GEOLOGY OF THE PRECAMBRIAN CRYSTALLINE ROCKS, CAMBRO-ORDOVICIAN SEDIMENTS, AND DIKES OF THE SOUTHERN PART OF THE MONROE QUADRANGLE

H. W. Jaffe and E. B. Jaffe

TRIP B

The area covered by this trip lies in the southern part of the Monroe 7 $\frac{1}{2}$' quadrangle, and consists chiefly of Precambrian crystalline rocks of the Hudson Highlands. The crystalline prong is thrust at a high angle to the west over Ordovician and Devonian sediments of the northern extension of the Green Pond syncline. The fault trough is filled with lakes and glacial deposits. To the east, a high-angle fault running roughly parallel to Route 17 and continued through Tuxedo Lake to the south separates the block from the main body of the Ramapo Mountains. A small inlier of Wappinger dolomite, possible ~~downthrown, extends nearly a mile~~ into this fault trough, which also is covered by glacial deposits. The northern end of the block is unconformably overlain by Poughquag quartzite (Lower Cambrian) succeeded by Wappinger dolomite (Cambro-Ordovician), both dipping gently off and roughly parallelling the present outcrop pattern of the crystalline rocks. This may represent original sedimentary onlap with subsequent gentle warping during uplift of the crystalline block. This northern contact of the crystallines, and also some probable fault zones within the crystalline block, are obscured by glacial deposits which form a school of drumlins and drumlinoid hills, trending north to northwest across the regional strike of the crystallines and indicating glacial movement to the southeast. This is further corroborated by the thick glacial deposits on the east side of the northeast-southwest valleys.

Within the crystalline block, strikes and dips of the foliated gneisses indicate a series of folds trending about N 50° E and plunging very gently to the north, with some local warping indicated by south plunges. A generalized cross-section normal to the foliation might show: 1) a steep syncline overturned to the west in the easternmost belt of hornblende granite gneiss; 2) an isoclinally-folded recumbent anticline, possibly thrust to the west, in the belt east of Lake Mombasha; 3) a steep syncline, again overturned to the west, with an axis just west of the west shore of Lake Mombasha; and 4) a steep isoclinal anticline along the last ridge at the west of the block. This generalized picture is very difficult to corroborate in detail because of the complexity of the folding, the large amounts of glacial fill at crucial contacts, and the considerable amounts of faulting.

At least two series of faults may be recognized in addition to the aforementioned border faults to the east and west. The oldest group (not shown on the map), trending roughly N-S at a small angle to the foliation and dipping steeply, can be recognized by the small steep trenches they form, and at times by considerable silicification and skarn formation along their trend. They may have influenced the location of the frequent small magnetite deposits. This older series is offset by a set of high-angle gravity faults roughly normal to the foliation. Field and petrographic evidence indicates that these may be hinge or pivot faults, with the greatest displacement to the west. Vertical or steeply dipping transverse joints strike northwest, and several of these are filled with melano and leucophyr dikes, which also cut the Poughquag quartzite and Wappinger dolomite. A subordinate set of joints strikes northeast parallel to the gneissic foliation.

A description of the rock types is given in the detailed itinerary which follows. Speaking very broadly, a series of calcareous and siliceous sediments and basic volcanics of the flysch facies were folded in a eugeosyncline and wholly recrystallized with attendant modification by granitic liquids. Were these liquids derived by magmatic fractionation from a basaltic substratum, or by fractional melting of sediments in place, say 10-20 km down? Evidence for temperatures high enough to melt granitic rocks is found throughout the minerals of the crystalline block. For example, microperthites were probably homogeneous at temperatures ~~above~~ 640°C, below which they unmix. Further, the oxygen isotope thermometer gives a temperature range of 320-550°C for staurolite zone minerals and at least a part of this area is in the higher grade sillimanite zone. Almost all of the granitic rocks show concordant relations with the paragneisses. This leaves syntectonic magmatic intrusion or in-place fractional melting as the two most probable means of deriving the granitic rocks and migmatites. In either case, the granitic rocks would have passed through a magmatic stage. The persistence of shredded and partially ingested metasedimentary remnants in most of the granitic-quartz dioritic gneisses of the area would tend to favor an in-place fractional melting hypothesis.

