded gray and white dolomite marble; tan, cream colored, and locally pinkish-weathering dolomite marble; tan calc-schist and granulite.

There are several north-plunging sinistral folds with half wavelengths of three to four feet outlined by beds in the vicinity of the corner of the cut and the side of the cut parallel to the east side of the building. These are interpreted to be later stage folds and evidence for an earlier stage of Paleozoic folding is revealed locally by folded mineral lineation. There are many other minor folds throughout the exposure. It is noteworthy that the syncline at STOP 2 is very close (Figure 3) and that its orientation is apparently unrelated to the folds present here. This suggests that the syncline at STOP 2 is a structural feature that was developed due to deformation in the Precambrian.

A zone of closely spaced fractures that dip 65° west is present at the corner of the cut. This is probably related to late (Triassic?) minor fault movement.

14.3	-	Board the bus and proceed north on Route 9A (Saw Mill River Rd.). Several exposures of member B of the Inwood Marble are along the right (east) side of the road.
14.6	0.3	Turn right (northeast) onto Route 100B and proceed northeast across the Inwood Marble-Manhattan Schist contact.

16.5	1.9	Turn left (north) onto Route 100A (Knollwood Rd.). The broad valley to the northeast (right front) is underlain by Inwood Marble in the center of a south plunging anticline. Proceed northward along the west limb of this anticline.
17.3	0.8	Cross Route 119 (White Plains Rd.) and turn right in order to enter the Cross Westchester Expressway eastbound. Proceed east across the anticlinal valley.
18.2	0.9	Large road cuts expose members A, B, and C of the Manhattan Schist on the east limb of the anticline.
18.3	0.1	The extensive road cuts on the left (north) side of the expressway expose member C of the Manhattan Schist in the trough of a south plunging syncline.
18.6	0.1	The expressway overpasses the Bronx River Valley which is here underlain by Inwood Marble. We cross the Inwood-Fordham contact and proceed down through the upper limb and across the axial surface of an early stage nappe-like fold.
19.6	1.0	Extensive road cuts expose multiply deformed Fordham Gneiss and Yonkers Gneiss in the core of the early stage fold.
20.0	0.4	A road cut on the right (south) side of the expressway exposes interbedded calcite marble and schist at the base of member A of the Manhattan Schist. The contact of these rocks with the Fordham Gneiss is essentially exposed here and is an example of a place where the Middle Ordovician rocks rest directly on Precambrian. We are on the lower limb of the early stage nappe-like fold which has been refolded into an anticline and we are here located on the west limb of this later stage anticline. The lower part of the Manhattan exposed here compares favorably with the fossil bearing beds at Stop 5 and Stop 7 on Trip H (Ratcliffe, this guidebook).
20.4	0.4	COMPLICATED MANEUVERS FOLLOW! Bear right onto the ramp for exit 8.
20.7	0.3	Turn right (north) onto Bloomingdale Rd.
20.8	0.1	Turn right (east) onto Westchester Ave.
20.9	0.1	Turn left (north) onto South Kensico Ave.
21.0	0.1	Turn right (east) onto Brockway Place.
21.2	0.2	Turn left (north) onto Belway Place and bear right (east) at the corner in 0.1 mile.
21.6	0.4	Turn left (north) onto Underhill Ave. All of this maneuvering has allowed us to cross the axial plane of the later stage anticline to the east limb but we remain on the lower limb of the early stage

nappe-like fold. Proceed northward along the east limb of the later stage anticline.

21.9 0.3 Turn right (northeast) onto Lake St. and proceed along the west limb of the later stage anticline.

22.2 0.3 Make a sharp (nearly 180°) left turn and then right into Silver Lake Park. LUNCH.

STOP 5. Silver Lake. We are permitted to use this park through the courtesy of the town of Harrison. Please don't litter the area with trash.

