STRUCTURE AND PETROLOGY OF THE PRECAMBRIAN ALLOCHTHON AND PALEOZOIC SEDIMENTS OF THE MONROE AREA, NEW YORK

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INTRODUCTION

The area covered by this trip lies in the northern part of the Monroe 7 1/2' quadrangle, New York, and consists of a folded and faulted complex of autochthonous Precambrian gneisses, Lower Cambrian through Middle Devonian sediments and allochthonous Precambrian gneisses. Geologic maps covering the trip area have been published by Ries (1897), Fisher, et. al. (1961), and Jaffe and Jaffe (1962). Unpublished maps prepared by Colony and by Kothe (Ph.D. thesis, Cornell Univ.) undoubtedly contain valuable information but are not available for study. Recent workers in adjacent areas include Dodd (1965), Helenek (in progress) and Frimpter (in progress), all in the Precambrian autochthon, and Boucot (1959) and Southard (1960) in the stratigraphy and paleontology of the Paleozoic sediments. The work of Colony (1933), largely unpublished, is impressive.

An attempt to unravel the complex structural history of the region has suggested the following sequence of events:

1) Deposition in the Precambrian of a series of calcareous, siliceous, and pelitic sediments and basic volcanics of the flysch facies in a eugeosyncline; folding and metamorphism involving complete recrystallization to granulite facies gneiss assemblages which characterize the Precambrian autochthon (Jaffe and Jaffe, 1962; Dodd, 1965). Foliation in the autochthon trends northeast and is generally vertical or dips steeply to the east, with overturning west; fold axes most often plunge gently northeast. The metamorphic foliation appears essentially Precambrian in origin. The present Precambrian allochthon was deposited and recrystallized at about the same time as the autochthon recrystallization took place about 1100 million years ago. The sediments of the allochthon are graphitic, siliceous, calcareous and pelitic and appear to represent a clastic wedge (molasse) deposited in a reducing environment, possibly to the east. Graphitic gneisses are absent from the autochthon of the Monroe quadrangle, although they do occur in the Popolopen Lake quadrangle autochthon to the east (Dodd, 1965).

2) After extensive erosion, the Lower Cambrian Poughquag conglomerate, arkose, and quartzite were deposited unconformably on the Precambrian autochthon. As in most of the Hudson Highlands, the Poughquag has been only sporadically preserved and here occurs only in the buttressed area northeast of Block 2 (Fig. 2). The Poughquag dips gently to the north.

3) Deposition of the Cambro-Ordovician Wappinger Formation, which in this area consists entirely of dolomite. In Block 2 (Fig. 2), it also dips gently to the north. In Block 3 it is moderately to strongly folded along a northeast trend. In Block 5 it outcrops between the Ordovician shales and the Precambrian of Goose Pond klippe in a northeast-striking band that dips west. In about this same attitude it underlies the Precambrian Museum Village klippe in Block 9.

4) Intrusion of lamprophyre dikes into northwest-trending tension-fractures in Precambrian and overlying Cambro-Ordovician rocks (Jaffe and Jaffe, 1962). These dikes have been found only in Blocks 1, 2, and 3.

5) Deposition of the Hudson River shales (Middle? Ordovician) over the entire area. This was followed by either:

   a) gentle folding, followed by erosion, or

   b) upfaulting of the Wappinger dolomite against the shales.

6) Overthrusting of the Precambrian allochthon as a nappe from the east, most probably during the Taconic orogeny. Evidence for thrusting is:

   a) GEOMAGNETIC. The Precambrian autochthon everywhere shows a strong positive anomaly, whereas the klippen show none and can therefore be no more than 500-600 feet thick (R.W. Bromery, personal communication). The relief of Goose Pond Mountain is of this magnitude. Bull Mine Mountain, which contains a magnetite deposit, does show a positive anomaly.

   b) GEOLOGIC. The Precambrian of Bull Mine Mountain is perched on Ordovician shale; the Museum Village klippe can be seen to rest on Wappinger dolomite. At the base of Goose Pond Mountain is a fault breccia; such a zone also exists on Bull Mine Mountain at the contact of the shales and the gneiss.

      Near the klippen, the Ordovician shales are always more strongly folded than elsewhere in the area, and are often overturned.

   c) PETROGRAPHIC. Quartz pebbles and grains, commonly optically continuous except for strain, have length-width ratios up to 17:1. The texture of the klippe gneisses is consistently more deformed and cataclastic than that of the Precambrian autochthon.

7) Folding of the nappe along a northeast axis, followed by erosion, leaving (a) synclinal remnant (s) along the fold axis, extending from Goose Pond Mountain to Snake Hill, near Newburgh, and beyond, to just west of Balmville. The klippen must once have formed such a single line as would be left by an eroded downfold; the alignment from Bull Mine to Snake Hill is too perfect to be a coincidence, and Goose Pond Mountain is on strike with a klippe west of Balmville, a town just north of Newburgh.

8) N 75 W cross-faulting along the Quickway (N.Y. 17) with the north block moving east. This accounts for the present displacement of the Bull Mine-Snake Hill line of klippen from the Goose Pond klippe (The Museum Village klippe has been rotated from this line by a later fault, presumably Triassic). Apparent displacement is about one mile. The upper calcareous feldspathic quartzite member of the Hudson River shales, which outcrops on Lazy Hill, is essentially absent north of the Quickway fault. If its displacement north of the fault is the same as that of the line of klippen, its present position north of the fault is somewhere under the western talus slope of Schunemunk Mountain. Except for rotated Blocks 8 and 9, Silurian and younger formations line up on strike across the Quickway fault. The major lateral movement along this fault must therefore have been pre-Silurian.

9) After an erosion interval, the Shawangunk conglomerate and orthoquartzite (Lower to Middle Silurian) were deposited unconformably on the older rocks.

10) Deposition of Lower Devonian sediments.

11) Convincing evidence for the Acadian orogeny in the area is lacking. Such an event might account for pebble-stretching in the Shawangunk conglo-

merate, and for slight additional east-west movement along the Quickway cross-fault.

12) Deposition of the Cornwall shales and Bellvale graywackes in the Middle Devonian.

13) Appalachian folding. In the course of this folding, the relatively thin and brittle Shawangunk beds broke into detached plates which were thrust over the more yielding shales above and below. This thrusting produced the fluting parallel to the dip of the beds and the marked stretching of the Shawangunk pebbles in both the a and b fabric axes. Pebble beds in the thicker and more massive Bellvale graywackes show far less shattering and stretching of their pebbles.

