TRIP B-6

STRATIGRAPHIC AND STRUCTURAL GEOLOGY

IN WESTERN DUTCHESS COUNTY, NEW YORK

by

Donald W. Fisher
State Paleontologist, Geological Survey,
New York State Museum and Science Service, Albany, New York 12234*

and

A. Scott Warthin Jr.
Professor Emeritus, Geology, Vassar College,
Poughkeepsie, New York 12601

PROLOG

Sedimentary rocks with deceptively similar but subtly different physical characteristics and yielding rare and hard-to-identify fossils demand exeedingly careful scrutiny. When, however, a further measure of obscurity arises because such rocks are overprinted by polydeformational complex folds, faults, cleavage, and metamorphism, the demands made upon the investigating geologists are, indeed, taxing. This is the situation confronting those who attempt to unravel the geological maze of Dutchess County and eastern New York.

On this trip, our intention is to expose you to some of the knotty problems that beset us and permit you to examine some of the typical rock units and typical structures of the region. Owing to time limitations, we shall confine our visitations to western Dutchess County from Poughkeepsie northward--and not all the rock units nor all types of structures will be examined. If we make you aware of the fascination and frustration of Taconic geology, then we have succeeded in our mission.

ACKNOWLEDGEMENTS

John B. Skiba, Senior Cartographer with the New York State Geological Survey, skillfully prepared the charts and maps which accompany this article and make for better understanding of the perplexing geologic relationships. The pictures taken from the U-2 aircraft and the ERTS satellite image were furnished by Yngvar W. Isachsen of the New York State Geological Survey.

*Published by permission of the Director, New York State Science Service, Journal Series No. 217.

PREVIOUS WORK

Geologic investigations of the Paleozoic rocks in Dutchess County were pioneered by W.W. Mather (1843), J.D. Dana (1872, 1879), and W.B. Dwight (1879-1890). Mather's work was a reconnaissance of a broad area, the "First Geological District", which extended from the southern Champlain Valley on the north to Long Island on the south, and from the state line on the east to the Catskill Mountains on the west. Though rather superficial by design, there is a large amount of useful detail in this monograph. Dana's studies were primarily concerned with carbonates. Dwight's prolific significant disclosures of fossils in Dutchess County formed the groundwork for more exacting age determinations of the carbonates, in particular.

Later, C.E. Gordon (1911) mapped the geology of the Poughkeepsie 15-minute quadrangle, for the first time convincingly demonstrating the structural intricacy of the region. Robert Balk (1936) further elaborated on the petrologic and structural complexities in Dutchess County--chiefly in the eastern part. Vidale (1974) has added new information on the metamorphism in eastern Dutchess County--beyond the scope of our treatment. Eleanora B. Knopf (1962) mapped the stratigraphy and structure of the Stissing Mountain area in northern Dutchess County. This and her earlier work demonstrated the feasibility of subdividing the Wappinger carbonates. No additional paleontologic, stratigraphic, or structural studies have since been published for western Dutchess County.

Work by Holzwasser (1926), Jaffee and Jaffee (1973), Offield (1967), and Ruedemann (1942) in nearby areas to Dutchess County has contributed greatly to our understanding of Hudson Valley geology.

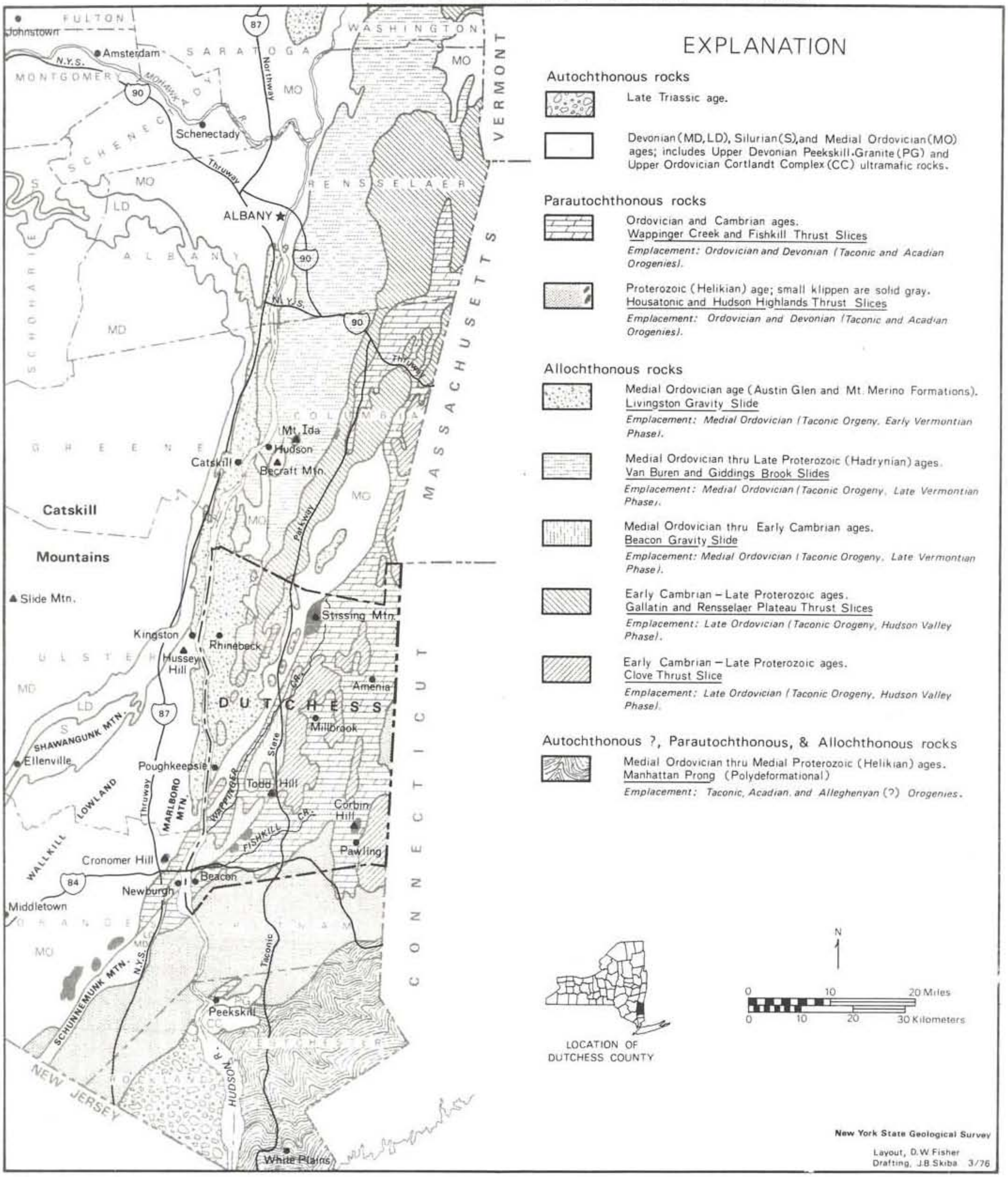
We have conducted a joint effort in order to fill the deficiencies in knowledge on these geological disciplines in western Dutchess County. One of us (A. Scott Warthin) began investigations in the late 1940's with the express purpose of mapping the Rhinebeck 15-minute quadrangle. The other (Donald W. Fisher), during the course of collecting field data for the State Geologic Map of 1960, became interested in the geology of Dutchess County. Jointly, we have completed mapping eight 7.5-minute quadrangles and portions of two others. These will be published in the New York State Museum and Science Service Map and Chart Series in 1977. On the north, Fisher has also mapped three 7.5-minute quadrangles in adjacent Columbia County. On the east, Fisher and Professor James McLelland of Colgate University are mapping portions of six 7.5-minute quadrangles.

And, lastly, Bird and Dewey (1970) and Zen (1967, 1972) have provided modern workable interpretations toward a fuller knowledge of the geologic history of the Taconic region.

PHYSIOGRAPHIC AND GEOLOGIC SETTING

Western Dutchess County is approximately midway between the State Capital at Albany on the north, and New York City on the south (Figure 1). It occupies the portion of the Mid-Hudson Valley where the low

FIGURE 1. INDEX AND GENERALIZED TECTONIC MAP OF EASTERN NEW YORK



Taconic highlands merge with the valley proper. On the east, in eastern Dutchess County are the high Taconics and across the state line, the Berkshire Highlands. On the west, are the dissected Allegheny Highlands (Plateau) known as the Catskill Mountains, with their foothills--the Helderbergs. To the south are the imposing Hudson Highlands. A north-south ridge extending from Kingston on the north to Newburgh on the south, the Hussey Hill-Marlboro Mountain ridge, parallels the Hudson River. A varied array of sedimentary and metamorphic rocks, folds, faults, and other structural features challenge the investigator.

In the Mid-Hudson Valley, rocks range in age from Middle Proterozoic (Helikean) through Late Triassic and an extensive road network provides good coverage for the investigating geologist.

The region is one steeped in early Dutch and Bicentennial History and the unwary geologist is easily distracted by the historical heritage of the region.

ROCK UNITS
(Figures 2, 3)

The rocks of Dutchess County (Figure 2, geologic map) may be conveniently segregated into three categories, based on their degree of structural transport--or lack of it! Autochthonous rocks were deposited where we now see them. Parautochthonous rocks have been transported a short distance from their depositional site but still remain in their general depositional realm (for example, shelf rocks moved westward but still within the shelf realm); amount of transport varies up to about 35 kilometers (22 miles). Allochthonous rocks have been transported a long distance and are now found in a depositional realm alien to their original site (for example, slope or basin rocks moved westward into an area occupied by shelf rocks); amount of transport varies up to about 120 kilometers (75 miles).