The age of the granitic rocks and associated gneisses is believed to be about 1100 million years, based upon the best evidence from radioactive dating. Pb/U isotope ages on zircon from the Storm King granite are essentially concordant at 1100 M.Y. Discordant Pb/U ages on uraninite and monazite in the Highlands, A/K ages on mica, and Pb/α ages on zircon range from 620-900 M.Y. A recent Pb/α age of 770 M.Y. was obtained on zircon from granite interlayered with amphibolite near the Suffern entrance to the N.Y. Thruway. All of the ages below 1100 M.Y. do not necessarily date a true recrystallization. For example, a metamorphism 300 M.Y. ago might cause 1100 M.Y. old zircon to lose enough of its lead to give an age of about 770 M.Y. The absence of any ages of 200 to 400 M.Y. on minerals from the Highlands, however, indicates that the Precambrian rocks were not completely recrystallized during the Acadian or Appalachian orogenies.

A detailed itinerary of the trip stops follows:

Detailed Itinerary

Starting point:

A. & P. Supermarket parking lot on N.Y. Route 17M. 0.8 miles south on Rt. 17M to the second traffic light; turn right at light on to Stage Road which becomes the Orange Turnpike. At 2.0 miles observe gently dipping Wappinger dolomite outcropping in field on west side of Orange Turnpike, and large drumlin directly ahead to the southeast.

Stop 1:

2.2 miles. Walk 0.16 miles due west over hilltop to edge of cliff formed by 10' section of Poughquag formation (Lower Cambrian). The section consists of alternating 2" to 2' thick beds of ferruginous quartzite, conglomerate, and arkose, striking N 50°W and dipping 8°NE. Return to top of ridge and note 5½' basic dike intrusive into Poughquag quartzite. Continuing east along hilltop note small outcrops of Poughquag quartzite and Wappinger dolomite on each side of concealed contact. Continuing east, stop at 10' thick basic dike on northeast edge of hill. The dike strikes N 18°W and is essentially vertical; it shows flow layering parallel to the strike, and chilled borders. The modal composition of this dike is:

	1	2
albite	23.6%	26.7%
dark red-brown alkalic hornblende	46.5	37.0
augite-pigeonite	6.0	13.1
epidote	7.9	5.2
chlorite	8.4	9.0
apatite	1.8	1.6
opaques	4.9	5.4
biotite	0.2	1.6
garnet	0.2	0.4
prehnite	0.2	---
calcite	0.3	---
	100.0%	100.0%

(calculated SiO_2 content: 44-46%)

The texture is seriate-porphyritic with hornblende and augite forming the phenocrysts, which lie in a groundmass of albite laths.

This rock is a melanophyr, here defined as a dark, dense, fine-grained, porphyritic dike in which only the mafic minerals form phenocrysts. The abundance of the alkali-rich red-brown hornblende and the low calculated silica content indicate that this dike is compositionally related to the undersaturated alkalic rocks (camptonite lamprophyre of Johanssen). It is not a diabase or a "basaltic dike" but a true alkalic rock. This dike and two others in the area intrude the Wappinger dolomite and are here considered to be of post-Ordovician age. Similar dikes are found in the

Adirondacks in close association with true diabases and in the Champlain Valley without the accompanying diabases. The Champlain Valley dikes are clearly post-Ordovician with the upper age-limit unknown. The melanophyr dikes in the southern and central part of the Monroe quadrangle are numerous; they intrude the crystalline rocks and Cambro-Ordovician Poughquag-Wappinger series; but none have yet been found cutting the immediately adjoining thick section of Devonian sediments in the same small quadrangle. This would suggest that the dikes are older than the Triassic diabase sequence. Further evidence suggesting a pre-Triassic age is the presence of garnet and abundant epidote presumably formed during a pre-Triassic orogeny. Inasmuch as albite should not be expected in a rock containing 75% of mafic minerals, the epidote may be assumed to have unmixed from an originally more calcic plagioclase during a regional metamorphism. In thin-section most of the epidote is included in the albite laths.