14) Following the Appalachian revolution, the area was uplifted and has remained positive. During the Triassic orogeny, faulting, partly with and partly across the grain of the country, reactivated old faults and produced a complicated pattern of tilted and rotated, up- and down-faulted blocks:

    a) Block 1 (Fig. 2) was uplifted along a N33 E fault to form the Ramapo Mountains.

    b) Block 2, which includes Poughquag quartzite and Wappinger dolomite nestled in the curve of the Precambrian massif and dipping gently north, was uplifted. Block 2 is truncated to the north by an eastward continuation of the Quickway fault, as is shown by geomagnetic evidence (R.W. Bromery, personal communication; Henderson, 1962). Block 2 is in fault contact with the younger sediments of Blocks 3 and 4.

    c) Block 3 is a graben about 1500' wide at the south end of the map, and perhaps one or two miles wide at the north end of Block 2. In this graben, the Wappinger dolomite is moderately to steeply folded on a northeast axis.

    d) Block 4 was downfaulted relative to Blocks 2 and 5, and upfaulted relative to Blocks 6, 8, and 9. Anomalous northeast dips at the north end of Block 4 may be the result of drag during faulting.

    e) Block 5 was uplifted relative to Block 4, but downthrown relative to the klippen north of the Quickway fault. The Precambrian of Goose Pond Mountain outcrops from an elevation of 480' upward; the Museum Village klippe rests on dolomite at about 600'. The shale-gneiss contact on Bull Mine Mountain was observed at about 840'.

    f) The main mass of Schunemunk Mountain, Block 6, is downthrown along northeast-southwest faults on both sides. It must also be considerably downthrown relative to its continuation to the south (Block 4), which has a moderate positive geomagnetic anomaly indicating that the basement is not very far down. The syncline's east limb is truncated to the south.

    g) Block 7, in which the Esopus dips about 25° N and under which the basement anomaly is absent, probably was tilted to the north during the uplift of Block 2 and the sinking of Block 6.

    h) Block 8, where the synclinal axis of Schunemunk swings to north-south, has been rotated counterclockwise.

i) The Museum Village klippe and Bull Mine Mountain (Block 9), with the dolomite beneath, have also been rotated counter-clockwise as a single block.

j) The Shawangunk sliver between Blocks 8 and 9 has been ground, thrust, rotated and crumpled during the rotation of the blocks.

Interrelations of the faults are highly problematic, partly owing to the masking effects of the Pleistocene glaciation.

ROAD LOG TRIP F

Co-leaders: Howard W. Jaffe and Elizabeth B. Jaffe

MILEAGE

0.0	Holiday Inn, Newburgh, New York.
15.0	N.Y. Thruway south to Exit 16-Harriman.
15.1	First right turn after the toll booth.
15.2	Intersection with N.Y. 32.
15.25	Left on N.Y. 32, then immediately right on Dunderburg Road.
17.1	Left at T-intersection on N.Y. 208.
17.6	Bear right at fork on to Spring Street.
18.6	Bear right on North Main Street for 0.9 miles to outcrop.
19.5	STOP 1: Oreco Terrace: Bellvale Graywacke

The outcrop is on Oreco Terrace, just above the intersection of NY 208 and Oxford Road. Here, the Bellvale graywacke of the Hamilton Group (Middle Devonian) is exposed in a section approximately 220 feet thick. It consists of 20-40 foot beds of dark blue-gray, green-gray, or gray, fine- to medium-grained (.08-.25mm-avge. grain size) lithic arenite or graywacke, rhythmically interbedded with thin beds of dark green-gray to blue-gray shale. A representative modal composition of the graywacke follows:

Mode Of Bellvale Graywacke

Detritals:		
	quartz	20%
	oligoclase	2
	shale phyllite	44?
	siltstone chert	15
	greenstone	1
Matrix:	clay, sericite, chlorite, Mn oxide	15?
Metamorphic:		
	chlorite	2
	muscovite	1
		100%

Texturally, the rock consists of angular, elongated slivers of detrital quartz and predominantly phyllitic rock fragments (.08-.25mm) set in a fine matrix of sericitic muscovite, clay, and chlorite. It is often difficult to distinguish smeared-out phyllitic fragments from balled-up micaceous matrix, both of which frequently blend or flow together. Depending upon the uncertainty of the matrix content, or the classification used, the Bellvale is either a low-rank graywacke (Krynine, 1948), a subgraywacke or a lithic graywacke (Pettijohn, 1957) or a graywacke (Folk, 1954). Larger bent grains of chlorite and muscovite in the matrix, are here interpreted to have grown from fine matrix material, marking the beginning of the chlorite zone - greenschist facies of regional metamorphism imprinted during the Appalachian orogeny.

In general, the Bellvale graywackes tend to show rhythmic interbedding with shale, with graded bedding low in the section and strong current cross-bedding higher in the section. Occasional brachiopods are found low in the section; plant fossils are found higher up. Both features suggest a gradation from marine to nonmarine depositional environment. The provenance was a low-rank metamorphic or sedimentary terrane.

The shattered outcrop at Oreco Terrace is at the southwest corner of Rotated Block 8 (Fig. 2) and lies near the intersection of four directions of faulting. Attitudes of prominent structures at the outcrop are tabulated:

	Strike	Dip	Plunge
Bedding	N 67 W	30NE	—
Cleavage	N 50 E	37SE	—
Fault	N 13 E	Steep W	
Slickensides			45 N
Fault	N 38 E	Steep W	
Slickensides			60 N
Fault	N 30 W	52SW	
Slickensides			39 W

MILEAGE

Drive north about 0.9 miles on N.Y. 208 and turn left on small road for about 1000 feet.

20.4 STOP 2: Spring Glen Golf Range: Shawangunk Conglomerate

The Shawangunk conglomerate and quartzite (Greenpond conglomerate unit) of Lower to Middle Silurian age occurs in a series of small outcrops extending northeastward along the western edge of the Shunemunk Mountain syncline. At this stop the Shawangunk forms a small, relatively inconspicuous topographic knob as contrasted with its occurrence near Stop 5, where the same unit forms the spine of the steep, southeast-facing escarpment of Lazy Hill. At the present stop the Shawangunk consists of about 75% buff pebble conglomerate intercalated with 25% fine-grained green-gray quartzite.

The conglomerate consists of white pebbles of milky vein quartz (averaging 15-40mm in length) in a matrix of finer pebbles and grains of rounded quartz, all cemented by secondary silica and buff-orange-red ferric oxides. Occasional pebbles of white orthoclase are present as are black pebbles consisting of a mixture of green tourmaline and quartz. The color of the weathered surface of the outcrop varies from pink (hematite) to yellow-brown (goethite)

Fig. 1

GEOLOGIC MAP OF THE MONROE AREA, N.Y.