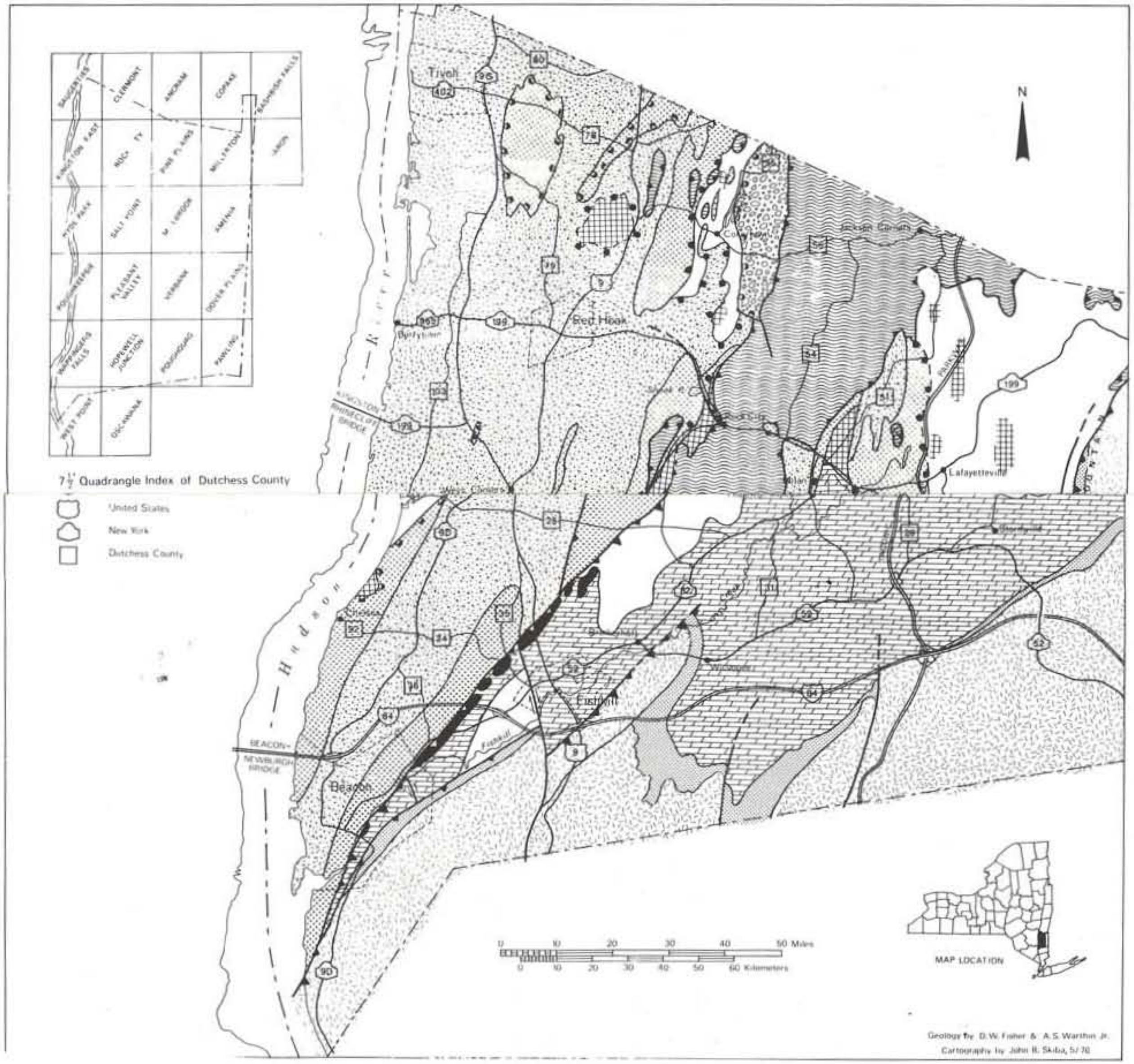
AUTOCHTHONOUS ROCKS

The only certainly identified autochthonous rocks in Dutchess County are the Middle Ordovician Snake Hill Shale and the quasi-autochthonous Poughkeepsie Mélange. In neighboring Ulster and Orange Counties on the west side of the Hudson River, the Middle Ordovician Snake Hill and Quassaic Formations are autochthonous as are the younger Silurian and Devonian strata. In this and succeeding stratigraphic lists, the rocks are listed in order of decreasing age.

Snake Hill Shale (R. Ruedemann, 1912, p. 58) up to 1500 m

Gray-black silty shale, mudstone, and argillite (frequently laminated) alternating with thin-bedded siltstones (frequently laminated and cross-laminated). Siltstones hold benthonic fauna of brachiopods, pelecypods, bryozoans, crinoid stems, and ostracodes; shales, in addition to the benthonic forms, contain graptolites which correlate with the standard

FIGURE 2. GENERALIZED BEDROCK GEOLOGY OF WESTERN DUTCHESS COUNTY, NEW YORK



Diplograptus multidens, *Corynoides americanus*, and *Orthograptus ruedemanni* zones (Figure 4).

Poughkeepsie Mélange (D.W. Fisher, 1976, in press) 150 m +

Haphazardly oriented clasts of varying angularity, size, and type in an unbedded or poorly bedded gray, argillaceous matrix. Clasts angular to rounded, pebble to mega-block size, principally graywacke but also siltstone, quartzite, laminated argillite, sandstone, chert, limestones, dolostones. The Poughkeepsie Mélange is distributed irregularly in the lower and middle Snake Hill Shale.

Quassaic Quartzite (D.W. Fisher, 1970, map) 650 m +

Lower portion has massive pink and green quartzites with polymict conglomerates having an arkosic, pelitic, red matrix, grading upward into hard green-gray sandstones with few green-gray shale interbeds. Benthonic fauna of brachiopods, gastropods, pelecypods, bryozoans, ostracodes, and rare straight cephalopods. The Quassaic appears to be equivalent to the Schenectady Formation of the lower Mohawk Valley and, like that formation, to represent a molasse, resulting from subaerial erosion of the gravity slides, which filled the Magog (Snake Hill) Trough. The Quassaic is absent in Dutchess County but forms the conspicuous north-south highland extending from Kingston on the north (Hussey Hill) to Newburgh on the south (Marlboro Mountain), on the west side of the Hudson River.

PARAUTOCHTHONOUS ROCKS

Proterozoic Gneisses

Rocks of the Proterozoic (Helikean) Basement occur at Todd Hill (Stop 2), Stissing Mountain near Pine Plains, Cronomer Hill and I-84 roadcut at Newburgh, series of small fault slivers from Beacon to Fishkill, Corbin Hill north of Pawling, and the Housatonic and Hudson Highlands. Geophysical evidence suggests that none of these occurrences are rooted. Quartz-feldspathic gneisses predominate, though varying types occur, some with relatively high biotite or hornblende.

Poughquag Quartzite (J.D. Dana, 1872, p. 250) 10-75 m

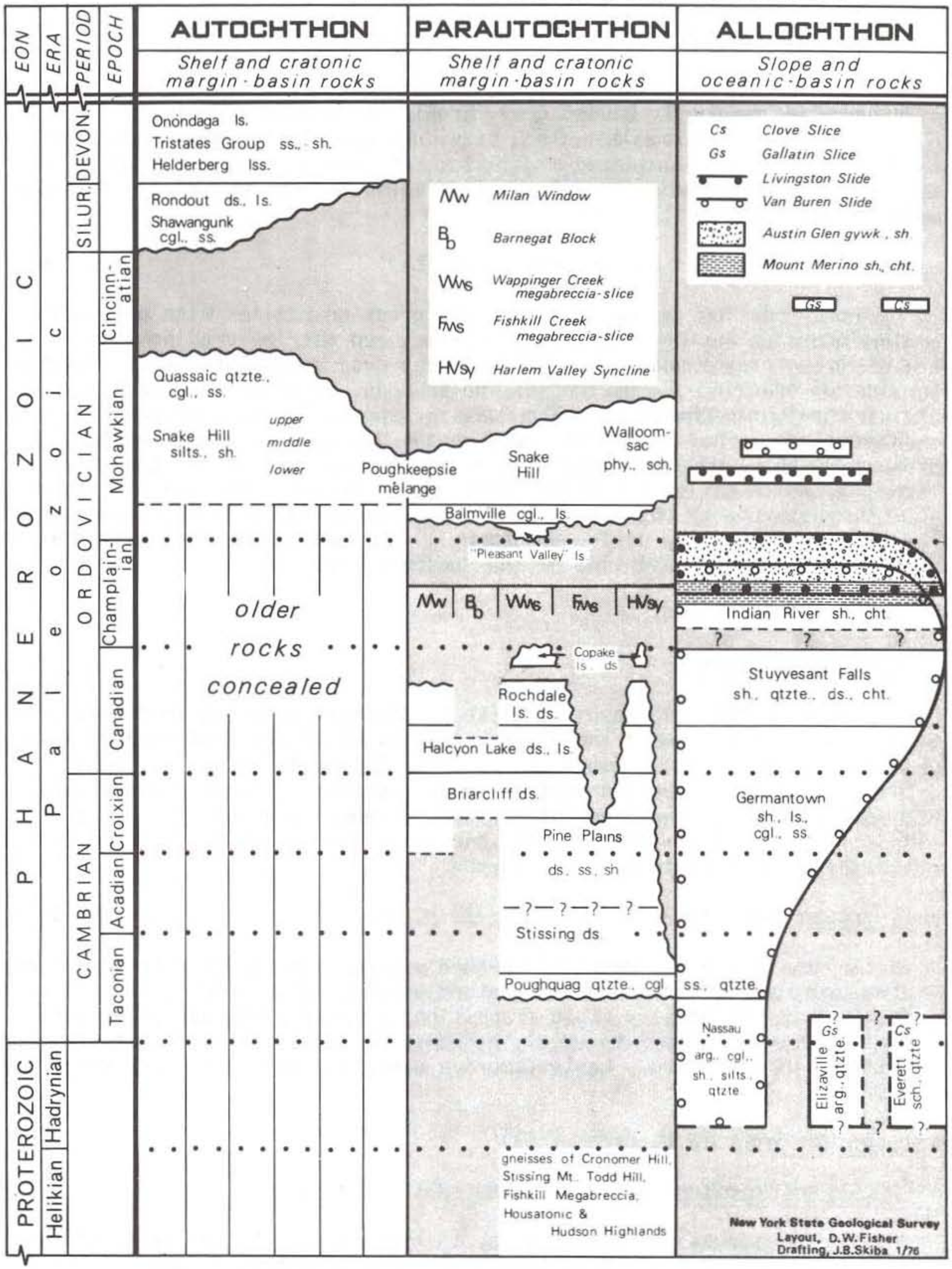
White, tan, pink, massively bedded vitreous quartzite with localized conglomerates at base. Quartz content exceeds 90%. Bedding is difficult to observe. Relatively rapid transition of interlayed quartzites and quartzose dolostones into overlying Stissing Formation over a stratigraphic distance of 10 meters. Early Cambrian olenellid trilobites are very rarely found.

Wappinger Group (J.D. Dana, 1879)

Stissing Dolostone (C.D. Walcott, 1891, p. 360) 150 m

Typically massive, nearly white to light gray, coarse-fine textured dolostones and calcitic dolostones; weathers pale gray. Some intervals

FIGURE 3. STRATIGRAPHY & TECTONICS - MID-HUDSON VALLEY



of gray, green, or red shale. Local chert and quartzose layers. In places has dark gray laminated, conchoidally fracturing, dolostone. Rare fossils denote an Early Cambrian age although the uppermost part may be Medial Cambrian.

Pine Plains Formation (E.B. Knopf, 1946, p. 1212) 350 m

The Pine Plains Formation is characterized by its extreme lithologic variability. Varying colors and textures of dolostone alternate with sandstone or quartzose dolostone beds. Bedding varies from thick to thin; silty, dark gray shale interbeds are common. Cyclical and graded bedding are ubiquitous. Oolites, ripple marks, cross-laminations, and dessication cracks are common. It is obvious that this unit is a product of deposition in the intertidal zone. No fossils, except stromatolites, are known from the Pine Plains.

Briarcliff Dolostone (E.B. Knopf, 1946, p. 1212) 150 m

The Briarcliff is typically a gray-tan weathering, light gray to dark gray dolostone with massive bedding. Detrital quartz is much less frequent than in the underlying Pine Plains. Chert nodules, quartz knots, and vugs with dolomite and quartz crystals are common. Rare trilobites (*Plethometopus, Plethopeltis, Prosaukia*) denote a Late Cambrian (Trempealeauan) age.

Halcyon Lake Dolostone (E.B. Knopf, 1946, p. 1212) 75 m

This is the most elusive of the Wappinger carbonates to find and identify. Where known, it is a calcitic dolostone, slightly quartzose and with chert pods. It is steel-gray, weathering to a medium-dark gray. It is usually medium-thick bedded. It is customarily coarse-medium textured. Rare gastropods (*Ecculiomphalus, Ophileta*) and cephalopods (*Ellesmeroceras*) denote an Early Ordovician (Gasconadian) age (Figure 4).

Rochdale Limestone (W.B. Dwight, 1887, p. 32) 75-125 m

The lower portion consists of interbedded fine-textured, buff-weathering dolostones and calcitic dolostones. The upper portion contains purer limestones, dark gray-black, and bluish-gray weathering. Locally, sandy beds or intraformational conglomerates are common. Laminations and faint cross-bedding are occasionally seen. Dark-gray to black chert pods are rare. The gastropod *Lecanospira compacta*, the trilobite *Hystricurus conicus*, and the cephalopods *Bassleroceras, Dwightoceras*, and *Vassaroceras* are diagnostic of an Early Ordovician and specifically a Medial Canadian (Demingian) age (Figure 4).