An exposure of member A of the Inwood Marble is present near the entrance to Silver Lake Park. Walk northward along the east side of Silver Lake and, in so doing, proceed along the east limb of the northerly plunging later stage anticline and at the same time along the lower limb of the earlier stage nappe-like isoclinal fold. (Figure 4). The steep topography on the west side and at the north end of the lake is underlain by Fordham Gneiss and the ridge on the east by Yonkers and Fordham. We are located on the Paleozoic rocks and the contact at their stratigraphic base projects in the air above our heads so that the stratigraphy is completely inverted here. Walk to the north end of the lake where the hinge of the later stage anticlinal fold is located (Figure 4). Walk northward, up the hill and down the stratigraphic section through the Lowerre Quartzite into the Fordham Gneiss. Note that the bedding in the Lowerre dips northward and thus projects beneath the older Fordham. In walking up the hill we are proceeding across the lower limb of the earlier stage nappe-like fold and essentially along the axial trace of the later stage fold.

The Lowerre here consists of tan to brown weathering gray feldspathic granulite, tan-weathering quartzite and micaceous quartzite, interbedded half-inch to two-inch thick beds of white quartzite and feldspathic granulite. Brown to rusty-weathering feldspathic granulite and feldspathic schist with local sillimanite nodules characterize the basal Lowerre here. The Fordham consists predominantly of gray biotite-quartz-feldspar gneiss.

Minor structural features abound in these rock exposures. Most of the linear elements plunge at 40° to 60° northwestward and apparently are parallel to the plunge of the later stage anticline.

Return to the bus.

22.2 - Leave Silver Lake Park by making a right turn at the exit and then travel southwest.

22.5 0.3 Bear right onto Lake St. and proceed southwest. There is an exposure of Lowerre Quartzite behind the milk plant on the northwest side of Silver Lake.