H.W.& E.B.Jaffe, 1967

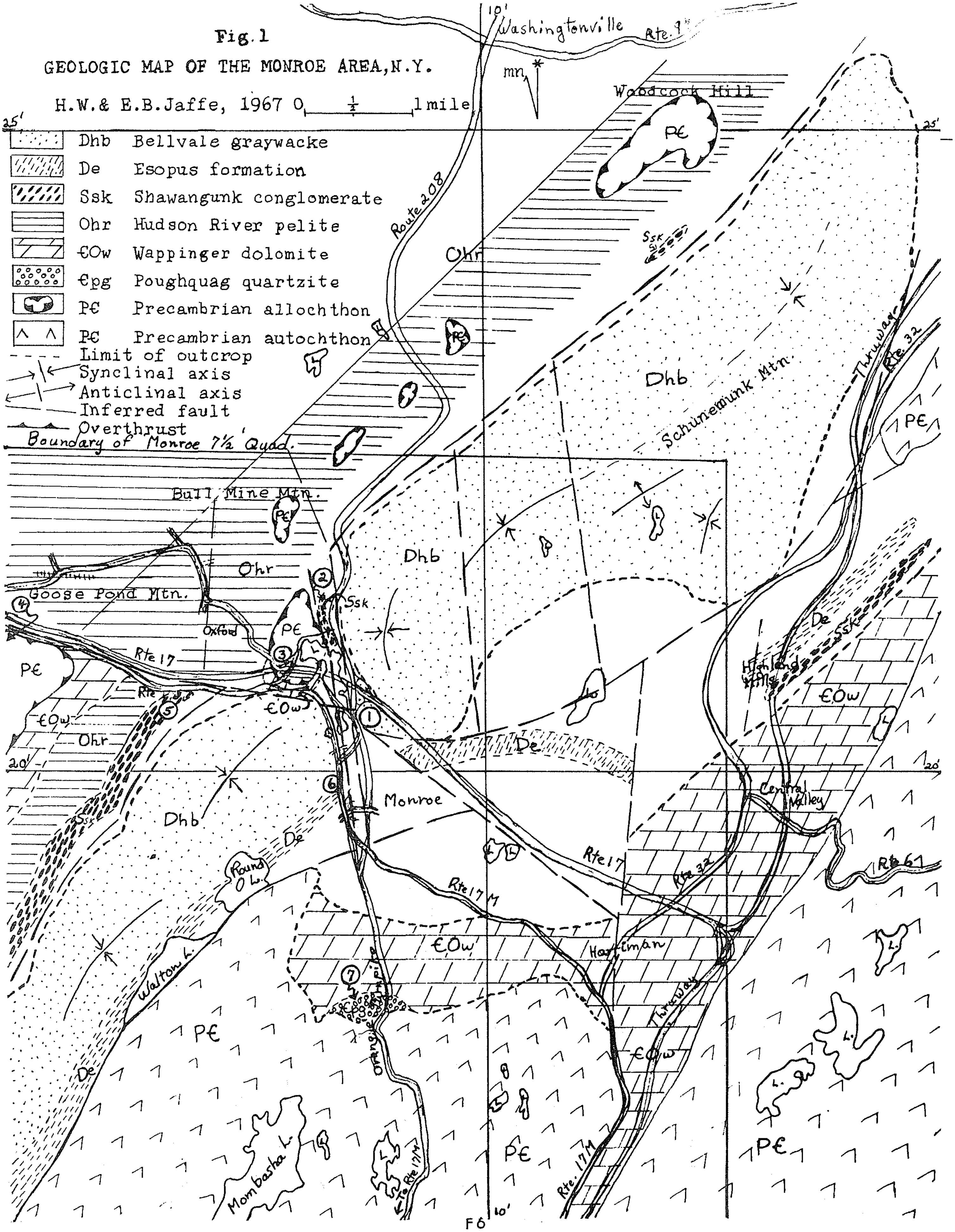
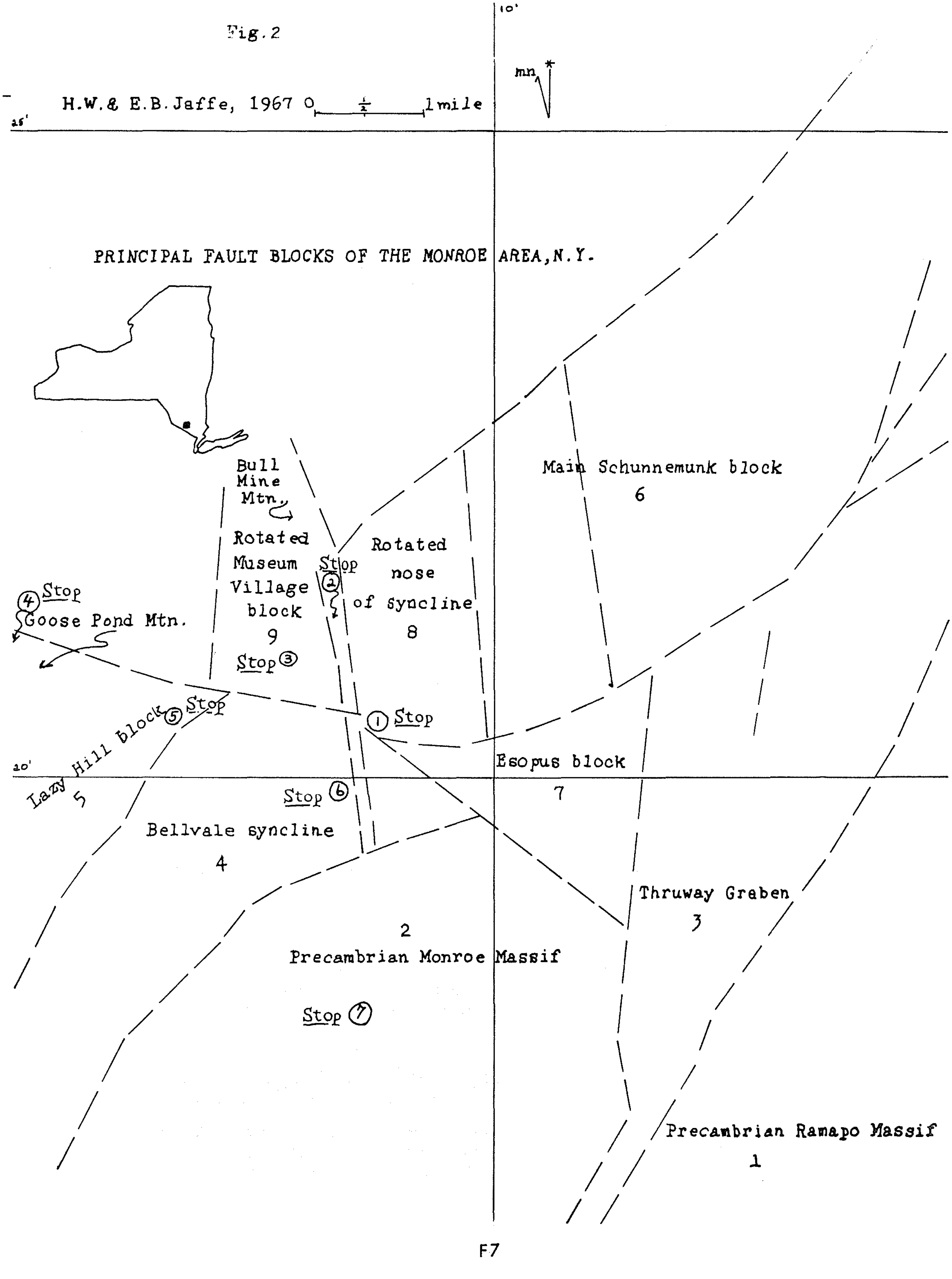