Copake Limestone (J.D. Dana, 1879, p. 376-383) 0-10 m

This uppermost unit of the Wappinger Group is better displayed and thicker in eastern Columbia and eastern Dutchess Counties. Because of the pronounced erosional surface atop the Wappinger Group, the Copake is usually eroded away. The unit is medium-light gray weathering, light gray-medium gray, medium-coarse textured limestone, dolomitic limestone, and dolostone; the base is frequently a dolomitic, laminated siltstone. Rare trilobites and cephalopods indicate an Early Ordovician and Late Canadian (Cassinian) age (Figure 4).

Balmville Limestone (F. Holzwasser, 1926, p. 40) 0.5-4 m

In western Dutchess County, the Balmville is a very thin limestone conglomerate and coarse-medium textured light-medium gray limestone. It is fossil-fragmental with whole specimens being very rare. The Balmville fills cracks and pockets in the underlying erosion surface atop the Wappinger Group. The Balmville represents the initial transgressive deposit of a Medial Ordovician (Mohawkian) sea atop the long-eroded Early Ordovician surface. Brachiopods, trilobites (including *Encrinurus cybeliformis*), corals, bryozoans, crinoid debris, ostracodes, conodonts, and algae all demonstrate a correlation with the lower Trenton Limestone Group of the Mohawk, Black, and Champlain Valleys. The physical and organic makeup of the Balmville denotes deposition in a high energy, beach environment; the intertidal zone must have been very restricted or almost non-existent at the time of Balmville sedimentation. Elsewhere, in the Hudson Valley, the Balmville may be absent and the overlying Medial Ordovician shales may rest directly on differing divisions of the Wappinger Group. The Balmville, locally, may reach thicknesses up to 35 m.

At Pleasant Valley, there are 10-15 m of lighter gray, finer-textured, thinner bedded, argillaceous limestones between the Balmville above and the Wappinger Group below. This interval yields trace fossils very similar to those in the Black River Group Lowville Limestone of the Black River Valley. If this localized pocket at Pleasant Valley is a remnant of the Black River Group, it is the sole occurrence known to indicate that the Black River seas inundated Dutchess County. Chazy Group limestones are absent in the Hudson Valley; if they were deposited here they were removed by erosion prior to the deposition of the Balmville Limestone.

Snake Hill Shale (R. Ruedemann, 1912, p. 58)

On the eastern side of some of the parautochthonous fault blocks, the Snake Hill Shale (previously described under autochthonous rocks) is exposed for a few meters. At Rochdale, for example, Dr. John Riva of Laval University has recovered graptolites, indicative of the *Diplograptus multidens* zone, in the dark gray shales overlying the Balmville Limestone. This is an important find in that it enables a tie-in of the graptolite and shelly faunas and fixes the Balmville as of pre-Canajoharie (Medial Mohawkian) age.

ALLOCHTHONOUS ROCKS

Everett Schist (W.H. Hobbs, 1893), p. 717-736) 500 m

This unit was named for exposures on Everett Mountain in southwestern Massachusetts. Typically, the Everett consists of green-gray, silvery schists and phyllites with local green-tan quartzites. It is strongly cleaved and the cleavage is always folded; bedding is extremely difficult to distinguish. Quartz knots are plentiful. Muscovite predominates over biotite and where the proper metamorphic rank is present, garnet and staurolite are common. The Everett forms the tops of most of the higher hills of the high Taconics in the County and always is in thrust-fault contact with its subjacent units; occasionally, carbonate slivers or quartz zones exist at the fault contact. Perhaps due to its higher metamorphic rank, the Everett has not yielded any fossils; it is presumed to be equivalent to the Elizaville and Nassau to its west and thus of earliest Cambrian or Late Proterozoic (Hadrynian) age.

Elizaville Formation (J.D. Weaver, 1957, p. 739) 300 m +

Lithologically, the Elizaville is quite uniform, consisting of green-gray hard, compact argillite, weathering olive-green, and with interbedded green-gray quartzites; some of the quartzites attain a thickness of 10 m. Cleavage is dominant over bedding, which may be laminated, and the cleavage is unfolded or only slightly folded. The Elizaville is the only rock unit identified in the Gallatin Thrust Slice and is present only in the northern part of Dutchess County, west of Stissing Mountain and east of Rhinebeck. The Elizaville is thought to be correlative to part of the Nassau Formation, although no fossils have been found to substantiate this supposition.

Nassau Formation (R. Ruedemann, 1914, p. 70) 700 m +

In Dutchess County, the Nassau consists of olive-green, micaceous, quartzose shale with local green-gray quartzites up to 10 m thick. To the north, in Columbia and Rensselaer Counties, the Nassau is thicker and has purple and green micaceous, silty shales and thin-bedded quartzites in its lower part and a significant, fossiliferous limestone conglomerate near its summit. The purple strata and the limestone conglomerate have not been found in Dutchess County. No fossils have been discovered in Dutchess County although to the north in Columbia County Early Cambrian trilobites and several types of Early Cambrian phosphatic fossils are known. The Nassau is the oldest unit in the Van Buren Gravity Slide.

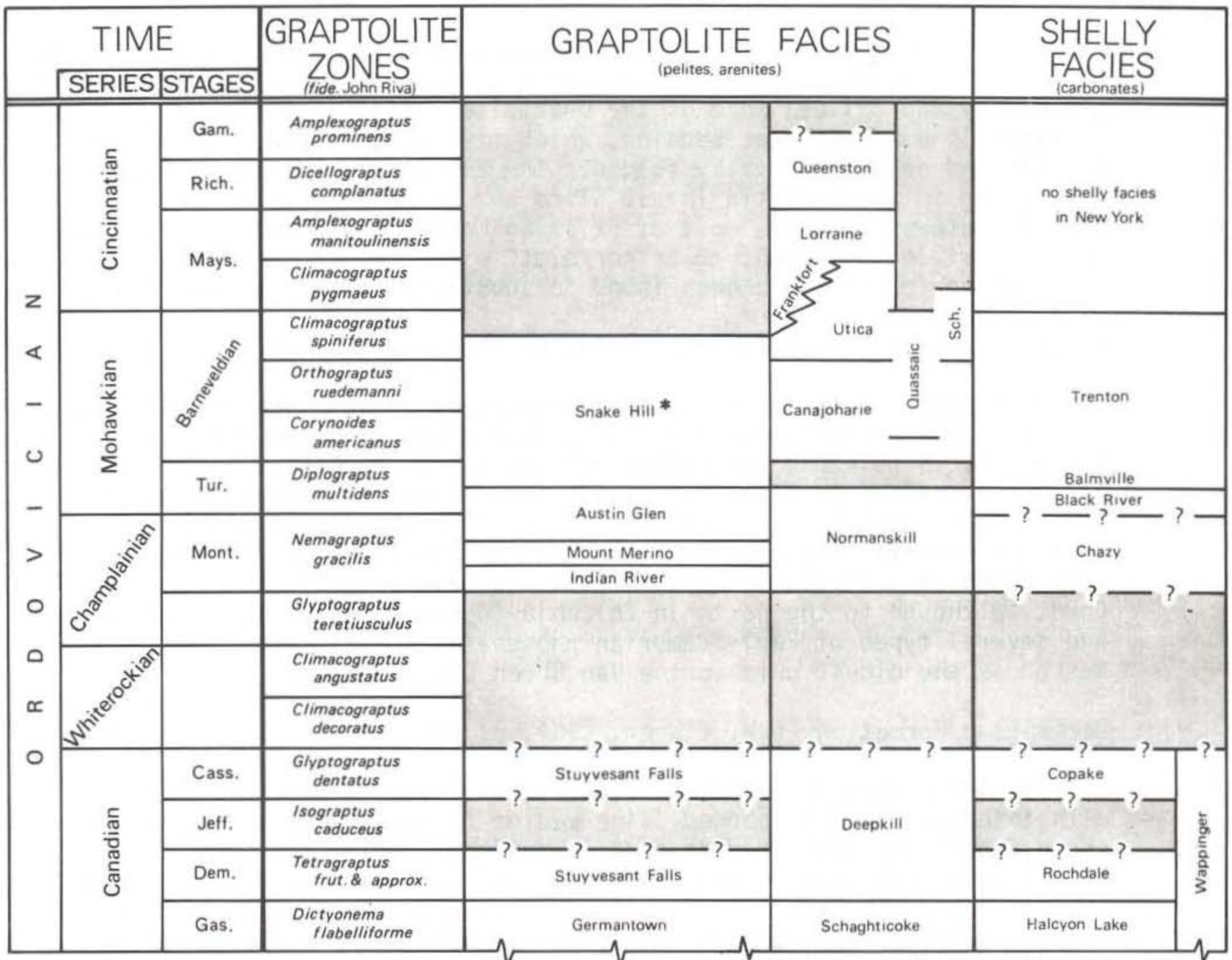
Germantown Formation (D.W. Fisher, 1961, p. D9) 100-300 m

The Germantown is composed of dark gray-black, silty, platey, shale with interbeds of thin-bedded, fine-medium textured medium-dark gray limestone (sometimes laminated or cross-laminated), dolomitic sandstone, thin-bedded to medium bedded tan quartzites, and carbonate-clast conglomerates. The conglomerates have a quartz-sand matrix with large well rounded and frosted grains, black angular phosphate pebbles, and angular-rounded clasts of differing dolostones and fine-textured dark gray limestones. The quartzites are usually basal and believed to correlate with the Diamond Rock Quartzite in Rensselaer County. Some of the conglomerates grade laterally into dolomitic sandstones; both are lensitic. In Columbia County to the north, intensive search has been made for fossils with the result that Early Ordovician graptolites (*Dictyonema flabelliforme*), and trilobites and conodonts of Early Cambrian, Medial Cambrian, Late Cambrian, and Early Ordovician ages have been recognized (Bird and Rasetti, 1968; Rasetti, 1966, 1967; Landing, 1974a, 1974b). The Germantown seems to be a deposit on an ancient continental slope with the conglomerates being lag turbidites.

Stuyvesant Falls Formation (D.W. Fisher, 1961, p. D9) 100-350 m

The Stuyvesant Falls consists of light green shale with interbedded thin beds of orange-tan weathering dolostone and green-gray quartzite and bedded green-gray chert; thin black shale seams and black chert occur occasionally. Rare graptolites (*Diplograptus dentatus* fauna) denote an Early

FIGURE 4. ORDOVICIAN GRAPTOLITE ZONES, APPALACHIAN PROVINCE



New York State Geological Survey; Layout D.W. Fisher, Drafting J.B. Skiba 6/76

Abbreviations: Gam - Gamachian, Rich - Richmondian, Mays - Maysvillian, Tur - Turinian, Mont - Montyan, Cass - Cassinian, Jeff - Jeffersonian, Dem - Demingian, Gas - Gasconadian, frut - fruticosus, approx - approximatus, Sch - Schenectady.

*Much of what we call Snake Hill in Dutchess County (on the Vassar campus, for example) contains only shelly facies.

Ordovician (Canadian) age. The Stuyvesant Falls is a distal slope and oceanic basin deposit.