Return east to the road and observe outcrop of blue-gray Poughquag arkose or feldspathic quartzite. This rock consists of 1-3 mm subrounded strained detrital quartz, microcline-microperthite, and minor oligoclase in a finer-grained quartzo-feldspathic-clay-sericite-"limonite" matrix. The principal cement is authigenic quartz overgrown in optical continuity on detrital quartz. The absence of rock fragments and the low interstitial paste content indicates that the rock is not a graywacke. Minor amounts of zircon, sphene, brown tourmaline, anatase, and opaques are present. The abundance of microcline microperthite and quartz suggests that the rock was derived from the adjoining Precambrian granitic gneisses.

Stop 2:

2.6 miles. Leaving Stop 1, the Orange Turnpike turns southwest and crosses the concealed unconformable Cambrian-Precambrian contact. Beyond the Lipalian interval, the first Precambrian rock encountered is a fine-grained pink alaskite with no more than 1% of dark minerals. It is composed mainly of 1-3 mm microcline microperthite, microcline, and quartz, with much less sericitized albite-oligoclase and an occasional flake of biotite or chlorite. Within 100' to the south, the pink alaskite grades through a narrow zone of coarse biotite microperthite oligoclase granite and granodiorite into a medium-grained, gray, essentially massive quartz diorite gneiss which forms the bulk of the southern outcrop at this stop. The quartz diorite gneiss (quartz oligoclase gneiss of other workers) consists of oligoclase antiperthite about 70%, quartz about 25% and hypersthene, biotite, magnetite, chlorite about 5%. In thin-section, quartz is not uniformly distributed and forms long tongues which embay adjoining oligoclase grains. Oligoclase is well-twinned and antiperthitic. On top of the outcrop, observe several tongues of biotite hornblende hypersthene labradorite (An_{55}) pyribolite infolded in the quartz diorite gneiss. Foliation measured on the pyribolite is N 35^{o}-50^{o}E, dip is essentially vertical. Slickensided joint faces strike N 24^{o}W and N 65^{o}W.

About 0.3 miles south (not a scheduled stop) the quartz diorite gneiss darkens in color, the quartz content drops and the rock grades to an augite diorite gneiss with abundant interlayered hornblende hypersthene oligoclase-andesine pyribolite. Where quartz becomes locally abundant, it embays and replaces both plagioclase and the ferromagnesian minerals.

The quartz diorite gneiss is thus formed from the reconstitution of pyribolite accompanied by the introduction of silica and small amounts of potash. These constituents could logically be derived from granitic liquids formed from the fractional melting of sediments.

Stop 3:

3.6 miles. Turn east on Harriman Heights Road. A fresh road-cut exposes a dark gray and pink banded migmatite. The gray rock is a calcarious siliceous paragneiss composed of quartz, microcline, bytownite (An_{80}, n_γ 1.575), augite, epidote, dark brown sphene, zircon, apatite, and magnetite. The pink bands consist mainly of quartz and microcline or microcline microperthite. Other samples of this migmatite carry anorthite with An_{95} ($n_\alpha = 1.574$, $n_\beta = 1.581$, n_γ 1.585, $2V \sim 75°$, opt. -). This migmatite carries abundant epidote produced by a retrograde metamorphic alteration of anorthite and augite.

Stop 4:

5.1 miles. Return west to Orange Turnpike and turn south, parking at Monroe Town Line sign. The prominent road-cut on the east side of the road is gray and pink banded biotite migmatite. The dark gray rock is a siliceous, calcareous paragneiss composed of quartz, labradorite (An_{50}), biotite, microcline, hornblende, epidote, apatite, zircon, augite, and ilmenite. The pink bands consist wholly of quartz and microcline, the latter occasionally microperthitic. These kalialaskite bands are believed to be formed from low-temperature metasomatic introduction of quartz and microcline. In-place melting would require an appreciable amount of albite, which is not present. As the microcline is only occasionally microperthitic, it is doubtful that it could hold much soda in solid solution. The foliation strikes N 24°E and dips 45°SE; fold axes plunge gently NE.