Fig. 2


H.W. & E.B. Jaffe, 1967
0 ½ 1 mile
mn
10'
25'
20'
PRINCIPAL FAULT BLOCKS OF THE MONROE AREA, N.Y.
Bull Mine Mtn.
Rotated Museum Village block
9
Stop ③
Stop ②
Rotated nose of syncline
8
Main Schunnemunk block
6
④ Stop
Goose Pond Mtn.
Lazy Hill block ⑤ Stop
5
① Stop
Esopus block
7
Stop ⑥
Bellvale syncline
4
Thruway Graben
3
2
Precambrian Monroe Massif
Stop ⑦
Precambrian Ramapo Massif
1

or black (manganese oxide dendrites) with some greens contributed by lichens.

The pebbles, obviously well-rounded when deposited on the Late Ordovician erosion surface, have taken on a secondary angularity and elongation due to stretching, crowding, rotation, and slippage in bedding planes produced during Paleozoic orogenies. Most of the pebbles show maximum elongation parallel to the fold axis (b-direction) and modest elongation parallel to the bedding (a-fabric axis). Many of the pebbles have been corrugated and a large number are cracked and sliced parallel to the b-c fabric plane. Bedding surfaces are slickensided, fluted, and warped parallel to the a-axis (down-dip). The fine-grained, gray-green interbedded quartzite is composed of quartz and minor orthoclase cemented by authigenic quartz, muscovite and chlorite, and Fe-oxides.

The elongation and shattering of the pebbles here and at Lazy Hill to the southwest greatly exceeds that observed in pebble beds in Lower and Middle Devonian rocks (Connelly conglomerate of Oriskany age, and Bellvale graywacke, respectively) in this area, suggesting that the Shawangunk was involved in an additional deformation episode of possible pre-Oriskany age. A pre-Acadian, Silurian deformation period in New York was reported by Megathlin (1939) and discussed by Kay (1942). The sporadic outcrops of Shawangunk quartzite to the north along the western limb of the Schunemunk Mountain syncline are all heavily silicified and sheared, again much more so than quartzites of Oriskany and Bellvale age.

The conglomerate and quartzite outcrop is S-shaped, with the attitudes of the bedding and a cross-fault as follows:

	Strike	Dip
Bedding, Cgl., North end of hill	N 8 E	77 E
Bedding, Cgl., North center of hill	N 59 W	70 NE
Bedding, Cgl., Center of hill	N 27 W	50 NE
Cross-fault	N 77 W	90
Bedding, Qtz., South end of hill	N 2 W	60 E

The cross-fault displaces the stratigraphically higher Shawangunk quartzite member to the west, putting it on strike with the lower conglomerate member of the Shawangunk Formation. On first viewing the outcrop, the alternating coarse pebble beds and fine feldspathic quartzites lead one to suspect that the beds are overturned. On close inspection this does not appear to be the case.

MILEAGE

Return south on N.Y. 208 for 0.5 miles turning right at the first paved road (Museum Village Road). After 0.5 miles turn right on Old Mansion Road and drive to the far west edge of the outcrop on the right.

21.7 STOP 3: Museum Village Klippe: Allochthonous Pre-Cambrian Leucogneiss Resting On Cambro-Ordovician Wappinger Dolomite

From the Old Mansion Road cut in the Precambrian Museum Village klippe, look south across the N 75°W-trending Quickway cross-fault. The ridge due south is the Bellvale synclinal extension of

Schunemunk Mountain. The next ridge to the west is Lazy Hill, held up by Shawangunk conglomerate, and offset from the Golf Range Shawangunk conglomerate of Stop 2. To the west of Lazy Hill, the next prominent ridge is the Goose Pond Precambrian klippe, formerly continuous with the Museum Village klippe and now offset about 2 miles along the Quickway cross-fault.

Museum Village klippe is a thin, synclinal, saucer-shaped slice of gray-white albite-quartz-microperthite leucogneiss that has survived five or six orogenies. The rocks of the allochthon were deposited as a clastic wedge (molasse) in a reducing environment, perhaps as long ago as 1500 million years; they were folded and metamorphosed to the sillimanite-almandine-orthoclase metamorphic grade about 1100 million years ago; thrust from the east in Taconic or Late Ordovician time; refolded and faulted in Taconic time; possibly again in Acadian time; refolded and faulted in Appalachian time; and finally shattered by Triassic block faulting and associated block rotation. In outcrop, the leucogneiss is heavily shattered and slickensided with lineations often running in three directions at a given place. Quartz grains and pebbles are stretched into thin corrugated tongues and sheets showing elongations of 15:1 and 20:1 parallel to the b- and a- fabric axes. Over most of the outcrop, biotite and garnet are extensively retrograded to chlorite, and abundant calcite veinlets cross the rocks at all angles.

Towards the central and western part of the cut there occur occasional thin layers rich in fresh biotite and uncommonly coarse laths (not needles) of fresh blue-gray sillimanite that have survived the complex orogenic history. As none of the Cambro-Ordovician or younger rocks in the area show any metamorphic grade higher than chlorite zone metamorphism, the sillimanite is assumed Precambrian in age, and its preservation in large fresh grains in an otherwise extensively retrograded outcrop is remarkable.

The original sedimentary record of Precambrian deposition is preserved in graphite-rich quartzitic layers and in microscopic placer layers rich in apatite, zircon, sphene and ilmenite. In places, volcanic rocks associated with the sediments may be represented by amphibolites such as those in the Bull Mine Mountain klippe to the north.