Normanskill Group

Indian River Shale (A. Keith, 1932, p. 360) 50-300 m

Maroon to bright red and pale green shale with intercalated bedded red and green radiolaria-bearing chert. Local pockets of fine-textured, green-gray limestone, somewhat brecciated, may be turbidite slides. No benthonic fauna; rare graptolites denote the *Nemagraptus gracilis* zone (Figure 4). This is a distal slope and oceanic basin deposit.

Mount Merino Shale (R. Ruedemann, 1942, p. 23) 30-350 m

Dark gray-black mudstone, shale, slate with intercalated bedded dark gray-black radiolaria-bearing chert. No benthonic fauna; scarce graptolites denote *Nemagraptus gracilis* zone. This is an oceanic basin deposit.

Austin Glen Graywacke (R. Ruedemann, 1942, p. 28) up to 300 m

The lower division consists of thin-medium bedded graywacke and subgraywacke and sandstone interbedded with much bluish dark gray shale. The upper division has thick massive coarse textured graywacke, with some thinner bedded graywacke, graywacke conglomerate, and relatively little shale (mostly as rare seams). The upper portion also displays a great variety of sedimentary features (load casts, climbing ripple marks, cross-bedding, cross-lamination, intra-shale clasts, graded bedding, etc.). No benthonic fauna; graptolites in the lower half are indicative of the *Nemagraptus gracilis* zone whereas graptolites in the upper division are indicative of the *Diplograptus multidens* zone. The graptolites of the upper division of the Austin Glen are the same as those in the lowermost Snake Hill Shale. Graptolite identifications are by Dr. John Riva of Laval University. Austin Glen sedimentation ceased just prior to, during, or shortly after Balmville Limestone deposition. Sufficient time had to elapse for the youngest graywackes to become lithified prior to their transportation westward into the Magog (Snake Hill) Trough--as the Poughkeepsie Mélange. The Austin Glen is a poorly sorted, rapidly deposited sediment on an unstable continental slope and was derived from an adjacent relatively rapidly rising land mass or island arc.

GEOLOGIC AND TECTONIC HISTORY
(Figure 5)

In an area of dense underbush, extensive cover of glacial deposits, ever increasing housing developments, scarce fossils, and complexly deformed rocks, the geologic and tectonic history is not as fully understood as we would like and, thus, many of our statements on the chronology of events must remain equivocal. As we view the past sedimentation and tectonic events, they appear to be as follows:

(1) Deformation, metamorphism, and recrystallization of Middle Proterozoic (Helikean), or older, rocks during the Grenville Orogeny (1100-980 mya).

(2) Rifting of a single tectonic plate during the Late Proterozoic (Hadrynian) and earliest Cambrian with formation of fault-trough deposits of poorly sorted graywackes, siltstones, pelites and volcanics during the initial stages of the Proto-Atlantic Ocean.

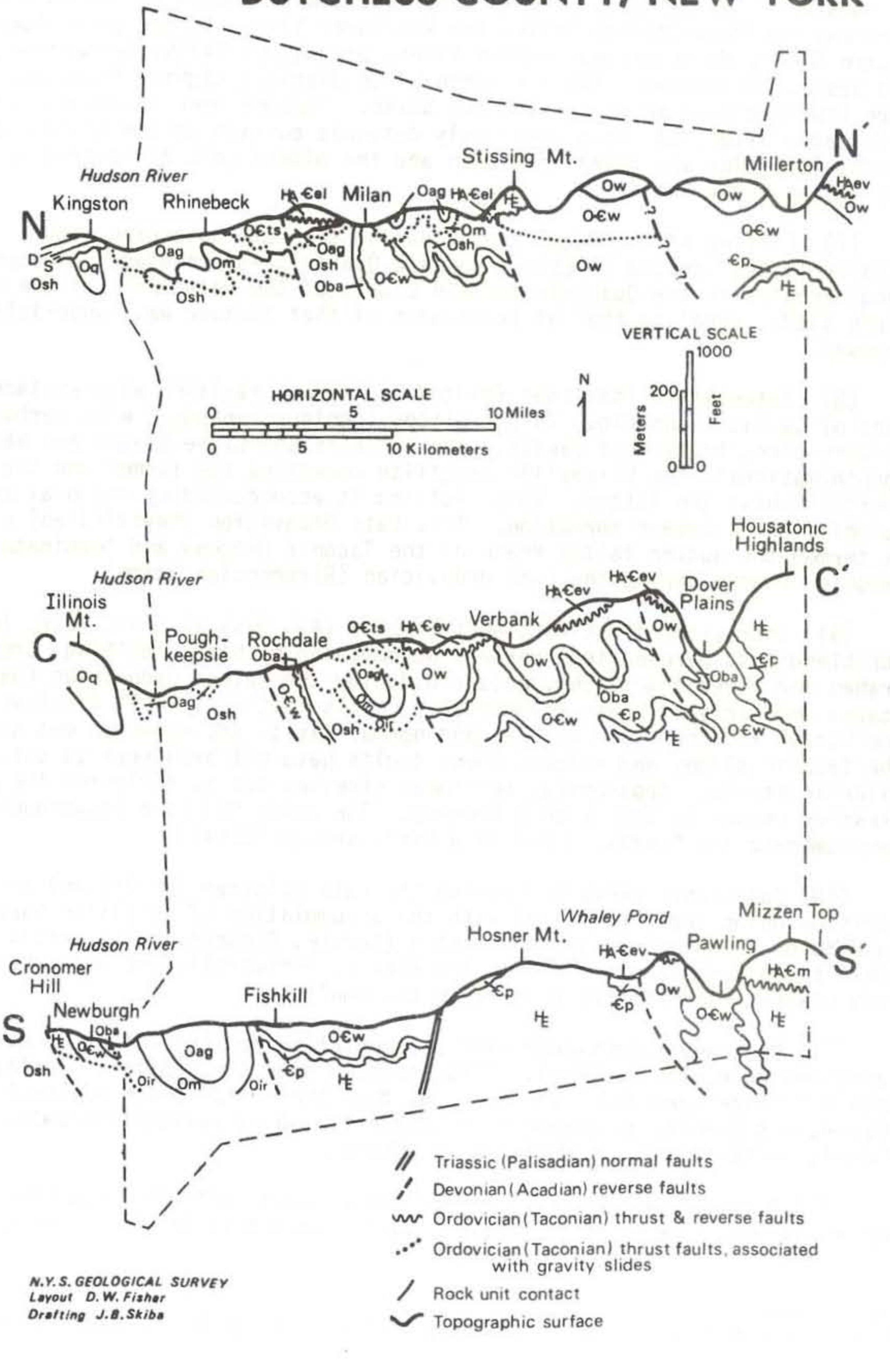
(3) Development of a broad continental shelf on the American stable plate (craton) which continued to receive a seaward-thickening wedge of carbonates throughout the Cambrian and into the Early Ordovician. The initial deposits were clean, quartz sands (Poughquag) whereas the younger carbonates (Wappinger Group) reflected different but similar environments on the broad and enduring shelf. The equivalent deposits on the continental slope were the Germantown (Early Cambrian through Early Ordovician) and in the oceanic basin the upper Nassau (Cambrian) and Stuyvesant Falls (Early Ordovician).

(4) Fracturing by normal and strike-slip tear faults, uplift (accompanied by some folding in the east), and subsequent subaerial erosion (Quebecian or Penobscot Orogeny) closed the Canadian Epoch (Early Ordovician). This represents the change from an expanding to a contracting Proto-Atlantic Ocean. The break atop the Lower Ordovician rocks in North America is one of the most pronounced and widespread in the stratigraphic column and faunally, sedimentologically, and structurally it marks a catastrophic change on the face of the earth.

(5) Compressional stresses, bringing about closure of the Proto-Atlantic Ocean, produced welts and troughs. Accelerated erosion of these welts or island arcs caused the resulting detritus to accumulate rapidly on the steepening slopes and downwarped troughs. These graywackes, pelites, and cherts comprise the Normanskill Group of Early Medial Ordovician age and were formed east of present-day New York--perhaps as much as 100 km east of Poughkeepsie. Partly contemporaneous Chazy carbonates were forming on a relatively narrow continental shelf in what is now the Champlain Valley. This is the early phase of the Taconic Orogeny--called in Newfoundland, the Bonnian Phase. In New York at this time there was little to presage the cataclysmic events that were to follow.

(6) Continued and intensified compressional stresses caused the welts to become greatly elevated and to create new troughs where none had been before (Snake Hill Trough developed on the existing continental shelf). The relief differential caused earlier formed slope and basin rocks (now greatly elevated) to move westward by gravity sliding into the newly created Magog or Snake Hill Trough during the Middle Mohawkian. This westward transport caused westward imbrication of portions of the old shelf, bulldozing carbonate blocks in front of and beneath the moving gravity slides until these blocks came to rest, haphazardly, in the Medial Ordovician Snake Hill mud. Such a northeastern-trending megabreccia of carbonate blocks is superbly shown along the Wappinger Creek Valley. In addition, blocks of the moving gravity slides spalled off and were chaotically mixed with ripped-up sole rocks and newly formed sediment to form a wildflysch or mélange. This gravity sliding event is termed the Vermontian Phase of the Taconic Orogeny, named from the large welt Vermontia, from whence the slides originated. In Dutchess County, at least two principal gravity slides are recognized, the earlier Livingston Slide and the later Van Buren Slide (this may be approximately the same age as Zen's Giddings Brook Slide

FIGURE 5. TENTATIVE STRUCTURAL SECTIONS- DUTCHESS COUNTY, NEW YORK



in the northern Taconics, although it is geometrically discrete). The Livingston Slide consists of both upper and lower members of the Austin Glen and the Mount Merino Shale; the Van Buren Slide is made up of lower Austin Glen*, Mount Merino, Indian River, Stuyvesant Falls, Germantown, and Nassau Formations. The Van Buren Slide displays tighter folding and more imbrication than the Livingston Slide. Another more southerly slide, the Beacon Slide, may be a physically detached portion of the Livingston Slide; its folds are relatively open and the oldest unit discovered is the Indian River Shale.

(7) Filling of the Magog Trough during the Late Mohawkian with a relatively well-sorted molasse (Quassaic Quartzite-Schenectady Sandstone). Conglomerates in the Quassaic contain clasts of the rock units of the Van Buren Slide, denoting that at least part of that feature was subaerially exposed.

(8) Intensified isoclinal folding and thrust faulting with emplacement of Gallatin and Clove Thrust Slices (contemporaneous?) with carbonate slivers along the thrust faults. The Gallatin and Clove Slices are each monoformational--the Elizaville Argillite comprises the former and the Everett Schist the latter. This faulting is accompanied by regional metamorphism and cleavage formation. This Late Ordovician (Maysvillian) episode is termed the Hudson Valley Phase of the Taconic Orogeny and terminates the Taconic Orogeny during the Late Ordovician (Richmondian Stage).

(9) Intrusion of the Cortlandt Complex (435 mya) of mafic rocks (norites, hornblendites, pyroxenites) perhaps accompanied by block faulting, creating graben and horst topography, occurred during the latest Ordovician (Gamachian Stage) and Early Silurian (Llandovery). This rifting is well displayed in the Mohawk and Champlain Valleys and normal faults are known to cut and trim the Taconic slides and slices; these faults have not been seen to cut Late Silurian strata. Apparently, tensional stresses set in following the compressive events of the Taconic Orogeny. The Lower Silurian Shawangunk Conglomerate and Sandstone may be a fault-trough deposit.

(10) Quiescence prevailed during the Late Silurian (Pridolian) and Early Devonian (Helderbergian) with the accumulation of localized basal sandstones (Binnewater) and carbonates (Bertie, Rondout, Helderberg); small patch coral reefs occur in the Glasco, Cobleskill, and Helderberg with blanket stromatoporoid reefs in the Manlius.