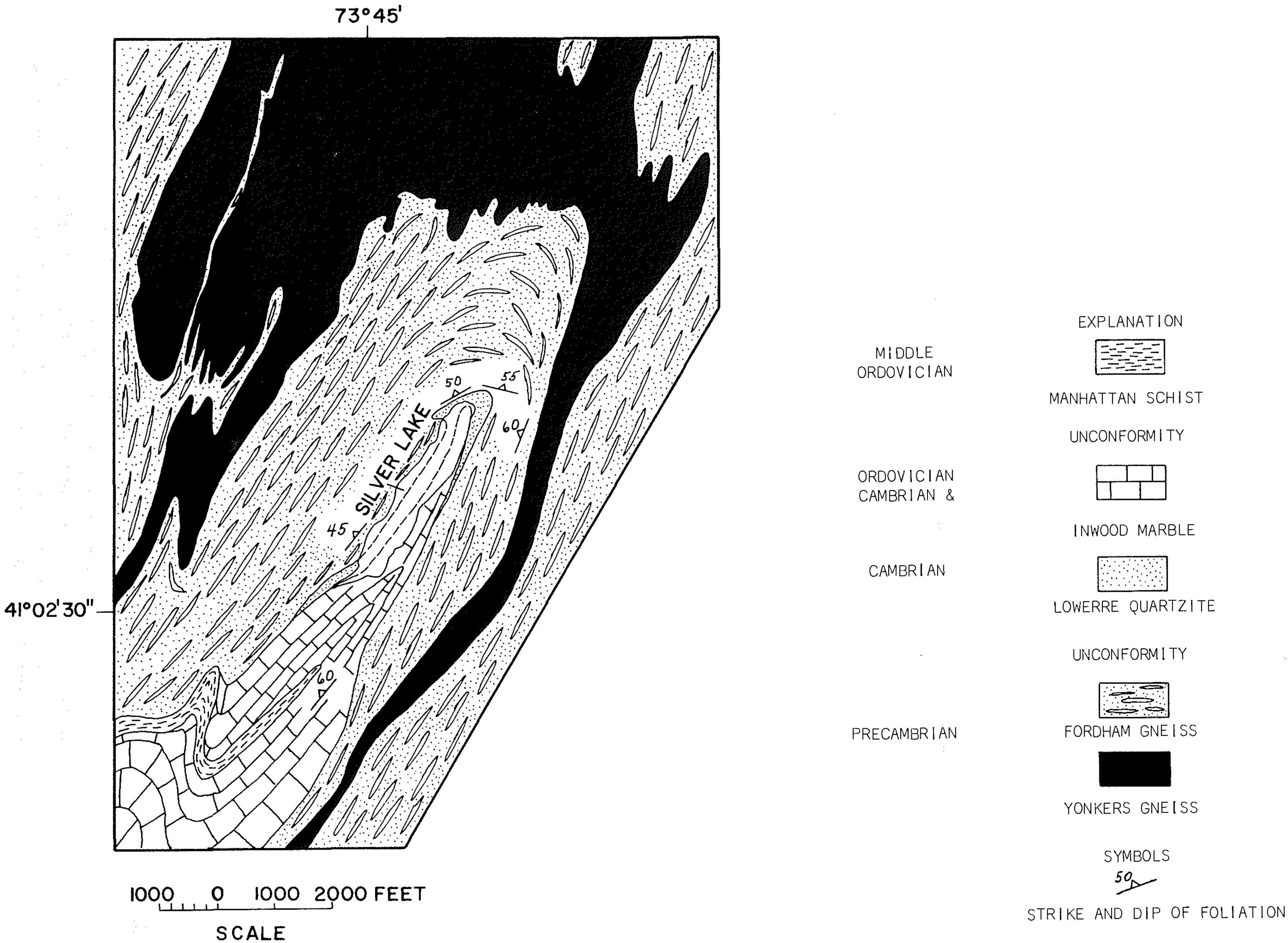

Figure 4 - Geologic map in the vicinity of Silver Lake, STOP 5.

23.0	0.5	Turn right (north) at Kensico Place and proceed northward onto North Kensico Ave.
23.5	0.5	Turn left (west) onto Grant Ave.
23.6	0.1	Turn right (north) onto Beech St., then left & right onto Central Westchester Parkway and proceed north across unexposed Fordham Gneiss and up through the axial surface of the nappe-like fold to the upper limb.
24.3	0.7	Proceed straight (northward) through the intersection, thus joining Route 22. Exposures along either side of the road are Fordham Gneiss.
25.7	1.4	Turn left (west) across the Kensico Dam onto W. Lake Drive. The rock facing on this dam is Yonkers Gneiss that was quarried from the hills to the east of the Kensico Reservoir called "Quarry Heights". Fordham Gneiss is at the east end of the dam, Manhattan Schist is at the west end and the Inwood Marble, though not exposed, is in between. Proceed northwesterly on W. Lake Drive.
27.0	1.3	Turn right (north) onto Columbus Ave. The New York City Water Supply aerators are on the right.
29.3	2.3	Turn left (northwest) onto Kensico Rd.
29.5	0.2	Interbedded calcite marble and schist at the base of member A of the Manhattan Schist are exposed in the road cut on the right (northwest) side of the road.
30.0	0.5	Turn left (south) onto Commerce St.
30.2	0.2	STOP 6. United States Post Office in Thornwood. Member A of the Manhattan Schist is exposed in the cuts alongside and behind the buildings. Characteristic gray and dark-gray sillimanite-garnet muscovite-biotite schist of member A is present here. Before the recent construction and paving, there was an exposure of interbedded white calcite marble and schist here. These rocks compare favorably with the lower portions of the Manhattan Schist that are to be visited on Trip H (Ratcliffe, this guidebook).
30.2	-	Board the bus and continue south on Commerce St.
31.2	1.0	Bear right onto Elwood St.
31.4	0.2	STOP 7. Exposures along the east side of Elwood St. The exposures of member A of the Manhattan Schist behind the buildings as well as on the wooded slope consist of the typical fissile schist and some gray and white calcite marble beds. Definite interbedding of marble and schist cannot be proven here although there are at least two exposures that strongly suggest such a relationship.