Modal analyses of samples collected along an east-west traverse across the Museum Village klippe follows:

	East Side	Center		West Side
Mineral / Sample No.	36	769-Si	769-N	769-W
Microperthite	49.5%	37.0%	22.5%	68.8%
Albite (An 0-5)	20.2	–	–	3.3
Andesine (An 32)	–	36.0	32.4	–
Quartz	22.2	2.0	35.1	21.5
Chlorite	5.8	-	-	2.5
Biotite	-	8.0	6.0	-
Almandine-pyrope	0.1	2.0	-	-
Graphite	-	3.0	-	-
Sericite	0.7	-	0.3	-
Sillimanite	-	12.0	3.7	-

Tourmaline	-	+	+	-
Calcite	+	-	-	3.4
Apatite	0.7	+	+	+
Zircon	0.1	-	-	+
Ilmenite	0.7	+	+	+
Pyrite	+	+	-	0.5
Sphene	+	-	-	+
	100.0%	100.0%	100.0%	100.0%

The presence of albite in the most retrograded gneisses of this and the other allochthonous Precambrian blocks studied fairly consistently suggests that it may be a retrograded mineral after an originally more calcic plagioclase. The K-feldspar in all of these rocks is microperthite (usually microcline microperthite) and is indicative of a temperature of Precambrian metamorphism of the order of 660° C. The presence of two plagioclases, one as free grains and the other exsolved in microcline microperthite, is characteristic of many of the granitic gneisses of both the autochthon and the allochthons. In some of the allochthonous leucogneisses, the microperthite and the albite tend to occur in separate bands which may reflect original compositional differences.

Park on Oxford Road and cautiously descend hill to the Quickway (N.Y. 17-West=U.S. 6). Beware of high speed traffic and stay close to the outcrop which parallels the highway. Walk to the extreme west edge of the roadcut where the Precambrian leucogneiss rests in overthrust contact on the light gray Cambro-Ordovician Wappinger dolomite. Note the occasional flat-lying, slippery fracture planes at the contact.

The metamorphic layering in the allochthon dips to the east whereas the dolomite bedding dips predominantly west.

The average foliation of the leucogneiss is N 33 E, 20 SE. The average attitude of the dolomite beds is N 22 W, 35 W. Prominent faults in the klippe parallel the metamorphic layering and trend N 22, E 20 SE. The fault contact of the dolomite and the klippe is irregular and has the same general attitude. Both the dolomite and the klippe are cut by vertical faults trending N 27 W.

MILEAGE

Drive west along Old Mansion Road observing the flat topography superposed on the Hudson River pelites. These are more gently folded with increasing distance from the Precambrian allochthone.

22.7 After one mile, turn right on to Oxford Road at a T-intersection.

23.2 After 0.5 miles turn hard left on to Greycourt Road.

24.4 After 1.25 miles bear left across railroad bridge and continue straight ahead for about 1 mile to Quickway overpass.

26.1 Cross the Quickway (N.Y. 17) overpass and bear hard left (east) on N.Y. 17-M. Drive about 1.1 miles east noting rolling folds in the Hudson River pelites. Road parallels Quickway fault.

27.5 Pull off route 17-M just west of the ridge of Goose Pond Mountain (Goose Pond west).

STOP 4: Goose Pond Mountain: Precambrian Allochthon Over Overturned Hudson River Pelite.

Observe black, fissile Hudson River shales (Middle? Ordovician) in the road cut at the northwest edge of the Precambrian allochthon. Careful observation will show that the attitude of the bedding and cleavage is N 78 E; the bedding dips 70 S and the cleavage 40 S. This indicates that the outcrop is on the limb of an overturned fold with the synclinal axis to the north. The shales both here and at Bull Mine Mountain klippe to the north are all wildly folded and overturned close to the overriding Precambrian allochthons.

Many of the Hudson River black shales are calcareous, and consist of fine laminae (.05-.1mm) of dolomitic silt or mud (marl) intercalated rhythmically (occasionally cross-bedded) with carbonaceous shale. An estimated thin-section mode of a representative Hudson River "shale" follows:

Mineral	Calcareous laminae	Carbonaceous laminae
Detritals and matrix:		
dolomite, calcite	30%	5%
quartz	45	25
plagioclase, microcline	10	+
mica, clay, chlorite	15	50
carbonaceous matter, graphite	-	15
pyrite	-	+
Metamorphic:		
chlorite, muscovite, biotite	-	5
	100%	100%

MILEAGE

In the woods about 100-150 feet southwest of the shale outcrop on N.Y. 17-M, moss-covered rubble of shale, dolomite, and "limonitized" fault breccia indicate where the covered contact has been crossed. The edge of the Precambrian allochthon of Goose Pond Mountain is found in place about 130 feet south from the road, and the first rock found in place is a graphitic calcareous quartzite of which sample No. 527 is representative.

27.9 Drive 0.4 mi. on N.Y. 17-M, stopping at a white albite-quartz-microcline microperthite leucogneiss (sample No. 20), in places graphitic, biotitic or rarely, garnetiferous. Note the extreme elongation and smearing out of quartz pebbles and grains similar to that seen at the Museum Village outcrop of Stop 3. Further to the east, the rocks become increasingly calcareous (sample No. 788). At the extreme eastern edge, prehnitized calc-silicate leucogneiss is interlayered with some amphibolite, the latter of probable basic volcanic origin. Modes of representative rock types of the Goose Pond allochthon follow:

Modes Of Gneisses Of The Goose Pond Mountain Allochthon

	East Side	Center		West Side
Sample No.	529	788	20	527
Mineral				
microperthite	- %	10.0%	42.2%	2.6%
albite (An 0-5)	65.6	-	27.7	-
oligoclase (An 20)	-	49.0	-	-
quartz	16.8	5.0	29.0	81.7
biotite	-	2.5	-	-
chlorite	1.7	-	-	0.3
sericite	7.2	-	0.8	-
graphite	-	-	+	4.2
actinolite	0.2	-	-	3.0
brown hornblende	0.2	33.0	-	-
diopside	1.3	+	-	8.0
sphene	-	-	-	0.2
apatite	+	0.3	0.1	+
ilmenite	-	0.2	0.2	-
prehnite	7.0	-	-	-
zircon	+	+	+	+
	100.0%	100.0%	100.0%	100.0%

Here, as in the Museum Village klippe of Stop 2, the greatest amount of retrograding occurs at the eastern and western margins of the allochthon with some fresh rock occurring near the center. If the klippen are indeed synclinal saucers the presently exposed centers of the masses would lie at a further distance from the sole of the thrust and would be expected to show less alteration. It should be emphasized that the Precambrian autochthonous gneisses in the southern part of the Monroe quadrangle (Jaffe and Jaffe, 1962) are not comparably retrograded except near the Triassic border faults.

MILEAGE

Continue east on N.Y. 17-M about 1.6 miles.