(11) Oriskany-Esopus-Schoharie sedimentation reflect influx of quartz sands and much clay material. This, coupled with the erosional surface atop the Helderberg limestones, argues that the intial phase of the Acadian Orogeny was already in progress--as demonstrated by radiometric dates and fossils in Maine and the Maritime Provinces.

(12) A succeeding interval of carbonate-coral reef (Onondaga) deposition was relatively short-lived; however, volcanism persisted as evidenced by

---

*No upper Austin Glen has been recognized in this or the Giddings Brook Slide.

volcanic ash beds within this limestone interval.

(13) The second more intense phase of the Acadian Orogeny made its presence felt during the deposition of the Hamilton clastics and continued during the Early Late Devonian (Senecan). At this time, tight folding (napping?), thrusting, high-angle reverse faulting (ex. Chatham, Wappinger Creek, Fishkill Creek, Pawling Faults), and metamorphism occurred. The Peekskill Pluton (371 $\pm$ 14 my; Mose, and others, 1976) probably was injected and cooled during the first phase of the Acadian Orogeny--contemporaneous with the White Mountain Magma Series in New Hampshire. At the beginning of Late Devonian (Chatauquan) time, the Acadian Orogeny had ended. The merging of the tectonic plates and the disappearance of the Proto-Atlantic Ocean were completed.

(14) The effect of Late Paleozoic (Alleghenyan) deformations in the Hudson Valley are unknown. A thermal event dated at 225 my is established in western Connecticut but bonafide Alleghenyan folding is unproved in the Hudson Valley.

(15) Late Triassic rifts, diabase intrusion (185 my), and fault-trough deposits (Newark Group) exist a short way to the south in Rockland County. Some of these lengthy, northeast-trending, faults, such as those that bound the Schunnemunk Mountain Graben, can be traced into Dutchess County where they trim earlier gravity slides and thrust slices. Some of this tensional stress probably lasted into succeeding Jurassic time.

(16) Later Mesozoic and Cenozoic history is unrecorded in the Hudson Valley; Late Cretaceous (and possibly Tertiary) sediments occur on Staten and Long Islands.

(17) Pleistocene glaciers have excavated the surface and deposited great quantities of gravels, sands, silts, and clays in the Hudson Valley. This combination of erosion and sedimentation has both exposed and concealed rock for study.

"TWENTY QUESTIONS"

(CONTROVERSIAL MATTERS AND UNANSWERED QUESTIONS RELEVANT TO DUTCHESS COUNTY GEOLOGIC HISTORY)

1. What is the precise relationship of the graptolite-bearing Normanskill rocks (Indian River, Mount Merino, Austin Glen) to the shelly carbonate sequence?

2. Is the upper Snake Hill Shale unconformable on the rocks of the Livingston gravity slide?

3. What is the relationship between the Poughkeepsie Mélange and the Wappinger Creek megabreccia? And the relationship of the Wappiner Creek megabreccia to the Fishkill Creek megabreccia?

4. Are the Housatonic and Hudson Highlands rooted? or parautochthounous?

5. What is the origin and mechanism for the isolated occurrences of Proterozoic (Helikian) gneisses at Stissing Mountain, Cronomer Hill, Todd Hill, Corbin Hill?

6. Were the slides and slices physically connected during westward transport?

7. Why does the Everett Schist (Clove Slice) always rest on the Walloomsac (metamorphosed Snake Hill) Schist?

8. Does the Everett Schist equate with several rock units that are present in the more westerly slides?

9. What is the precise age of the Pine Plains Formation?

10. Is the Briarcliff an easterly thickening facies?

11. Are the Barnegat and New Hamburg blocks rooted? Is their western contact a high angle reverse fault or an apparent fault?

12. Does the Nassau equate with the Elizaville? with the Everett?

13. Was the Van Buren Slide a single large gravity slide or a series of smaller discrete slides?

14. Are two periods of Acadian deformation recognizable in Dutchess County?

15. Are Late Triassic-Jurassic age block faults really present in Dutchess County?

16. Are the large-scale folds in Orange County (Green Pond, Schunnemunk Mountain, possibly east edge of Shawangunk) continued into Dutchess County? What is their age?

17. Are the pre-Mount Merino beds along the railroad tracks at St. Andrews (now Culinary Institute of America) Germantown? If so, why do they differ from the Germantown elsewhere in the county?

18. Are the apparent strike-slip tear faults of the Milan Window, Wappinger Creek, and Fishkill-Beacon areas pre-gravity sliding in age?

19. What is the significance of the parallelism of the Shawangunk Ridge and the Hudson Highlands? and the northern termination of the Shawangunk conglomerate and sandstone?

20. Is there any napping prior to hard-rock thrusting?

ROAD LOG

T.S.P. - Taconic State Parkway
U.S. - Federal Highway
N.Y. - New York State Highway
D.C. - Dutchess County Highway

Time	Accumulated Mileage	Trip Mileage	Descriptions & Directions
8:15 a.m.	0	0	LEAVE Vassar College South Parking Lot on NE corner of Raymond Ave. and Hooker Ave. (N.Y. 376), N(right) on Raymond Ave.
	1.00	1.00	E(right) on Main St. (U.S. 44).
	1.3	0.3	V-intersection with N.Y. 55. Stay on U.S. 44(left).
	2.1	0.8	Middle Ordovician Snake Hill Shale on left. Proceeding in Lower Ordovician-Cambrian carbonate valley. Megabreccia (?) of carbonate blocks deposited on Snake Hill mud.
	6.7	4.6	Road cut in Rochdale Dolostone.
	7.5	0.8	Village of Pleasant Valley, crossing Wappinger Creek.
	7.9	0.4	Lower Cambrian Nassau pelites; have entered the Van Buren gravity slide.
	8.50	0.6	Lower Ordovician Stuyvesant Falls green shale, and thin quartzites on NW(left).
	8.55	0.05	SE(right) on Rossway Rd.
8:35 a.m.	10.2	1.65	STOP 1 -- Intersection of Drake-Rossway Rds. & T.S.P. Exposures of Cambrian-Lower Ordovician Germantown Formation along both lanes of T.S.P., north of intersection. We shall examine only the western cut on the southbound lane. Here, almost vertical dipping platey, silty shale with very thin-bedded limestones and carbonate-clast carbonates are superbly exposed. Tight drag folding indicates that we are on the eastern limb of a larger synclinorium. Note the quartzose limestone beds. These and the

Figure 6. Carbonate-clast conglomerate in Germantown Formation; west side of Taconic State Parkway near Drake Road. Stop 1 of field trip.

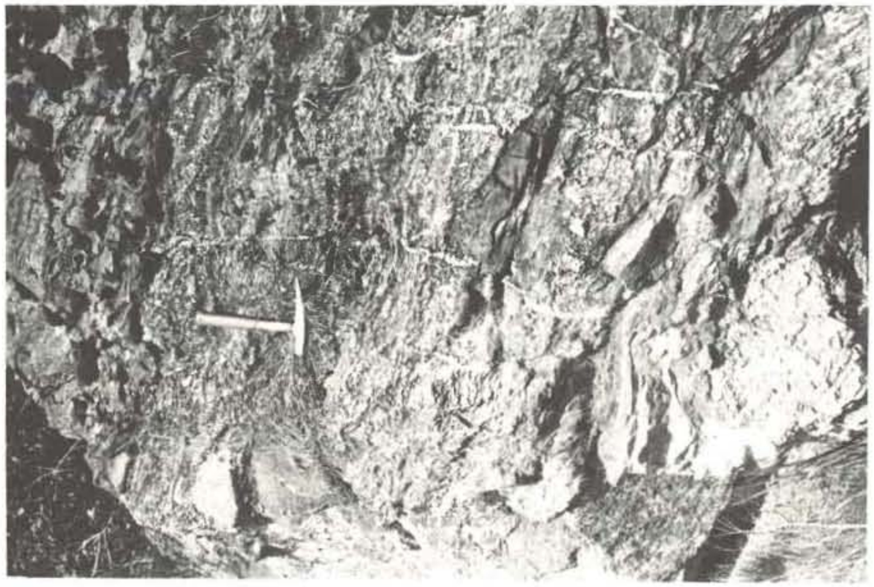


Figure 7. Proterozoic gneiss along east side of Taconic State Parkway and comprising Todd Hill (in center). Stop 2 of field trip.

			carbonate-clast conglomerates have large and well-rounded frosted quartz grains; the clasts consist of fine-textured limestones and differing types of dolostones and black phosphate pebbles. These conglomerates are thought to be lag-turbidites on an ancient continental slope.
9:10 a.m.	10.2		LEAVE STOP 1. SE across T.S.P. on Rossway Rd.
	10.35	0.15	Lower Cambrian Nassau shales and argillites.
	12.65	2.30	E(left) on Mountain Rd.
	12.85	0.20	S(right) on Skidmore Rd., in valley floored with outwash gravels.
	14.3	1.45	Kame terrace on E side of valley.
	14.9	0.6	SE(left) on Velie Rd.
	15.35	0.45	Cross N.Y. 55 on Velie Rd.
	15.7	0.35	Lower Cambrian or Late Proterozoic Everett Schist in hill on left. Everett is thrust-faulted, westwardly, onto Middle Ordovician Snake Hill (=Walloomsac) Shale.
	16.3	0.6	Fork left.
	16.45	0.15	W(right) on Todd Hill Rd.
9:35 a.m.	16.95	0.5	STOP 2 -- Intersection of Todd Hill Rd. and T.S.P. Here we have a geological enigma--an exposure of Proterozoic gneiss in an area far removed from larger masses of Proterozoic gneiss. This orange feldspar-rich granite gneiss does not have a normal shelf stratigraphy (Poughquag Quartzite, Wappinger carbonates) associated with it as does the Cronomer Hill section at Newburgh or the Stissing Mt. section near Pine Plains. Todd Hill and a smaller hill to the SW are flanked on the east by Everett Schist and Mount Merino(?) Shale, respectively. These two gneiss hills are bounded

on the W by a major NE-trending fault. The field relations deny the views that these gneiss hills were islands around which Cambrian and Ordovician sediments accumulated or that the gneisses were up-punched due to doming or normal block faulting (horst). The gneiss owes it position as a result of far-travelled movement--either as a sliver along a low thrust fault or as an erosional outlier of a once larger overthrust mass of gneiss, such as the Hudson Highlands. We prefer the sliver supposition.