31.4	-	Board the bus and proceed south on Elwood St.
31.5	0.1	Turn right (west) onto Route 141 and proceed west across the bridge overpassing the New York Central railroad tracks.
31.6	0.1	Turn left (south) at the west end of the bridge and proceed southeasterly.
31.7	0.1	STOP 8. Member E of the Inwood Marble. Park beyond the United States Post Office at the end of the street. Walk south over the hill toward the Taconic State Parkway. An exposure of member E of the Inwood is on the west side of the hill along the east edge of the Taconic State Parkway. The contact between gray-weathering calcite marble (member D?) and tan-weathering calcite marble, typical of member E, outline a tight isoclinal fold.
31.7	-	Board the bus and return to Route 141.
31.9	0.2	Turn left (west) onto Route 141 and proceed northwesterly.
32.3	0.4	Turn left (southwest) onto Route 9A. The large roadcut on the south side of the intersection is in member D of the Inwood and there are exposures of member E up on the hill south of the road cut. Proceed southward on Route 9A along the west limb of a syncline with Fordham Gneiss underlying the hills on the west and Manhattan Schist those on the east.
34.1	0.8	Turn right (southwest) into the Consolidated Edison Company driveway.
34.3	0.2	STOP 9. Member E of the Inwood Marble. These exposures are typical of member E of the Inwood Marble and consist predominantly of tan and gray-weathering calcite marbles. Note the many northeast plunging folds.
34.3	-	Board the bus and return to Route 9A.
34.5	0.2	Turn right (south) onto Route 9A and proceed southward continuing in the Inwood Marble.
36.3	0.8	There is an excellent exposure of the unconformity at the base of the Lowerre Quartzite in a cut behind the A & P warehouses west of Route 9A. There are extensive exposures of Lowerre on the hillside extending all the way across the Saw Mill River Parkway to the west. Continue southward through Elmsford more or less along the Inwood-Manhattan contact.
39.1	2.8	Turn left (east) onto Route 100B.
41.0	0.9	Turn right (south) onto Route 100A (Hartsdale Ave.).
41.4	0.4	Turn left (east) entering the campus of Greenburgh School District No. 8.