29.5 Turn right (south) on Bull Mill Road for 0.2 miles.

29.7 Turn right at dirt road and park.

STOP 5: Lazy Hill: Shawangunk Quartzite

Walk 0.2 mile west crossing buried northeast-trending fault contact between the Shawangunk ridge of Lazy Hill rising steeply ahead and the Bellvale ridge of Durland Hill to the rear. Walk to the north nose of Lazy Hill (permission of the owners, the Durlands, is necessary) where a large outcrop of Shawangunk quartzite is exposed. The rock is a thin-bedded, pink, buff and white orthoquartzite consisting of:

Mode Of Shawangunk Orthoquartzite, Durland Property

Quartz	93%
Chert	5
Sericite, Chlorite	2
Zircon	+
Hematite	+
Goethite	+
Pyrite	+
Green tourmaline	+
	100%

The quartz grains are well-rounded, moderately elongated, well-sorted (average diameter, 0.75mm), and the rock is very tightly cemented. Each grain of quartz is cemented to another by authigenic quartz overgrown in optical continuity with the detrital cores. Undulatory extinction due to deformation passes through both the core and overgrowth of each grain. The Lazy Hill ridge-top to the south (not visited) is formed of a coarse white pebble conglomerate interbedded with white orthoquartzite (occasionally ripple-marked) and grades eastward to a red arkosic conglomerate below the ridge-top. Quartz pebbles and orthoclase pebbles are strongly elongated (3:1 and 4:1) and heavily shattered and veined in both the red arkosic and the white conglomerate.

MILEAGE

29.9 Return to N.Y. 17-M and turn right (south).

32.0 Drive south about 2.0 miles to the Monroe Bowl-O-Fun parking lot.

STOP 6: Monroe Bowl-O-Fun: Connelly (Oriskany) - Esopus Contact

The outcrop at Monroe Bowl-O-Fun consists of about 300 feet of the Esopus Formation underlain at the rear of the cut by red and white pebble conglomerate, the Connelly Conglomerate of Oriskany age. Here, the Connelly consists of weathered, yellow, "limonitic" conglomerate (3' or more), succeeded by white to buff, pebble-bearing orthoquartzite (5'), which is in turn overlain by bright red hematitic quartzite (10'). The pebbles in the Connelly conglomerate are of white, round to slightly elongated quartz, averaging 1-2mm in maximum dimension. The Connelly is disconformably overlain by a lowermost member of the Esopus Formation, recognized by Southard (1960). The attitude of the bedding of both the Connelly and the Esopus at their contact is N 68 E, 45 N. A heavily slickensided fault surface, trending N 53 E, 60SE cuts across the Connelly beds and presumably also cuts the overlying Esopus Formation.

The lowermost member of the Esopus, at its base, consists of fissile, blue-gray siltstones which weather to brown and orange on cleavage surfaces. Many of the rocks are marked with Taonurus cauda-galli on bedding planes. At this outcrop the authors have collected a remarkable fauna including a specimen of the giant trilobite, Coronura myrmecophorus, not previously reported from the Esopus Formation. According to D.W. Fisher, New York State Paleontologist who identified the specimen, it has previously been reported from the Schoharie and Onondaga Formations. The specimen was donated to the N.Y. State Museum collection.

The lowermost member is also relatively rich in conulariids, none of which have yet been identified. Other fauna include the brachiopods: Leptocaelia flabellites, Schuchertella sp, Acrospirifer macrothyris, as well as some chonetid and orbiculoid genera. Platyostomid and loxonemid gastropods, rugose corals and a dalmanited trilobite were also collected by the authors.

The lowermost member grades into the black, poorly fossiliferous Lower Mudstone member which in turn grades into a purple sandstone at the north end of the 350 foot exposure. The sandstone is presumably the lower part of the Highland Mills member of the Esopus Formation. The fauna of the lowermost member at the Bowl-O-Fun appears to differ significantly from that of the Highland Mills member of the Esopus Formation found at Bakertown and Highland Mills (described by Boucot, 1959). The fauna should receive some serious study by specialists before the outcrop is demolished by new construction.

MILEAGE

32.7 Drive 0.7 miles south on N.Y. 17-M to the second traffic light.

34.1 Turn right at light on to Stage Road which becomes the Orange Turnpike and continue south for 1.4 miles. Park along the roadside before reaching a house on the right side.

STOP 7: Orange Turnpike: Poughquag Quartzite (Lower Cambrian)

Walk 0.16 miles due west over hilltop to the edge of a cliff formed by a 10 foot section of the Poughquag Formation (Lower Cambrian). The section consists of alternating 2 inch to 2 foot thick beds of ferruginous orthoquartzite, conglomerate, and arkose, striking N 75 W and dipping 8°N, overlying the vertically dipping Precambrian autochthon with marked angular unconformity. This represents original sedimentary onlap with only gentle warping or folding in subsequent geologic time.

Apparently the Precambrian Monroe Massif (Block 2) was sufficiently rigid throughout the Paleozoic to prevent the deformation of the overlapping embayment of Poughquag quartzite and Wappinger dolomite. This is indicated by both the gentle warping observed and also by the relative sphericity of the quartz pebbles in various Poughquag beds.

Several of the beds are feldspathic, a feature uncommon in the Poughquag of the Poughkeepsie quadrangle (Gordon, 1911). One such bed at the Monroe outcrop is a conglomeratic arkose which is a true high rank arkose in the sense of Krynine (1948). A remarkable textural feature of this rock is the abundance of authigenic feldspar (microcline?) which is the principal cementing medium in sample No. 466. The specimen consists of 1-2mm quartz and microcline pebbles (all very round) lying in a matrix of 0.2mm grains of microcline and much less quartz. The microcline grains, each with a dirty outline (Fe and Mn oxides), tend to float in the matrix of authigenic microcline (?) cement which is clear in appearance. Some sawtooth or hacksaw terminations on the detrital microcline cores (Edelman and Doeglas, 1931) indicate that interstratal solution has taken place after deposition, presumably in situ. The authigenic feldspar overgrowths show only weak twinning when grown around detrital cores showing strongly developed microcline twinning. A mode of such rock is as follows:

Mode Of Lower Cambrian Poughquag Conglomerate Arkose
Specimen No. 466

Microcline	47.4%
Microcline microperthite	+
Quartz	48.6
Albite-oligoclase	+
Muscovite	+
Rutile, Anatase, Tourmaline (green + brown)	0.5
Zircon	0.5
Hematite Mn oxides	3.0
	100.0%

The mineralogical composition of the Poughquag at Monroe leaves little doubt that it was derived from erosion of the granitic gneisses it overlies.

On the return walk to the road, stops may be made at exposures of post-Wappinger lamprophyre dikes which the authors believe to be of Late Ordovician age (Jaffe and Jaffee 1962). The authors have studied the dikes in considerable detail and would suggest a possible age of intrusion similar to that of the ultramafic intrusion of the Cortland Complex at Stony Point, New York (Ratcliffe, 1967). The Cortland Complex has been dated by Long and Kulp (1962) at 435 million years by K/A isotopic ratios obtained on biotite from the complex, a date close to the accepted Ordovician-Silurian boundary.

Return to NYSGA Field Headquarters at the Holiday Inn, Newburgh: north on Orange Turnpike and Rte. 208 to N.Y. 17-Quickway; west on Quickway to N.Y. Thruway Harriman Exit-16; north on N.Y. Thruway to Newburgh Exit-17 and Holiday Inn.