The outcrop on the west side of the road, just south of the Town Line, is the same rock. Here the foliation strikes N 22 E, dips only 12°SE and fold axes plunge 5°NE. The gentle dip is due to isoclinal folding overturned to the west.

Stop 5:

5.5 miles. Continue south on Orange Turnpike to top of hill with prominent overhanging cliff to the east side of the road. The cliff is made up of a silicified epidotized migmatite with some coarse recrystallized hornblendes in the granitic component. The outcrop is strongly warped, part of it showing recumbent isoclinal folding overturned west, part of it showing fairly steep dips east. The undersides of overhanging bedding planes are commonly slickensided and silicified. Both this outcrop and the one immediately preceding it suggest an old period of thrusting to the west.

Stop 6:

6.9 miles. Continue south to the junction with the second of two roads entering from the west. Outcrop on the west side of the road shows a 20-25' hornblende albite melanophyr (spessartite) dike which strikes N 38°W, dips 86°NE, and cuts across the foliation of the granite gneiss which strikes N 55-75°E and dips 80°SE. The dike shows normal green hornblende phenocrysts up to $\frac{1}{4}$" lying in a matrix of albite laths, 0.2 x 0.4 mm. The modal composition of the dike is:

albite	53.3%
hornblende	21.5
epidote	12.6
chlorite	7.3
apatite	0.1
opaque	3.2
quartz	1.2
calcite	0.4
K-spar	0.4
	100.0%

(calculated SiO_2 content = 53.5%)

The granite gneiss contains occasional schlieren of biotite-rich gneiss.

Lunch:

Proceed south $\frac{1}{2}$ mile to N.Y. 17, turn right, and continue another $\frac{1}{2}$ mile south on 17 to Red Apple Rest on east side of road. Lunch and return by the same route to stop 6. At 8.7 miles, note swamp in major cross-fault.

Stop 7:

8.7 miles (lunch mileage not included). Turn west at second road beyond stop 6 (Bramertown Road - note sign to Lake Mombasha Farms), and turn right on first dirt road (East Mombasha Road) heading north. The road parallels the contact of granite gneiss (east) and pyribolite (west). At 8.4 miles the road crosses this contact. Stop 7 shows a 16' thick granodiorite leucophyr dike which strikes N 48°W, cross-cutting the foliation of the surrounding amphibolite which strikes N 57°E and dips 20°SE. Note large wedge of amphibolite in center of dike and occasional pink potash-feldspar-quartz bands in the amphibolite. This dike is unique in this quadrangle and perhaps in the Highlands. It is composed of sparse phenocrysts of oligoclase, quartz, less microcline, and rare biotite, lying in a matrix which is again porphyritic on a microscopic scale. The second generation of micro-phenocrysts is made up of square to rhombic zoned potash feldspar and laths of albite-oligoclase. These lie in a very fine granophyric groundmass made up of feldspar, quartz, mica, chlorite, and "limonite." The "limonite" forms megascopic crenulated black streaks which give the dike a flow layering in places. A mode was not obtained because of the fine-grained nature of the groundmass. X-ray data on a powdered sample indicate that oligoclase > quartz > microcline, hence the dike is of granodioritic composition. East of the road the dike is not found, and may be cut off by a north-south fault; if this is so the dike is very old. An outcrop of the same type of rock was found 0.25 miles to the west cutting migmatite: this may be an extension of the same dike.

Stop 8:

9.3 miles. Continue north on East Mombasha Road stopping at steep cliff on east side of road. This is a fine-banded dark gray and pink biotite migmatitic paragneiss, the fine-bedded analogue of stop 4. The dark gneiss bands here are more altered and are marked by the appearance of muscovite and epidote replacing biotite and plagioclase. A small amount of rutile is formed from the titanium present in biotite. Occasional large pods of pink alaskite are concordantly interleaved in the migmatite. The foliation strikes N 37°E and dips 20°SE.