10:00 a.m.	16.95		LEAVE STOP 2. W across T.S.P. on Todd Hill Rd.
	17.25	0.3	SW(left) on Stringham Rd.
	18.25	1.0	SE(left) on Old Noxon Rd. at housing development. W(right) into relatively new rock cut on both sides. Park on Old Noxon Rd.
10:05 a.m.	18.55	0.3	STOP 3 -- Noxon Rd. (D.C. 21) rock cut, E of Sprout Creek. Here, we have the Mt. Merino Shale on the west and the Indian River Shale on the east, -- the middle and lower divisions of the Normanskill Group, respectively. The Mt. Merino is a gray to black shale or mudstone locally with gray to black chert; the Indian River is a pale green to red to maroon shale or mudstone with light green to red chert; within the Indian River here is an unfossiliferous dove-tan-gray, fine-textured limestone. Three and possibly four episodes of folding are displayed here. One set has horizontal axial planes, another has westward dipping axial planes with N-plunging folds, and a third are small drag folds which appear to be refolded. In addition, the penetrative cleavage is folded. The interpretation is that this outcrop exposes a portion of a lower limb of a westwardly overturned fold (nappe). Small discrete bodies of graywacke, more convex upward and to the east, are probably turbidites; they too, are upside down. No fossils have been found at this exposure but

			elsewhere, where less deformed, the Indian River and Mt. Merino yield graptolites characteristic of the *Nemagraptus gracilis* zone of the Early Medial Ordovician.
10:45 a.m.	18.55		<u>LEAVE STOP 3.</u> W on Noxon Rd. (D.C. 21) to Titusville Rd. (D.C. 49).
	21.25	2.7	W(left) on Titusville Rd. (D.C. 49).
	22.25	1.0	S(left) on Red Oaks Mill Rd. (D.C. 44).
	22.95	0.7	W(right) on N.Y. 376 at bridge over Wappinger Creek. Get into left lane for left turn at signal between two gas stations at Red Oaks Mill onto
	23.15	0.2	Spackenkill Rd. (D.C. 76).
	23.75	0.6	Slow, but no full stop. On S(left) side of Spackenkill Rd. is a block of Wappinger (Briarcliff) carbonate in the Snake Hill Shale. This is regarded to be part of an extensive NE-trending megabreccia extending from the Cronomer Hill area at Newburgh, generally following Wappinger Creek and reaching Stissing Mountain near Pine Plains. Although the precise sequence of deformational events is uncertain, this megabreccia is believed to be an early mélange deposit in the Snake Hill mud, created by the ripping-up of underlying shelf carbonates as the pelitic Van Buren gravity slide moved westward. This exposure is but one of many carbonate blocks illustrating various attitudes and differing Wappinger units.
	23.9	0.15	NE(right) on Cedar Valley Rd.
11:00 a.m.	24.4	0.4	<u>STOP 4</u> -- W side of Cedar Valley Rd. (NO ROCK BREAKING OR SAMPLING, PLEASE.) Here, we have opportunity to see the significant Middle-Lower Ordovician contact, -- a profound erosional unconformity on a regional scale. At this exposure, the Middle Ordovician (Mohawkian) Balmville Limestone rests on the Lower Ordovician (Canadian) Rochdale Limestone. In some parts of

the Hudson Valley, the Balmville rests on older rocks--as old as Medial Proterozoic gneisses.

The Balmville consists of medium-dark gray, coarse-fine textured limestone, fossil fragmental, and, locally, with a pebble conglomerate composed of clasts of finer textured, light gray weathering limestone of buff-weathering dolostone. Some "clasts" are colonies of the alga *Solenopora*. The Balmville is relatively fossiliferous but whole specimens are difficult to obtain. Brachiopods, crinoids, and bryozoans are the principal taxa; algae, conodonts, gastropods, ostracodes, and trilobites are secondary taxa. The subjacent Rochdale Formation is fine-textured, bluish-gray to black limestone with interbedded paler bluish-gray, buff weathering dolostones. In some beds, the proportion of calcite to dolomite varies considerably; this produces a fretwork appearance to the weathered surface. The Rochdale is Medial Canadian (Demingian) age as evidenced by the diagnostic discoidal gastropod, *Lecanospira*, the trilobite *Hystricurus conicus*, and the cephalopods *Bassleroceras*, *Dwightoceras*, and *Vassaroceras*. Stromatolites are also occasionally seen. The Rochdale seems to have been deposited in a low-energy, distal intertidal environment whereas the Balmville is a product of extremely high-energy conditions on an ancient beach.

The dip varies from 55° E at the northern end of the exposure to near vertically at the southern end. The observed rocks are on the eastern edge of an elongated carbonate block with Middle Ordovician Snake Hill Shale occupying the lowland to the east and the adjacent lowland to the west of the NE-trending carbonate ridge.

11:25 a.m.	24.4		LEAVE STOP 4.
	24.8	0.4	Return to Spackenkill Rd., turn W(right).

	24.95	0.15	Turn N(right) on Boardman Rd. through area of IBM Research and Development Facility.
	26.65	1.75	W(left) at blinking signal onto Hooker Ave. (N.Y. 376), keeping in left lane preparatory to continuing W through next signal.
	27.35	0.7	S(left) on Cedar Ave. at Sunoco gas station.
11:35 a.m.	28.75	1.5	STOP 5 -- E side of Cedar Ave. (D.C. 74); park cars or buses on W side. This long exposure is in the Briarcliff Dolostone division of the Wappinger Group. Note the variation in textures and colors in the dolostones. Small faults with only a few centimeters displacement and microbreccias are common. A more prominent normal fault across from the parking area trends N70°E and dips almost 90°. A short distance to the east, the Briarcliff abruptly ends in a cliff; Snake Hill Shale occupies the bounding lowland. This is the eastern extremity of the relatively large block of carbonate that is exposed in the large Clinton Point Quarry on the Hudson River. Here, earthquakes have been documented from 1937 to the present. It is speculative whether this Cedar Ave.-Clinton Point block is (1) an exceedingly large block in a megabreccia, (2) an up-punched block bounded by normal faults, (3) the leading edge of a thrust block, or (4) a megabreccia block trimmed by subsequent block faulting. Because of its proximity to known, but smaller, megabreccia blocks, we favor views (1) or (4).
12 noon	28.75		LEAVE STOP 5. S on Cedar Ave.
	28.95	0.2	W(right) on Spackenkill Rd. (D.C. 76). Note gentle dips in Briarcliff Dolostone in every exposure.
	30.30	1.35	N(right) on U.S. 9. Note outcrop of Briarcliff Dolostone just north of Robert Hall Store. Dips are abnormally steep and may record bevelled isoclinal folds or indicate proximity to a fault.

Figure 8. Middle Ordovician Balmville Limestone (darker gray) disconformably on the Lower Ordovician Rochdale Limestone of the Wappinger Group; along west side of Rochdale Road and Wappinger Creek.

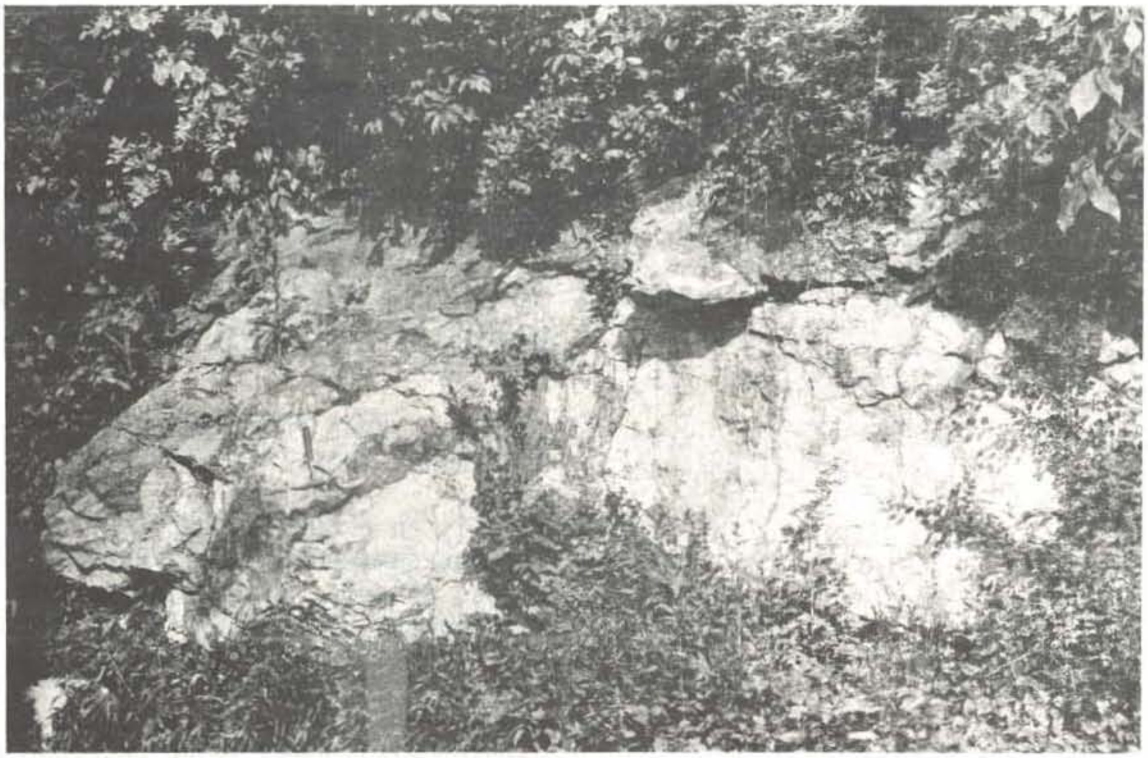
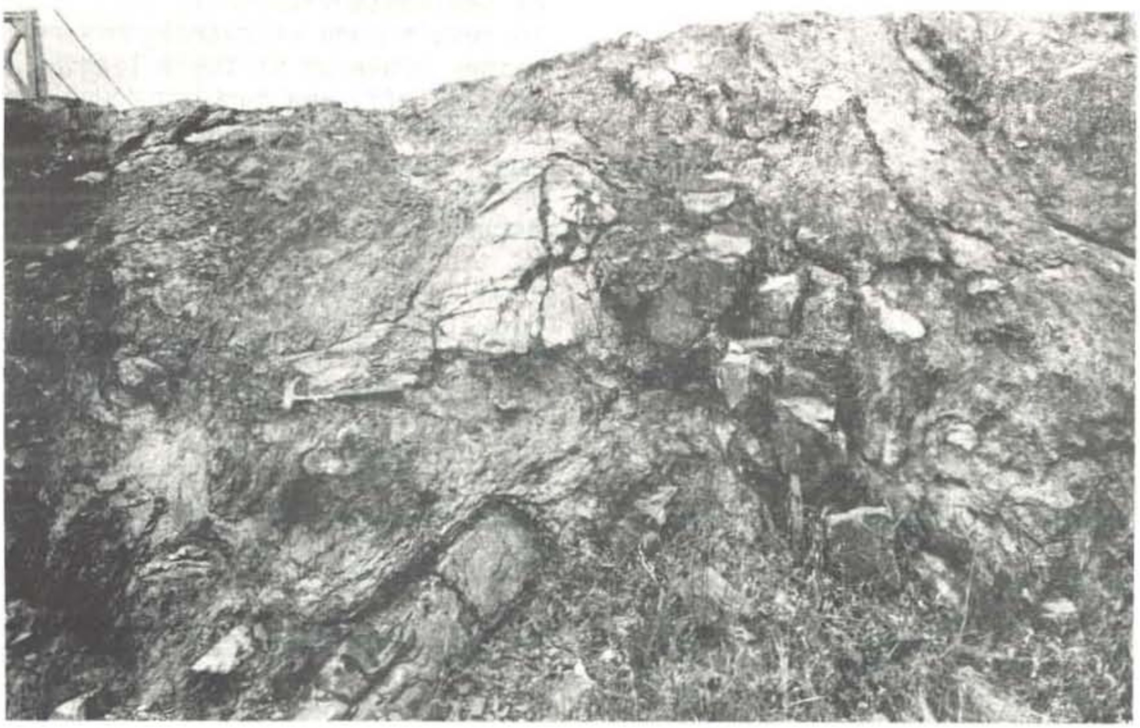


Figure 9. Poughkeepsie Mélange, illustrating exotic blocks of Austin Glen Graywacke in unbedded Snake Hill Shale; Kaal Park under east end of Mid-Hudson Bridge. Stop 6 of field trip.