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ROAD LOG TRIP G*

Leader: G. Gordon Connally

TOTAL MILES	Miles from last stop	
00.0	0.0	Assembly Point: The west parking lot, Holiday Inn, Route 17M Newburgh, New York, near Thruway Exit 17.
		Departure Time: 8:15 a.m. Travel will be by car caravan — cars will form after the buses for the other trips have cleared the area.
		Leave Holiday Inn and turn left (east) on Route 17K.
00.2	0.2	STOP G-1. Examine the ablation till exposed in the cut behind the Carrol's stand. Compare this till to the lodgement till exposed at Stop A-2 on trip A. There will be a discussion of weathering profile and soil development.
		Turn right (west) on Route 17K and proceed back toward the Holiday Inn.
00.4	0.2	Pass the Holiday Inn on the right.
01.4	1.2	Stewart Air Force Base is on the left.
03.1	2.9	Turn right (north) on Rock Cut Road.
04.3	4.1	Turn left (west) onto Route 52 at the Stop Sign.
05.3	5.1	Bear right (north) on St. Andrews Road.
05.5	5.3	Cross the Catskill Aqueduct. The aqueduct follows the road on the right for 1/2 mile until it is re-crossed. After re-crossing the aqueduct note the lithology of the stone walls, particularly the absence of Shawangunk boulders.
07.2	7.0	Continue straight at the Stop Sign at the village of St. Andrews.
07.4	7.2	Ascend the till ridge that trends north-south. This is a ridge of drumlinized crests that can be traced for about 10 miles east of the Wallkill Moraines.
07.6	7.4	Railroad Crossing!
07.8	7.6	Bear right (straight) onto Hoyt Road. This road traverses a flat-topped outwash deposit that has a 400 foot crest on the distal side of the Wallkill moraines. This suggests that the ice occupied the Wallkill position during the development of the 400 foot lake level.
08.3	8.1	Ascend the gentle distal slope of the outermost Wallkill Moraine and then descend the proximal slope into the stagnant ice complex.

* For text see Article p. A1 — A21.

TOTAL MILES	Miles from last stop	
09.1	8.9	Cross the first inner Wallkill Moraine.
09.3	9.1	STOP G-2. Here can be seen some of the Wallkill Moraines. Their possible relationships and the relation of the Wallkill River to the glacial deposits will be discussed.
		Continue north on Hoyt Road.
10.0	0.7	Bear left.
10.4	1.1	Turn right (east) onto Route 208 at the Wallkill Central School. The Wallkill Moraines are well displayed on the right.
12.2	2.9	Cross the distal slope of the second inner Wallkill Moraine. This moraine is on a bedrock escarpment and is not nearly as massive as the topography makes it appear. The State Prison Moraine (?) is on the left in the distance.
13.9	4.6	Cross the Catskill Aqueduct.
14.8	5.5	A striated bedrock knob is exposed on the right.
15.6	6.3	The State Prison Moraine (?) is immediately adjacent to the road on the left and will be crossed in the vicinity of Ireland Corners.
16.3	7.0	Continue straight at the Ireland Corners traffic light.
19.6	10.3	On a clear day a splendid panorama can be viewed on the left. In the foreground is the Lower Wallkill Valley with the Shawangunk Mountain cuesta in the distance. The Catskill Mountains can also be observed on the skyline behind, and north of, the Shawangunks.
20.5	11.2	Turn left (west) on Cedar Lane.
20.8	11.5	Turn right (north) on Plains Road.
21.5	12.2	STOP G-3. Leave the cars and walk through the field on the left to the sand pit. Examine the relationship between proglacial lakes, deglaciation, and the present course of the Wallkill River. This deposit is the remnant of a delta formed in the final 230 foot lake in the Wallkill Valley.
		Continue north on Plains Road.
21.9	0.4	The Wallkill River is on the left.
22.0	0.5	Railroad Crossing!
22.2	0.7	Bear left on Water Street.
22.3	0.8	Railroad Crossing!
22.4	0.9	Cross Main Street and continue north on Huguenot Street. The floodplain of the Wallkill River can be seen on the left. The floodplain evidently extends only to the low

TOTAL MILES	Miles from last stop	
		escarpment a few hundred feet west of the River with undisected lake plain from the scarp to the west valley wall.
22.7	1.2	Stay left on Huguenot Street. This street contains the old stone houses for which New Paltz is famous. These stone houses were built by the Huguenots in the late 1600's and early 1700's.
22.9	1.4	As the road bends right and then left it is following an abandoned meander of the Wallkill that now exists as an Oxbow Lake. This oxbow may be seen behind the houses to the left.
23.7	2.2	Railroad Crossing!
23.8	2.3	Stay left on the Old Kingston Road.
24.2	2.7	Turn right (east) on Shivertown Road.
24.3	2.8	Turn left (north) on Route 32. From this point to Stop G-4 Route 32 follows the shoreline of the 230 foot lake. This may explain the frequently exposed bedrock along the east side of the road.
27.7	6.2	Route 213 joins from the right just south of the bridge over the Wallkill River. Note that the Wallkill is cutting a bedrock channel to the right while flowing over lake sediment on the left.
27.9	6.4	<u>STOP G-4</u>. Here will be discussed the geomorphology of the Wallkill River drainage basin and its relation to the Rosendale sand plain.
		Continue north on Route 32.
28.4	0.5	Descend from 240' on the sand plain to 65' in the Rondout Creek Valley.
29.2	1.3	Bridge across Rondout Creek. Note the channel bars in the creek; these did not exist before the recent drought.
31.2	3.3	Pass over the New York State Thruway.
31.8	3.9	Cross a remnant of the 200 foot Lake Albany (?) plain.
32.8	4.9	Turn right (east) on Dewitt Lake Road.
33.5	5.6	Bear left on Mountain Road and parallel the Fly Mountain fault scarp.
34.3	6.4	Route 213 joins from the right and the road is adjacent to Rondout Creek.
34.8	6.9	<u>STOP G-5</u>. This is the Wilbur gravel pit of the City of Kingston. It is the type locality for the Wilbur limestone member of the Rondout Formation (Silurian). Leave the cars on the road and walk up into the pit to examine the relationship between the ice-contact gravels and the slumped, overlying Lake Albany (?) sands, silts,