Stop 8A:

9.7 miles. Continue north on East Mombasha Road stopping at the sillimanite-bearing outcrop just north of number 8A on the map. This is a tightly folded, crenulated biotitic paragneiss in the sillimanite zone of metamorphism. It is composed of thin bands of a gray biotite microcline labradorite quartz paragneiss interlayered with orthoclase cryptoperthite (anorthoclase) quartz bands. Abundant garnet (almandite-pyrope), dark blue-green tourmaline, and minor prismatic sillimanite are developed at the interfaces of the biotitic and alaskitic layers. The biotite is pleochroic from "paprika-red" to almost colorless and is an iron-rich variety. Sillimanite and tourmaline lie in the foliation planes with their long axes parallel to the fold axes. The fine paragneiss bands have an average grain size of 0.3 mm; the coarse alaskitic bands, up to 10 mm.

Stop 9:

10.2 miles. Continue north on East Mombasha Road to sharp bend north after short jog east. Outcrop on east side of road contains abundant garnet in biotite migmatitic paragneiss. Outcrop to the west in an open field, near swamp, shows a biotite migmatitic paragneiss and pyribolite intimately folded in medium to coarse massive alaskite. The alaskite forms the core of a fold plunging north and the outcrop may be a small anticline overturned to the west. Here chloritized amphibolite pods are completely enclosed in alaskite. A thin section of the dark gneissic rock showed completely fresh hypersthene (normally an unstable mineral) and biotite associated with completely scapolitized plagioclase, and quartz. Garnet occurs sparingly. To the west the rocks grade rapidly to almost pure alaskite. This is the northernmost outcrop of garnet migmatite.

Stop 10:

10.9 miles. Continue northeast on East Mombasha Road to bottom of hill at rough track to the west. On the east side of the road is an outcrop of coarse, gneissic, partly recrystallized amphibolite. It contains plagioclase ranging from andesine to bytownite with abundant hypersthene, brown and green hornblende, and less biotite, the composition varying with layering. To the east in the woods (not visited) the plagioclase is all scapolitized, the hypersthene serpentinized, and a pale blue-green hastingsite or edenite amphibole is developed near the contact with the alaskite of stop 2. On the west side of the road, about 60' in the woods, a thin layer of foliated green hypersthene quartz oligoclase gneiss (quartz diorite gneiss) is in sharp contact with fine-grained pink alaskite. This may be a fault contact. Boulders of Poughquag conglomerate, and a melanophyr dike (camptonite), parallel the contact zone.

Stop 11:

13.7 miles. Continue NE to Orange Turnpike, then NW past stop 1 to Rye Hill Road. Turn sharply SW, noting NW-trending drumlins to the west. Stop 11 is the first outcrop beyond the glacial fill on the east side of the road, which now is called Berry Road. The outcrop contains abundant layers and schlieren of biotite two-feldspar quartz paragneiss in coarse pink granodiorite and granite with abundant antiperthite, microperthite, and oligoclase. A swarm of eight or ten small melanophyr (camptonite) dikes, up to 2' thick, fill a tension fracture pattern striking N 8 W to N 48^{o}W. The foliation of the host granitic rock strikes N 52^{o}E, and dips 50-60^{o}SE. To the west, in the woods, the biotitic paragneiss is resorbed by massive biotite granite-granodiorite. Occasional samples are of quartz syenite composition.

It is worth noting here that melting of biotite would yield an additional large amount of potash feldspar and magnetite:

$$\underset{\text{biotite}}{KFe_3AlSi_3O_{10}(OH)_2} \longrightarrow \underset{\text{K-feldspar}}{KAlSi_3O_8} + \underset{\text{magnetite}}{Fe_3O_4}$$