			This is the western margin of the Cedar Ave.-Clinton Point carbonate block.
	33.75	3.45	Exit from U.S. 9 on access road(right) for Main St.
	33.85	0.1	W(left) on Main St.
	33.95	0.1	S(left) on Rinaldi Blvd., continuing beneath overpass of Mid-Hudson Bridge.
	34.30	0.35	W(right) on entrance road to Kaal Park, turning W(left) 34.40 and downhill into Kaal Park.
12:20 p.m.	34.55		STOP 6 -- KAAL PARK (LUNCH!) NO HAMMERING, THIS IS A CITY PARK.
			This is an exquisite exposure of a tectono-sedimentary unit known as chaos, mélange, olistostrome, or wildflysch. Fisher (1976, in press) has named this unit the Poughkeepsie Mélange. It consists of various sized, angular to rounded clasts of rock (with varying attitudes) in an unbedded or poorly bedded argillaceous matrix. Here, the blocks are almost exclusively Austin Glen Graywacke; elsewhere, there are varying amounts of quartzite, sandstone, shale, and carbonate. This type of sedimentary-tectonic unit is believed to result when westwardly moving rock masses broke up at their leading edge, spalled off, and tumbled downslope into a deepening basin which was receiving mud. Evidences of soft-sediment deformation are widespread. This deposit accumulated during the Vermontian Phase of the Taconic Orogeny (mid-Mohawkian time) when the Livingston and Van Buren Gravity Slides were emplaced into the Magog (Snake Hill-Martinsburg) Trough. Rocks of the Livingston Slide are superbly exposed at the western end of the Mid-Hudson Bridge.
1:20 p.m.	34.55	0.3	LEAVE STOP 6. Exit east via Kaal Park Rd., crossing Rinaldi Blvd. and passing under U.S. 9.
	34.85	0.3	N(left) on access road to U.S. 9.

Figure 10. Cross-section of load casts in Austin Glen Graywacke; north side of St. Andrews Road (Dutchess County 40). Stop 7 of field trip.

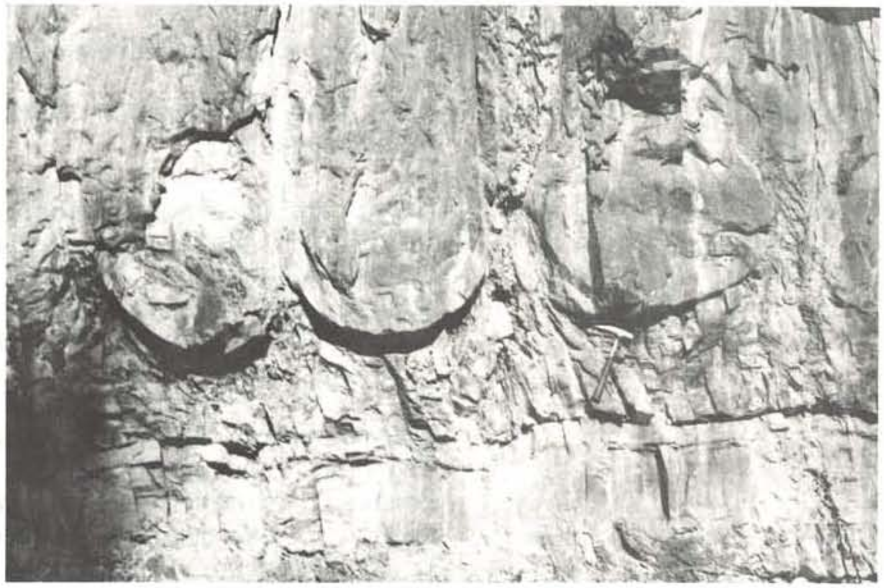
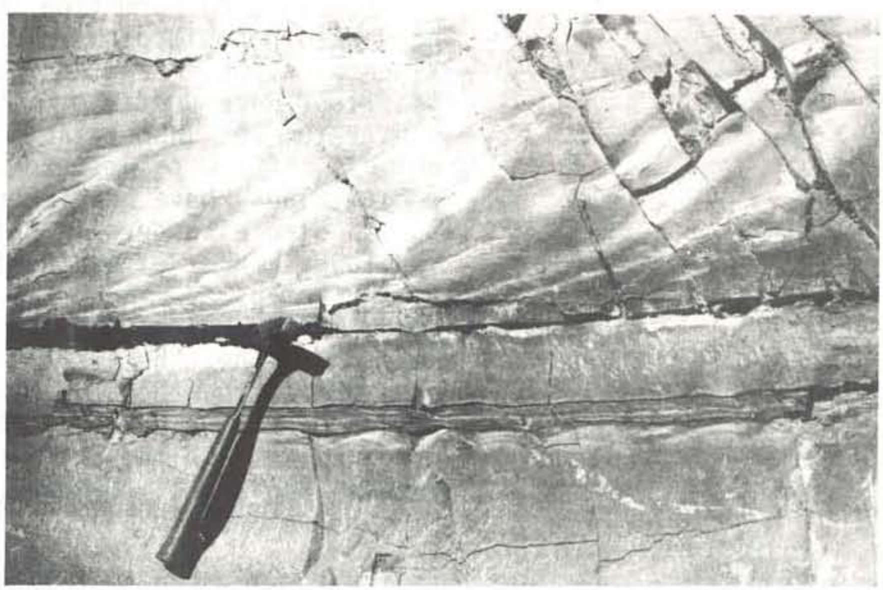


Figure 11. Climbing crossbedding in Austin Glen Graywacke; north side of St. Andrews Road (Dutchess County 40). Stop 7 of field trip.



	35.35	0.5	Numerous exposures of Poughkeepsie Mélange.
	37.05	1.70	Culinary Institute of American on W(left).
	39.30	0.55	E(right) on St. Andrews Rd. (D.C. 40).
1:40 p.m.	39.85		STOP 7 -- Exposures on both sides of St. Andrews Rd.

Here, the uppermost member of the Middle Ordovician Austin Glen Graywacke is deformed into broad, low amplitude folds. The somewhat cyclical shale-graywacke succession is cleaved and the cleavage is slightly bent, denoting that here we are at the western limit of a folding episode which deformed the earlier regional fracture cleavage. This stop, however, is more instructive for the wealth of sedimentary features that are to be observed: load casts, cross-lamination, cross-bedding, graded bedding, intra-bed clasts, climbing ripple marks, etc. Note also, the micro-folding of the thinnest seams. The abrupt change from arenite sedimentation (graywacke) to pelite sedimentation (argillite, shale) is striking. Many of the graywackes, especially the thicker ones, are turbidites as evidenced by the variety of load casts and trapped shale or pelite clasts.

The Austin Glen Formation is thought to have been deposited on an ancient continental slope where the sediments on the sea floor were unstable. This type of substratum was inhospitable to benthonic animals. A few pelagic forms (graptolites, radiolarians) have been recorded from the Austin Glen elsewhere in Dutchess County. The lower member of the Austin Glen belongs to the *Nemagraptus gracilis* zone and the upper member belongs to the *Diplograptus multidens* zone. Because of the absence of a shelly, benthonic fauna from all divisions of the Normanskill Group, its correlation with the shelf carbonates remains equivocal. Outcrop is in the Livingston Gravity Slide.

2:20 p.m.	39.85		LEAVE STOP 7. E on St. Andrews Rd. (D.C. 40).

Figure 12. Interbedded quartzite and argillite, with quartz cross-veining in thicker quartzites in Elizaville Formation; north side of Slate Quarry Road (Dutchess County 19). Stop 8 of field trip.

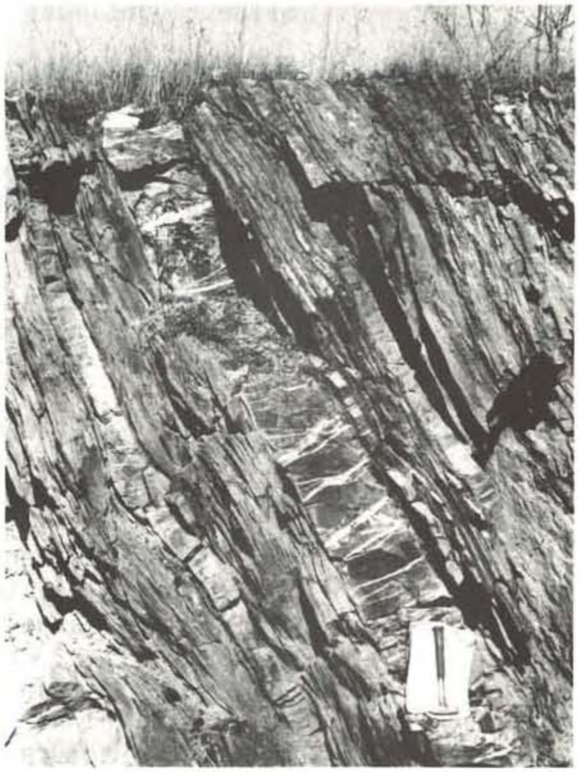


Figure 13. Deformed cleavage ("crinkled layers") in Everett Schist; north side of N.Y. 55, east of the Taconic State Parkway.

	40.45	0.6	N(left) on N.Y. 9G at signal.
	42.30	1.85	Exposures of very massive Austin Glen Graywacke in Livingston Gravity Slide. Continues to 43.2.
	52.20	9.90	E(right) on Slate Quarry Rd. (D.C. 19). Outcrops of mélange near intersection.
	52.65	0.45	Germantown conglomerates, limestone, and shale on N(left) side. Have just entered Van Buren Gravity Slide.
	53.30	0.65	Entering Gallatin Thrust Slice; Elizaville argillite and quartzite in numerous exposures on both sides.
2:50 p.m.	55.05	1.75	STOP 8 -- Early Cambrian or Late Proterozoic Elizaville Argillite and Quartzite on Slate Quarry Rd.

The Elizaville consists of hard, compact greenish-gray slate and argillite (weathering tan to orange) and interbedded greenish-gray quartzite. Elsewhere, some of the quartzites attain 10 meters thickness. Here, the thinner quartzites are traversed by cross-fractures filled with milky quartz and iron carbonate (siderite). NO HAMMERING OR COLLECTING SIDERITE!!! On the west end of the exposure, the strata form a low fold with cleavage dipping 50-60° E. Further east, the bedding and cleavage are parallel (dipping 60° E). Where this coincidence exists, the chances for good quality commercial slate are better; abandoned slate quarries may be found on both N and S sides of the road in the woods. In general, in the Gallatin Slice, cleavage is predominant over bedding. And, cleavage is virtually undeformed.

No fossils have been discovered in the Elizaville Formation. It is presumed to be equivalent to part of the Nassau Formation of the Van Buren Slide.

3:30 p.m.	55.05		LEAVE STOP 8. E on D.C. 19.
	55.70	0.65	Exiting from Gallatin Thrust Slice into Livingston Gravity Slide; Mt. Merino black shale on N(left) side.

3:40 p.m.	56.15	0.45	STOP 9 -- MILAN WINDOW: WAPPINGER (HALCYON LAKE?) carbonate on N side of D.C. 19 near intersection with D.C. 18.

This is a NNE-trending valley floored by Wappinger carbonates, Balmville Limestone, and Snake Hill Shale. Rimming this sequence of shelf rocks are slope and basin Normanskill graywackes and pelites of the allochthonous Livingston Slide. The window of parautochthonous shelf rocks was produced by differential erosion of part of the covering Livingston Slide and additional covering Gallatin Slice; the Van Buren Slide was presumably eroded prior to the emplacement of the Gallatin Slice. Subsequent normal faulting may have accelerated erosion and the creation of the Milan Window. This stacking of gravity slides and thrust slices is seen to no better advantage than in this region of the Rock City Quadrangle. Mapping of the divisions of the Wappinger Group has disclosed here, and in other lengthy carbonate terranes, the existence of a NW-SE trending fault set (strike-slip faults) which, seemingly predate the gravity slides. These faults may have been the product of stresses in effect during expansion of the Proto-Atlantic Ocean. The slides and slices were formed during contraction of the Proto-Atlantic Ocean.