TOTAL MILES	Miles from last stop	
		and clays. Examine the pebble lithologies and compare them with those at Stops A-1, A-6, and A-8 on Trip A.
		Continue north on Route 213.
35.4	0.8	Turn left (north) on Dunn Street, following Route 213.
35.5	0.9	Turn left (west) on Wilbur Avenue, following Route 213.
36.7	2.1	Continue straight on Route 213 at the Stop Sign.
36.8	2.2	Turn right at the first Stop Sign and then right again at the second Stop Sign and follow Henry Street to the north.
37.0	2.4	Continue straight at the traffic light.
37.3	2.7	Turn left (north) at the traffic light and proceed on Route 32-28.
37.6	3.0	Continue straight at the traffic light and join Interstate 587.
38.8	4.2	Bear right and continue 1/8 turn at the circle. At this point those cars going north or those picking up passengers in Newburgh may get on the New York Thruway. Other cars going south at a more leisurely pace may take an alternate route not contained in the roadlog and may visit some karst features in the Rondout Valley before proceeding south or west.
38.9	4.3	Bear right on the Thruway - stay left for New York-New Jersey.
47.1	12.5	Lake Albany (?) clays crop out on both sides of the Thruway.
47.5	12.9	Cross Rondout Creek cutting a bedrock channel at this point.
50.0	15.4	Cross Wallkill River cutting bedrock channel at this point.
55.9	21.3	Exit 18 for New Paltz.
71.8	37.2	Bear right at EXIT 17 for Newburgh.
72.6	38.0	Stay left to Route 17K.
72.8	38.2	Bear right toward Route 17K (Middletown).
73.0	38.4	Join Route 17K proceeding west.
73.1	38.5	Continue straight at the traffic light.
73.3	38.7	Arrive at the Holiday Inn, Newburgh, New York.

Your turn now Walt!

ROAD LOG FIELD TRIP H

Co-leaders: Russell H. Waines and Florence Grosvenor Hoar

TOTAL MILES	Miles Between Points	Remarks
0.0	0.0	Holiday Inn parking lot. Exit, turning left (east) onto NY 17K. Proceed to New Paltz, New York, via NYS Thruway as directed in Road Log for Field Trip D (p. D17).
16.9	16.9	Bear right for NYS Thruway Exit 18 (New Paltz) and proceed past toll booth (north).
17.5	0.6	Fork. Bear left and proceed to stop sign. Turn left (west) onto NY 299 and cross over NYS Thruway.
18.6	1.1	Traffic light. NY 32 south on left. Continue straight on NY 299.
18.8	0.2	Turn left (north) downhill onto NY 32.
18.9	0.1	Stop Sign. Turn right onto NY 32 and proceed north. Outcrops and road cuts for the next 4.8 miles expose Ordovician shales and siltstones of Snake Hill (?) aspect. Remarks concerning the Ordovician strata north and south of New Paltz in the Road Log for Field Trip D (p. D17) also apply to this trip.
21.9	3.0	Clearwater Road on the left. Road cuts in the Ordovician shales on this road have produced a small fauna of Snake Hill (and equivalent) aspect.
23.6	1.7	Bridge over Wallkill River.
25.5	1.9	Park opposite extensive road cut on right (east) at bottom of long hill.
		STOP 10: (numbered from sequence in Trip D) Rosendale; Rosendale Dolomite (part), Binnewater Sandstone, High Falls Shale and Shawangunk Conglomerate (part) Sequence: Examine the almost continuous exposure of northwest-dipping strata. The sequence consists of a few feet of Rosendale Dolomite (north) overlying a completely exposed section of Binnewater Sandstone which in turn overlies a partly covered section of High Falls Shale overlying an exposure of several feet of Shawangunk Conglomerate (south). The total thickness of the conglomerate is not known at this point. The Rosendale-Binnewater-High Falls-Shawangunk contacts are all well-exposed and worth noting.
		Return to transportation and continue north on NY 32.
31.1	0.6	Bridge over Rondout Creek. Turn left road just past bridge. Stop before turning left onto NY 213. Proceed west on NY 213 through the Village of Rosendale.

TOTAL MILES	Miles Between Points	
31.9	0.8	Pass under New York Central railroad trestle.
32.0	0.1	Turn sharp right uphill onto Binnewater Road and proceed north.
32.4	0.4	Century Cement Company natural cement kilns on left; still in occasional operation.
33.0	0.6	Keators Corner (Binnewater). Continue straight north on Binnewater Road.
33.3	0.3	Leave Binnewater Road by keeping straight (north) into entrance to Williams Lake Hotel grounds.
33.4	0.1	Keep straight.
33.5	0.1	Turn right across railroad track into private turning area. Park, taking care not to block access; walk back to railroad, turn right (north) and proceed to nearby railroad cuts.
		STOP 7: For description of this stop refer to stop of same number in Road Log for Trip D (p. D23).
		Continue walking north along track toward Stops 11 and 6.
33.75	0.25	Extensive exposure of High Falls Shale continues for about 0.1 miles on right (east).
33.9	0.15	Dirt road crossing track.
34.0	0.1	Railroad cuts along track for next 0.15 miles.
		STOP 11: Fourth Lake (South); Kalkberg, Coeymans, Thacher, Rondout, Binnewater (part) Sequence: Examine the easterly-dipping sequence of strata on the east side of the track. (Because the exposures on the west side are fault-complexed they are not considered here). Beginning with the Binnewater Sandstone (south) a more or less regular sequence follows: Binnewater Sandstone (Are there Fossils in the upper Part?); Rondout Formation (Are all the members recognizable? Note the mine in the Rosendale Dolomite.); Thacher Limestone (Is a complete section present?); Ravena Limestone (Where is the Thacher - Ravena contact? Is it disconformable?); and Kalkberg Limestone (Hannacroix Member) (Where is the Ravena - Kalkberg contact? Is *Gypidula coeymanensis* present?).
		Continue walking north to northeast another 0.05 miles along track. Fourth Lake is on the left.
34.3	0.2	For the next 0.2 miles a continuous sequence is exposed on the left (west) which descends stratigraphically from lower Thacher Limestone through Ordovician shale.

TOTAL MILES	Miles Between Points	
		STOP 6: For description of this stop refer to stop of same number in Road Log for Trip D (p. D 22). The sequence is now in reverse order. When inspection of the section is completed find path on the right (east) which leads over waste rock dump and downhill over glaciated outcrop of Ordovician shale ending in front of abandoned natural cement kilns. Time permitting, the kilns can be inspected, a nearby cement mine visited and a lower Thacher Limestone rock pile searched for fossils and sedimentary structures.
		Board waiting transportation and drive to eastern exit (to the northeast) of large open field.
34.6	0.3	Exit right (south) from open field onto Hickory Bush Road and proceed south.
35.3	0.7	Junction with Breezy Hill Road on right. Keep straight on Hickory Bush Road.
35.6	0.3	Kallops Corners. Turn right (south) onto Old NY 32 and proceed south.
36.1	0.5	Stop Sign. Bear left and proceed south on NY 32.
36.7	0.6	Bridge over Rondout Creek. Retrace original route to this point via NY 32 south to New Paltz and then by NYS Thruway south to Holiday Inn, Newburgh, near Exit 17 NYS Thruway.
67.8	31.1	Holiday Inn parking lot.