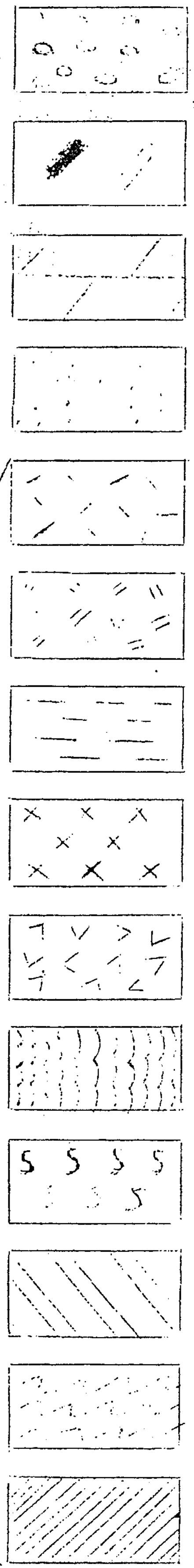
This would sweeten the granitic liquid and perhaps explain the frequent occurrence of potash-feldspar pegmatites in association with the many small magnetite deposits of the area. It should further be noted that many of the alaskites in the quadrangle contain magnetite as the only accessory mineral of consequence.

Stop 12:

15.9 miles. Continue SW on Berry Road, noting alternation of folded dark gneiss and pink granite-granodiorite; turn NW on West Mombasha Road, then NE on Cedar Cliff Road to stop 12, about 200' beyond farmhouse. Outcrop on east side of road shows fine-grained narrow bands of folded pyribolite (here amphibolite) overturned slightly to the west and being replaced by coarse massive buff-gray granodiorite. The granodiorite cuts across the folded amphibolite and contains schlieren of the latter which retain their original attitude in the folds. The infolded amphibolite contains brown hornblende, albite-oligoclase, microperthite (introduced), biotite, magnetite, and apatite. The granodiorite is composed of albite-oligoclase, quartz, less microcline microperthite, biotite, hornblende, zircon, and some fragments of altered hornblende, plagioclase, and calcite.

Pyribolite layers are very abundant in this zone but are not continuous, the widest observed being 80' thick near the old magnetite mine on Mine Road. Westward the rocks grade to contaminated gneisses and then alaskite, which forms the western edge of the crystalline block.

Continue north along Cedar Cliff Road to Lakes Road. Turn right, and follow Lakes Road to traffic light at Route 17M. Final mileage 18.1.



Quaternary alluvium and glacial deposits

Melanophyr and leucophyr dikes: Post-Ordovician

Wappinger dolomite: Cambro-Ordovician

Poughquag quartzite, arkose, and conglomerate: Lower Cambrian

PRECAMBRIAN

Alaskite (Magnetite biotite albite-oligoclase microperthite quartz)

Andesine alaskitic gneiss
(Garnet magnetite oligoclase-andesine microperthite quartz gneiss)

Hornblende granite gneiss
(Biotite hornblende albite-oligoclase microcline microperthite quartz gneiss)

Biotite granite-granodiorite-quartz syenite with abundant schlieren of biotite two feldspar quartz paragneiss.

Quartz diorite gneiss
(Biotite hypersthene quartz oligoclase-antiperthite gneiss with paragneiss and pyribolite schlieren and inclusions)