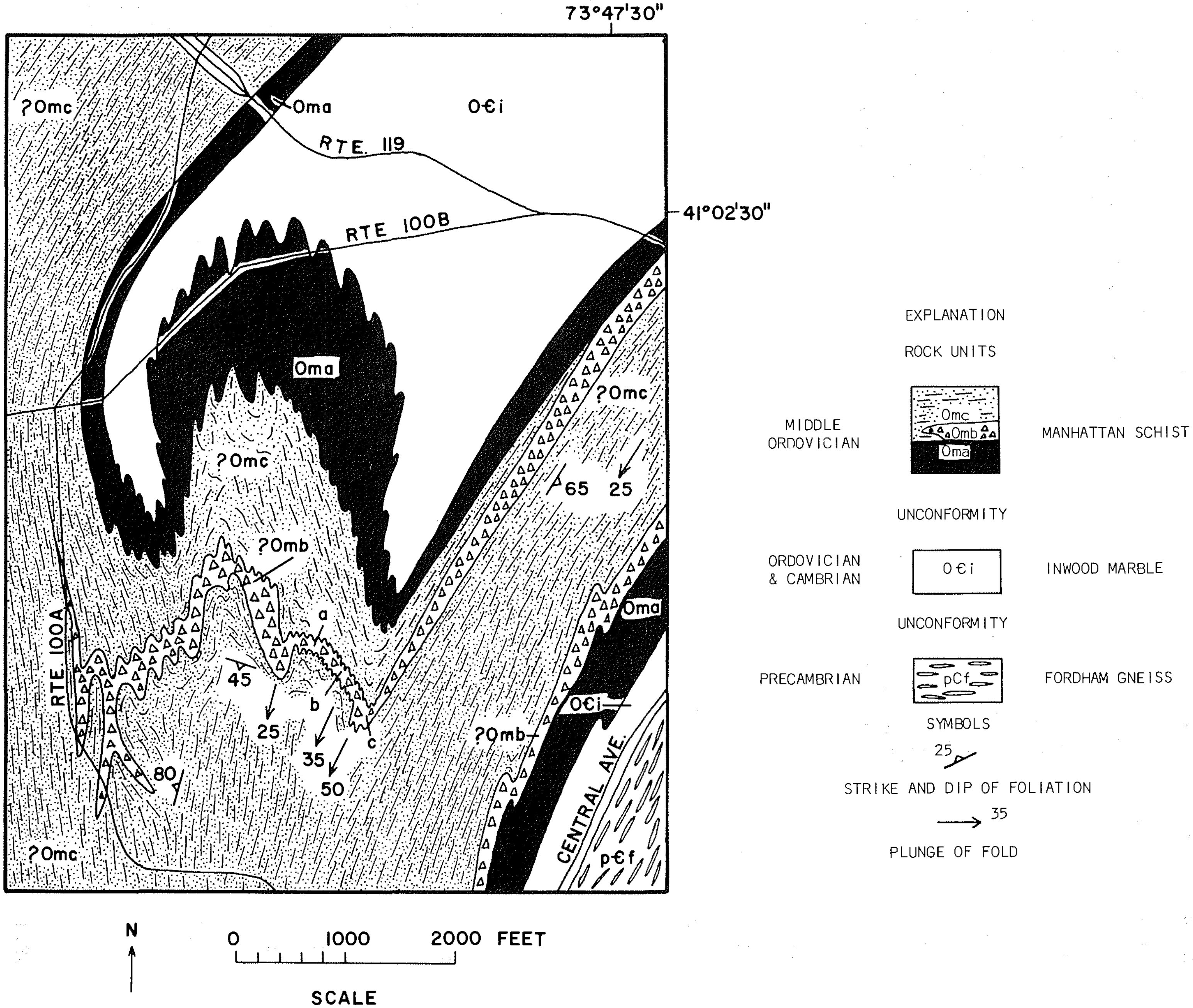

Figure 5 - Geologic map of the vicinity of the Warburg Campus, STOP 10.

41.8	0.4	Turn right (south) into the driveway leading to Woodlands High School; bear left at the fork.
42.0	0.2	STOP 10. Warburg Campus. Park in the parking lot north of Woodlands High School. This 160 acre campus is a former estate of Felix Warburg that was given to the town of Greenburgh for educational purposes. The classroom buildings on the campus accommodate 3000 students from kindergarten through high school. We have been granted permission to visit this area by the administration of Greenburgh School District No. 8. The rocks here are at the nose of a southwest-plunging later-stage anticline (Figure 5). Evidence for two, and possibly three, phases of deformation is displayed by minor structural features. The contacts between amphibolite (member B of the Manhattan) and schist, schistose gneiss and granulite that are typical of member C of the Manhattan outline the fold (Figure 5). Note that member B is above the base of member C here. Some areas of particular interest are indicated on the map (Figure 5) by lower case letters. The upper and lower contacts of the amphibolite are easily identified in the vicinity of point "a" where gray to brownish-weathering feldspathic garnet-muscovite-biotite schistose gneiss, gneiss and granulite with local white sillimanite nodules is below as well as above the amphibolite. Trace the contacts south-eastward by walking across the valley to exposures on the steep slope west of the classroom building in the vicinity of point "b" on Figure 5. The lower amphibolite contact is folded here and though there are several examples of the results of multiple deformation, a particularly fine example of a refolded fold is present near the north end of these exposures. Evidence for three stages of deformation is found here where the slip cleavage that deforms an earlier foliation appears to be folded. Proceed southeast over the top of the hill where amphibolite is well exposed. An unusual occurrence of magnetite with white quartz-feldspar rims is present in the amphibolite on the southeast side of the hill. Many interesting minor structural features are present in the rocks on the hill in the vicinity of "c" (figure 5). Toward the north between the gym and the classroom building is an exposure of schist with particularly good examples of sillimanite nodules.
42.0	-	Board the bus and leave Woodlands High School parking lot.
42.1	0.1	Turn left at the "T" intersection with the stop sign.
42.7	0.6	Turn right (north) onto Route 100A (West Hartsdale Ave.).
43.1	0.4	Turn left (west) onto Route 100B (Dobbs Ferry Rd.).
44.4	1.3	Bear left (southwest) and proceed to Route 9A.