Field relations at the Milan Window demonstrate that the parautochthonous carbonates (megabreccia?) were emplaced prior to the transport of the slides and slices--an important criterion in documenting the regional geologic history.

4:00 p.m.	56.15		LEAVE STOP 9. E on D.C. 19 (now named Bulls Head Rd.).
	56.70	0.55	E edge of Milan Window (56.75 Milan Hollow Rd. corner). Several exposures of Mt. Merino black shale on both sides of road almost to T.S.P. (56.90 black shale on S side of road).
	58.55	1.65	Cross T.S.P. Melange exposures on T.S.P. near the intersection. Continue E and SE on D.C. 19.

	62.9	4.35	Everett Schist on both sides of road.
	63.75	0.85	S(right) on N.Y. 82 at Stanfordville.
	64.55	0.8	Everett Schist on E(left).
	65.65	1.1	Crossing into Van Buren Slide near intersection with Knight Rd. Indian River green and red shales and cherts.
	70.45	4.8	W(right) on U.S. 44 at Washington Hollow. State Police Troop K Headquarters on E side of road intersection. Germantown gray-black shale in borrow pit on S side of intersection; Stuyvesant Falls Formation in cliff NW of intersection.
	71.25	0.8	Pass under T.S.P. in a southwesterly direction.
	72.25	1.0	Indian River green and red mottled slates near Tinkertown Rd.
	73.25	1.0	Rossway Rd. intersection.
	74.75	1.5	Re-enter Wappinger carbonate valley at Pleasant Valley.
	75.05	0.3	(Traffic light in Pleasant Valley)
	75.65	0.6	Rochdale limestone and dolostone on both sides.
	78.55	2.9	Delaval Plant on E(left).
	79.05	0.5	Turn SE(left) on DeGarmo Rd. (D.C. 43).
	79.85	0.8	Straight ahead on D.C. 46.
	80.65	0.8	At signal turn W(right) on N.Y. 55 at Manchester Bridge.
	80.70	0.05	After crossing Wappinger Creek and immediately before railroad underpass, turn NW(right) into Page Industrial Park and continue west to westernmost parking lot against hill and near railroad embankment.
4:55 p.m.	81.20	0.50	STOP 10 -- rock cut and fault along Penn Central R.R.

At the western end of the railroad cut is an apparent high-angle reverse fault with Late Cambrian Briarcliff Dolostone on the east and the Middle Ordovician Snake Hill Shale on the west. Note the gouge (mylonitized) zone along the contact. The question here is whether this is a bonafide high-angle reverse fault, east being the overriding block, or rather a carbonate block which has gravity slid into the Snake Hill mud; the illusion of a high-angle fault may have been created subsequent to sliding by rotation of the strata during an Acadian (Middle Devonian) folding episode.

The fault plane dips 75-80° E and there is no apparent drag here or anywhere else along the western margin of this carbonate block. At New Hamburg, along the railroad on the Hudson River, the fault plane dips 35-40° E. The absence of drag and variable dips of the "fault plane" tend to argue for a "block-in-shale" situation.

5:15 p.m.	81.20		<u>LEAVE STOP 10.</u> Return to N.Y. 55 W(right) on N.Y. 55 and merge with U.S. 44.
	83.65	2.45	S(left) on Raymond Ave. at first signal after Howard Johnson's Restaurant.
	84.65	1.00	E(left) into Vassar College South Parking Lot at intersection with Hooker Ave. (N.Y. 376).
5:30 p.m.			<u>END OF TRIP.</u>

BIBLIOGRAPHY

Balk, Robert, 1936. Structural and petrologic studies in Dutchess County, New York, pt. 1 - Geologic structures of sedimentary rocks. Geol. Soc. Amer. Bull., 47:685-774, geologic map (1:62,500).

Bird, John M. and Dewey, John, 1970. Lithosphere plate-continental margin tectonics and the origin of the Appalachian Orogen. Geol. Soc. Amer. Bull., 81:1031-1060.

__________ and Rasetti, Franco, 1968. Lower, Middle, and Upper Cambrian faunas in the Taconic Sequence of eastern New York: stratigraphic and biostratigraphic significance. Geol. Soc. Amer. Spec. Paper 113, 66 pgs., 14 figs.

Dana, James D., 1872. Quartzite of Poughquag, Dutchess County, New York. Am. Jour. Sci., (3) 3:250-256.

__________, 1879. On the Hudson River age of the Taconic Schists, and on the dependent relations of the Dutchess County and western Connecticut limestone belts. Am. Jour. Sci., (3) 17:375-388.

Dwight, William B., 1879. On some recent explorations in the Wappinger Valley limestone of Dutchess County, New York. Am. Jour. Sci., (3) 17:389-392.

__________, 1880a. Recent explorations in the Wappinger Valley limestone of Dutchess Co., N.Y. Am. Jour. Sci., (3) 19:50-54, 451-453.

__________, 1880b. The results of some recent paleontological investigations in the vicinity of Poughkeepsie [N.Y.]. Poughkeepsie Soc. Nat. Sci., Pr. 1879-80:15-20.

__________, 1881. Further discoveries of fossils in the Wappinger Valley or Barnegat limestone. Am. Jour. Sci., (3) 21:78-79.

__________, 1884a. Recent explorations in the Wappinger Valley limestone of Dutchess Co., N.Y. Am. Jour. Sci., (3) 27:249-259.

__________, 1884b. An interesting geological locality at Cornwall, Orange Co., N.Y. Vassar Bros. Inst., Tr. 2:74-83.

__________, 1884c. Report of progress in geological investigations in the vicinity of Poughkeepsie [N.Y.]. Vassar Bros. Inst., Tr. 2: 141-152.

__________, 1886. Recent explorations in the Wappinger Valley limestone of Dutchess Co., N.Y.; No. 5, Discovery of fossiliferous Potsdam strata of Poughkeepsie, N.Y. Am. Jour. Sci., (3) 31:125-133. Vassar Bros. Inst., Tr. 4:130-141.

________________, 1887. Recent explorations in the Wappinger Valley limestone of Dutchess Co, N.Y.; No. 6, Discovery of additional fossiliferous Potsdam strata, and pre-Potsdam strata of the Olenellus group, near Poughkeepsie, N.Y. Am. Jour. Sci., (3) 34:27-32. Vassar Bros. Inst., Tr. 4:206-214.

________________, 1889. Recent explorations in the Wappinger Valley limestones and other formations of Dutchess Co., N.Y., No. 7. Am. Jour. Sci., (3) 38:139-153.

________________, 1890a. Discovery of a locality of Trenton limestone rich in ostracoid Entomostraca and other fossils, at Pleasant Valley, N.Y. Vassar Bros. Inst., Tr. 5:75-77.

________________, 1890b. Discovery of fossiliferous strata of the Middle Cambrian, at Stissing, N.Y. Vassar Bros. Inst., Tr. 5:102-109.

Fisher, Donald W., Isachsen, Yngvar W., and Rickard, Lawrence V., 1971. Geologic Map of New York, 1970. New York State Mus. and Sci. Serv. Map and Chart Ser. 15, colored map (1:250,000).

________________, 1976 (in press). Correlation of the Hadrynian, Cambrian, and Ordovician rocks in New York State. New York State Mus. and Sci. Serv. Map and Chart Ser. 25 (colored charts).

________________ and McLelland, James, 1975. Stratigraphy and structural geology in the Amenia-Pawling Valley, Dutchess County, New York. Guidebook for field trips in western Massachusetts, northern Connecticut, and adjacent areas of New York. New England Inter. Geol. Conf., Great Barrington, Mass., p. 280-312.

Gordon, Clarence E., 1911. Geology of the Poughkeepsie Quadrangle. New York State Mus. Bull. 148, 121 pgs., 27 figs., 26 pls., colored geologic map (1:62,500).

Holzwasser, Florrie, 1926. Geology of Newburgh and vicinity. New York State Mus. Bull. 270, 95 pgs., 12 figs., 39 pls., colored geologic map (1:62,500).

Jaffee, Howard W. and Jaffee, Elizabeth B., 1973. Bedrock geology of the Monroe Quadrangle, Orange County, New York. New York State Mus. and Sci. Serv. Map and Chart Ser. 20, 74 pgs., 41 figs, colored map (1:24,000).

Knopf, Eleanor B., 1927. Some results of recent work in the Taconic area. Am. Jour. Sci., (5) 14: 429-458.

________________, 1946. Stratigraphy of the lower Paleozoic rocks surrounding Stissing Mt., Dutchess County, N.Y. Geol. Soc. Amer. Bull., 57:1211-1212.

________________, 1962. Stratigraphy and structure of the Stissing Mountain area, Dutchess County, New York. Stanford Univ. Publ., Geol. Sci., v. 7, no. 1, 55 pgs., colored geologic map (1:24,000).

Landing, Ed, 1974a. Early and Middle Cambrian conodonts from the Taconic Allochthon, eastern New York. Jour. Paleont. 48:1241-1248, 1 pl.

__________, 1974b. Lower Ordovician conodont and graptolite biostratigraphy of the Taconic Province, eastern New York. Geol. Soc. Amer. Abstracts with Program, Boulder, Col., p. 525-526.

Mather, W.W., 1843. Geology of New York, Part 1, comprising the First Geological District. 653 pgs., Albany.

Mose, Douglas G., Ratcliffe, Nicholas M., Odum, A. Leroy, and Hayes, John, 1976. Rb-Sr geochronology and tectonic setting of the Peekskill pluton, Southeastern New York. Geol. Soc. Amer. Bull. (March).

Offield, Terry, W., 1967. Bedrock geology of the Goshen-Greenwood Lake area, N.Y. New York State Mus. and Sci. Serv. Map and Chart Ser. 9, 77 pgs., 40 figs., 4 pls., colored geologic map (1:48,000).

Rasetti, Franco, 1966. New Lower Cambrian trilobite faunule from the Taconic Sequence of New York. Smithsonian Misc. Coll. 148(9):52 p., 12 pls.

______________, 1967. Lower and Middle Cambrian trilobite faunas from the Taconic Sequence of New York. Smithsonian Misc. Coll. 152(4):111 p., 14 pls.

Rickard, Lawrence V. and Fisher, Donald W., 1973. Middle Ordovician Normanskill Formation, eastern New York, age, stratigraphic, and structural position. Am. Jour. Sci., 273:580-590.

Riva, John, 1968. Graptolite faunas from the Middle Ordovician of the Gaspe north slope. Naturaliste Can. 95:1379-1400, 2 figs., 1 pl.

Ruedemann, Rudolf, 1942. Geology of the Catskill and Kaaterskill Quadrangles: Part 1 - Cambrian and Ordovician geology of the Catskill Quadrangle. New York State Mus. Bull. 331, 251 p., 82 figs., colored geologic map (1:62,500).

Vidale, Rosemary J., 1974. Vein assemblages and metamorphism in Dutchess County, New York. Geol. Soc. Amer. Bull., 85:303-306.

Zen, E-an, 1967. Time and space relationships of the Taconic allochthon and autochthon. Geol. Soc. Amer. Spec. Paper 97, 107 p.

________, 1972. The Taconide Zone and the Taconic Orogeny in the western part of the northern Appalachian orogen. Geol. Soc. Amer. Spec. Paper 135, 72 p.