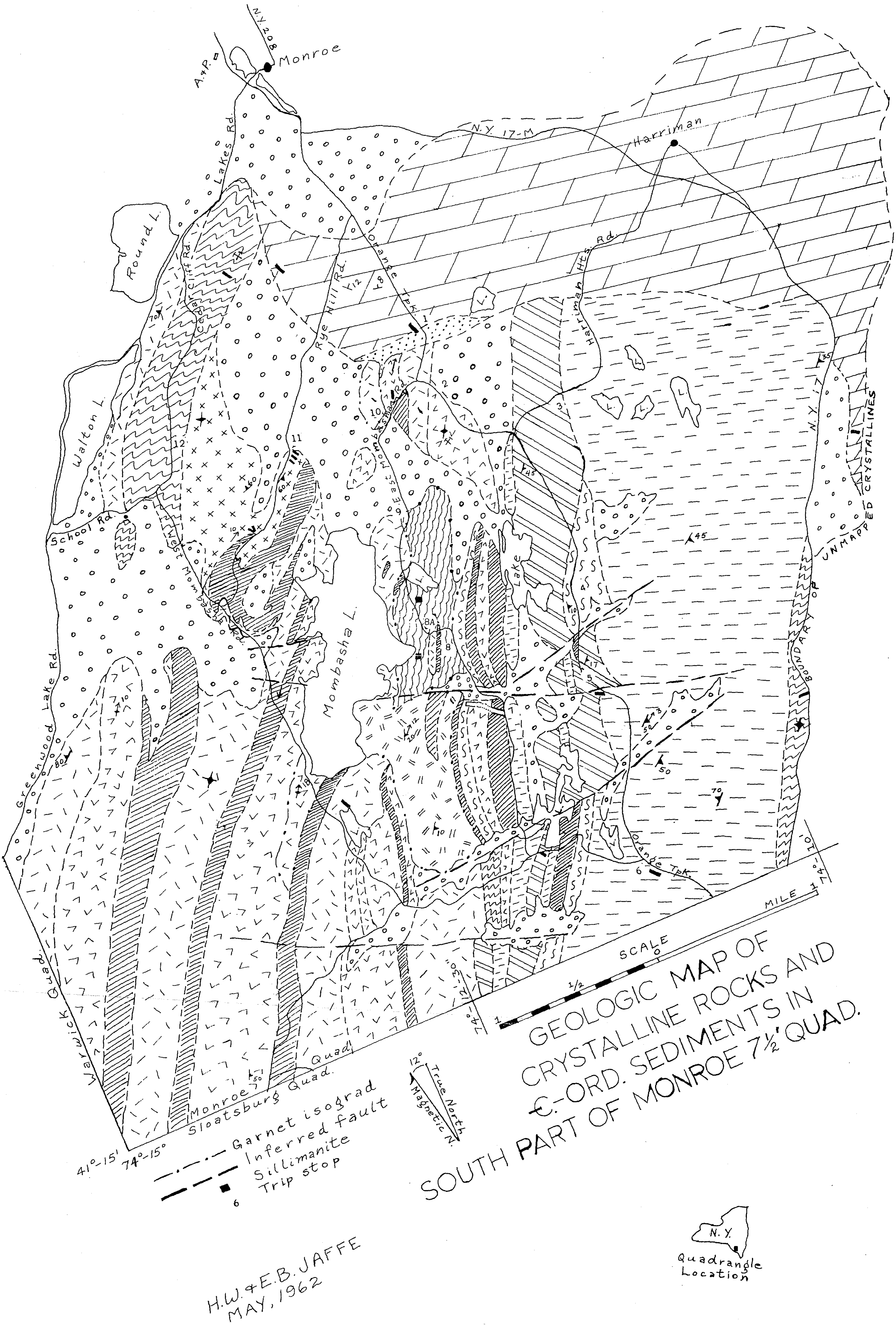
Garnet migmatite
(Granite interleaved with crenulated biotite paragneiss)

Biotite migmatite
(Epidote hornblende biotite andesine-labradorite quartz paragneiss/microcline quartz

Pyroxene migmatite
(Epidote sphene pyroxene bytownite-anorthite quartz paragneiss/microcline-quartz)

Granite and granodiorite gneiss with abundant schlieren and inclusions of pyribolite

Pyribolite (metavolcanic or paragneiss)


GEOLOGIC MAP OF CRYSTALLINE ROCKS AND Є.-ORD. SEDIMENTS IN SOUTH PART OF MONROE 7½' QUAD.
SCALE
0
½
1
MILE
True North
Magnetic N.
12°
Garnet isograd
Inferred fault
Sillimanite
Trip stop
6
N.Y.
Quadrangle Location
H.W. & E.B. JAFFE
MAY, 1962
Monroe
N.Y. 208
A.&P.
Harriman
N.Y. 17-M
N.Y. 17
Harriman Hts. Rd.
Orange Tpk.
Rye Hill Rd.
Lakes Rd.
Cedar Cliff Rd.
Round L.
Walton L.
School Rd.
West Mombasha Rd.
East Mombasha Rd.
Mombasha L.
Lake
Greenwood Lake Rd.
Warwick Quad.
Monroe Quad.
Sloatsburg Quad.
BOUNDARY OF UNMAPPED CRYSTALLINES
41°-15'
74°-15'
74°-12'-30"
74°-10'