45.0	0.6	Turn left (south) onto Route 9A (Saw Mill River Rd.).
46.4	1.4	Proceed through the intersection, south on Route 9A.
46.6	0.2	Bear left onto southbound New York Thruway entrance. Road cuts here expose member B of the Inwood Marble and a particularly good exposure of member B is present on the east (left) side of Route 9A between the Thruway overpass and the southbound Thruway entrance.
47.3	0.7	Manhattan C on the left (east).
47.4	0.1	Manhattan C on both sides of the highway.
48.6	1.2	Road cuts in the Fordham Gneiss.
48.9	0.3	Toll booth.
50.0	1.1	Yonkers Gneiss on the left (east).
50.5	0.5	Fordham Gneiss is on the right (west).
50.8	0.3	Fordham Gneiss is on both sides of the highway.
51.2	0.4	Fordham Gneiss is on the right (west).
51.5	0.3	Fordham Gneiss is on both sides of the highway.
51.8	0.3	Yonkers Gneiss is exposed in the old quarry on the right (west) and there are active quarries in the Yonkers a little further west. This is in the area specified by Merrill (1890, p. 388) as typifying the Yonkers Gneiss.
52.0	0.2	Yonkers Gneiss is exposed in a cut along the Thruway exit ramp on the left (east).
53.6	1.6	Highview Reservoir is on the left (east).
53.9	0.3	Bear right onto the exit ramp for Hall Place and McLean Ave.
54.1	0.2	Continue to McLean Ave.
54.3	0.2	Turn right (west) onto McLean Ave. Follow the winding, hilly course of McLean Ave. westerly and then northwesterly.
55.7	1.4	Turn left (west) onto Wolffe St.
55.8	0.1	Continue straight through the intersection of Wolffe St. with Van Cortlandt Park Ave. and park on the old railroad bed behind the buildings.

STOP 11. Type locality of the Lowerre Quartzite. This is the type locality of the Lowerre Quartzite designated by Merrill (1896, p. 26).

The portion of the Lowerre now exposed here is predominantly well bedded gray and tan-weathering feldspathic granulite and gray feldspathic muscovite-biotite schist that weathers tan to brown. Typical tan-weathering quartzite is present about forty to fifty feet above the base but is subordinate. It seems likely that more of the characteristic quartzite was exposed here when Merrill originally defined the Lowerre but that it has since been removed through the work of man. It also appears that Merrill used the modifier "quartzite" in the name Lowerre Quartzite because the most distinct rock types that characterize the assemblage of rocks in this formation are tan weathering quartzite and feldspathic quartzite.

The Fordham Gneiss beneath the Lowerre consists mainly of amphibolite with some gray garnet-biotite-gneiss. This is another place, similar to STOP 5, where the base of the Lowerre is "dirty". There are other places, such as the cut behind the A & P warehouses at mileage 36.3 (this field trip), where clean quartzite and feldspathic quartzite are directly in contact with Fordham.

The unconformity here is deformed into a series of northeast plunging sinistral folds. This is in accord with the map pattern in this vicinity (Merrill and others, 1902) which indicates the rocks here are on the west limb of a stratigraphic syncline.

55.8	-	Board the bus and return to Van Cortlandt Park Ave. and turn right (south) onto Van Cortlandt Park Ave.
56.0	0.2	Turn left (east) onto Coyle Place.
56.1	0.1	Turn right (south) onto McLean Ave. and wind south and southeasterly.
57.4	1.3	Turn right (south) onto the Major Deegan Expressway.

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